CONTENTS

A. PHILOSOPHY OF OUR CURRICULUM

Like most institutions of higher learning, the teaching-learning process of NIT Rourkela is expressed in terms of course credits, one credit being approximately equal to 1 hour of lecture class or 1.5 hours of laboratory or design class per week. M. Tech, M.A, M.Sc programms are expected to contain about 98 to 110 credits.

In the global context, M. Tech, M.Sc and MA programme contains 98 to 102 credits. A close examination of the curricula will, however M.Tech curriculum reveals that nearly 56 credits of the 102 credits are dedicated to seminar and technical writing, research, summer research or industrial projects and comprehensive viva-voce that contribute to a student's personality growth without taking the time to the same extent as the hard academic credits of other subjects. Further, as per our academic traditions in India, supplementary reading, as a fraction of the total academic content of a course, is normally well below that in European or American universities. In the opinion of the NIT Senate, the curriculum prescribed strikes a judicious balance between need for formal instruction and free time to think beyond the course work.

The postgraduate curriculum of NIT Rourkela has strived to offer both theory courses as well as laboratory and design practice in all major areas of study. It has, however, consciously avoided combining theory and laboratory classes in the same course (e.g. L-T-P = 3-0-3). It was felt that an inflexible combination of theory and laboratory components will limit the opportunity to study a wider variety of subjects and increase failure rate. Instead, the NITR system offers separate courses for theory and laboratory components in the form of (3-0-0) or (3-1-0) theory courses and (0-0-3) laboratory courses. In order to make the time table simple and easily implementable, the variety of course volume has been limited to only three types – (0-0-3) 2 credits, (3-1-0) 4 credits and (0-0-0) 2, 4, 20 credits. Teachers are expected to package appropriate volume of teaching material in a subject to justify one of these three modes.

Theory Courses

Type of Course	**No. of Courses**	**Credits**
Professional Core Courses:	4	16
Professional Electives:	6	24
Total:	**10**	**40**

Practical/Design Courses

Type of Course	**No. of Courses**	**Credits**
Professional Laboratory Courses:	4	8
Total:	**4**	**8**

Miscellaneous Subjects

Type of Course	**No. of Courses**	**Credits**

Summer Research/Industrial Project	1	4
Seminar & Technical Writing:	4	8
Research Project Work:	2	40
Comprehensive Viva-Voce:	1	4
Total:		**56**

NIT Rourkela curriculum has certain innovative features that are rather uncommon in traditional universities and institutes in India. Among them are:

(1) Special Topic in <specialization name> [Course Nos.: AA 681 and AA 682, AA standing for the Department code]. While for a normal subject, the syllabus needs to be approved by the Senate and notified in advance, the syllabus of a special topic shall be approved by the Departmental Academic Committee of the offering department and reported to the Senate at its earliest meeting. The contents may change semester to semester and multiple instances may be floated in a single semester. A student, may however, register for maximum one special topic in an odd semester (AA 681) and another in an even semester (AA 682). Such courses give opportunity to departments to convert new ideas of existing faculty, expertise of new and visiting faculty, suggestions of employers etc. to tangible courses without waiting for prior approval of the Senate. It is expected that if a course is offered as a special topic and is expected to continue, the department will take steps to introduce a formal course on the subject with approval of the Senate.

(2) Special Laboratory in <specialization name> [Course Nos.: AA 683 and AA 684:] Similar to special topics AA 681 and AA 682 except that the latter are for theory courses, while the special laboratories cover practical, design and CAD courses.

(3) Research Project I & II [AA 591 and AA 592 (M.Sc)], [AA 693 and AA 694 (M.Tech)]: Postgraduate research is receiving increasing emphasis in institutions of higher learning. It is an important component of NIT Rourkela's curriculum. The total credits in M.Tech shall be 40 which may be split as 20+20 as per the department. Other details are given in the regulations.

    Postgraduate projects also constitute important components of the R&D programmes of the departments. Students carry out the research ideas of their supervisors, and in the process learn the techniques of research. It is essential that they become proficient on computer assisted literature search, patent search, experimental and computational techniques, systematic recording of data, writing of thesis and presentation before a scholastic audience. Needless to say, original scientific concepts and their effective exploration shall get due credit in evaluation of the projects.

    Normally, thesis evaluation shall be based on 3 components – (a) evaluation by supervisor based on day to day work by the student, (b) that by departmental committees that will lay emphasis on proper research methodology and maintenance of records, and (c) that by institute level committees which will strive to ensure that students have demonstrated effective use of institutional resources such as computer aided literature search, patent search, use of advanced fabrication and characterization equipment, industrially relevant R&D problems and the like that bring glory to the institute. The Senate, at its discretion, may delegate this responsibility to the department concerned or to a committee of teachers.

All theses of NIT Rourkela shall be made available to scientific workers around the globe. Any dishonest practice or plagiarism will lead to severe academic penalty to the student and appropriate administrative steps against the supervisors. The Project record book shall be the key element of the exercise. Continuous discussions and signatures by supervisors on the record book, and faithful reproduction of record books on the thesis will ensure an honest scholastic environment in the Institute.

(4) Seminar & Technical Writing [AA 685 to AA 688 (M.Tech)]: These subjects are introduced in the first year and final year of M. Tech. and the courses of [AA 593, AA 594] in M. Sc. Courses to:

(a) give students exposure to variety of topics through the medium of attending seminars, and

(b) teach them the skill of writing technical articles, concepts of abstract, Introduction, material and methods, conclusion, references, acknowledgement etc.

The students shall not be required to present seminars; they will attend seminars presented by others, as per recommendation of the teacher. These will include seminars by faculty and research students in the department and by invited experts in the same or related departments. Every student will be required to write a brief (1/2 page) report on what he learnt in the seminar. The technical writing shall cover writing of scientific articles on any subject chosen jointly by the student and the teacher. The article may be presented either as a printed document, a poster, a recorded video/audio presentation or as combinations of more than one media.

In a semester, a student shall be required to attend 6 – 10 seminars and write 2 scientific (including popular science) articles or posters. The record books, articles and posters will be on display in departmental libraries, web sites or in any other media for public benefit. Copies shall be made freely available on demand. The teacher will announce his plan of activities at the beginning of the semester and make it continuously available to students through the institute's intranet site.

Evaluation shall normally be made solely by the teacher, but may be moderated by committees appointed by the Senate as per Institute rules.

(5) Short Term Industrial / Research Experience (SIRE) [AA 595 (M.Sc)] and Summer Research / Industrial Project [AA 691 (M.Tech)]

Summer industrial training has been a part of engineering education for a long time. NIT Rourkela insists on an eight week summer internship either in industry or in an R&D organization, including educational institutes with excellent research culture. The student is expected to submit a formal report at the end of the programme. This requirement is applicable to both M.Tech and M.Sc students. In exceptional cases, a project may be carried out within the Institute; but that is discouraged.

(6) Comprehensive Viva-Voce [AA 596 (M.Sc), AA 692 (M.Tech)]

Postgraduates of NIT study many theory and laboratory courses, while resource constraints force the Institute to adopt a credit and subject based curriculum. It appreciates the value of holistic learning. The comprehensive viva-voce aims to test the holistic comprehension of the student covering all the subjects taught. The questions in the oral examination will, generally, be such as to use contents of two or more subjects for framing an answer.

(7) Emphasis on Quantitative Approach

Quantitative analysis is often considered the corner stone of engineering education. In fact, in our country, universities often offer both M.Tech. and M.Sc. degree in the same subject such as Biotechnology, Materials Science and Electronics, the distinction between the two streams being the degree of quantitative and numerical approach. All branches of engineering shall make a conscious effort to introduce quantitative analysis and numerical problem solving in most theory papers. Examination questions will also reflect this spirit. Basic science courses offered to engineering students will also inculcate the quantitative approach.

(8) Use of Computers and Modern Educational Technology Tools

The faculty shall make a conscious effort to exploit the massive computational and data handling capacity of modern day computers (hardware and software) and related devices. They will specifically include equation solving tools (e.g. EES, MALTAB), simulation software etc. Technology Enhanced Learning may be used in theory subjects, design courses, laboratories, projects, examination and evaluation. Innovative and creative approaches shall, in general, be encouraged as long as they do not compromise on academic standards.

(9) Multi-Disciplinary Approach

Unlike our counterparts in developed countries, many colleges and universities in India draw a bold line between science and engineering. At NIT Rourkela, while the line is quite bold at organization level, it almost vanishes in research and teaching. There is no distinction between courses offered by Science and Engineering Departments; a student can take courses from any department oblivious of its character, as long as he is within the curricular constraints prescribed by the department.

(10) Maintenance of Curricular Standards

Creating an ambitious curriculum is one thing, but following the prescriptions is another. In a scholastic environment, it is neither feasible nor desirable to have a policing system imposed from outside. Compliance to curricular requirements must be voluntary, at best dictated by peer pressure. Faculty students, technicians and the administration — all are stake holders. The Senate, the ultimate guardian of academic standards shall monitor compliance by the faculty and students. There will be an Academic Programme Monitoring Committee which will routinely examine the activities in the departments and report to the Senate. It will also give suggestions for continuous improvement of standards and greater compliance by all concerned.

Occasionally the Senate may prescribe repetition of a curricular activity or additional work to compensate for activities not done. Such prescriptions shall be binding on all – faculty, students and technicians. Stake holders who silently encouraged missed classes or similar failures without drawing attention of concerned authorities should gladly accept such additional assignment. The best way, however, will be to maintain high standards as a matter of habit.

1. EXCERPTS FROM REGULATIONS

The M.Tech, M.Sc, MA and MBA Programme of NIT Rourkela are governed by the undergraduate regulations approved by the Senate and the Board of Governor as. In this chapter, some important sections of this document are reproduced for ready reference by the students and the faculty. Students are advised to consult the original book of regulations and amendments issued from time to time for complete guidance. This section and subsections numbers given in this chapter refers to the corresponding section numbers in the original document.

Academic Calendar

1.1 The academic session is -divided into two semesters each of approximately 17 weeks duration: An Autumn / Odd semester (July - November) and a Spring / Even semester (January - May). In addition, a summer session (May - July) may be offered at the discretion of the Senate under special circumstances.

1.2 The candidates have to take admission to the institute on the dates as per Academic Calendar approved by the Senate. Under special circumstances, e.g. foreign students nominated by the Government of India or a serious medical illness, the Senate (or Chairman Senate on its behalf) may condone delay up to one month from the starting of classes.

1.3 The Senate will approve the academic calendar consisting of schedule of activities for a session inclusive of dates for registration, Mid semester and End-semester examinations; inter-semester breaks etc. well in advance of start of a semester. The academic calendar shall usually provide for at least 80 working days (including examination dates) in each semester, excluding holidays and days when classes are suspended.

1.4 The academic calendar will also reflect the scheduled holidays. Classes lost in holidays need not be compensated. In addition to holidays, the Director, in capacity of Chairman Senate, may announce suspension of classes when a situation so demands. Such suspended classes mayor may not be compensated on a weekend/holiday as per decision of the Director.

1.5 Unlike many traditional universities in India, NIT Rourkela's academic programme is based on a direct contact between the teacher and the student. The teacher enjoys considerable freedom in deciding the contents and method of instruction, evaluation and grading. The printed syllabus is a guideline, rather than a legally enforced constraint. It is mandatory for the class (teacher and students) to conduct all scheduled classes. There is no concept of "finishing a course" because the syllabi are flexible, and permit instruction and practice till the last day of the semester.

Course Structure

1.1 The duration of the course leading to M. Tech. degree will ordinarily be two years. A student may, however, opt for the slow pace programme if he does not feel comfortable with the workload. The maximum duration allowed to complete the M. Tech. programme is 4 years (8 semesters).

1.2 The curricula of the different degree programmes as proposed by the respective departments and recommended by the Post-graduate Programme and Evaluation Committee (PGPEC) shall have the approval of the Senate. The departments will also prepare the syllabus of each subject containing the scope of studies and instructions to be imparted which must have the approval of the Senate.

1.3

(a) All subjects will have Lecture - Tutorial Laboratory / Design components (L- T -P) to indicate the contact hours. Theory courses will have 3-0-0 (3 credits) or 3-1-0 (4 credits) structure. Design or laboratory courses will be offered as distinct (0 - 0 - P) courses without being mixed with lecture components. For the benefit of standardization, other combinations, though permitted, should be avoided. There may be a few special courses of structure 0-0-2

(1 credit). Some courses may have pre- and co-requisites. Co-requisite courses may be taken in the same or different semesters.

(b) Normally, subjects based on engineering or scientific principles or on thought provoking information, where it is possible to conduct a closed book examination, will be taught as theory courses, whereas those based on applications and practice (conceptual, computational or experimental) will be covered under Design or Practical courses. The dividing line between the two, however, is fuzzy and will be decided by Departmental Academic Committees.

(c) All subjects will have a credit count 'C'. Teaching of subjects will be reckoned in terms of credits.

(d) Every course, identified by a single course identifier, shall be taught by a single teacher, who may be assisted by adjunct faculty, teaching assistants, postgraduate and research students, and by other faculty members. The administrative responsibility including decision on contents of instruction and examination as well as submission of grades shall rest solely on the subject teacher. The academic office will recognize only one teacher per course, who will be a regular member of the Institute faculty unless otherwise arranged with approval of Director.

(e) Student feedbacks on courses [Forms AC/118 and AC/119] assist a teacher to improve the contents and delivery. It is the duty of every student to give his thoughtful response to the questions in Form AC/118.

1.4 The prescribed coursework shall be grouped under 2 heads - core courses and professional electives. The core courses, not to exceed 40% of the course load will cover all essential skills associated with a given department and specialization. Professional electives will be taken from a list prescribed by the department, covering courses from the same and allied departments. These courses shall reflect the different specialized topics in a field including the latest developments taking place around the world. Provision of electives helps a student to further specialize on his chosen field.

1.5 The total number of credits in the coursework and seminars in 1st and 2nd semesters together will range between 46 and 50 credits, and that in the entire programme shall be between 98 and 102 credits.

1.6 The summer vacation will constitute a part of the 3rd semester. A student will carry out a mini project during the summer vacation, which should be distinguished from the traditional summer training or SIRE (Short term Industrial or Research Experience) undergone by UG students. The summer project (an internship in industry or an R&D institution, an assigned work in the Institute or a combination of the three) will carry 4 credits which will be counted in the 3rd semester.

The summer project (either in-house or industrial) will be assigned and monitored by the student's thesis supervisor. It may be related to the thesis topic or may be an independent work, to be decided by the thesis supervisor. The topic and place of work will be decided before the middle of the Spring Semester.

There is no summer or winter vacation for M.Tech. Students

1.7 In addition to regular course work, an M. Tech. student must carry out a major project in final year under the guidance of one or two supervisors. The project will be of 2 semesters duration and carry 20 credits in each semester. While the Principal Supervisor shall normally be a faculty member of the department, the second supervisor can be from the same or another department, or from another organization. In special circumstances, the Principal Supervisor may be from another department.

1.8 Every programme shall provide a "Seminar and Technical Writing" course [2 credits] during the 3rd and 4th semesters where the students shall learn and practice essential writing and presentation skills, and attend seminars by reputed engineers and scientists organized by the Departments. Each student will also present 1 or 2 seminars and/or poster presentations before his class. Evaluation will be based on attendance in departmental and Institute seminars, presentation in seminars, poster presentations and technical writing supervised by the course teacher.

1.9 The 4th semester programme shall contain a comprehensive viva voce of 4 credits. It will cover all material learnt in course work over the first two semesters and basic skills learnt in course of the project work. It will be conducted by a board constituted by the HOD in consultation with the DAC (PG&R).

1.10 When circumstances so permit, it will be possible for a student to spend a semester or more in another NIT, IIT or another reputed institute of comparable standing and transfer the credits to NIT Rourkela. The core (compulsory) courses need to have a one-to-one correspondence between the participating institutions. The Senate shall constitute a course equivalence committee to establish the adequacy of the education received in another institution.

1.11 All instructions, practices and examinations will use the SI system of units or any unit system recognized by Government of India.

1.12 Slow Pace programme for local students: The M. Tech. programme is also offered in the slow pace mode to students from Rourkela area who are employed in Government or private institutions and cannot join full time programmes. Under the slow pace programme a student will be registered for half the courses in a semester and will take 4 semesters to complete the course work, and upto 4 years to complete the full programme. There is no other concession and no compromise in quality. The student is not entitled to a hostel room but will be attached to a hostel for administrative purposes. He needs to pay full tuition and other fees for all semesters of study even if he takes only partial academic load. In case a student completes 8 semesters with a few F grades or has a course CGPA less than 6.00, he must leave the Institute without obtaining a degree.

Registration

1.1 Every student of the M. Tech. programme is required to be present and do semester registration at the commencement of each semester on the date fixed and notified in the Academic Calendar. The registration process has 3 components:

(a) Physical presence of the student in campus on the first day of semester.
(b) Payment of semester fees including any unpaid dues of past semesters, and
(c) Selection of courses to be studied during the semester

For selection of courses, a "Pre-Registration" process may be organized during the previous semester. Based on pre-registration data, low demand courses may be dropped, student strength in high-demand courses may be limited and sections may be formed.

If courses of a student's choice are not available, he may be given alternative courses with approval of his Faculty Advisor.

1.2 Registration of students in each semester will be organized by the Academic Section. The registration will be done in respective departments supervised by the Faculty Advisors; the choice of subjects being finalized by the student and his Faculty Advisor. Payment of dues etc. will be verified by the Academic Section. An appropriate semester registration form (Form AC/109) will be used for the purpose.

Once registered, a student may amend the registration within a week of the original registration date. The same form (AC/109) shall be used for the purpose with "Amended Registration" written on the top.

1.3 A student who does not register on the day announced for the purpose may be permitted by Dean (AA), in consideration of any compelling reason, late registration within next 5 working days on payment of an additional fee as prescribed by the Institute. Normally no late registration shall be permitted after the fifth working day from the scheduled date, except in special cases like those directed by MHRD or MHRD approved authorities in 1st semester, a serious medical problem, a family calamity or participation in a national event, to be approved by the Director on recommendation of Dean (AA). However, under no circumstances, late registration after 45 calendar days from the scheduled date of registration is allowed. A student must repeat the semester in the following year. The percentage of attendance of students registering late will be calculated from the date of their joining. However no special allowance may be claimed in the matter of assessment / evaluation or grading.

1.4 Students who have become non-resident with approval of the Institute may be permitted late registration by Dean (AA). They may register anytime during the semester; but registration must be done in person.

1.5 Only those students will be permitted to register who have:

(i) Cleared all Institute and Hall dues of the previous semesters
(ii) Paid all required prescribed fees for the current semester
(iii) Not been debarred from registering for a specified period on disciplinary or any other ground,
(iv) Satisfied the academic requirements of the course,
(v) Not been struck off from the rolls of the Institute

1.6 Students who secure CGPA less than 6.00 but above 5.00 in the First Semester will be permitted to register in the Second semester. Fellowship will be temporarily suspended till publication of second semester results. If the CGPA improves above 6.00, fellowship will be restored with arrears. If the CGPA is still less than 6.00 at the end of second semester, the student shall leave the institute. The unpaid scholarships of second semester will not be paid.

1.7 To be able to register in the 2nd year (3rd semester) and continue his/her study in the Institute at the end of 1st year, a student must

i) complete satisfactorily at least 32 credits of courses prescribed for the two semesters, i.e., secure 'P' or higher grade in at least 32 credits. [The courses with F grade must be cleared as backlog papers in 3rd and 4th semesters to qualify for a degree.], and
ii) obtain a Cumulative Grade Point Average (CGPA) of not lower than 6.00 (considering all courses including those in which the student has secured an F grade).
iii) The method for calculating SGPA and CGPA is illustrated in Appendices I & II.

1.8 While registering in 3rd or 4th semester, a student will register for backlog papers of 1st or 2nd semester respectively. A student need not attend classes in papers registered as "backlog papers". He has to sit for both mid-semester and end-semester examinations and the grade will be awarded based on the scores of the latest examinations. The Teacher's assessment component will be same as that given by the instructor in the original semester, when he attended classes. The registration for backlog papers must be done at the time of semester registration. In all such cases of "backlog paper", the grade awarded will be one step lower than what the student actually obtained, except for the grade 'P' which remains unchanged. A student can appear in a backlog paper only once per subject, in the year following the year when he took the course for the first time.

1.9 Alternatively, a student may opt to repeat a course afresh, in which case he will attend classes, and there will be no reduction of grade awarded. He will, however, be ineligible for awards of medals and prizes which are based on academic performance. If regulations and examination schedule otherwise permit, a student may register for an even semester elective in odd semester and vice versa. A student may change an elective course if he satisfies the pre-requisites and if the timetable permits.

1.10 Ordinarily a student is not permitted to repeat a course in which he has obtained a P or higher grade. But if his CGPA is less than 6.00 he may repeat courses to improve the grade. He is also permitted to replace one elective course by another. In such cases, he will be ineligible for medals and prizes based on academic performance.

1.11 A student who has been debarred from appearing at an examination either (i) as a measure of disciplinary action or (ii) for adopting malpractice at an examination and consequently awarded a grade 'X', may register for the subject(s) as backlog papers in the following semester, if he satisfies attendance requirements. Otherwise he needs to formally register for the courses and attend classes.

1.12 If a student is debarred from examination or his paper cancelled due to unsatisfactory attendance, he will be given UR grade in that paper. He will need to register for the course afresh and attend classes.

1.13 If a student spends a part of his time in third or fourth semester in course work (except as backlog papers) as a consequence of poor grades or unsatisfactory attendance in first two semesters, his thesis submission date will be forwarded by one semester. His thesis will be evaluated along with those of the next batch students, and he will be awarded the degree in the following year. The extension period will be without fellowship.

Attendance and Leave

1.1

a) Unlike many examining universities, NIT Rourkela's academic programme is based primarily on the teaching-learning process. Attendance in classes, participating in class room discussions and participating in the continuous evaluation process is the most essential component of the academic programme. All teachers and students must appreciate that the number of classes scheduled for a course under the approved academIc calendar and time table must be held during the semester. Form AC/117 gives the format of a monthly attendance sheet.

b) If because of personal leave or official duty, or on student request, a teacher is unable to hold a class on the scheduled hour, he will hold the compensating classes at a mutually convenient hour. A teacher may communicate with his class by announcing in the class, through messages on Institute and hostel notice boards or through e-mail. Attendance in these compensatory classes is mandatory for every student.

c) Under special situations, when a teacher is unable to communicate with the students in advance about his absence from a scheduled class, the students present may mark their attendance in the departmental office. If the class is compensated by the teacher on a later date, this attendance sheet will be replaced by the attendance record provided by the teacher.

d) A teacher, at his discretion, may hold additional classes beyond what is originally scheduled, particularly when several classes are lost due to holidays or suspension of classes. Attendances in these classes are also mandatory for the students.

1.2 Attendance in all classes (Lectures, Tutorials, Laboratories, and Seminars etc.) is compulsory. A student shall be debarred from appearing at an examination or, if he has already written the examination, the grades will be rejected on ground of unsatisfactory attendance, if the attendance is below what is prescribed in clause 7.3, or if in the opinion of the course teacher the student has not participated effectively in the class in terms of home assignments, class tests etc.

In such a case a student shall be given UR grade, and the student will need to register for the course once again and attend classes with seriousness.

1.3

a) Considering that attendance in classes, participating in the teaching-learning process is the basic foundation of our academic programme, a student is expected to attend all classes conducted as per Institute calendar and time table.

However, to provide for exigencies, absence to the extent of 15% of scheduled number of classes in every course will be condoned as a matter of routine.

b) In deserving cases, a further relaxation of 15% (i.e., 30% of scheduled number of classes) may be made by Dean(AA); but the student's grade will be reduced by one step. A 'P' grade will be reduced to 'F', and the student will be permitted register for the course as a backlog paper in the following year.

c) The following table gives the number of classes that a student may miss with or without penalty in grade.

L-T-P	Without Penalty	With reduction of one step in grade
3-0-0	6	12
3-1-0	8	16
0-0-3	2	4

It may be noted that missed classes are of 1 hour duration in theory courses and of 3 hour sessions in lab (0-0-3) courses.

d) If a student has attendance lower than that prescribed under item (c), he will get UR grade. He may register in a summer course if offered or register for the course in a subsequent semester. In the latter case he may not be able to complete the programme in two years.

e) The Institute will fix a cutoff date before every examination to compute the percentage of absence.

f) In case there are truly exceptional circumstances, the Senate or the Director as Chairman Senate, may relax attendance requirements as they think fit.

1.4 It is possible for a student to get leave of absence from classes in deserving cases [Use Form AC/110 to apply for leave]. Dean (AA) may sanction leave on recommendation of Faculty Advisor and Head of the Department on one of the following grounds:

(i) Upto 10 working days of CASUAL LEAVE per year for incidental purposes.

(ii) Upto 15 (including intervening holidays) days of medical leave per year based on prescription of "Unfit for class" by Institute Medical Officer or on hospitalization and post-hospitalization rest approved by attending physician of the hospital, countersigned by Institute Medical Officer. The medical rest recommended by Institute Medical Officer must be on the student's medical record book, and that of external hospitals on the discharge certificate. Advice of rest must be dated prior to the rest period, not later, except under special circumstances**. It may be noted that such advice of rest is not sufficient for missing examinations, for which a specific recommendation must be obtained on Form AC/112.** The first five days of medical leave will count towards payment of fellowship, but not for satisfying attendance requirement. It is because the 15% concession in attendance requirement includes few days of minor sickness.

(iii) Participation in inter-NIT or other national level student competitions inside or outside the Institute. To avail such leave of absence from classes, a student should be selected by SAC to represent the Institute through a process of open competition. A copy of appropriate office order of SAC must be enclosed with the application. (Limited to 5 working days per semester.) [use Form AC/111]

(iv) for academic work or presentation of papers related to final year project, if the project involves visit to Industry or other Institutes or to participate in a Conference. The application must be recommended by the Project Guide and relevant documents are to be enclosed. (Limited to 5 working days in a semester.) [use Form AC/111]

(v) for officially arranged placement programmes on recommendation of Professor, T & P. (Limited to 5 working days in a semester.) [use Form AC/111]

(vi) The Director, as Chairman Senate may approve leave beyond this period upto 40 working days on ground of prolonged illness or unusually serious circumstances. Consideration will be given to students who give prior and continuous information either directly or through parents, project guide or faculty advisor. Family functions (social or religious), illness of family members, participation in student activities such as organizing functions or raising money, preparing for other examinations or searching of jobs are not adequate grounds for leave of absence from classes (including project work).

It should also be appreciated that a single student is unlikely to require all the categories of leave listed above during all the semesters. The Dean (AA) or Director will sanction leave under any of the above categories only when he is convinced that the leave will not adversely affect the student's academic programme.

1.5 A student will give a list of missed classes (course wise) in his leave application. If approved, the student will be deemed to be present in classes during that many hours for the purpose of computing unauthorized absence from classes.

1.6 In the project period (3rd and 4th semesters), if a student has poor attendance or unsatisfactory record of active work in. the department, as perceived by the supervisor and concurred by the DAC, the date of thesis submission shall be extended by 2 to 6 months without fellowship. The evaluation of the thesis may be done along with the student's batch mates or with students of next batch as decided by DAC.

1.7 A student may be given mess rebate (in units of one day) by the Warden of the hall for the period of approved leave and permission to leave station. For this purpose he must produce the approval by the competent authority and submit a photocopy if the Warden so desires. Medical 'rest' while in Rourkela will not qualify for mess rebate, nor will absence from hostel without proper approval to leave station. Minimum duration of absence should be 5 days to qualify for mess rebate.

1.8 No sanction of leave is necessary if a student wants to leave station over weekend or holidays, except when there is a scheduled compensatory class. No mess rebate is admissible for such absence. The student, however, is required to inform the Warden of his hall of residence before leaving Rourkela.

1.9 Form AC/111 will be used by students seeking permission with or without financial support to travel for academic or extra-curricular work. Such absence from classes shall NOT be counted as leave.

Assessment of Performance

1.1 There will be continuous assessment of a student's performance throughout the semesters and grades will be awarded by the Subject Teacher.

1.2 In general, there is no strict marks-to-grade linkage. The following should be taken as a guideline to ensure uniformity of grading among, all courses.

(a) For arriving at a grade obtained by a student for a particular subject, initially numeric marks obtained by the student out of 100 (hundred) are to be determined and then the same is to be converted to letter grade following the guidelines given in Appendix-II.

(b) For theory subjects, the subcomponents and the respective weights assigned to them are given below.

Subcomponent	**Weight**
Teacher's Assessment (T.A.)	20%
Mid-Semester Examination	30%
End-Semester Examination	50%

(c) For assigning marks in Teacher's Assessment (T.A.), performance in home assignments, class tests, tutorials, quizzes, viva-voce, attendance etc. are to be considered. It is recommended that at least two class tests for 4 credit theory courses and 1 test for 3 credit theory courses are to be conducted for a subject. The weights of different subcomponents of T.A. may be announced to the students by the teacher at the beginning of the Semester.

(d) In case of students given an F, I or X grade, the teacher must submit the marks under T.A. head to the Department Office for use in future.
(e) For assignment of marks in design/ laboratory component (P - component) the relevant subcomponents that are to be considered are: day-to-day work, regularity, tests, assignments, viva-voce etc. Percentage weights of the different subcomponents in deciding the final marks are to be announced at the beginning of the Semester. The evaluation process must be completed before the beginning of end semester examination.

Unlike purely examining universities, design and laboratory courses at NIT Rourkela will put greater emphasis on day to day work than on end semester examinations. To the extent possible, design and laboratory work should be completed and evaluated every class thus ensuring continuous evaluation. Final examination and/or viva voce, if any, may not carry more than 20% marks. No external examiner shall be associated with evaluation of design/laboratory or theory courses.

1.3 Class tests, assignments, tutorials, viva-voce, laboratory assignments, etc., are the constituent components of continuous assessment process, and a student must fulfill all these requirements as prescribed by the teacher of the subject. If due to any compelling reason (such as participation in national/international events with due approval of the institute, personal illness, calamity in the family, etc.) a student fails to meet any of the requirements within the scheduled date and time, the teacher may take such steps (including conduction of compensatory tests/examinations) as are deemed fit to ensure a fair assessment.

Examination

1.1 The departments will conduct the Mid-semester and End-semester Examinations in respect of theory subjects unless otherwise arranged. The Chairman of the Departmental Academic Committee (PG&R) will arrange the examination schedule, invigilation duties, and dispatch of answer scripts to the teachers and collection of grades. In departments with a single M.Tech. Programme, the course teacher may conveniently (not mandatory) be assigned the invigilation duty for the examination. The examinations will normally be "closed book type", where the students are not permitted to bring any material from home or hostel. All necessary charts, tables, codes etc. will be provided by the department. It is the teacher's responsibility to ensure that the required materials are made available to the invigilators. While normal scientific calculators are permitted, other electronic devices such as advanced programmable calculators and calculators containing communication devices are forbidden. Any exception to these provisions must be specially approved by the Senate.

On request from a department, the Institute shall provide sick room facility with medical attention inside the Institute building or in a nearby hospital as deemed convenient by the Institute to assist students who may fall sick during the examinations.

1.2 (a) A student will be permitted to appear in an examination, only if he/she has:
(i) attendance record as per these regulations in theory and laboratory classes and has completed the assignment works given.
(ii) paid all Institute and Hall dues of the semester.
(iii) not been debarred from appearing in the examination as a result of disciplinary proceedings, or on recommendation of the subject teacher.
(iv) has formally registered for the subjects at the beginning of the semester.

(b) A student may be debarred from appearing at the Mid-Semester or End-Semester Examination in the subject on the report of Subject Teacher if his
(i) attendance at lecture/tutorial/ laboratory classes in that subject has not been satisfactory during the period, and/or,
(ii) Performance in the assignment works in that subject during the semester has not been satisfactory.

1.3 The final grades awarded to the students in a subject must be submitted by the teacher, within ten days from the date of holding the Examination to the concerned Head of the Department for onward transmission to the Examination Office, which has to be done by the. Head on the same or next working day. The teacher will submit a separate report on all students obtaining F 0T I grades on Forms AC/121 and AC/122. A teacher, at his discretion, may display the grades (including partial lists) on his door or on any electronic forum. Display of grades by a teacher is for benefit of students, and cannot be cited for legal purposes.

1.4 The Examination Office will place the results and statistical reports of all examinations before the PGPEC, which will examine them and recommend to the Senate for approval. In case the Senate meeting is delayed, the recommended results can be published with approval of the Chairman, Senate. The same may be ratified by the Senate it its next meeting. The Senate has the authority to correct any mistake in the results, even if they are already approved by the Chairman.

1.5 For the benefit of and as a process of learning by the students, the scripts after correction of all class tests, mid-semester examinations assignments etc. will be shown to the students within 3 weeks from the date of Tests / Examinations. The evaluated scripts of the end-semester examinations are to be shown to the students at the beginning of the next semester, but not later than 2 weeks from the starting of classes. There is no limit on how early a teacher can show the evaluated scripts to the students.

1.6 Any change of grade of a student in a subject [Form AC/120], consequent upon detection of any genuine error of omission and/or commission on part of the concerned teacher, must be recommended by the Departmental Academic Committee and forwarded by the Head of the concerned Department to the Examination Office within three weeks from the date of commencement of the next semester. Every Department will send one comprehensive report for each semester in a standard format.

1.7 If a student is dissatisfied with his/her grade, he/she may bring it to the attention of the teacher within two weeks from the first day of commencement of classes in the next semester. The teacher may change the grades if he finds an error in evaluation. The teacher will report the change of grade to the Departmental Academic Committee [Form AC/120] along with all relevant papers (answer scripts, attendance register etc.) before a specified date. The DAC will submit a consolidated report as per standard form to the Examination office for correction of records. If the student still feels aggrieved, he/ she will file a formal complaint with Dean (AA) through his/her faculty advisor and HOD with a copy to the teacher (evaluator). If no complaint is filed within one month from the first day of classes in the next semester, the student is deemed to have accepted the results and no further change of grade is permitted.

1.8 The teachers are expected to retain all answer scripts, assignments and laboratory records for a period of two months from the starting of classes in the next semester. After that the material may be disposed off, except for the students who have filed a complaint. In case of complaint filed before the expiry of two months, the material need to be saved till all disputes are settled and final grade awarded. All relevant material will be handed over by the teacher to the Head of the Department for safe keeping in the department office. The teacher, at his discretion, may retain a photo copy.

1.9 There is no provision for supplementary or alternative mid semester exams in an M.Tech. Course. A student who secures an F grade in First or Second semester or misses an examination due to a compelling reason, may appear at the examinations during 3rd or 4th semester as backlog papers, the later being subject to satisfactory attendance record. In such cases the grade will be reduced by one step, except in case of P grades which remain unchanged. A student can get full credit if he misses examination for a compelling reason and has over 95% attendance. If a student does not satisfy attendance requirements, he will have to formally register for the courses during 3rd or 4th semesters, in which case his date of thesis submission gets deferred.

Withdrawal

1.1 In case of a student already employed, or if he secures new placement (including long term internship), he may be allowed to become nonresident on the recommendation of Faculty adviser and Head of the Department and with approval of Dean (AA) after he has completed successfully two semesters of course work. [Students with any F, I, X or UR grade at the end of second semester will not be granted withdrawal.] The student so permitted has to pay the prescribed fees in all subsequent semesters till submission of thesis. In such cases, however, the student has to submit the dissertation not later than four years from the date of admission.

1.2 The following arrangement will be made for carrying out the project after a student takes withdrawal from the Institute in accordance with clause 10.1:

(i) If the withdrawal is taken before the end of the autumn semester, it will be necessary for the student to start afresh on his project with a joint supervisor from his employing organization. The student has to identify a suitable supervisor from the organization where he joins and submit the bio-data of the supervisor, his willingness to supervise the student and the consent of the organization to the Departmental Supervisor, who shall subsequently forward it to the Dean (Academic Affairs) through HOD for approval. The student can submit thesis from outside with a delay of at least one year.

(ii) If the withdrawal is taken after completion of the autumn semester, the student can work under the guidance of his present supervisor (if the supervisor certifies it to be feasible) and submit his thesis at least one year after his normal date of submission.

(iii) As a special case of clause 10.3 (ii), if the withdrawal is sought within one month prior to the scheduled date of thesis submission, the student is required to ask the employer for an extension of date of joining. If not agreed to by the employer, he may be granted withdrawal by Dean (AA). Copies of all relevant correspondence need to be submitted by the student to establish that an honest attempt was made by the student and his supervisor to obtain an extension of joining date. In such a scenario, the student may submit a partial thesis for evaluation. He / She can also appear at viva voce examination along with his batch mates. He / She will submit the complete thesis after putting in additional work before the end of following autumn semester which will be evaluated by a departmental board for award of the final grades. He / She will be awarded degree along with the next batch of students.

1.3 Students will not be entitled to any fellowship after taking withdrawal from the course.

Project Work and Submission of Thesis

1.1 The project is an important component of the Institute's M.Tech. programme. It gives an opportunity to the student to express his creative talents and prepare for his future career.

1.2 Each topic will be taken by one student only. In case of specially challenging problems, larger teams may work on a single problem, with the prior approval of Dean (AA).

1.3 The Departmental Academic Committee will invite research topics for M.Tech. projects from its own faculty (including adjunct faculty) and from other departments across the Institute towards the middle of the first semester. One member of the Committee may be designated to coordinate this activity. Faculty members may propose project topics, singly or in collaboration with a colleague from the same or another department. Co-Supervisors from industry or other institutions may also be accepted. The topics should be advanced in academic content and, preferably, relevant to industry/field application. It is expected that research topics offered by an academic group fall into a pattern, and reflect the long term research plans of the faculty members.

1.4 The Departmental Academic Committee will assign research topics to students at the end of the first semester (preferably by September 30), after taking into consideration the requirements of the projects and choice of the students.

Initial assignments of projects will generally be broad titles, which will crystallize as the work progresses. It is not mandatory for the student or his supervisor to inform the DAC about such incremental changes. In case of a major change of field during the course of a work, the DAC should be informed to decide if the student shall need additional time to complete the work.

1.5 M.Tech. projects may be analytical, computational, experimental or developmental or combination thereof. The department will make the necessary resources available to the students, including access to laboratory and computing facilities outside normal working hours. It will be the moral and legal responsibility of the supervisor (s) to arrange the facilities. Students are encouraged to discuss such matters with their supervisors, and if not satisfied, with HODs and higher authorities.

1.6 The Institute encourages research projects in collaboration with industry, R&D organizations and other reputed educational institutions. Such projects must be proposed and actively pursued by the faculty supervisor, instead of being a private arrangement between the student and the external Institution. The supervisor may propose to DAC a co-supervisor from the collaborating institution. The student may accept financial support from the external institution, to offset the additional cost of travel, and living expenses. But he cannot accept a second fellowship/scholarship while enjoying a fellowship from the Institute.

The Institute specifically discourages internships in industry where a student works in an organization without active participation by his supervisor in pursuing the research topic. Indicators of such arrangement are initiation of a problem after allotment of research topics, interview of the student by the company, long stay of student in the premises of the employing organization with intermittent visit to the Institute, absence of meetings between the supervisors from the industry and the Institute, withholding of information in the thesis by the company, absence of share of IPR to the faculty supervisor etc. Reputation of the industry, expertise of its engineers and standard of the research topic do not justify non-participation of the student in the Institute's academic programme.

1.7 The Head of the Department is the competent authority to approve travel of students for all academic purposes including those for working on research projects irrespective of the duration. Travel support from the Institute, however, needs to be approved by Dean (AA).

1.8 Each student will be given an official "Project Record Book" by the Institute. A guideline for Project Book is given in Appendix-III. All concepts, drawings, formulas, derivations, experimental observations, graphs, charts, photographs, computer flow charts and pseudo codes must be recorded by the student on this note book, which must be produced before all evaluation boards. There shall no blank pages in between the writings.

1.9 The student is required to submit formal project reports at the end of 3rd and 4th semesters that submitted at the end of the 4th semester being in the form of a well bound thesis. The Departmental Academic Committee will constitute one or more evaluation boards, for continuous monitoring of the projects. The Boards will examine the day to day records and conduct viva-voce and/or oral presentations by the students at least twice in each semester.

1.10 For the purpose of assignment of a grade in the 3rd semester, the following will be weightage of the different components:

Mid Semesters assessment by Supervisor (s) (based on day to day work and record book)	=	20%
Mid Semester assessment by Evaluation Board (based on record book only)	=	20%
End Semester assessment by Supervisor(s) (based on day to day work and record book)	=	20%
End Semester Assessment by Evaluation Board	=	20%

(based on oral presentation, viva-voce and record book)
Interim Project Report = 20%
(assessed by Evaluation Board)

1.11 For the assignment of a grade in the 4th semester, the following will be weightage of the different components.

Supervisor’s assessment
(twice in a semester 20% + 20%) = 40%
Assessment by Evaluation Board along with external examiner through oral presentation and viva -
Voce = 40%
Project Report = 20%
(external examiner)

The external examiners will be selected by Dean (AA) out of a panel of five experts suggested by the Departmental Academic Committee. Depending on the number of students and the variety of topics either one or two external experts may be invited. The invitation will be issued by the AR (Acad), further correspondence regarding date of viva voce and travel plans being made by the HOD or his nominee.

1.12 On completion of the examination process a student shall submit two bound copies of the thesis (three if there are two supervisors) to the Head of the Department - one for the Departmental Library and one copy to each of his supervisors. Loosely bound copies will not be accepted. The student is also required to submit two electronic copies of the thesis in prescribed format (PDF). The paper and electronic copies of the thesis will be archived in Institute and Departmental libraries and will be distributed by the Institute through Internet and other means.

1.13 On completion of evaluation, the Departmental Academic Committee or its subcommittee constituted for the purpose shall decide the grade awarded. If the performance of a student is unsatisfactory, the Committee may recommend one of the following:

(i) Rewriting of report and submission for evaluation.
(ii) Extension of time for completion of the work (the time duration is to be specified), [No fellowship to be given during extension period.)
(iii) Complete repetition of the project in the following year.

The resubmitted thesis will be evaluated by the Committee and the grade will be sent to the examination office. The committee may, at his discretion, seek advice of the external examiner.

1.14 Students who have been absent for a substantial duration during the project period, or have otherwise invested less than required time will be granted extension of time on recommendation of the supervisor or of the Evaluation Board. Such extension will be without fellowship.

The extension of duration shall not be less than the number of days lost by unauthorized absence during the project period.

If the extension of thesis submission is for duration less than 2 months, the oral examination can be carried out along with the same batch students. Otherwise, a student can complete his work and submit his thesis; but his thesis will be evaluated along with the student of next batch.

1.15 Rights to all intellectual property generated in the project shall be distributed equally among the students, technicians and the supervisors, except where the concerned workers mutually settle on a distribution formula. If a project is supported by a sponsor, the sponsoring organization will be given IPR as per the contract, and the balance divided among the faculty, students and technicians.

1.16 Like course credits, it will be possible for a student to carry out his project in another NIT, lIT or institution of comparable standing in India or abroad under the joint supervision of faculty members of both institutions, and transfer the credits to NIT Rourkela. Such arrangements will need the approval of the Senate [or Chairman Senate on its behalf] on case to case basis.

Graduation Requirement

1.1 In order to qualify for the M. Tech. degree of the Institute, a student must:
   (a) complete all credit requirements for the degree as laid down in the prescribed curriculum of the discipline, with a minimum grade' P , in each subject.
   (b) obtain a CGPA of 6.00 or higher at the end of the semester in which he completes all the requirements of the degree, separately in both course work (1st and 2nd semesters) and thesis (3rd and 4th semesters) components.
   (c) have cleared all dues of the Institute, Halls of residence, Library, Department and Student Activity Centre.

1.2 Normally a student should complete all the requirements consecutively in four semesters for the M. Tech. degree. [Six semesters in the Slow Pace programme.] Students taking withdrawal in the middle of a programme will be governed by rules given in Section 10.

1.3 All graduating students are required to submit their suggestion for improvement of courses to the Director in Form AC/123. The suggestions will be summarized on Form AC/124 and presented before the Senate.

1.4 Students who do not satisfy all graduation requirements within 4 years from the date of admission will leave the institute without being awarded a degree.

CURRICULA OF M.TECH PROGRAMME

DEPARTMENT OF BIOTECHNOLOGY AND MEDICAL ENGINEERING

Curriculum of M. Tech. (BIOTECHNOLOGY ENGINEERING)

FIRST SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 643	Advanced Protein Engineering	3-1-0	4
2	BM 623	Advanced Tissue Engineering	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	BM 673	Cell and Protein Processing Laboratory	0-0-3	2
7	BM 671	Advanced Tissue Engineering Laboratory	0-0-3	2
8	BM 685	Seminar & Technical Writing – I	0-0-3	2
		TOTAL	15-5-9	**26**

SECOND SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 652	Advanced Biochemical Engineering	3-1-0	4
2	BM 654	Advanced Bioseparation	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	BM 670	Advanced Biochemical Engineering Laboratory	0-0-3	2
7	BM 672	Advanced Bioseparation Laboratory	0-0-3	2
8	BM 686	Seminar & Technical Writing – II	0-0-3	2
		TOTAL	15-5-9	**26**

THIRD SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 687	Seminar & Technical Writing – III	0-0-3	2
2	BM 691	Summer Research/ Industrial Project	0-0-0	4
3	BM 693	Research Project Work – I	0-0-0	8
4	BM 695	Research Project Review – I	0-0-0	8
		TOTAL	0-0-3	**22**

FOURTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 688	Seminar & Technical Writing – IV	0-0-3	2
2	BM 692	Comprehensive Viva Voce	0-0-0	4
3	BM 694	Research Project Work – II	0-0-0	8
4	BM 696	Research Project Review - II	0-0-0	4
5	BM 699	Dissertation	0-0-0	8
		TOTAL	0-0-3	**26**

DEPARTMENT OF BIOTECHNOLOGY AND MEDICAL ENGINEERING

Curriculum of M. Tech. (BIOMEDICAL ENGINEERING)

FIRST SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 621	Advanced Biomaterials	3-1-0	4
2	BM 611	Biomedical Signal Processing and Analysis	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	BM 675	Biomedical Equipment Design Laboratory	0-0-3	2
7	BM 677	Biomedical Signal Processing Laboratory	0-0-3	2
8	BM 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL			15-5-9	**26**

SECOND SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 612	Advanced Biomedical Instrumentation		4
2	BM 614	Medical Image Processing	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	BM 674	Advanced Biomedical Instrumentation Laboratory	0-0-3	2
7	BM 676	Biomedical Image Processing Laboratory	0-0-3	2
8	BM 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL			15-5-9	**26**

THIRD SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 687	Seminar & Technical Writing – III	0-0-3	2
2	BM 691	Summer Research/ Industrial Project	0-0-0	4
3	BM 693	Research Project Work – I	0-0-0	8
4	BM 695	Research Project Review – I	0-0-0	8
TOTAL			0-0-3	**22**

FOURTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	BM 688	Seminar & Technical Writing – IV	0-0-3	2
2	BM 692	Comprehensive Viva Voce	0-0-0	4
3	BM 694	Research Project Work - II	0-0-0	8
4	BM 696	Research Project Review - II	0-0-0	4
5	BM 699	Dissertation	0-0-0	8
TOTAL			0-0-0	**26**

LIST OF PROFESSIONAL ELECTIVES

SL.No	Sub. code	Subjects	L-T-P	Credits
1.	BM 601	Quantitative Physiology	3-1-0	4
2.	BM 603	Diagnostic Imaging and Radiation Biology	3-1-0	4
3.	BM 613	Safety consideration of Medical Devices	3-1-0	4
4.	BM 616	BioMems and Biosensors	3-1-0	4
5.	BM 622	Nanotechnology in Medical Application	3-1-0	4
6.	BM 624	Surface Engineering of Medical Implants	3-1-0	4
7.	BM 625	Nanobiotechnology	3-1-0	4

8.	BM 626	Biomaterials and Tissue Characterization	3-1-0	4
9.	BM 627	Cryo-Tissue Engineering	3-1-0	4
10.	BM 628	Bioceramics and Biocomposites	3-1-0	4
11.	BM 629	Regenerative medicine and stem cell	3-1-0	4
12.	BM 631	Computational Methods in Biomedical Engineering	3-1-0	4
13.	BM 632	Computational Fluid Dynamics in Bioengineering	3-1-0	4
14.	BM 633	Artificial organ and Rehabilitative Engineering	3-1-0	4
15.	BM 634	Advanced Biomechanics	3-1-0	4
16.	BM 640	Fluorescence Techniques in Bioengineering	3-1-0	4
17.	BM 641	Immunotechnology	3-1-0	4
18.	BM 642	Biophysics & Structural Biology	3-1-0	4
19.	BM 644	Advanced Cell & Molecular Biology	3-1-0	4
20.	BM 645	Cell and Protein Processing	3-1-0	4
21.	BM 646	Molecular Biology of Cancer	3-1-0	4
22.	BM 647	Advanced Bioinformatics	3-1-0	4
23.	BM 648	Protein conformational diseases and therapy	3-1-0	4
24.	BM 649	Recombinant DNA Technology	3-1-0	4
25.	BM 651	Industrial Microbiology	3-1-0	4
26.	BM 653	Bioprocess and Plant Design	3-1-0	4
27.	BM 656	Pharmaceutical Technology	3-1-0	4
28.	BM 661	Biological Waste Treatment	3-1-0	4
29.	BM 662	Nutritional Sciences and Plant Based Products	3-1-0	4
30.	BM 681	Special Topics in Biotechnology & Medical Engineering – I		3/4
31.	BM 682	Special Topics in Biotechnology & Medical Engineering - II		3/4
32.	BM 683	Special Laboratory in Biotechnology & Medical Engineering - I	0-0-3	2
33.	BM 684	Special Laboratory in Biotechnology & Medical Engineering - II	0-0-3	2

LIST OF PROFESSIONAL ELECTIVES OFFERED BY OTHER DEPARTMENTS

SL.No	Sub. code	Subject	L-T-P	Credits
1.	CH 646	Nano Science & Technology	3-1-0	4
2.	CR 626	Advanced Composites	3-1-0	4
3.	CR 646	Advances in Bio-ceramics	3-1-0	4
4.	CR 652	Computer Aided Designing and Modeling of Ceramic Systems	3-1-0	4
5.	CS 638	Pattern Recognition	3-1-0	4
6.	CS 643	Embedded Systems	3-1-0	4
7.	EC 600	Architecture of DSP	3-1-0	4
8.	EC 628	VLSI Signal Processing	3-1-0	4
9.	EC 642	Advanced Techniques in Digital Signal	3-1-0	4
10.	EC 644	Soft Computing	3-1-0	4
11.	EC 646	Adaptive Signal Processing	3-1-0	4
12.	EE 634	Robotics & Automation	3-1-0	4
13.	EE 636	Intelligent Control	3-1-0	4
14.	EE 637	Soft Computing Techniques	3-1-0	4
15.	EE 644	Digital Image Processing	3-1-0	4
16.	EE 668	Instrumentation and Sensors	3-1-0	4

SUMMARY OF COURSES

Sub Discipline: Miscellaneous

BM 601	Quantitative Physiology	3-1-0	4
BM 603	Diagnostic Imaging and Radiation Biology	3-1-0	4

Sub Discipline: Medical Electronics and Instrumentation

BM 611	Biomedical Signal Processing and Analysis	3-1-0	4
BM 612	Advanced Biomedical Instrumentation	3-1-0	4
BM 613	Safety consideration of Medical Devices	3-1-0	4
BM 614	Medical Image Processing	3-1-0	4
BM 616	BioMems and Biosensors	3-1-0	4

Sub Discipline: Tissue Engineering and Biomaterials

BM 621	Advanced Biomaterials	3-1-0	4
BM 622	Nanotechnology in Medical Application	3-1-0	4
BM 623	Advanced Tissue Engineering	3-1-0	4
BM 624	Surface Engineering of Medical Implants	3-1-0	4
BM 625	Nanobiotechnology	3-1-0	4
BM 626	Biomaterials and Tissue Characterization	3-1-0	4
BM 627	Cryo-Tissue Engineering	3-1-0	4
BM 628	Bioceramics and Biocomposites	3-1-0	4
BM 629	Regenerative medicine and stem cell	3-1-0	4

Sub-Discipline: Biotransport and Biomechanics

BM 631	Computational Methods in Biomedical Engineering	3-1-0	4
BM 632	Computational Fluid Dynamics in Bioengineering	3-1-0	4
BM 633	Artificial organ and Rehabilitative Engineering	3-1-0	4
BM 634	Advanced Biomechanics	3-1-0	4

Sub-Discipline: Cell and Molecular Engineering

BM 640	Fluorescence Techniques in Bioengineering	3-1-0	4
BM 641	Immunotechnology	3-1-0	4
BM 642	Biophysics & Structural Biology	3-1-0	4
BM 643	Advanced Protein Engineering	3-1-0	4
BM 644	Advanced Cell & Molecular Biology	3-1-0	4
BM 645	Cell and Protein Processing	3-1-0	4
BM 646	Molecular Biology of Cancer	3-1-0	4
BM 647	Advanced Bioinformatics	3-1-0	4
BM 648	Protein conformational diseases and therapy	3-1-0	4
BM 649	Recombinant DNA Technology	3-1-0	4

Sub-Discipline: Bioprocess Engineering

BM 651	Industrial Microbiology	3-1-0	4
BM 652	Advanced Biochemical Engineering	3-1-0	4
BM 653	Bioprocess and Plant Design	3-1-0	4
BM 654	Advanced Bioseparation	3-1-0	4
BM 656	Pharmaceutical Technology	3-1-0	4

Sub-Discipline: Agricultural and Environmental Biotechnology

BM 661	Biological Waste Treatment	3-1-0	4

BM 662	Nutritional Sciences and Plant Based Products	3-1-0	4

Sub-discipline: Laboratory Courses

BM 670	Advanced Biochemical Engineering Laboratory	0-0-3	2
BM 671	Advanced Tissue Engineering Laboratory	0-0-3	2
BM 672	Advanced Bioseparation Laboratory	0-0-3	2
BM 673	Cell and Protein Processing Laboratory	0-0-3	2
BM 674	Advanced Biomedical Instrumentation Laboratory	0-0-3	2
BM 675	Advanced Biomedical Equipment Design Lab	0-0-3	2
BM 676	Biomedical Image Processing Laboratory	0-0-3	2
BM 677	Biomedical Signal Processing Laboratory	0-0-3	2

Sub-discipline: Project, Seminar and Special Courses

BM 681	Special Topic in Biotechnology & Medical Engineering - I		3/4
BM 682	Special Topic in Biotechnology & Medical Engineering – II		3/4
BM 683	Special Laboratory in Biotechnology & Medical Engineering	0-0-3	2
BM 684	Special Laboratory in Biotechnology & Medical Engineering	0-0-3	2
BM 685	Seminar & Technical Writing - I	0-0-3	2
BM 686	Seminar & Technical Writing - II	0-0-3	2
BM 687	Seminar & Technical Writing - III	0-0-3	2
BM 688	Seminar & Technical Writing - IV	0-0-3	2
BM 691	Summer Research/ Industrial Project		4
BM 692	Comprehensive Viva Voce		4
BM 693	Research Project – I		8
BM 694	Research Project – II		8
BM 695	Research Project Review-I		8
BM 696	Research Project Review-II		4
BM 699	Dissertation		8

DEPARTMENT OF CIVIL ENGINEERING

Curriculum of M.Tech. (STRUCTURAL ENGINEERING)

FIRST SEMESTER

Sl. No	Subj. Code	Subjects	L-T-P	Credits
1.	CE 611	Matrix Method of Structural Analysis	3-1-0	4
2.	CE 613	Analysis and Design of Plates & Shells	3-1-0	4
3.		Professional Elective - I	3-1-0	4
4.		Professional Elective - II	3-1-0	4
5.		Professional Elective - III	3-1-0	4
6.	CE 671	Structural Engineering Laboratory	0-0-3	2
7.	CE 681	Computational Laboratory	0-0-3	2
8.	CE 685	Seminar and Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1.	CE 604	Finite Element Method	3-1-0	4
2.	CE 610	Structural Dynamics and Earthquake Engg.	3-1-0	4
3.	CE 612	Stability of Structures	3-1-0	4
4.		Professional Elective-IV	3-1-0	4
5.		Professional Elective-V	3-1-0	4
6.	CE 670	Structural Engineering Design Practice	0-0-3	2
7.	CE 680	Computational Laboratory – II	0-0-3	2
8.	CE 686	Seminar and Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 687	Seminar & Technical Writing – III	0-0-3	2
2	CE 691	Summer Research/Industrial Project	0-0-0	4
3	CE 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 688	Seminar & Technical Writing – IV	0-0-3	2
2	CE 692	Comprehensive Viva Voce	0-0-0	4
3	CE 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M.Tech. (GEO TECHNICAL ENGINEERING)

FIRST SEMESTER

Sl. No	Subj. Code	Subjects	L-T-P	Credits
1	CE 621	Advanced Soils Mechanics	3-1-0	4
2	CE 623	Soil-Structure Interaction	3-1-0	4
3	CE 625	Soil Exploration and Analysis of Foundations	3-1-0	4
4		Professional Elective-I	3-1-0	4
		Professional Elective-II	3-1-0	4
6	CE 673	Geotechnical Engineering Laboratory	0-0-3	2
7	CE 681	Computational Laboratory	0-0-3	2
8	CE 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1.	CE 620	Ground Improvement Techniques	3-1-0	4
2.	CE 622	Stability Analysis of Slopes, Dams and Embankments	3-1-0	4
3.		Professional Elective – III	3-1-0	4
4.		Professional Elective – IV	3-1-0	4
5.		Professional Elective – V	3-1-0	4
6.	CE 672	Geotechnical Engineering Practice	0-0-3	2
7.	CE 682	Computer Aided Foundation Engineering Design	0-0-3	2
8.	CE 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 687	Seminar & Technical Writing - III	0-0-3	2
2	CE 691	Summer Research/Industrial Project	0-0-0	4
3	CE 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 688	Seminar & Technical Writing – IV	0-0-3	2
2	CE 692	Comprehensive Viva Voce	0-0-0	4
3	CE 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M.Tech. (TRANSPORTATION ENGINEERING)

FIRST SEMESTER

Sl. No.	Sub. Code	Subjects	L-T-P	Credits
1	CE 641	Transportation Systems Planning	3-1-0	4
2	CE 643	Highway and Airport Pavement Materials	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	CE 681	Computational Laboratory	0-0-3	2
7	CE 677	Transportation Engineering Laboratory	0-0-3	2
8	CE 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No.	Sub. Code	Subjects	L-T-P	Credits
1.	CE 640	Analysis and Structural Design of Pavements	3-1-0	4
2.	CE 642	Traffic Engineering & Traffic Flow	3-1-0	4
3		Professional Elective – III	3-1-0	4
4		Professional Elective – IV	3-1-0	4
5		Professional Elective – V	3-1-0	4
6.	CE 676	Traffic &Transportation Engineering Design Practice	0-0-3	2
7.	CE 702	Traffic & Transportation Engineering Laboratory	0-0-3	2
8.	CE 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 687	Seminar & Technical Writing – III	0-0-3	2
2	CE 691	Summer Research/Industrial Project	0-0-0	4
3	CE 693	Research Project Work – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 688	Seminar & Technical Writing – IV	0-0-3	2
2	CE 692	Comprehensive Viva Voce	0-0-0	4
3	CE 694	Research Project Work – II	0-0-0	20
		TOTAL		**26**

Curriculum of M.Tech. (WATER RESOURCES ENGINEERING)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	CE 651	Hydrologic Element and Analysis	3-1-0	4
2	CE 653	Advanced Fluid Mechanics	3-1-0	4
3	CE 655	Computational Fluid Dynamics	3-1-0	4
4		Professional Elective – I	3-1-0	4
5		Professional Elective – II	3-1-0	4
7	CE 675	Hydraulics and Hydrologic Engineering Laboratory	0-0-3	2
8	CE 681	Computational Laboratory	0-0-3	2
9	CE 685	Seminar and Technical Writing – I	0-0-3	2
		TOTAL		**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	CE 650	Hydrology and Hydraulics of Surface and Sub-surface Water	3-1-0	4
2	CE 652	Open Channel Flow	3-1-0	4
3	CE 654	Water Resources Management	3-1-0	4
4		Professional Elective – III	3-1-0	4
5		Professional Elective – IV	3-1-0	4
6	CE 636	Water Resources Engineering Design Practice	0-0-3	2
7	CE 684	Computer Application in Water Resources Engineering	0-0-3	2
8	CE 686	Seminar and Technical Writing – II	0-0-3	2
		TOTAL		**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 687	Seminar & Technical Writing – III	0-0-3	2
2	CE 691	Summer Research/Industrial Project	0-0-0	4
3	CE 693	Research Project Work – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 688	Seminar & Technical Writing – IV	0-0-3	2
2	CE 692	Comprehensive Viva Voce	0-0-0	4
3	CE 694	Research Project Work – II	0-0-0	20
		TOTAL		**26**

Curriculum of M.Tech. (ENVIRONMENTAL ENGINEERING & MANAGEMENT)

FIRST SEMESTER

Sl. No.	Sub. Code	Subjects	L-T-P	Credits
1	CE 624	Ground Water & Flow Through Porous Media	3-1-0	4
2	CE 631	Principles of Environmental Management	3-1-0	4
3	CE 633	Water and Wastewater Engineering	3-1-0	4
4		Professional Elective – I	3-1-0	4
5		Professional Elective – II	3-1-0	4
6	CE 679	Environmental Engineering Laboratory	0-0-3	2
7	CE 681	Computational Laboratory	0-0-3	2
8	CE 685	Seminar and Technical Writing – I	0-0-3	2
		TOTAL		**26**

SECOND SEMESTER

Sl. No.	Subj. Code	Subjects	L-T-P	Credits
1	CE 630	Advanced Wastewater Treatment	3-1-0	4
2	CE 632	Advanced Air Quality Management	3-1-0	4
3		Professional Elective – III	3-1-0	4
4		Professional Elective – IV	3-1-0	4
5		Professional Elective – V	3-1-0	4
6	CE 678	Environmental Engineering Design Practice	0-0-3	2
7	CE 704	Remote Sensing & GIS Laboratory	0-0-3	2
8	CE 686	Seminar and Technical Writing – II	0-0-3	2
		TOTAL		**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 687	Seminar & Technical Writing – III	0-0-3	2
2	CE 691	Summer Research/Industrial Project	0-0-0	4
3	CE 693	Research Project Work – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CE 688	Seminar & Technical Writing – IV	0-0-3	2
2	CE 692	Comprehensive Viva Voce	0-0-0	4
3	CE 694	Research Project Work – II	0-0-0	20
		TOTAL		**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Subj. Code	Subjects	L-T-P	Credits
1.	CE 601	Material Technology	3-1-0	4
2.	CE 602	Optimization Methods & Its Application in Civil Engineering	3-1-0	4
3.	CE 614	Advanced Reinforced Concrete Design	3-1-0	4
4.	CE 615	Applied Elasticity and Plasticity	3-1-0	4
5.	CE 616	Advanced Steel Design	3-1-0	4
6.	CE 617	Bridge Engineering	3-1-0	4
7.	CE 618	Pre-Stressed Concrete	3-1-0	4
8.	CE 619	Composite Structures	3-1-0	4
9.	CE 626	Rock Mechanics	3-1-0	4
10.	CE 627	Dynamics of Soils and Foundations	3-1-0	4

11.	CE 628	Earth Retaining Structures	3-1-0	4
12.	CE 629	Earthquake Geotechnical Engineering	3-1-0	4
13.	CE 634	Industrial Pollution Prevention & Clean Technologies	3-1-0	4
14.	CE 635	Environmental Impact & Risk Assessment	3-1-0	4
15.	CE 638	Environmental Legislation & Policy	3-1-0	4
16.	CE 644	Planning & Design of Airports	3-1-0	4
17.	CE 645	Geometric Design of Highways	3-1-0	4
18.	CE 646	Evaluation and Strengthening of Pavements	3-1-0	4
19.	CE 647	Transportation and Environment	3-1-0	4
20.	CE 648	Transportation Systems, Analysis & Modeling	3-1-0	4
21.	CE 649	Advanced Railway Engineering	3-1-0	4
22.	CE 657	Water Quality Modeling & Management	3-1-0	4
23.	CE 660	High Rise Structures	3-1-0	4
24.	CE 661	Strength & Deformation Behaviour of Soil	3-1-0	4
25.	CE 662	Environmental Geotechnics	3-1-0	4
26.	CE 663	Mass Transit Systems	3-1-0	4
27.	CE 664	Advances in Remote Sensing and GIS	3-1-0	4
28.	CE 665	Ground Water Assessment & Development	3-1-0	4
29.	CE 668	Special Topic in Civil Engineering-I	3-1-0	4
30.	CE 669	Special Topic in Civil Engineering –II	3-1-0	4
31.	CE 689	Special Laboratory in Civil Engineering – I	0-0-3	2
32.	CE 690	Special Laboratory in Civil Engineering – II	0-0-3	2
33.	CE 888	Design of Hydraulic Systems	3-1-0	4
34.	CE 999	Fluvial Hydraulics	3-1-0	4

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

1.	CH 643	Environmental Management System	3-1-0	4
2.	CH 645	Bioprocess Engineering	3-1-0	4
3.	CH 648	Advanced Environmental Biotechnology	3-1-0	4
4.	CH 668	Evolutionary Computation	3-1-0	4
5.	CR 651	Techniques of Materials Characterization	3-1-0	4
6.	CS 612	Software Engineering	3-1-0	4
7.	CS 637	Digital Signal Processing	3-1-0	4
8.	EE 637	Soft Computing Techniques	3-1-0	4
9.	MA 524	Statistical Methods	3-1-0	4
10.	MA 551	Numeric Analysis	3-1-0	4
11.	MA 630	Advanced Fluid Dynamics	3-1-0	4
12.	ME 611	Vibration Analysis & Diagnostics	3-1-0	4
13.	ME 614	Experimental Stress Analysis	3-1-0	4
14.	MM 646	Composite Materials	3-1-0	4
15.	MN 608	Tunneling	3-1-0	4
16.	MN 614	Rock Mechanics Application to Environmental Problems	3-1-0	4
17.	MN 618	Hazardous Waste Management	3-1-0	4

SUMMARY OF COURSES

Sub discipline: Structural Engineering

CE 601	Material Technology	3-1-0	4
CE 604	Finite Element Method	3-1-0	4
CE 610	Structural Dynamics and Earthquake Engineering	3-1-0	4
CE 611	Matrix Method of Structural Analysis	3-1-0	4
CE 612	Stability of Structures	3-1-0	4
CE 613	Analysis & Design of Plates & Shells	3-1-0	4
CE 614	Advanced Reinforced Concrete Design	3-1-0	4
CE 615	Applied Elasticity and Plasticity	3-1-0	4
CE 616	Advanced Steel Design	3-1-0	4
CE 617	Bridge Engineering	3-1-0	4
CE 618	Pre Stressed Concrete	3-1-0	4
CE 619	Composite Structures	3-1-0	4
CE 660	High Rise Structures	3-1-0	4

Sub discipline: Geotechnical Engineering

CE 602	Optimization Methods &Its Application In Civil Engineering	3-1-0	4
CE 620	Ground Improvement Techniques	3-1-0	4
CE 621	Advanced Soil Mechanics	3-1-0	4
CE 622	Stability Analysis of Slopes, Dams and Embankments	3-1-0	4
CE 623	Soil-Structure Interaction	3-1-0	4
CE 624	Ground Water & Flow through Porous Media	3-1-0	4
CE 625	Soil Exploration and Analysis of Foundations	3-1-0	4
CE 626	Rock Mechanics	3-1-0	4
CE 627	Dynamics of Soils and Foundations	3-1-0	4
CE 628	Earth Retaining Structures	3-1-0	4
CE 629	Earthquake Geotechnical Engineering	3-1-0	4
CE 661	Strength & Deformation Behaviour of Soil	3-1-0	4
CE 662	Environmental Geotechnics	3-1-0	4

Sub discipline: Environmental Engineering

CE 630	Advanced Wastewater Treatment	3-1-0	4
CE 631	Principles of Environmental Management	3-1-0	4
CE 632	Advanced Air Quality Management	3-1-0	4
CE 633	Water and Wastewater Engineering	3-1-0	4
CE 634	Industrial Pollution Prevention & Clean Technologies	3-1-0	4
CE 635	Environmental Impact & Risk Assessment	3-1-0	4
CE 638	Environmental Legislation & Policy	3-1-0	4

Sub discipline: Transportation Engineering

CE 640	Analysis and Structural Design of Pavements	3-1-0	4
CE 641	Transportation Systems Planning	3-1-0	4
CE 642	Traffic Engineering and Traffic Flow	3-1-0	4
CE 643	Highway and Airport Pavement Materials	3-1-0	4
CE 644	Planning & Design of Airports	3-1-0	4
CE 645	Geometric Design of Highways	3-1-0	4
CE 646	Evaluation and Strengthening of Pavements	3-1-0	4
CE 647	Transportation and Environment	3-1-0	4
CE 648	Transportation Systems, Analysis & Modeling	3-1-0	4

CE 649	Advanced Railway Engineering	3-1-0	4
CE 663	Mass Transit Systems	3-1-0	4

Sub discipline: Water Resources Engineering

CE 650	Hydrology and Hydraulics of Surface and Sub-Surface Water	3-1-0	4
CE 651	Hydrologic Element and Analysis	3-1-0	4
CE 652	Open Channel Flow	3-1-0	4
CE 653	Advanced Fluid Mechanics	3-1-0	4
CE 654	Water Resources Management	3-1-0	4
CE 655	Computational Fluid Dynamics	3-1-0	4
CE 656	Ground Water Resources Assessment and Management	3-1-0	4
CE 657	Water Quality Modeling & Management	3-1-0	4
CE 659	Water Resources Management	3-1-0	4
CE 664	Advances in Remote Sensing and GIS	3-1-0	4
CE 665	Ground Water Assessment & Development	3-1-0	4

Sub discipline: Miscellaneous

CE 668	Special Topic in Civil Engineering – I	3-1-0	4
CE 669	Special Topic in Civil Engineering – II	3-1-0	4

Sub discipline: Laboratory Courses

CE 636	Water Resources Engineering Design Practice	0-0-3	2
CE 670	Structural Engineering Design Practice	0-0-3	2
CE 671	Structural Engineering Laboratory	0-0-3	2
CE 672	Geotechnical Engineering Design Practice	0-0-3	2
CE 673	Geotechnical Engineering Laboratory	0-0-3	2
CE 675	Hydraulics and Hydrologic Engineering Laboratory	0-0-3	2
CE 676	Traffic & Transportation Engineering Design Practice	0-0-3	2
CE 677	Transportation Engineering Laboratory	0-0-3	2
CE 678	Environmental Engineering Design Practice	0-0-3	2
CE 679	Environmental Engineering Laboratory	0-0-3	2
CE 680	Computational Laboratory-II	0-0-3	2
CE 681	Computational Laboratory		
CE 682	Computer Aided Foundation Engineering Design Practice	0-0-3	2
CE 684	Computer Application in Water Resources Engineering	0-0-3	2
CE 704	Remote Sensing & GIS Laboratory	0-0-3	2

Sub discipline: Project, Seminar and Special Courses

CE 685	Seminar & Technical Writing – I	0-0-3	2
CE 686	Seminar & Technical Writing – II	0-0-3	2
CE 687	Seminar & Technical Writing – III	3-1-0	2
CE 688	Seminar & Technical Writing – IV	0-0-3	2
CE 689	Special Laboratory in Civil Engineering – I	0-0-3	2
CE 690	Special Laboratory in Civil Engineering – II	0-0-3	2
CE 691	Summer Research/Industrial Project	0-0-3	2
CE 692	Comprehensive Viva Voce	0-0-3	2
CE 693	Research Project Work – I	0-0-6	4
CE 694	Research Project Work – II	0-0-0	4

DEPARTMENT OF CHEMICAL ENGINEERING

Curriculum of M. Tech (CHEMICAL ENGINEERING)

FIRST SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CH 611	Advanced Fluid Dynamics	3-1-0	4
2	CH 613	Advanced Mass Transfer	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	CH 671	Chemical Engineering Lab – I	0-0-3	2
7	CH 673	Chemical Engineering Lab – II	0-0-3	2
8	CH 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				26

SECOND SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CH 632	Advanced Process Control	3-1-0	4
2	CH 638	Advanced Reaction Engineering & Reactor Design	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	CH 670	Chemical Engineering Lab – III	0-0-3	2
7	CH 672	Chemical Engineering Lab – IV	0-0-3	2
8	CH 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CH 687	Seminar & Technical Writing – III	0-0-3	2
2	CH 691	Summer Research/Industrial Project	0-0-0	4
3	CH 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CH 688	Seminar & Technical Writing – IV	0-0-3	2
2	CH 692	Comprehensive Viva Voce	0-0-0	4
3	CH 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	CH 612	Computational Transport Phenomena	3-1-0	4
2.	CH 614	Advanced Separation Technology	3-1-0	4
3.	CH 615	Advanced Heat Transfer	3-1-0	4
4.	CH 616	Advanced Fluidization Engineering	3-1-0	4
5.	CH 620	Pinch Technology	3-1-0	4
6.	CH 621	Bioenergy Engineering	3-1-0	4
7.	CH 622	Membrane Science & Technology	3-1-0	4
8.	CH 623	Environmental Management System	3-1-0	4
9.	CH 624	Advanced Thermodynamics	3-1-0	4
10.	CH 625	Bioprocess Engineering	3-1-0	4

11.	CH 626	Nano Science & Technology	3-1-0	4
12.	CH 628	Advanced Environmental Biotechnology	3-1-0	4
13.	CH 629	Interfacial Science and Engineering	3-1-0	4
14.	CH 631	Process Plant Simulation	3-1-0	4
15.	CH 634	Chemical Engineering analysis: Application of mathematical and statistical methods	3-1-0	4
16.	CH 636	Evolutionary Computation	3-1-0	4
17.	CH 681	Special Topics in Chemical Engineering – I		3/4
18.	CH 682	Special Topics in Chemical Engineering – II		3/4
19.	CH 683	Special Laboratory in Chemical Engineering – I	0-0-3	2
20.	CH 684	Special Laboratory in Chemical Engineering – II	0-0-3	2

SUMMARY OF COURSES

Sub discipline: Transfer Operations

CH 611	Advanced Fluid Dynamics	3-1-0	4
CH 612	Computational Transport Phenomena	3-1-0	4
CH 613	Advanced Mass Transfer	3-1-0	4
CH 614	Advanced Separation Techniques	3-1-0	4
CH 615	Advanced Heat Transfer	3-1-0	4
CH 616	Advanced Fluidization Engineering	3-1-0	4

Sub discipline: Process Engineering and Technology

CH 620	Pinch Technology	3-1-0	4
CH 621	Bioenergy Engineering	3-1-0	4
CH 622	Membrane Science and Technology	3-1-0	4
CH 623	Environmental Management System	3-1-0	4
CH 624	Advanced Thermodynamics	3-1-0	4
CH 625	Bioprocess Engineering	3-1-0	4
CH 628	Advanced Environmental Biotechnology	3-1-0	4
CH 629	Interfacial Science and Engineering	3-0-0	4

Sub discipline: Design and Simulation

CH 631	Process Plant Simulation	3-1-0	4
CH 632	Advanced Process Control	3-1-0	4
CH 634	Chemical Engineering Analysis: Application of Mathematical and Statistical Methods	3-1-0	4
CH 636	Evolutionary Computation	3-1-0	4
CH 638	Advanced Reaction Engineering & Reactor Design	3-1-0	4

Sub discipline: Laboratory Courses

CH 670	Chemical Engineering Lab – III	0-0-3	2
CH 671	Chemical Engineering Lab – I	0-0-3	2
CH 672	Chemical Engineering Lab – IV	0-0-3	2
CH 673	Chemical Engineering Lab – II	0-0-3	2

Sub discipline: Project, Seminar and Special Courses

CH 681	Special Topics in Chemical Engineering – I		3/4
CH 682	Special Topics in Chemical Engineering – II		3/4
CH 683	Special Laboratory in Chemical Engineering – I	0-0-3	2
CH 684	Special Laboratory in Chemical Engineering – II	0-0-3	2
CH 685	Seminar & Technical Writing – I	0-0-3	2

CH 686	Seminar & Technical Writing – II	0-0-3	2
CH 687	Seminar & Technical Writing – III	0-0-3	2
CH 688	Seminar & Technical Writing – IV	0-0-3	2
CH 691	Summer Research/Industrial Project	0-0-6	4
CH 692	Comprehensive Viva Voce	0-0-0	4
CH 693	Research Project Work – I	0-0-20	20
CH 694	Research Project Work – II	0-0-20	20

DEPARTMENT OF CERAMIC ENGINEERING

Curriculum of M. Tech. (INDUSTRIAL CERAMICS)

FIRST SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	CR 631	Industrial Ceramic Processing	3-1-0	4
2	CR 635	Whiteware Production and Practices	3-1-0	4
3		Professional Elective - I	3-1-0	4
4		Professional Elective - II	3-1-0	4
5		Professional Elective - III	3-1-0	4
6	CR 671	Process Ceramics Laboratory	0-0-3	2
7	CR 673	Characterization of Whitewares	0-0-3	2
8	CR 685	Seminar & Technical Writing – I	0-0-3	2
	TOTAL		15-5-9	**26**

SECOND SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	CR 610	Advanced Refractories	3-1-0	4
2	CR 620	Industrial Glass Making	3-1-0	4
3		Professional Elective - IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective - VI	3-1-0	4
6	CR 672	Refractory Laboratory	0-0-3	2
7	CR 674	Glass Laboratory	0-0-3	2
8	CR 686	Seminar & Technical Writing – II	0-0-3	2
	TOTAL		15-5-9	**26**

THIRD SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	CR 687	Seminar & Technical Writing – III	0-0-3	2
2	CR 691	Summer Research/ Industrial Project	0-0-0	4
3	CR 693	Research Project Work – I (Industrial Based)	0-0-0	20
	TOTAL			**26**

FOURTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	CR 688	Seminar & Technical Writing – IV	0-0-3	2
2	CR 692	Comprehensive Viva Voce	0-0-0	4
3	CR 694	Research Project Work - II (Industrial Based)	0-0-0	20
	TOTAL			**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	CR611	Industrial Furnace Technology	3-1-0	4
2	CR 612	Refractories for Metallurgical & Allied Processes	3-1-0	4
3	CR 614	Monolithic Refractories	3-1-0	4
4	CR622	Glass and Glass Ceramic for Technical Application	3-1-0	4
5	CR 624	Advanced Glasses	3-1-0	4
6	CR 645	Design and Modeling of Industrial Ceramics	3-1-0	4
7	CR 647	Advanced Composites	3-1-0	4
8	CR 652	Applications of Phase Diagrams in Ceramic Industries	3-1-0	4
9	CR 653	Manufacturing Technology of Electroceramics	3-1-0	4
10	CR 654	Sintering and Microstructure	3-1-0	4
11	CR 661	Technical Ceramics	3-1-0	4

12	CR 662	Ceramics in Energy Sectors	3-1-0	4
13	CR 663	Testing and Ceramic Characterization	3-1-0	4
14	CR 664	Ferrite Technology	3-1-0	4
15	CR 681	Special Topic in Ceramic Engineering - I	3-1-0	4
16	CR 682	Special Topic in Ceramic Engineering - II	3-1-0	4
17	CR 683	Special Laboratory in Ceramic Engineering - I	0-0-3	2
18	CR 684	Special Laboratory in Ceramic Engineering - II	0-0-3	2

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	CE 634	Industrial Pollution Prevention & Clean Technologies	3-1-0	4
2	CH 615	Advanced Heat Transfer	3-1-0	4
3	CH 623	Environmental Management System	3-1-0	4
4	CH631	Process Plant Simulation	3-1-0	4
5	ME 631	Production Technology	3-1-0	4
6	ME 637	Production System & Computer Integrated Manufacturing	3-1-0	4
7	ME 647	Production Management	3-1-0	4
8	ME 648	Quality Engineering and Reliability	3-1-0	4
9	ME 665	Furnace Design	3-1-0	4
10	ME 668	Energy Conservation and Management	3-1-0	4
11	MM 616	Alloy Steel Technology	3-1-0	4
12	MM 618	Joining of Materials	3-1-0	4
13	MM 623	Iron & Steel Making	3-1-0	4
14	MM 628	Advances in Steel Making	3-1-0	4
15	MM 636	Mechanical Working of Materials	3-1-0	4

SUMMARY OF COURSES

Sub Discipline: Industrial Ceramics

CR 610	Advanced Refractories	3-1-0	4
CR611	Industrial Furnace Technology	3-1-0	4
CR 612	Refractories for Metallurgical & Allied Processes	3-1-0	4
CR 614	Monolithic Refractories	3-1-0	4
CR 620	Industrial Glass Making	3-1-0	4
CR622	Glass and Glass Ceramic for Technical Application	3-1-0	4
CR 624	Advanced Glasses	3-1-0	4
CR 635	Industrial Whiteware Technology	3-1-0	4

Sub Discipline: Structural & Advanced Ceramics

CR 661	Technical Ceramics	3-1-0	4
CR 647	Advanced Composites	3-1-0	4

Sub Discipline: Electroceramics

CR 653	Manufacturing Technology of Electroceramics	3-1-0	4
CR 662	Ceramics in Energy Sectors	3-1-0	4
CR 664	Ferrite Technology	3-1-0	4

Sub Discipline: Fundamental Core

CR 631	Industrial Ceramic Processing	3-1-0	4
CR 652	Applications of Phase Diagrams in Ceramic Industries	3-1-0	4
CR 654	Sintering and Microstructure	3-1-0	4
CR 663	Testing and Ceramic Characterization	3-1-0	4
CR 645	Design and Modeling of Industrial Ceramics	3-1-0	4

Sub-discipline: Project, Seminar and Special Courses

CR 681	Special Topic in Ceramic Engineering - I	3-1-0	4
CR 682	Special Topic in Ceramic Engineering - II	3-1-0	4
CR 683	Special Laboratory in Ceramic Engineering - I	0-0-3	2
CR 684	Special Laboratory in Ceramic Engineering - II	0-0-3	2
CR 685	Seminar & Technical Writing - I	0-0-3	2
CR 686	Seminar & Technical Writing - II	0-0-3	2
CR 687	Seminar & Technical Writing - III	0-0-3	2
CR 688	Seminar & Technical Writing - IV	0-0-3	2
CR 691	Summer Research/ Industrial Project	0-0-0	4
CR 692	Comprehensive Viva Voce	0-0-0	4
CR 693	Research Project – I	0-0-0	20
CR 694	Research Project – II	0-0-0	20

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

Curriculum of M. Tech. (COMPUTER SCIENCE AND ENGINEERING)

FIRST SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 616	Algorithm Design	3-1-0	4
2	CS 625	Data Mining and Data Warehousing	3-1-0	4
3		Elective – I	3-1-0	4
4		Elective – II	3-1-0	4
5		Elective – III	3-1-0	4
6		Elective Lab – I	0-0-3	2
7	CS 670	Data Mining Lab (Programming Laboratory - I)	0-0-3	2
8	CS 685	Seminar and Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 612	Software Engineering	3-1-0	4
2	CS 622	Design of Computer Networks	3-1-0	4
3		Elective – IV	3-1-0	4
4		Elective – V	3-1-0	4
5		Elective – VI	3-1-0	4
6		Elective Lab – II	0-0-3	2
7	CS 672	Software Engineering Lab	0-0-3	2
8	CS 686	Seminar and Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 687	Seminar & Technical Writing – III	0-0-3	2
2	CS 691	Summer Research / Industrial Project	0-0-0	4
3	CS 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 688	Seminar & Technical Writing – IV	0-0-3	2
2	CS 692	Comprehensive Viva-Voce	0-0-0	4
3	CS 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE: 104

NB: For M.Tech. (Information Security) the students have to study minimum **four** numbers of security related papers in first and second semester and do a thesis work on security topic to earn the degree.

Curriculum of M. Tech. (INFORMATION SECURITY)

FIRST SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 621	Cryptographic Foundations	3-1-0	4
2	CS 631	Information Theory Coding	3-1-0	4
3		Elective – I	3-1-0	4
4		Elective – II	3-1-0	4
5		Elective – III	3-1-0	4
6	CS 676	Cryptography Laboratory – I	0-0-3	2
7	CS 680	Cryptography Laboratory – II	0-0-3	2
8	CS 685	Seminar and Technical Writing – I	0-0-0	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 629	Network Security	3-1-0	4
2	CS 626	Intrusion Detection Systems	3-1-0	4
3		Elective – IV	3-1-0	4
4		Elective – V	3-1-0	4
5		Elective – VII	3-1-0	4
6	CS 678	OS and Database Security Laboratory	0-0-3	2
7	CS 679	Network Security Lab	0-0-3	2
8	CS 686	Seminar and Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 687	Seminar & Technical Writing – III	0-0-3	2
2	CS 691	Summer Research / Industrial Project	0-0-0	4
3	CS 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 688	Seminar & Technical Writing – IV	0-0-3	2
2	CS 692	Comprehensive Viva-Voce	0-0-0	4
3	CS 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE: 104

Curriculum of M. Tech. (SOFTWARE ENGINEERING)

FIRST SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 614	Software Project, Process and Quality Management	3-1-0	4
2	CS 619	Software Engineering Requirements, and Modeling	3-1-0	4
3		Elective – I	3-1-0	4
4		Elective – II	3-1-0	4
5		Elective – III	3-1-0	4
6	CS 670	Programming Lab – I	0-0-3	2
7		Elective Laboratory – I	0-0-3	2
8	CS 685	Seminar and Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 610	Software Design	3-1-0	4
2	CS 620	Software Testing	3-1-0	4
3		Elective IV	3-1-0	4
4		Elective V	3-1-0	4
5		Elective VI	3-1-0	4
6	CS 666	Software Design Laboratory	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	CS 686	Seminar and Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 687	Seminar & Technical Writing – III	0-0-3	2
2	CS 691	Summer Research / Industrial Project	0-0-0	4
3	CS 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. code	Subject	L-T- P	Credits
1	CS 688	Seminar & Technical Writing – IV	0-0-3	2
2	CS 692	Comprehensive Viva-Voce	0-0-0	4
3	CS 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE: 104

NB: For M.Tech. (Information Security) the students have to study minimum **four** numbers of security related papers in first and second semester and do a thesis work on security topic to earn the degree.

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code.	Subject	L-T-P	Credits	Offered to
1	CS 611	Foundations of E – Commerce	3-1-0	4	#
2	CS 612	Software Engineering	3-1-0	4	$
3	CS 613	Combinatorial Optimization	3-1-0	4	#
4	CS 614	Software Project, Process and Quality Management	3-1-0	4	@,$
5	CS 615	Software Testing	3-1-0	4	@,$
6	CS 616	Algorithm Design	3-1-0	4	$,%
7	CS 617	Graph Theory and Network Algorithms	3-1-0	4	#
8	CS 618	Real Time Systems Design	3-1-0	4	#
9	CS 621	Cryptographic Foundations	3-1-0	4	@,%
10	CS 622	Design of Computer Networks	3-1-0	4	$,%
11	CS 623	Ad-hoc and Wireless Networks	3-1-0	4	@,$
12	CS 624	Database Engineering	3-1-0	4	#
13	CS 625	Data Mining and Data Warehousing	3-1-0	4	$,%
14	CS 626	Intrusion Detection Systems	3-1-0	4	@,$
15	CS 627	Wireless Network Security	3-1-0	4	@,$
16	CS 628	Wireless Sensor Networks	3-1-0	4	@,$
17	CS 629	Network Security	3-1-0	4	@

18	CS 630	Artificial Intelligence	3-1-0	4	#
19	CS 631	Information Theory and Coding	3-1-0	4	$,%
20	CS 632	Distributed Operating Systems	3-1-0	4	#
21	CS 633	Game Theory	3-1-0	4	@,$
22	CS 634	Bioinformatics	3-1-0	4	@,$
23	CS 635	Biometric Security	3-1-0	4	@,$
24	CS 636	Image Processing	3-1-0	4	@,$
25	CS 637	Digital Signal Processing	3-1-0	4	@,$
26	CS 638	Pattern Recognition	3-1-0	4	@,$
27	CS 639	Soft Computing	3-1-0	4	#
28	CS 640	Requirements Engineering	3-1-0	4	%
29	CS 641	Advanced Computer Architecture	3-1-0	4	#
30	CS 642	Cluster and Grid Computing	3-1-0	4	@,$
31	CS 643	Embedded Systems	3-1-0	4	@,$
32	CS 644	Fault Tolerant Computing	3-1-0	4	#
33	CS 645	Parallel Algorithms	3-1-0	4	#
34	CS 646	Parallel and Distributed Computing	3-1-0	4	#
35	CS 647	Performance Evaluation of Computer Systems	3-1-0	4	#
36	CS 648	Security and Fault Tolerance in Distributed System	3-1-0	4	#
37	CS 649	VLSI System Design	3-1-0	4	@,$
38	CS 649	Web Technologies	3-1-0	4	%
39	CS 650	Software Metrics	3-1-0	4	%
40	CS 651	Software Reliability	3-1-0	4	%
41	CS 652	Software Architecture	3-1-0	4	%
42	CS 653	Software Processes	3-1-0	4	%
43	CS 656	Software Configuration Management	3-1-0	4	%
44	CS 657	Principles of Management	3-1-0	4	%
45	CS 666	Software Design Lab	0-0-3	2	%
46	CS 670	Data Mining Lab (Programming Laboratory - I)	0-0-3	2	@
47	CS 671	Programming Laboratory – II	0-0-3	2	@,$
48	CS 672	Software Engineering Laboratory	0-0-3	2	@,$
49	CS 673	Image Processing Laboratory	0-0-3	2	@,$
50	CS 674	Network Simulation Laboratory	0-0-3	2	#
51	CS 675	Soft Computing Laboratory	0-0-3	2	#
52	CS 676	Cryptography Laboratory – I	0-0-3	2	@,$
53	CS 678	OS and Database Security Laboratory	0-0-3	2	@,$
54	CS 679	Biometrics Laboratory	0-0-3	2	@
55	CS 681	Special Topics in Computer Science /Special Topics in Software Engineering – I	3-1-0	4	#
56	CS 682	Special Topics in Information Security/ Special Topics in Software Engineering – II	3-1-0	4	#
57	CS 683	Special Laboratory in Computer Science Engineering/ Special Laboratory in Software Engineering – I	0-0-3	2	#
58	CS 684	Special Laboratory in Information Security Engineering/ Special Laboratory in Software Engineering	0-0-3	2	#
59	CS 689	Artificial Intelligence Laboratory	0-0-3	2	%

Note: @ - for Computer Science & Engineering, $ - for Information Security
% - for Software Engineering, #- for all specializations

LIST OF PROFESSIONAL ELECTIVES OFFERED BY OTHER DEPARTMENTS

SL. NO	SUB CODE	SUBJECT NAME	L-T-P	CREDITS	OFFERED TO
1	EC 600	Architecture of DSP	3-1-0	4	@, $
2	EC 611	Digital Communication	3-1-0	4	@, $
3	EC 613	Optical Communication	3-1-0	4	@, $
4	EC 614	Information Theory and Coding	3-1-0	4	@, $
5	EC 615	Mobile Communication	3-1-0	4	@, $
6	EC 619	Computer Communication Networks	3-1-0	4	@, $
7	EC 621	Digital VLSI Design	3-1-0	4	@, $
8	EC 624	Embedded Computing Systems	3-1-0	4	@, $
9	EC 640	Pattern Recognition Application	3-1-0	4	@, $
10	EC 642	Advanced Techniques in Digital Signal Processing	3-1-0	4	@, $
11	EC 643	Digital Image Processing	3-1-0	4	@, $
12	EC 644	Soft Computing	3-1-0	4	#
13	EC 646	Adaptive Signal Processing	3-1-0	4	@, $
14	EC 648	Evolutionary Computing Techniques	3-1-0	4	@, $
15	EC 670	Mobile Communication Laboratory	0-0-3	2	@, $
16	EC 671	DSP Laboratory	0-0-3	2	@, $
17	EC 672	Advanced Techniques in DSP Laboratory	0-0-3	2	@, $
18	EC 674	Soft Computing Laboratory	0-0-3	2	@, $
19	EC 675	High Level Design Laboratory	0-0-3	2	@, $
20	EC 678	Embedded Computing Systems Laboratory	0-0-3	2	@, $
21	EC 774	Image Processing Laboratory	0-0-3	2	@, $
22	EE 637	Soft Computing Techniques	3-1-0	4	%
23	EE 665	Digital Speech Processing	3-1-0	4	@, $
24	MA 523	Discrete Mathematics	3-1-0	4	%
25	MA 524	Statistical Methods	3-1-0	4	%
26	MA 552	Fuzzy logic and Set Theory	3-1-0	4	%
27	MA 553	Optimization Techniques	3-1-0	4	%
28	MA 554	Graph Theory	3-1-0	4	%
29	MA 555	Stochastic Process	3-1-0	4	%
30	MA 623	Advanced Number Theory	3-1-0	4	@, $
31	MA 624	Advanced Statistical Methods	3-1-0	4	@, $
32	MA 625	Stochastic Processes	3-1-0	4	@, $
33	MA 626	Combinatorics	3-1-0	4	@, $
34	MA 627	Optimization Techniques with Applications	3-1-0	4	@, $
35	MA 645	Group Theory and its applications	3-1-0	4	@, $
36	MA 647	Abstract Algebra with Application	3-1-0	4	@, $
37	MA 648	Finite Groups	3-1-0	4	@, $

Note: @ - for Computer Science & Engineering, $ - for Information Security
% - for Software Engineering, # - for all specializations

SUMMARY OF COURSES

Sub Discipline: Software Engineering

CS 610	Software Design	3-1-0	4
CS 611	Foundations of E Commerce	3-1-0	4
CS 612	Software Engineering	3-1-0	4
CS 613	Combinatorial Optimization	3-1-0	4
CS 614	Software Project, Process and Quality Management	3-1-0	4

CS 615	Software Testing	3-1-0	4
CS 616	Algorithm Design	3-1-0	4
CS 617	Graph Theory and Network Algorithms	3-1-0	4
CS 618	Real Time Systems Design	3-1-0	4
CS 619	Software Engineering Requirements, and Modeling	3-1-0	4
CS 620	Software Testing	3-1-0	4
CS 624	Database Engineering	3-1-0	4
CS 640	Requirements Engineering	3-1-0	4
CS 649	Web Technologies	3-1-0	4
CS 650	Software Metrics	3-1-0	4
CS 651	Software Reliability	3-1-0	4
CS 652	Software Architecture	3-1-0	4
CS 653	Software Processes	3-1-0	4
CS 656	Software Configuration Management	3-1-0	4
CS 657	Principles of Management	3-1-0	4

Sub Discipline: Network and Secured Computing

CS 621	Cryptographic Foundations	3-1-0	4
CS 622	Design of Computer Networks	3-1-0	4
CS 623	Ad-hoc and Wireless Networks	3-1-0	4
CS 624	Database Engineering	3-1-0	4
CS 625	Data Mining and Data Warehousing	3-1-0	4
CS 626	Intrusion Detection Systems	3-1-0	4
CS 627	Wireless Network Security	3-1-0	4
CS 628	Wireless Sensor Networks	3-1-0	4
CS 629	Network Security	3-1-0	4
CS 647	Performance Evaluation of Computer Systems and Networks	3-1-0	4
CS 648	Security and Fault Tolerance in Distributed System	3-1-0	4

Sub Discipline: Intelligent Computing and Computer Vision

CS 613	Combinatorial Optimization	3-1-0	4
CS 616	Algorithm Design	3-1-0	4
CS 617	Graph Theory and Network Algorithm	3-1-0	4
CS 630	Artificial Intelligence	3-1-0	4
CS 631	Information Theory Coding	3-1-0	4
CS 632	Distributed Operating Systems	3-1-0	4
CS 633	Game Theory	3-1-0	4
CS 634	Bioinformatics	3-1-0	4
CS 635	Biometric Security	3-1-0	4
CS 636	Image Processing	3-1-0	4
CS 637	Digital Signal Processing	3-1-0	4
CS 638	Pattern Recognition	3-1-0	4
CS 639	Soft Computing	3-1-0	4

Sub Discipline: Computer Hardware

CS 641	Advanced Computer Architecture	3-1-0	4
CS 642	Cluster and Grid Computing	3-1-0	4
CS 643	Embedded Systems	3-1-0	4
CS 644	Fault Tolerant Computing	3-1-0	4
CS 645	Parallel Algorithms	3-1-0	4
CS 646	Parallel and Distributed Computing	3-1-0	4

CS 647	Performance Evaluation of Computer Systems	3-1-0	4
CS 648	Security and Fault Tolerance in Distributed System	3-1-0	4
CS 649	VLSI System Design	3-1-0	4

Sub Discipline: Laboratory Courses

CS 670	Programming Laboratory – I	0-0-3	2
CS 671	Programming Laboratory – II	0-0-3	2
CS 672	Software Engineering Laboratory	0-0-3	2
CS 673	Image Processing Laboratory	0-0-3	2
CS 674	Network Simulation Laboratory	0-0-3	2
CS 675	Soft Computing Laboratory	0-0-3	2
CS 676	Cryptography Laboratory	0-0-3	2
CS 678	OS and Database Security Laboratory	0-0-3	2
CS 679	Network Security Lab	0-0-3	2
CS 666	Software Design Laboratory	0-0-3	2
CS 689	Artificial Intelligence Laboratory	0-0-3	2

Sub Discipline: Projects, Seminar and Special Courses

CS 680	Cryptography Laboratory - II	0-0-3	2
CS 681	Special Topics in Computer Science	3-1-0	4
CS 682	Special Topics in Information Security	3-1-0	4
CS 683	Special Laboratory in Computer Science Engineering	0-0-3	2
CS 684	Special Laboratory in Information Security	0-0-3	2
CS 685	Seminar and Technical Writing – I	0-0-0	2
CS 686	Seminar and Technical Writing - II	0-0-0	2
CS 687	Seminar & Technical Writing – III	0-0-0	2
CS 688	Seminar & Technical Writing – IV	0-0-3	2
CS 691	Summer Research / Industrial Project	0-0-0	4
CS 692	Comprehensive Viva-Voce	0-0-0	4
CS 693	Research Project Work – I		20
CS 694	Research Project Work – II		20

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Curriculum of M. Tech (Specialization: COMMUNICATION & SIGNAL PROCESSING)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 611	Digital Communication	3-1-0	4
2	EC 641	Digital Signal Processing	3-1-0	4
3		Professional Elective- I	3-1-0	4
4		Professional Elective - II	3-1-0	4
5		Professional Elective - III	3-1- 0	4
6	EC 671	Digital Signal Processing Lab	0-0-3	2
7		Elective Laboratory – I	0-0-3	2
8	EC 685	Seminar Technical Writing – I	0-0-3	2
		TOTAL		**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 642	Advanced Techniques in DSP	3-1-0	4
2	EC 644	Soft Computing	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	EC 673	Advanced Communication Laboratory	0-0-3	2
7		Elective Laboratory – II	0-0-0	2
8	EC 686	Seminar Technical Writing – II	0-0-3	2
		TOTAL		**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 687	Seminar Technical Writing – III	0-0-3	2
2	EC 691	Summer Research / Industrial Project	0-0-0	4
3	EC 693	Research Project – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 688	Seminar Technical Writing – IV	0-0-3	2
2	EC 692	Comprehensive Viva Voce	0-0-0	4
3	EC 694	Research Project – II	0-0-0	20
		TOTAL		**26**

Curriculum of M. Tech (Specialization: VLSI Design & Embedded System)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 621	Digital VLSI Design	3-1-0	4
2	EC 623	HDL and High Level VLSI Design	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6		Elective Laboratory – I	0-0-3	2
7	EC 677	VLSI Design Laboratory	0-0-3	2
8	EC 685	Seminar & Technical Writing – I	0-0-3	2

TOTAL	**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 622	Design of Analog and Mixed Mode VLSI Circuits	3-1-0	4
2	EC 624	Embedded Computing Systems	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6		Elective Laboratory – II	0-0-3	2
7	EC 678	Embedded Computing System Lab	0-0-3	2
8	EC 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 687	Seminar & Technical Writing - III	0-0-3	2
2	EC 691	Summer Research / Industrial Project	0-0-0	4
3	EC 693	Research Project – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 688	Seminar & Technical Writing - IV	0-0-3	2
2	EC 692	Comprehensive Viva Voce	0-0-0	4
3	EC 694	Research Project – II	0-0-0	20
TOTAL				**26**

Curriculum of M. Tech. (ELECTRONICS AND INSTRUMENTATION)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	EC 631	Analytical Instrumentation	3-1-0	4
2	EC 633	PC Based Instrumentation	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	EC 773	Advanced Instrumentation Lab	0-0-3	2
7		Elective Laboratory – I	0-0-3	2
8	EC 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 630	Industrial Electronics & Instrumentation	3-1-0	4
2	EC 639	Advanced Process Control	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	EC 776	Advanced Process Control Lab	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	EC 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 687	Seminar Technical Writing - III	0-0-3	2
2	EC 691	Summer Research / Industrial Project	0-0-0	4
3	EC 693	Research Project – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 688	Seminar & Technical Writing - IV	0-0-3	2
2	EC 692	Comprehensive Viva Voce	0-0-0	4
3	EC 694	Research Project – II	0-0-0	20
		TOTAL		**26**

Curriculum of M. Tech (COMMUNICATION AND NETWORKS)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 611	Digital Communication	3-1-0	4
2	EC 615	Mobile Communication	3-1-0	4
3		Professional Elective - I	3-1-0	4
4		Professional Elective - II	3-1-0	4
5		Professional Elective - III	3-1-0	4
6	EC 673	Advance Communication Laboratory	0-0-3	2
7		Elective Laboratory – I	0-0-3	2
8	EC 685	Seminar Technical Writing – I	0-0-3	2
		TOTAL		**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 619	Communication Networks	3-1-0	4
2	EC 762	Advanced Wireless Communication	3-1-0	4
3		Professional Elective - IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective - VI	3-1-0	4
6	EC 670	Mobile Communication Laboratory	0-0-3	2
7		Elective Laboratory - II	0-0-0	2
8	EC 686	Seminar Technical Writing – II	0-0-3	2
		TOTAL		**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 687	Seminar Technical Writing – III	0-0-3	2
2	EC 691	Summer Research / Industrial Project	0-0-0	4
3	EC 693	Research Project – I	0-0-0	20
		TOTAL		**25**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 688	Seminar Technical Writing – IV	0-0-3	2
2	EC 692	Comprehensive Viva Voce	0-0-0	4
3	EC 694	Research Project – II	0-0-0	20
		TOTAL		**26**

Curriculum of M. Tech (SIGNAL & IMAGE PROCESSING)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 651	Digital Filter Design	3-1-0	4
2	EC 653	Image Processing & Computer Vision	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1- 0	4
6	EC 775	Image Processing & Computer Vision Lab	0-0-3	2
7		Elective Laboratory – I	0-0-3	2
8	EC 685	Seminar Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 646	Adaptive Signal Processing	3-1-0	4
2	EC 652	Video Signal Processing	3-1-0	4
3		Professional Elective - IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective - VI	3-1-0	4
6	EC 778	Adaptive Signal Processing Laboratory	0-0-3	2
7		Elective Laboratory - II	0-0-0	2
8	EC 686	Seminar Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 687	Seminar Technical Writing – III	0-0-3	2
2	EC 691	Summer Research / Industrial Project	0-0-0	4
3	EC 693	Research Project – I	0-0-0	20
TOTAL				**25**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EC 688	Seminar Technical Writing – IV	0-0-3	2
2	EC 692	Comprehensive Viva Voce	0-0-0	4
3	EC 694	Research Project – II	0-0-0	20
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credit	Offered To
1	EC 600	Architecture of DSP	3-1-0	4	#
2	EC 611	Digital Communication	3-1-0	4	$,%,*
3	EC 612	Antenna Analysis and Synthesis	3-1-0	4	@,&,*
4	EC 613	Optical Communication	3-1-0	4	#
5	EC 614	Information Theory and Coding	3-1-0	4	#
6	EC 615	Mobile Communication	3-1-0	4	@,$,%,*
7	EC 616	Microwave Engineering	3-1-0	4	$,&
8	EC 617	Satellite Communication	3-1-0	4	@,&,*
9	EC 619	Computer Communication Network	3-1-0	4	@,$,%,*
10	EC 620	Modeling and Circuit Simulators for VLSI	3-1-0	4	#

		Systems			
11	EC 621	Digital VLSI Design	3-1-0	4	@,%,&,*
12	EC 622	Design of Analog and Mixed mode VLSI	3-1-0	4	@,&,*
13	EC 623	HDL and High Level VLSI Design	3-1-0	4	@,%,&,*
14	EC 624	Embedded Computing System	3-1-0	4	@,%,&,*
15	EC 626	Low Power VLSI Design	3-1-0	4	@,$,&,*
16	EC 627	VLSI Fabrication Technology	3-1-0	4	$
17	EC 628	VLSI Signal Processing	3-1-0	4	#
18	EC 629	VLSI Testing and Testability	3-0-0	3	$,@,&,*
19	EC 637	Medical Instrumentation	3-0-0	3	$,%,*
20	EC 640	Pattern Recognition Application	3-1-0	4	#
21	EC 641	Digital Signal Processing	3-1-0	4	%,&,*
22	EC 642	Advanced Techniques in Digital Signal Processing	3-1-0	4	$,%,&,*
23	EC 643	Digital Image Processing	3-1-0	4	$,%,*
24	EC 644	Soft Computing	3-1-0	4	$,%,&,*
25	EC 646	Adaptive Signal Processing	3-1-0	4	@,$,%,&
26	EC 648	Evolutionary Computing Techniques	3-1-0	4	#
27	EC 651	Digital Filter Design	3-1-0	4	@,$,%,&
28	EC 652	Video Signal Processing	3-1-0	4	@,$,%,&
29	EC 653	Image Processing & Computer Vision	3-1-0	4	@,$,%,&
30	EC 654	Statistical Signal Processing	3-1-0	4	#
31	EC 655	Transform Domain Signal Processing	3-1-0	4	#
32	EC 656	Data Compression	3-1-0	4	#
33	EC 657	Radar Signal Processing	3-1-0	4	#
34	EC 658	Advanced Theory on Detection & Estimation	3-1-0	4	#
35	EC 659	Multimedia Signal Processing	3-1-0	4	#
36	EC 661	Wireless Sensor Network	3-1-0	4	#
37	EC 662	Communication Networks	3-1-0	4	@,$,%,*
38	EC 667	Signal Processing for Communication	3-1-0	4	#
39	EC 668	Telecommunication and Switching Network	3-1-0	4	#
40	EC 681	Special Topics in Communication & Signal Processing – I		3/4	@,$,%,&
41	EC 682	Special Topics in Communication & Signal Processing – II		3/4	@,$,%,&
42	EC 683	Special Laboratory in Communication & Signal Processing – I	0-0-3	2	@,$,%,&
43	EC 684	Special Laboratory in Communication & Signal Processing – II	0-0-3	2	@,$,%,&
44	EC 700	High-Vacuum Technology & Application	3-1-0	4	%
45	EC 701	Optical Engineering and Laser Instrumentation	3-1-0	4	%
46	EC 702	Instrumentation for Energy Conservation & Management	3-1-0	4	%
47	EC 704	Digital Design of Instrumentation	3-1-0	4	%
48	EC 705	Safety & Reliability	3-1-0	4	%
49	EC 707	Micro controller & Application	3-1-0	4	%
50	EC 708	Micro-system Materials, Processes & Devices	3-1-0	4	%

51	EC 709	Micro-Electronic Devices & Application	3-1-0	4	%
52	EC 710	Digital Control System	3-1-0	4	%
53	EC 751	Digital Array Signal Processing	3-1-0	4	#
54	EC 752	Optimization Techniques for Signal Processing	3-1-0	4	#
55	EC 753	Bayesian Signal Processing	3-1-0	4	#
56	EC 754	Model Based Signal Processing	3-1-0	4	#
57	EC 755	Special Theory on Signal Detection	3-1-0	4	#
58	EC 756	Biometrics Systems & Data Analysis.	3-1-0	4	#
59	EC 761	Optical Communication and Networks	3-1-0	4	#
60	EC 762	Advanced Wireless Communication	3-1-0	4	@,$,%,*
61	EC 781	Special Topic in Signal & Image Processing – I/ Special Topic in VLSI Design and Embedded System– I/ Special Topic in Electronics and Instrumentation – I/ Special Topic in Communication and Networks – I		3/4	*
62	EC 782	Special Topic in Signal & Image Processing – II/ Special Topic in VLSI Design and Embedded System– II/ Special Topic in Electronics and Instrumentation – II/ Special Topic in Communication and Networks – II		3/4	*
63	EC 783	Special Laboratory in Signal & Image Processing – I/ Special Laboratory in VLSI Design and Embedded System– I/ Special Laboratory in Electronics and Instrumentation – I/ Special Laboratory in Communication and Networks – I	0-0-3	2	*
64	EC 784	Special Laboratory in Signal & Image Processing – II/ Special Laboratory in VLSI Design and Embedded System–II/ Special Laboratory in Electronics and Instrumentation – II/ Special Laboratory in Communication and Networks – II	0-0-3	2	*
65	EE 625	System and Control Theory	3-1-0	4	%
66	EE 626	State Space and Digital Control	3-1-0	4	%
67	EE 627	Robust and Optimal Control	3-1-0	4	%
68	EE 646	Estimation of Signals & Systems	3-1-0	4	#
69	EE 665	Digital Speech Processing	3-1-0	4	#
70	MA 624	Advanced Statistical Methods	3-1-0	4	#
71	MA 625	Stochastic Processes	3-1-0	4	#

Note: @- for Communication and Signal Processing
$ - for VLSI Design and Embedded System
%- for Electronics and Instrumentation
& - for Communication and Networks
*- for Signal and Image Processing
- Common for all Specializations

LIST OF PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	CS 418	Real Time Systems	3-1-0	4
2	CS 623	Ad-Hoc and Wireless Networks	3-1-0	4

3	CS 627	Wireless Network Security	3-1-0	4

LIST OF ELECTIVE LABORATORY COURSES

Sl. No	Sub. Code.	Subject	L-T-P	Credit	Offered To
1	EC 670	Mobile Communication Laboratory	0-0-3	2	@,$,%,*
2	EC 671	DSP Laboratory	0-0-3	2	%,&,*
3	EC 672	Advanced Techniques in DSP Lab	0-0-3	2	#
4	EC 673	Advance Communication Laboratory	0-0-3	2	$,%,*
5	EC 674	Soft Computing Lab	0-0-3	2	#
6	EC 675	High Level Design Lab	0-0-3	2	$
7	EC 676	Analog and Mixed Signal IC Lab	0-0-3	2	$,&
8	EC 679	Antenna Design & Simulation Laboratory	0-0-3	2	@,%,&,*
9	EC 771	Digital Communication Lab	0-0-3	2	@,%,&,*
10	EC 772	DSP Hardware Lab	0-0-3	2	#
11	EC 774	Image Processing Lab	0-0-3	2	@,%,&,*
12	EC 775	Image Processing & Computer Vision Lab	0-0-3	2	@,$,%,&
13	EC 777	Digital Filter Design Lab	0-0-3	2	#
14	EC 778	Adaptive Signal Processing Laboratory	0-0-3	2	@,$,%,&
15	EC 779	Video Signal Processing Lab	0-0-3	2	#
16	EC 785	Transform Domain Signal Processing Lab	0-0-3	2	#
17	EC 786	Biomedical Signal Processing Lab	0-0-3	2	#
18	EC 787	Speech Processing Lab	0-0-3	2	#
19	EC 788	Multimedia Signal Processing Lab	0-0-3	2	#
20	EC 791	Microwave Lab	0-0-3	2	#
21	EC 792	Sensor Lab	0-0-3	2	#
22	EC 793	Communication Networks Lab	0-0-3	2	#

Note: @- for Communication and Signal Processing $ - for VLSI Design and Embedded System
%- for Electronics and Instrumentation & - for Communication and Networks
* - for Signal and Image Processing # - Common for all above Specializations

SUMMARY OF COURSES

Sub Discipline: Communication

EC 600	Architecture of DSP	3-1-0	4
EC 611	Digital Communication	3-1-0	4
EC 612	Antenna Analysis and Synthesis	3-1-0	4
EC 613	Optical Communication	3-1-0	4
EC 614	Information Theory and Coding	3-1-0	4
EC 615	Mobile Communication	3-1-0	4
EC 616	Microwave Engineering	3-1-0	4
EC 617	Satellite Communication	3-1-0	4
EC 619	Computer Communication Network	3-1-0	4
EC 661	Wireless Sensor Network	3-1-0	4
EC 662	Communication Networks	3-1-0	4
EC 667	Signal Processing for Communication	3-1-0	4
EC 668	Telecommunication and Switching Network	3-1-0	4
EC 700	High-Vacuum Technology & Application	3-1-0	4
EC 701	Optical Engineering and Laser Instrumentation	3-1-0	4
EC 702	Instrumentation for Energy Conservation & Management	3-1-0	4
EC 704	Digital Design of Instrumentation	3-1-0	4
EC 705	Safety & Reliability	3-1-0	4
EC 707	Micro controller & Application	3-1-0	4
EC 708	Micro-system Materials, Processes & Devices	3-1-0	4

EC 709	Micro-Electronic Devices & Application	3-1-0	4
EC 710	Digital Control System	3-1-0	4
EC 761	Optical Communication and Networks	3-1-0	4
EC 762	Advanced Wireless Communication	3-1-0	4

Sub Discipline: VLSI and Embedded Systems

EC 620	Modeling and Circuit Simulators for VLSI Systems	3-1-0	4
EC 621	Digital VLSI Design	3-1-0	4
EC 622	Design of Analog and Mixed Mode VLSI Circuits	3-1-0	4
EC 623	HDL and High Level VLSI Design	3-1-0	4
EC 624	Embedded Computing System	3-1-0	4
EC 626	Low Power VLSI Design	3-1-0	4
EC 627	VLSI Fabrication Technology	3-1-0	4
EC 628	VLSI Signal Processing	3-1-0	4
EC 629	VLSI Testing and Testability	3-0-0	3
EC 630	Industrial Electronics & Instrumentation	3-1-0	4
EC 631	Analytical Instrumentation	3-1-0	4
EC 633	PC Based Instrumentation	3-1-0	4
EC 637	Medical Instrumentation	3-0-0	3
EC 639	Advanced Process Control	3-1-0	4

Sub Discipline: Signal Processing

EC 600	Architecture of DSP	3-1-0	4
EC 640	Pattern Recognition Application	3-1-0	4
EC 641	Digital Signal Processing	3-1-0	4
EC 642	Advanced Techniques in Digital Signal Processing	3-1-0	4
EC 643	Digital Image Processing	3-1-0	4
EC 644	Soft Computing	3-1-0	4
EC 646	Adaptive Signal Processing	3-1-0	4
EC 648	Evolutionary Computing Techniques	3-1-0	4
EC 651	Digital Filter Design	3-1-0	4
EC 652	Video Signal Processing	3-1-0	4
EC 653	Image Processing & Computer Vision	3-1-0	4
EC 654	Statistical Signal Processing	3-1-0	4
EC 655	Transform Domain Signal Processing	3-1-0	4
EC 656	Data Compression	3-1-0	4
EC 657	Radar Signal Processing	3-1-0	4
EC 658	Advanced Theory on Detection & Estimation	3-1-0	4
EC 659	Multimedia Signal Processing	3-1-0	4
EC 751	Digital Array Signal Processing	3-1-0	4
EC 752	Optimization Techniques for Signal Processing	3-1-0	4
EC 753	Bayesian Signal Processing	3-1-0	4
EC 754	Model Based Signal Processing	3-1-0	4
EC 755	Special Theory on Signal Detection	3-1-0	4
EC 756	Biometrics Systems & Data Analysis.	3-1-0	4

Sub Discipline: Laboratory Courses

EC 670	Mobile Communication Lab	0-0-3	2
EC 671	DSP Laboratory	0-0-3	2
EC 672	Advanced Techniques in DSP Lab	0-0-3	2
EC 673	Advanced Communication Laboratory	0-0-3	2
EC 674	Soft Computing Lab	0-0-3	2

EC 675	High Level Design Lab	0-0-3	2
EC 676	Analog and Mixed Signal IC Lab	0-0-3	2
EC 677	VLSI Design Laboratory	0-0-3	2
EC 678	Embedded Computing System Lab	0-0-3	2
EC 679	Antenna Design & Simulation Laboratory	0-0-3	2
EC 771	Digital Communication Lab	0-0-3	2
EC 772	DSP Hardware Lab	0-0-3	2
EC 773	Advanced Instrumentation Lab	0-0-3	2
EC 774	Image Processing Lab	0-0-3	2
EC 775	Image Processing & Computer Vision Lab	0-0-3	2
EC 776	Advanced Process Control Lab	0-0-3	2
EC 777	Digital Filter Design Lab	0-0-3	2
EC 778	Adaptive Signal Processing Laboratory	0-0-3	2
EC 779	Video Signal Processing Lab	0-0-3	2
EC 785	Transform Domain Signal Processing Lab	0-0-3	2
EC 786	Biomedical Signal Processing Lab	0-0-3	2
EC 787	Speech Processing Lab	0-0-3	2
EC 788	Multimedia Signal Processing Lab	0-0-3	2
EC 791	Microwave Lab	0-0-3	2
EC 792	Sensor Lab	0-0-3	2
EC 793	Communication Networks Lab	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

EC 681	Special Topic in Electronics & Communication Engg - I		3/4
EC 682	Special Topic in Electronics & Communication Engg – II		3/4
EC 683	Special Lab. in Electronics & Communication Engg - I	0-0-3	2
EC 684	Special Lab. in Electronics & Communication Engg - II	0-0-3	2
EC 685	Seminar Technical Writing – I	0-0-3	2
EC 686	Seminar Technical Writing – II	0-0-3	2
EC 687	Seminar Technical Writing – III	0-0-3	2
EC 688	Seminar Technical Writing – IV	0-0-3	2
EC 691	Summer Research / Industrial Project	0-0-0	4
EC 692	Comprehensive Viva Voce	0-0-0	4
EC 693	Research Project – I	0-0-0	20
EC 694	Research Project – II	0-0-0	20
EC 781	Special Topic in Signal & Image Processing – I/ Special Topic in VLSI Design and Embedded System– I/ Special Topic in Electronics and Instrumentation – I/ Special Topic in Communication and Networks – I		3/4
EC 782	Special Topic in Signal & Image Processing – II/ Special Topic in VLSI Design and Embedded System– II/ Special Topic in Electronics and Instrumentation – II/ Special Topic in Communication and Networks – II		3/4
EC 783	Special Laboratory in Signal & Image Processing – I/ Special Laboratory in VLSI Design and Embedded System– I/ Special Laboratory in Electronics and Instrumentation – I/ Special Laboratory in Communication and Networks – I	0-0-3	2
EC 784	Special Laboratory in Signal & Image Processing – II/ Special Laboratory in VLSI Design and Embedded System–II/ Special Laboratory in Electronics and Instrumentation – II/ Special Laboratory in Communication and Networks – II	0-0-3	2

DEPARTMENT OF ELECTRICAL ENGINEERING

Curriculum for M.Tech (ELECTRONIC SYSTEMS & COMMUNICATIONS)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	EE 641	Digital Communication	3-1-0	4
2	EE 643	Microwave & Antenna Systems	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	EE 671	Microwave & Antenna Laboratory	0-0-3	2
7	EE 673	Modeling & Simulation Laboratory	0-0-3	2
8	EE 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	EE 642	Wireless Communication	3-1-0	4
2	EE 654	Satellite Communication	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	EE 672	Advanced Communication Laboratory	0-0-3	2
7	EE 674	Embedded Systems Laboratory	0-0-3	2
8	EE 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 687	Seminar & Technical Writing – III	0-0-3	2
2	EE 691	Summer Research / Industrial Project	0-0-0	4
3	EE 693	Research Project Work-I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 688	Seminar & Technical Writing – IV	0-0-3	2
2	EE 692	Comprehensive Viva –Voce	0-0-0	4
3	EE 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M. Tech (POWER ELECTRONICS & DRIVES)

FIRST SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 611	Machine Analysis	3-1-0	4
2	EE 621	Power Electronic Converters & Machine Drives	3-1-0	4
3		Professional Electives – I	3-1-0	4
4		Professional Electives – II	3-1-0	4
5		Professional Electives – III	3-1-0	4
6	EE 675	Power Electronics and Drives Laboratory – I	0-0-3	2
7	EE 677	Machines and Control Laboratory	0-0-3	2
8	EE 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 612	Advanced Machine Drives	3-1-0	4
2	EE 622	Advanced Power Electronic Converters	3-1-0	4
3		Professional Electives – IV	3-1-0	4
4		Professional Electives – V	3-1-0	4
5		Professional Electives – VI	3-1-0	4
6	EE 676	Power Electronics and Drives Lab – II	0-0-3	2
7	EE 678	Power Electronics and Drives Simulation Lab	0-0-3	2
8	EE 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 687	Seminar & Technical Writing – III	0-0-3	2
2	EE 691	Summer Research / Industrial Project	0-0-0	4
3	EE 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 688	Seminar & Technical Writing – IV	0-0-3	2
2	EE 692	Comprehensive Viva –Voce	0-0-0	4
3	EE 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M. Tech (CONTROL & AUTOMATION)

FIRST SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 625	Systems and Control Theory	3-1-0	4
2	EE 629	Digital Control	3-1-0	4
3		Professional Electives – I	3-1-0	4
4		Professional Electives – II	3-1-0	4
5		Professional Electives – III	3-1-0	4
6	EE 673	Modeling and Simulation Laboratory	0-0-3	2
7	EE 679	Control Systems Laboratory	0-0-3	2
8	EE 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 628	Industrial Process Automation	3-1-0	4
2	EE 636	System Identification and Adaptive Control	3-1-0	4
3		Professional Electives – IV	3-1-0	4
4		Professional Electives – V	3-1-0	4
5		Professional Electives – VI	3-1-0	4
6	EE 670	Instrumentation Laboratory	0-0-3	2
7	EE 674	Embedded Systems Laboratory	0-0-3	2
8	EE 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 687	Seminar & Technical Writing – III	0-0-3	2
2	EE 691	Summer Research / Industrial Project	0-0-0	4
3	EE 693	Research Project Work – I	0-0-0	20
		TOTAL		**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	EE 688	Seminar & Technical Writing – IV	0-0-3	2
2	EE 692	Comprehensive Viva –Voce	0-0-0	4
3	EE 694	Research Project Work – II	0-0-0	20
		TOTAL		**26**

Curriculum of M. Tech. (INDUSTRIAL ELECTRONICS)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 631	Industrial Electronics	3-1-0	4
2	EE 625	Systems and Control Theory	3-1-0	4
3		Professional Elective - I	3-1-0	4
4		Professional Elective - II	3-1-0	4
5		Professional Elective - III	3-1- 0	4
6	EE 679	Control Systems Laboratory	0-0-3	2
7	EE 773	Industrial Electronics Laboratory	0-0-3	2
8	EE 685	Seminar Technical Writing – I	0-0-3	2
		TOTAL		**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 632	Modelling and Control of Power Converters	3-1-0	4
2	EE 732	System Design using HDL	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	EE 670	Instrumentation Laboratory	0-0-3	2
7	EE 674	Embedded Systems Laboratory	0-0-3	2
8	EE 686	Seminar Technical Writing – II	0-0-3	2
		TOTAL		**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 687	Seminar Technical Writing – III	0-0-3	2
2	EE 691	Summer Research / Industrial Project	0-0-0	4
3	EE 693	Research Project – I	0-0-0	20
		TOTAL		**25**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	EE 688	Seminar Technical Writing – III	0-0-3	2
2	EE 692	Comprehensive Viva Voce	0-0-0	4
3	EE 694	Research Project – II	0-0-0	20
		TOTAL		**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credits	Offered To
1	EE 604	Flexible AC Transmission Systems	3-1-0	4	$,&
2	EE 605	Power Plant Control and Instrumentation	3-1-0	4	%
3	EE 606	Transient in Power Systems	3-1-0	4	$
4	EE 607	Extra High Voltage transmission	3-1-0	4	$
5	EE 608	Fault Detection and Diagnosis	3-1-0	4	%
6	EE 615	Power System Dynamics	3-1-0	4	$,&
7	EE 616	Electrical Energy Systems	3-1-0	4	$,&
8	EE 621	Power Electronics Converters and Machine Drives	3-1-0	4	%,&
9	EE 623	Control of Electric Drives	3-1-0	4	%,&
10	EE 624	Distributed Control & Communication Networks	3-1-0	4	@,%,&
11	EE 625	Systems and Control Theory	3-1-0	4	@,$
12	EE 626	Nonlinear Control Systems	3-1-0	4	$,%
13	EE 627	Optimal Control	3-1-0	4	$,%
14	EE 629	Digital Control	3-1-0	4	@,&
15	EE 630	Robust Control	3-1-0	4	$,%
16	EE 631	Industrial Electronics	3-1-0	4	@,%
17	EE 632	Control and Guidance	3-1-0	4	%
18	EE 633	Power Plant Control and Instrumentation	3-1-0	4	%
19	EE 634	Robotics & Automation	3-1-0	4	#
20	EE 637	Soft Computing Techniques	3-1-0	4	@,$,%
21	EE 638	Intelligent Control	3-1-0	4	#
22	EE 639	Industrial Applications of Power Electronics	3-1-0	4	&
23	EE 640	Pattern Recognition & Applications	3-1-0	4	@,%
24	EE 642	Wireless Communication	3-1-0	4	%
25	EE 644	Antenna Synthesis & Analysis	3-1-0	4	@
26	EE 645	Adaptive Signal Processing	3-1-0	4	@,$,%
27	EE 646	Estimation of Signals & Systems	3-1-0	4	@,$,%
28	EE 647	Wireless Networks & Protocols	3-1-0	4	@,%
29	EE 648	Computer Vision	3-1-0	4	@,%
30	EE 649	Wireless Sensor Networks	3-1-0	4	@,%,&
31	EE 650	Nano-electronic Devices Modeling & Simulation	3-1-0	4	@
32	EE 651	Digital Speech Processing	3-1-0	4	@
33	EE 652	Ad-Hoc Networks	3-1-0	4	@
34	EE 653	Digital Image Processing	3-1-0	4	@
35	EE 655	VLSI Signal Processing	3-1-0	4	@
36	EE 656	Computer Communication Networks	3-1-0	4	@,%
37	EE 657	Optical communication	3-1-0	4	@
38	EE 658	Evolutionary Computing Techniques	3-1-0	4	@,%
39	EE 659	Digital VLSI Design	3-1-0	4	@
40	EE 660	Fault Detection and Diagnosis	3-1-0	4	%
41	EE 661	Advanced Signal Processing	3-1-0	4	#
42	EE 663	Microprocessor and Microcontroller Systems	3-1-0	4	@,%
43	EE 664	Embedded Control System	3-1-0	4	#
44	EE 667	Microelectronic Devices and Circuits	3-1-0	4	@
45	EE 668	Instrumentation and Sensors	3-1-0	4	#

46	EE 681	Special Topics in Signal Processing/ Special Topics in Electrical Engineering – I/ Special Topic in Industrial Electronics – I		3/4	#
47	EE 682	Special Topics in Communication/ Special Topics in Electrical Engineering – II/ Special Topic in Industrial Electronics – II		3/4	#
48	EE 683	Special Laboratory in Electronics Systems Design/ Special Laboratory in Electrical Engineering – I/ Special Laboratory in Industrial Electronics – I	0-0-3	2	#
49	EE 684	Special Laboratory in Communication & Signal Processing/ Special Laboratory in Electrical Engineering –II/ Special Laboratory in Industrial Electronics – II	0-0-3	2	#
50	EE 732	System Design using HDL	3-1-0	4	&
51	EE 734	Super Conducting Magnets and Devices	3-1-0	4	&
52	EE 735	Automotive Electronics	3-1-0	4	&

Note: @- for Electronics Systems and Communication $- for Power Control and Drives
%- for Control and Automation &- for Industrial Electronics
- Common for all Specializations

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

Sl. No	Sub. Code	Subject	L-T-P	Credits	Offered To
1	CH 631	Process Plant Simulation	3-1-0	4	%
2	CH 632	Advanced Process Control	3-1-0	4	%
3	CH 641	Bioenergy Engineering	3-1-0	4	$
4	CH 668	Evolutionary Computation	3-1-0	4	@,$
5	CR 645	Nanomaterials	3-1-0	4	@,$
6	CS 613	Wireless Network Security	3-1-0	4	@
7	CS 614	Combinatorial Optimization	3-1-0	4	@
8	CS 618	Real Time Systems Design	3-1-0	4	%
9	CS 623	Real Time Systems	3-1-0	4	@
10	CS 624	Network Security	3-1-0	4	@
11	CS 625	Ad hoc and Wireless Networks	3-1-0	4	@
12	CS 632	Distributed Operating Systems	3-1-0	4	@
13	CS 633	Bioinformatics	3-1-0	4	@
14	CS 634	Bioinformatics	3-1-0	4	@,%
15	CS 636	Image Processing	3-1-0	4	&
16	CS 643	Embedded Systems	3-1-0	4	@,$
17	CS 649	VLSI System Design	3-1-0	4	@,$
18	CS 674	Network Simulations Laboratory	0-0-3	2	%
19	EC 600	Architecture of DSP	3-1-0	4	@,$
20	EC 620	Modeling and circuit Simulators for VLSI Systems	3-1-0	4	@,$
21	EC 621	Digital VLSI Design	3-1-0	4	@,$
22	EC 622	Analog and Mixed mode VLSI	3-1-0	4	@,$
23	EC 623	HDL and High Level VLSI	3-1-0	4	@,$
24	EC 624	Embedded Computing System	3-1-0	4	@,$
25	EC 626	Low Power VLSI	3-1-0	4	@,$
26	EC 628	VLSI Signal Processing	3-1-0	4	@,$
27	EC 640	Pattern Recognition Application	3-1-0	4	@,$
28	EC 641	Digital Signal Processing	3-0-0	3	&

29	EC 642	Advanced Techniques in Digital Signal Processing	3-1-0	4	%
30	EC 642	Advanced Techniques in DSP	3-1-0	4	&
31	EC 672	Advanced Techniques in DSP Lab	0-0-3	2	%
32	MA 522	Operation Research	3-1-0	4	@,$
33	MA 523	Discrete Mathematics	3-1-0	4	@,$
34	MA 524	Statistical Methods	3-1-0	4	@,$
35	MA 527	Fractals	3-1-0	4	@,$
36	MA 534	Geometry of Robotics	3-1-0	4	%
37	MA 551	Numerical Analysis	3-1-0	4	@,$,%
38	MA 552	Fuzzy logic and Set Theory	3-1-0	4	@,$
39	MA 553	Optimization Techniques	3-1-0	4	@,$,%
40	ME 601	Optimization Methods in Engineering Design	3-1-0	4	%
41	ME 602	Robotics	3-1-0	4	&
42	ME 604	Advanced Mechatronics	3-1-0	4	%
43	ME 611	Vibration Analysis & Diagnostics	3-1-0	4	%
44	ME 620	Nonlinear Oscillation	3-1-0	4	%
45	ME 625	Intelligent Industrial Automation and its Application	3-1-0	4	%
46	ME 645	Soft Computing for Intelligent Manufacturing	3-1-0	4	&
47	ME 764	Space Propulsion	3-1-0	4	%
48	ME 767	Fuel Cell Technology	3-1-0	4	%
49	PH 645	Non-linear dynamics, Chaos and its recent applications	3-1-0	4	@,$
50	PH 646	Synchronization and its recent applications in Chaotic systems	3-1-0	4	@,$

Note: @- for Electronics Systems and Communication $- for Power Control and Drives
%- for Control and Automation &- for Industrial Electronics

LIST OF ELECTIVE LABORATORY COURSES

Sl. No	Sub. Code.	Subject	L-T-P	Credit
1.	EE 670	Instrumentation Laboratory	0-0-3	2
2.	EE 674	Embedded System Laboratory	0-0-3	2
3.	EE 679	Control Systems Laboratory	0-0-3	2
4.	EE 773	Industrial Electronics Laboratory	0-0-3	2

SUMMARY OF COURSES

Sub Discipline: Machines and Power Systems

EE 604	Flexible AC transmission Systems	3-1-0	4
EE 605	Power Plant Control and Instrumentation	3-1-0	4
EE 606	Transient in Power Systems	3-1-0	4
EE 607	Extra High Voltage transmission	3-1-0	4
EE 608	Fault Detection and Diagnosis	3-1-0	4
EE 611	Machine Analysis	3-1-0	4
EE 615	Power System Dynamics	3-1-0	4
EE 616	Electrical Energy Systems	3-1-0	4

Sub Discipline: Control, Power Electronics and Drives

EE 612	Advanced Machine Drives	3-1-0	4
EE 621	Power Electronic Converters & Machine Drives	3-1-0	4
EE 622	Advanced Power Electronic Converters	3-1-0	4
EE 623	Control of Electric Drives	3-1-0	4

EE 624	Distributed Control & Communication Networks	3-1-0	4
EE 625	Systems and Control Theory	3-1-0	4
EE 626	Nonlinear Control Systems	3-1-0	4
EE 627	Optimal Control	3-1-0	4
EE 628	Industrial Process Automation	3-1-0	4
EE 629	Digital Control	3-1-0	4
EE 630	Robust Control	3-1-0	4
EE 631	Industrial Electronics	3-1-0	4
EE 632	Control and Guidance	3-1-0	4
EE 634	Robotics and Automation	3-1-0	4
EE 636	System Identification and Adaptive Control	3-1-0	4
EE 637	Soft Computing Techniques	3-1-0	4
EE 638	Intelligent Control	3-1-0	4
EE 639	Industrial Applications of Power Electronics	3-1-0	4
EE 661	Adaptive Signal Processing	3-1-0	4
EE 663	Microprocessor and Microcontroller Systems	3-1-0	4
EE 664	Embedded Control System	3-1-0	4
EE 668	Instrumentation and Sensors	3-1-0	4
EE 732	System Design using HDL	3-1-0	4
EE 734	Super Conducting Magnets and Devices	3-1-0	4
EE 735	Automotive Electronics	3-1-0	4

Sub Discipline: Electronics, Signal Processing and Communication

EE 640	Pattern Recognition & Applications	3-1-0	4
EE 641	Digital Communication	3-1-0	4
EE 642	Wireless Communication	3-1-0	4
EE 643	Microwave & Antenna Systems	3-1-0	4
EE 644	Antenna Synthesis & Analysis	3-1-0	4
EE 645	Adaptive Signal Processing	3-1-0	4
EE 646	Estimation of Signals & Systems	3-1-0	4
EE 647	Wireless Networks & Protocols	3-1-0	4
EE 648	Computer Vision	3-1-0	4
EE 649	Wireless Sensor Networks	3-1-0	4
EE 650	Nano-electronic Devices Modeling & Simulation	3-1-0	4
EE 651	Digital Speech Processing	3-1-0	4
EE 652	Ad-Hoc Networks	3-1-0	4
EE 653	Digital Image Processing	3-1-0	4
EE 654	Satellite Communication	3-1-0	4
EE 655	VLSI Signal Processing	3-1-0	4
EE 656	Computer Communication Networks	3-1-0	4
EE 657	Optical communication	3-1-0	4
EE 658	Evolutionary Computing Techniques	3-1-0	4
EE 659	Digital VLSI Design	3-1-0	4
EE 661	Advanced Signal Processing	3-1-0	4
EE 667	Microelectronic Devices and Circuits	3-1-0	4
EE 664	Embedded Computing Systems	3-1-0	4
EE 668	Instrumentation and Sensors	3-1-0	4

Sub Discipline: Laboratory Courses

EE 670	Instrumentation Laboratory	0-0-3	2
EE 671	Microwave & Antenna Laboratory	0-0-3	2
EE 672	Advanced Communication Laboratory	0-0-3	2

EE 673	Modeling & Simulation Laboratory	0-0-3	2
EE 674	Embedded System Laboratory	0-0-3	2
EE 675	Power Electronics and Drives Laboratory – I	0-0-3	4
EE 676	Power Electronics and Drives Laboratory – II	0-0-3	4
EE 677	Machines and Control Laboratory	0-0-3	4
EE 678	Power Electronics and Drives Simulation Laboratory	0-0-3	4
EE 679	Control Systems Laboratory	0-0-3	2
EE 773	Industrial Electronics Laboratory	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

EE 681	Special Topics in Signal Processing/ Special Topics in Electrical Engineering – I/ Special Topic in Industrial Electronics – I		3/4
EE 682	Special Topics in Communication/ Special Topics in Electrical Engineering – II/ Special Topic in Industrial Electronics – II		3/4
EE 683	Special Laboratory in Electronics Systems Design/ Special Laboratory in Electrical Engineering – I/ Special Laboratory in Industrial Electronics – I	0-0-3	2
EE 684	Special Laboratory in Communication & Signal Processing/ Special Laboratory in Electrical Engineering –II/ Special Laboratory in Industrial Electronics – II	0-0-3	2
EE 685	Seminar & Technical Writing – I	0-0-3	2
EE 686	Seminar & Technical Writing – II	0-0-3	2
EE 687	Seminar & Technical Writing – III	0-0-3	2
EE 688	Seminar & Technical Writing – IV	0-0-3	2
EE 691	Summer Research / Industrial Project		4
EE 692	Comprehensive Viva-Voce		4
EE 693	Research Project Work – I		20
EE 694	Research Project Work – II		20

DEPARTMENT OF MECHANICAL ENGINEERING

Curriculum of M.Tech (MACHINE DESIGN & ANALYSIS)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 603	Applied Elasticity & Plasticity	3-1-0	4
2	ME 610	Analysis and Synthesis of Mechanisms	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6		Elective Laboratory – I	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	ME 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 611	Vibration Analysis & Diagnostics	3-1-0	4
2	ME 612	Non-Traditional Parameter in Design	3-1-0	4
3		Professional Electives – IV	3-1-0	4
4		Professional Electives – V	3-1-0	4
5		Professional Electives – VI	3-1-0	4
6		Elective Laboratory III	0-0-3	2
7		Elective Laboratory IV	0-0-3	2
8	ME 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 687	Seminar & Technical Writing – III	0-0-0	2
2	ME 691	Summer Research / Industrial Project	0-0-0	4
3	ME 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 688	Seminar & Technical Writing – IV	0-0-0	2
2	ME 692	Comprehensive Viva Voce	0-0-0	4
3	ME 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M.Tech (PRODUCTION ENGINEERING)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 603	Applied Elasticity & Plasticity	3-1-0	4
2	ME 631	Production Technology	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6		Elective Laboratory – I	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	ME 685	Seminar & Technical Writing – I	0-0-0	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 632	Machine Tool Technology	3-1-0	4
2	ME 633	Modern Manufacturing Processes	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6		Elective Laboratory – III	0-0-3	2
7		Elective Laboratory – IV	0-0-3	2
8	ME 686	Seminar & Technical Writing – II	0-0-0	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 687	Seminar & Technical Writing – III	0-0-3	2
2	ME 691	Summer Research / Industrial Project	0-0-0	4
3	ME 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 688	Seminar & Technical Writing – IV	0-0-3	2
2	ME 692	Comprehensive Viva Voce	0-0-0	4
3	ME 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M.Tech (THERMAL ENGINEERING)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 650	Heat Transfer – I: Conduction and Radiation Heat Transfer	3-1-0	4
2	ME 651	Advanced Fluid Mechanics	3-1-0	4
3		Professional Electives – I	3-1-0	4
4		Professional Electives – II	3-1-0	4
5		Professional Electives – III	3-1-0	4
6		Elective Laboratory – I	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	ME 685	Seminar & Technical Writing - I	0-0-0	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 652	Heat Transfer – II: Convection Heat Transfer	3-1-0	4
2	ME 653	Computational Fluid Dynamics	3-1-0	4
3		Professional Electives – IV	3-1-0	4
4		Professional Electives – V	3-1-0	4
5		Professional Electives – VI	3-1-0	4
6		Elective Laboratory – III	0-0-3	2
7		Elective Laboratory – IV	0-0-3	2
8	ME 686	Seminar & Technical Writing - II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 687	Seminar & Technical Writing - III	0-0-3	2
2	ME 691	Summer Research / Industrial Project	0-0-0	4
3	ME 693	Research Project Work - I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1	ME 688	Seminar & Technical Writing – IV	0-0-3	2
2	ME 692	Comprehensive Viva Voce	0-0-0	4
3	ME 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M. Tech (CRYOGENICS AND VACCUM TECHNOLOGY)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	ME 659	Cryogenic Process Engineering	3-1-0	4
2	PH 667	Low Temperature properties of Matter	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6		Elective Laboratory - I	0-0-3	2
7		Elective Laboratory – II	0-0-3	2
8	ME 685	Seminar Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	ME 759	Air separation and Industrial Gases	3-1-0	4
2	ME 760	Vacuum Technology	3-1-0	4
3		Professional Elective - IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective - VI	3-1-0	4
6		Elective Laboratory – III	0-0-3	2
7		Elective Laboratory – IV	0-0-3	2
8	ME 686	Seminar Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	ME 687	Seminar Technical Writing – III	0-0-0	2
2	ME 691	Summer Research / Industrial Project	0-0-0	4
3	ME 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	ME 688	Seminar Technical Writing – IV	0-0-0	2
2	ME 692	Comprehensive Viva Voce	0-0-0	4
3	ME 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subjects	L-T-P	Credits	Offered To
1	ME 600	Applied Finite Element Analysis	3-1-0	4	#
2	ME 601	Optimization Method in Engineering Design	3-1-0	4	@,$,%
3	ME 602	Robotics	3-1-0	4	@,$
4	ME 603	Applied Elasticity & Plasticity	3-1-0	4	@,$
5	ME 604	Advanced Mechatronics	3-1-0	4	@,$,%
6	ME 605	Advanced Decision Modeling Technique	3-1-0	4	@,$
7	ME 606	Neural Network & Artificial Intelligence	3-1-0	4	@,$,%
8	ME 607	Concurrent Engineering	3-1-0	4	@,$
9	ME 608	Control system Engineering	3-1-0	4	@,$,%
10	ME 610	Analysis and Synthesis of Mechanisms	3-1-0	4	@
11	ME 611	Vibration Analysis & Diagnostics	3-1-0	4	@
12	ME 612	Non-Traditional Parameter in Design	3-1-0	4	@
13	ME 613	Design of Material Handling Equipment	3-1-0	4	@
14	ME 614	Experimental Stress Analysis	3-1-0	4	@
15	ME 615	Computer Aided Design of Machines	3-1-0	4	@
16	ME 616	Fatigue and Fracture of Engineering Components	3-1-0	4	@
17	ME 617	Intelligent System Control	3-1-0	4	@
18	ME 618	Rotor Dynamics	3-1-0	4	@
19	ME 619	Human Response to Vibration	3-1-0	4	@
20	ME 620	Nonlinear Oscillation	3-1-0	4	@
21	ME 621	Analytical Methods in Rotor Dynamics	3-1-0	4	@
22	ME 622	Bearing and Lubrication	3-1-0	4	@
23	ME 623	Design of Tribological Elements	3-1-0	4	@
24	ME 624	Materials for Tribological Applications	3-1-0	4	@
25	ME 625	Intelligent Industrial Automation and its Application	3-1-0	4	@
26	ME 631	Production Technology	3-1-0	4	$
27	ME 632	Machine Tool Technology	3-1-0	4	$
28	ME 633	Modern Manufacturing Processes	3-1-0	4	$
29	ME 634	Metal Cutting & Tool Design	3-1-0	4	$
30	ME 635	Product Design for Manufacturing	3-1-0	4	@,$
31	ME 636	Theory of Plastic Deformation	3-1-0	4	$
32	ME 637	Production System & Computer Integrated Manufacturing	3-1-0	4	$
33	ME 638	Advanced Analysis in Metal Deformation Processes	3-1-0	4	$
34	ME 639	Modeling of Welding Phenomena	3-1-0	4	$
35	ME 640	Laser Application in Manufacturing	3-1-0	4	$
36	ME 641	Knowledge Based Systems in Manufacturing	3-1-0	4	$
37	ME 642	CNC Machine Tools and Automated Manufacturing	3-1-0	4	$
38	ME 643	Advanced Topics in Non-Traditional Manufacturing Processes	3-1-0	4	$
39	ME 644	Micro-Machining and Precision Engineering	3-1-0	4	$
40	ME 645	Soft Computing for Intelligent Manufacturing	3-1-0	4	$
41	ME 646	Reliability analysis & Maintenance Management	3-1-0	4	$
42	ME 647	Production Management	3-1-0	4	$

43	ME 648	Quality Engineering and Reliability	3-1-0	4	$
44	ME 650	Heat Transfer – I: Conduction and Radiation Heat Transfer	3-1-0	4	%,&
45	ME 651	Advanced Fluid Mechanics	3-1-0	4	%,&
46	ME 652	Heat Transfer – II: Convection Heat Transfer	3-1-0	4	%,&
47	ME 653	Computational Fluid Dynamics	3-1-0	4	%,&
48	ME 654	Advanced Thermodynamics	3-1-0	4	%
49	ME 655	Refrigeration and Cryogenic Systems	3-1-0	4	%,&
50	ME 656	Gas Turbines and Jet Propulsion	3-1-0	4	%,&
51	ME 657	Computational Methods in Thermal Engg.	3-1-0	4	%,&
52	ME 658	Air-Conditioning and Ventilating System	3-1-0	4	%,&
53	ME 659	Cryogenic Process Engineering	3-1-0	4	%
54	ME 660	Heat Transfer Equipments	3-1-0	4	%
55	ME 661	Design of Thermal Systems	3-1-0	4	%,&
56	ME 662	Thermal Processes in Surface Engineering	3-1-0	4	%
57	ME 663	Radiation Heat Transfer	3-1-0	4	%,&
58	ME 664	Thermal Measurements	3-1-0	4	%,&
59	ME 665	Furnace Design	3-1-0	4	%
60	ME 666	Alternative Fuels for IC Engines	3-1-0	4	%
61	ME 667	Aircraft and Rocket Propulsion	3-1-0	4	%,&
62	ME 668	Energy Conservation and Management	3-1-0	4	%
63	ME 681	Special Topics in Mechanical Engineering – I		3/4	#,&
64	ME 682	Special Topics in Mechanical Engineering – II		3/4	#,&
65	ME 683	Special Laboratory in Mechanical Engineering - I	0-0-3	2	#,&
66	ME 684	Special Laboratory in Mechanical Engineering – II	0-0-3	2	#,&
67	ME 701	Composite Materials	3-1-0	4	#
68	ME 710	Advanced Composites	3-1-0	4	@
69	ME 711	Fundamentals of Tribology	3-1-0	4	@
70	ME 712	Fundamentals of Ergonomics	3-1-0	4	@
71	ME 750	Gas Dynamics and Free Molecular Flow	3-1-0	4	%
72	ME 751	Heat Exchanger Analysis and Design	3-1-0	4	@,%,&
73	ME 752	Advanced Turbo-Machinery	3-1-0	4	%,&
74	ME 753	Non-Conventional Energy Systems	3-1-0	4	%
75	ME 754	Theory of Combustion and Emission	3-1-0	4	%
76	ME 755	Cryogenic Heat Transfer & Superfluid	3-1-0	4	%,&
77	ME 756	Nuclear Power Generation and Safety	3-1-0	4	%
78	ME 757	Two-Phase Flow and Heat Transfer	3-1-0	4	%
79	ME 758	Superconducting Materials, Magnets and Devices	3-1-0	4	%,&
80	ME 759	Air Separation and Industrial Gases	3-1-0	4	%,&
81	ME 760	Vacuum Technology	3-1-0	4	%
82	ME 761	Bio-fluid Mechanics	3-1-0	4	%
83	ME 762	Transport Phenomena in Material Processing	3-1-0	4	%
84	ME 763	Microfluidics and Heat Transfer	3-1-0	4	%
85	ME 764	Space Propulsion	3-1-0	4	%,&
86	ME 765	Advanced IC Engine Technology	3-1-0	4	%
87	ME 766	Micro-scale Heat Transfer	3-1-0	4	%
88	ME 767	Fuel Cell Technology	3-1-0	4	%
89	ME 768	Turbulence	3-1-0	4	%
90	ME 769	Design of Cryo-Equipment and Accessories	3-1-0	4	&

91	ME 850	System Design for Cryogenic Applications	3-1-0	4	&

Note: @- for Machine Design and Analysis $ - for Production Engineering
%- for Thermal Engineering &- for Cryogenics and Vacuum Technology
- Common for all above specializations

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

Sl. No	Sub. Code.	Subject	L-T-P	Credit
1	CH 614	Advanced Separation Technology	3-1-0	4
2	MM 659	Vacuum Technology in Materials Engineering	3-1-0	4
3	PH 654	Physics of Thin Film Technology	3-1-0	4
4	PH 662	Superfluidity and Superconductivity	3-1-0	4
5	PH 663	Physical phenomena at low Temperature	3-1-0	4
6	PH 664	Magnetism: Principles and Applications	3-1-0	4
7	EE 734	Super Conducting Magnets and Devices	3-1-0	4

LIST OF ELECTIVE LABORATORY COURSES

Sl. No	Sub. Code.	Subject	L-T-P	Credit
1.	ME 676	Computational Heat Transfer Laboratory	0-0-3	2
2.	ME 677	Computational Fluid Flow Laboratory	0-0-3	2
3.	ME 678	Process Simulation Laboratory	0-0-3	2
4.	ME 774	Heat Transfer and Fluid Flow Laboratory	0-0-3	2
5.	ME 775	Thermal System Design Laboratory	0-0-3	2

SUMMARY OF COURSES

Sub Discipline: Stress Analysis & Tribology

ME 600	Applied Finite Element Analysis	3-1-0	4
ME 613	Design of Material Handling Equipment	3-1-0	4
ME 614	Experimental Stress Analysis	3-1-0	4
ME 615	Computer Aided Design of Machines	3-1-0	4
ME 616	Fatigue and Fracture of Engineering Components	3-1-0	4
ME 622	Bearing and Lubrication	3-1-0	4
ME 623	Design of Tribological Elements	3-1-0	4
ME 624	Materials for Tribological Applications	3-1-0	4
ME 701	Composite Materials	3-1-0	4
ME 710	Advanced Composites	3-1-0	4
ME 711	Fundamentals of Tribology	3-1-0	4
ME 712	Fundamentals of Ergonomics	3-1-0	4

Sub Discipline: Vibration & Robotics

ME 602	Robotics	3-1-0	4
ME 604	Advanced Mechatronics	3-1-0	4
ME 608	Control system Engineering	3-1-0	4
ME 610	Analysis and Synthesis of Mechanisms	3-1-0	4
ME 611	Vibration Analysis & Diagnostics	3-1-0	4
ME 612	Non-Traditional Parameter in Design	3-1-0	4
ME 617	Intelligent System Control	3-1-0	4
ME 618	Rotor Dynamics	3-1-0	4
ME 619	Human Response to Vibration	3-1-0	4
ME 620	Nonlinear Oscillation	3-1-0	4
ME 621	Analytical Methods in Rotor Dynamics	3-1-0	4
ME 625	Intelligent Industrial Automation and its Application	3-1-0	4

Sub Discipline: Manufacturing Science

ME 603	Applied Elasticity & Plasticity	3-1-0	4
ME 607	Concurrent Engineering	3-1-0	4
ME 631	Production Technology	3-1-0	4
ME 632	Machine Tool Technology	3-1-0	4
ME 633	Modern Manufacturing Processes	3-1-0	4
ME 634	Metal Cutting & Tool Design	3-1-0	4
ME 635	Product Design for Manufacturing	3-1-0	4
ME 636	Theory of Plastic Deformation	3-1-0	4
ME 637	Production System & Computer Integrated Manufacturing	3-1-0	4
ME 638	Advanced Analysis in Metal Deformation Processes	3-1-0	4
ME 639	Modeling of Welding Phenomena	3-1-0	4
ME 640	Laser Application in Manufacturing	3-1-0	4
ME 641	Knowledge Based Systems in Manufacturing	3-1-0	4
ME 642	CNC Machine Tools and Automated Manufacturing	3-1-0	4
ME 643	Advanced Topics in Non-Traditional Manufacturing Processes	3-1-0	4
ME 644	Micro-Machining and Precision Engineering	3-1-0	4
ME 645	Soft Computing for Intelligent Manufacturing	3-1-0	4

Sub Discipline: Industrial Engineering

ME 601	Optimization Method in Engineering Design	3-1-0	4
ME 605	Advanced Decision Modeling Technique	3-1-0	4
ME 606	Neural Network & Artificial Intelligence	3-1-0	4
ME 646	Reliability analysis & Maintenance Management	3-1-0	4
ME 647	Production Management	3-1-0	4
ME 648	Quality Engineering and Reliability	3-1-0	4

Sub Discipline: Fluid Flow and Heat Transfer

CH 614	Advanced Separation Technology	3-1-0	4
ME 600	Applied Finite Element Analysis	3-1-0	4
ME 650	Heat Transfer – I: Conduction and Radiation Heat Transfer	3-1-0	4
ME 651	Advanced Fluid Mechanics	3-1-0	4
ME 652	Heat Transfer – II: Convection Heat Transfer	3-1-0	4
ME 653	Computational Fluid Dynamics	3-1-0	4
ME 656	Gas Turbines and Jet Propulsion	3-1-0	4
ME 657	Computational Methods in Thermal Engg.	3-1-0	4
ME 658	Air-Conditioning and Ventilating System	3-1-0	4
ME 659	Cryogenic Process Engineering	3-1-0	4
ME 660	Heat Transfer Equipments	3-1-0	4
ME 661	Design of Thermal Systems	3-1-0	4
ME 663	Radiation Heat Transfer	3-1-0	4
ME 664	Thermal Measurements	3-1-0	4
ME 665	Furnace Design	3-1-0	4
ME 666	Alternative Fuels for IC Engines	3-1-0	4
ME 667	Aircraft and Rocket Propulsion	3-1-0	4
ME 668	Energy Conservation and Management	3-1-0	4
ME 750	Gas Dynamics and Free Molecular Flow	3-1-0	4
ME 751	Heat Exchanger Analysis and Design	3-1-0	4
ME 752	Advanced Turbo-Machinery	3-1-0	4

ME 753	Non-Conventional Energy Systems	3-1-0	4
ME 754	Theory of Combustion and Emission	3-1-0	4
ME 756	Nuclear Power Generation and Safety	3-1-0	4
ME 757	Two-Phase Flow and Heat Transfer	3-1-0	4
ME 761	Bio-fluid Mechanics	3-1-0	4
ME 762	Transport Phenomena in Material Processing	3-1-0	4
ME 763	Microfluidics and Heat Transfer	3-1-0	4
ME 764	Space Propulsion	3-1-0	4
ME 765	Advanced IC Engine Technology	3-1-0	4
ME 766	Micro-scale Heat Transfer	3-1-0	4
ME 767	Fuel Cell Technology	3-1-0	4
ME 768	Turbulence	3-1-0	4

Sub Discipline: Refrigeration & Cryogenics

ME 650	Heat Transfer – I: Conduction and Radiation Heat Transfer	3-1-0	4
ME 652	Heat Transfer – II: Convection Heat Transfer	3-1-0	4
ME 654	Advanced Thermodynamics	3-1-0	4
ME 655	Refrigeration and Cryogenic Systems	3-1-0	4
ME 656	Gas Turbines and Jet Propulsion	3-1-0	4
ME 658	Air-Conditioning and Ventilating System	3-1-0	4
ME 659	Cryogenic Process Engineering	3-1-0	4
ME 660	Heat Transfer Equipments	3-1-0	4
ME 662	Thermal Processes in Surface Engineering	3-1-0	4
ME 751	Heat Exchanger Analysis and Design	3-1-0	4
ME 752	Advanced Turbo-Machinery	3-1-0	4
ME 753	Non_ Conventional Energy Systems	3-1-0	4
ME 755	Cryogenic Heat Transfer & Superfluids	3-1-0	4
ME 758	Superconducting Materials, Magnets and Devices	3-1-0	4
ME 759	Air Separation and Industrial Gases	3-1-0	4
ME 760	Vacuum Technology	3-1-0	4
ME 764	Space Propulsion	3-1-0	4
ME 769	Design of Cryo-Equipment and Accessories	3-1-0	4
ME 850	Design of Cryogenic Application Systems	3-1-0	4
MM 659	Vacuum Technology in Materials Engineering	3-1-0	4
PH 654	Physics of Thin Film Technology	3-1-0	4
PH 662	Superfluidity And Superconductivity	3-1-0	4
PH 663	Physical phenomena at low temperature	3-1-0	4
PH 664	Magnetism: Principles and Applications	3-1-0	4

Sub Discipline: Laboratory Courses

ME 670	Advanced Manufacturing Laboratory	0-0-3	2
ME 671	Non-Conventional Machining Laboratory	0-0-3	2
ME 672	Industrial Engineering Laboratory	0-0-3	2
ME 673	Stress Analysis Laboratory	0-0-3	2
ME 674	Tribology Laboratory	0-0-3	2
ME 675	Vibration and Machine Dynamics Laboratory	0-0-3	2
ME 676	Computational Heat Transfer Laboratory	0-0-3	2
ME 677	Computational Fluid Flow Laboratory	0-0-3	2
ME 678	Process Simulation Laboratory	0-0-3	2
ME 770	Precession Engineering Laboratory	0-0-3	2
ME 771	Modeling & Simulation Laboratory	0-0-3	2

ME 772	Robotics and Mechatronics Laboratory	0-0-3	2
ME 773	CAD Laboratory	0-0-3	2
ME 774	Heat Transfer and Fluid Flow Laboratory	0-0-3	2
ME 775	Thermal System Design Laboratory	0-0-3	2
WS 671	Advanced Manufacturing Practice	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

ME 681	Special Topics in Mechanical Engineering – I		3/4
ME 682	Special Topics in Mechanical Engineering – II		3/4
ME 683	Special Laboratory in Mechanical Engineering – I	0-0-3	2
ME 684	Special Laboratory in Mechanical Engineering – II	0-0-3	2
ME 685	Seminar Technical Writing – I	0-0-0	2
ME 686	Seminar Technical Writing – II	0-0-0	2
ME 687	Seminar Technical Writing – III	0-0-0	2
ME 688	Seminar Technical Writing – IV	0-0-0	2
ME 691	Summer Research / Industrial Project	0-0-0	4
ME 692	Comprehensive Viva Voce	0-0-0	4
ME 693	Research Project – I	0-0-0	20
ME 694	Research Project – II	0-0-0	20

DEPARTMENT OF METALLURGICAL AND MATERIAL ENGINEERING

Curriculum of M.Tech (METALLURGICAL AND MATERIAL ENGINEERING)

FIRST SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	MM 601	Metallurgical Thermodynamics & Kinetics	3-1-0	4
2	MM 611	Phase Transformation of Materials	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
7	MM 673	Phase Transformation Laboratory	0-0-3	2
8	MM 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	MM 642	Advances in Materials Science & Engineering	3-1-0	4
2	MM 652	Experimental Techniques in Materials Engineering	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
7	MM 674	Material Science Lab.	0-0-3	2
8	MM 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	MM 687	Seminar & Technical Writing – III	0-0-3	2
2.	MM 691	Summer Research / Industrial Project	0-0-0	4
3.	MM 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	MM 688	Seminar & Technical Writing – IV	0-0-3	2
2.	MM 692	Comprehensive Viva - Voce	0-0-0	4
3.	MM 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

Curriculum of M. Tech (STEEL TECHNOLOGY)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MM 603	Metallurgical Thermodynamics and Kinetics	3-1-0	4
2	MM 620	Principles of Iron Making	3-1-0	4
3		Professional Elective - I	3-1-0	4
4		Professional Elective - II	3-1-0	4
5		Professional Elective - III	3-1- 0	4
6		Elective Laboratory - I	0-0-3	2
7		Elective Laboratory - II	0-0-3	2
8	MM 685	Seminar Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MM 622	Steel Making	3-1-0	4
2	MM 612	Phase Transformation	3-1-0	4
3		Professional Elective - IV	3-1-0	4
4		Professional Elective - V	3-1-0	4
5		Professional Elective - VI	3-1-0	4
6		Elective Laboratory – III	0-0-3	2
7		Elective Laboratory – IV	0-0-3	2
8	MM 686	Seminar Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MM 687	Seminar Technical Writing – III	0-0-3	2
2	MM 691	Summer Research / Industrial Project	0-0-0	4
3	MM 693	Research Project – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MM 688	Seminar Technical Writing – III	0-0-3	2
2	MM 692	Comprehensive Viva Voce	0-0-0	4
3	MM 694	Research Project – II	0-0-0	20
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub.Code	Subject	L-T-P	Credits	Offered to
1	MM 606	X – Ray & Electron Microscopy	3-1-0	4	$
2	MM 608	Welding of Steels	3-1-0	4	@
3	MM 615	Structure & Properties of Materials	3-1-0	4	$
4	MM 616	Alloy Steel Technology	3-1-0	4	$
5	MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4	$
6	MM 618	Joining of Materials	3-0-0	3	$
7	MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4	$
8	MM 623	Iron & Steel Making	3-1-0	4	$
9	MM 624	Advanced Foundry Technology	3-0-0	3	$
10	MM 625	Ferro – Alloy Technology	3-0-0	3	$
11	MM 626	Alternative Routes of Iron Making	3-1-0	4	@
12	MM 628	Advances in Steel Making	3-1-0	4	$
13	MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4	$
14	MM 636	Advanced Processing of Materials	3-0-0	3	@
15	MM 637	Mechanical Behaviour of Materials	3-1-0	4	@
16	MM 638	Mechanical Working of Materials	3-1-0	4	$
17	MM 646	Composite Materials	3-1-0	4	$
18	MM 647	Fuel Technology	3-1-0	4	@
19	MM 654	Characterization of Materials	3-1-0	4	@
20	MM 655	Transport Phenomena	3-0-0	3	$
21	MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3	$
22	MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3	$

23	MM 681	Special Topic in Steel Technology – I/ Special Topics in Metallurgical and Material Engineering - I		3/4	#
24	MM 682	Special Topic In Steel Technology – II/ Special Topics in Metallurgical and Material Engineering – II		3/4	#
25	MM 683	Special Laboratory in Steel Technology– I / Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2	#
26	MM 684	Special Laboratory in Steel Technology–II / Special Laboratory in Metallurgical and Material Engineering – II	0-0-3	2	#

Note: $ - for Matallurgical and Material Technology, @- for Steel Technology,
- for both specializations

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENT

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CR 603	Energetic	3-1-0	4
2	CR 613	Refractories for Metallurgical & Allied Processes	3-1-0	4
3	CR 625	Advanced Structural Ceramics	3-1-0	4
4	CR 638	Ceramics in High Tech. Applications	3-1-0	4
5	CS 612	Software Engineering	3-1-0	4
6	CS 630	Artificial Intelligence	3-1-0	4
7	CH 312	Transport Phenomenon	3-1-0	4
8	CR 612	Refractory for Mettalurgical and Allied Processes	3-1-0	4
9	ME 634	Metal Cutting and Tool Design	3-1-0	4

LIST OF ELECTIVE LABORATORY COURSES

Sl.No	Sub.Code	Subject	L-T-P	Credit
1.	MM 607	Characterization of Materials Laboratory	0-0-3	2
2.	MM 617	Heat Treatment Laboratory	0-0-3	2
3.	MM 627	Process Metallurgy Laboratory	0-0-3	2
4.	MM 667	Computational Metallurgy Laboratory	0-0-3	2

SUMMARY OF COURSES

Sub Discipline: Process Metallurgy

MM 601	Metallurgical Thermodynamics & Kinetics	3-1-0	4
MM 603	Metallurgical Thermodynamics and Kinetics	3-1-0	4
MM 620	Principles of Iron Making	3-1-0	4
MM 622	Steel Making	3-1-0	4
MM 623	Iron & Steel Making	3-1-0	4
MM 624	Advanced Foundry Technology	3-0-0	3
MM 626	Alternative Routes of Iron Making	3-1-0	4
MM 625	Ferro – Alloy Technology	3-0-0	3
MM 628	Advances in Steel Making	3-1-0	4
MM 647	Fuel Technology	3-1-0	4

Sub Discipline: Physical and Mechanical Metallurgy

MM 606	X – Ray & Electron Microscopy	3-1-0	4
MM 611	Phase Transformation of Materials	3-1-0	4
MM 612	Phase Transformation	3-1-0	4

MM 615	Structure & Properties of Materials	3-1-0	4
MM 616	Alloy Steel Technology	3-1-0	4
MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4
MM 618	Joining of Materials	3-1-0	4
MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4
MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4
MM 636	Advanced Processing of Materials	3-0-0	3
MM 637	Mechanical Behaviour of Materials	3-1-0	4
MM 638	Mechanical Working of Materials	3-1-0	4
MM 654	Characterization of Materials	3-1-0	4
MM 658	Welding of Steels	3-1-0	4

Sub Discipline: Advanced Materials

MM 642	Advances in Materials Science and Engineering	3-1-0	4
MM 646	Composite Materials	3-1-0	4

Sub Discipline: Allied Courses

MM 652	Experimental Techniques in Materials Engineering	3-1-0	6
MM 655	Transport Phenomena	3-0-0	3
MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3
MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3

Sub Discipline: Laboratory

MM 607	Characterization of Materials Laboratory	0-0-3	2
MM 617	Heat Treatment Laboratory	0-0-3	2
MM 627	Process Metallurgy Laboratory	0-0-3	2
MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
MM 673	Phase Transformation Laboratory	0-0-3	2
MM 674	Material Science Lab.	0-0-3	2
MM 667	Computational Metallurgy Laboratory	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

MM 681	Special Topics in Metallurgical and Material Engineering – I/Special Topic in Steel Technology –I		3/4
MM 682	Special Topics in Metallurgical and Material Engineering – II / Special Topic in Steel Technology – II		3/4
MM 683	Special Laboratory in Steel Technology – I/ Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 684	Special Laboratory in Steel Technology – II/ Special Laboratory in Metallurgical and Material Engineering – II	0-0-3	2
MM 685	Seminar & Technical Writing – I	0-0-3	2
MM 686	Seminar & Technical Writing – II	0-0-3	2
MM 687	Seminar & Technical Writing – III	0-0-3	2
MM 688	Seminar & Technical Writing – IV	0-0-3	2
MM 691	Summer Research / Industrial Project	0-0-0	4
MM 692	Comprehensive Viva – Voce	0-0-0	4
MM 693	Research Project – I	0-0-0	20
MM 694	Research Project – II	0-0-0	20

DEPARTMENT OF MINING ENGINEERING

Curriculum of M.Tech (MINING ENGINEERING)

FIRST SEMESTER

Sl. No	Sub Code	Subjects	L-T-P	Credit
1	MN 601	Rock Excavation Engineering	3-1-0	4
2	MN 623	Advance Environmental Engineering	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	MN 671	Rock Excavation Engineering Laboratory	0-0-3	2
7	MN 673	Mining Engineering Laboratory -I	0-0-3	2
8	MN 685	Seminar & Technical Writing – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub Code	Subjects	L-T-P	Credit
1	MN 602	Mine Management	3-1-0	4
2	MN 604	Advanced Mine Planning	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	MN 672	Advance Environmental Engineering Laboratory	0-0-3	2
7	MN 674	Mining Engineering Laboratory – II	0-0-3	2
8	MN 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub Code	Subjects	L-T-P	Credit
1	MN 687	Seminar & Technical Writing – III	0-0-3	2
2	MN 691	Summer Research / Industrial Project	0-0-0	4
3	MN 693	Research Project Work – I	0-0-0	20
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub Code	Subjects	L-T-P	Credit
1	MN 688	Seminar & Technical Writing – IV	0-0-3	2
2	MN 692	Comprehensive Viva Voce	0-0-0	4
3	MN 694	Research Project Work – II	0-0-0	20
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub Code	Subjects	L-T-P	Credit
1	MN 421	Rock Slope Technology	3-1-0	4
2	MN 603	Geo –aspects Management of low and high risk solid byproducts	3-0-0	3
3	MN 606	Strata Control Technology	3-1-0	4
4	MN 607	Ground Control Instrumentation	3-1-0	4
5	MN 608	Tunneling	3-1-0	4
6	MN 609	Advanced Surface Mining	3-1-0	4
7	MN 610	Mining of Deep Seated Deposits	3-1-0	4
8	MN 611	Advanced Coal Mining	3-1-0	4

9	MN 614	Rock Mechanics Application to Environmental Problems	3-1-0	4
10	MN 616	Advanced Metaliferrous Mining	3-1-0	4
11	MN 620	Application of Artificial Intelligence in Mining	3-1-0	4
12	MN 632	Environmental Management	3-1-0	4
13	MN 633	Mine Fires and spontaneous Heating	3-1-0	4
14	MN 635	Advanced Mine Ventilation	3-1-0	4
15	MN 637	Noise Impact Assessment And Control	3-1-0	4
16	MN 638	Hazardous Waste Management	3-1-0	4
17	MN 639	Safety Risk Assessment & Management	3-1-0	4
18	MN 681	Special Topics in Mining Engineering – I		3/4
19	MN 682	Special Topics in Mining Engineering – II		3/4
20	MN 683	Special Laboratory in Mining Engineering– I	0-0-3	2
21	MN 684	Special Laboratory in Mining Engineering– II	0-0-3	2

SUMMARY OF COURSES

Sub Discipline: Geomechanics

MN 601	Rock Excavation Engineering	3-1-0	4
MN 602	Mine Management	3-1-0	4
MN 603	Geo-aspects Management of Low And High Risk Byproducts	3-0-0	3
MN 604	Advanced Mine Planning	3-1-0	4
MN 605	Rock Slope Technology	3-1-0	4
MN 606	Strata Control Technology	3-1-0	4
MN 607	Ground Control Instrumentation	3-1-0	4
MN 608	Tunneling	3-1-0	4
MN 609	Advanced Surface Mining	3-1-0	4
MN 610	Mining of Deep Seated Deposits	3-1-0	4
MN 611	Advanced Coal Mining	3-1-0	4
MN 612	Surface Mining Systems	3-0-0	3
MN 613	Underground Mining Systems	3-0-0	3
MN 614	Rock Mechanics Application to Environmental Problems	3-1-0	4
MN 616	Advanced Metaliferrous Mining	3-1-0	4

Sub Discipline: Mine Environment

MN 620	Application of Artificial Intelligence in Mining	3-1-0	4
MN 623	Advance Environmental Engineering	3-1-0	4
MN 632	Environmental Management	3-1-0	4
MN 633	Mine Fires and spontaneous heating	3-1-0	4
MN 635	Advanced Mine Ventilation	3-1-0	4
MN 637	Noise Impact Assessment And Control	3-1-0	4
MN 638	Hazardous Waste Management	3-1-0	4
MN 639	Safety Risk Assessment & Management	3-1-0	4

Sub Discipline: Laboratory Courses

MN 671	Rock Excavation Engineering Laboratory	0-0-3	2
MN 672	Advance Environmental Engineering Laboratory	0-0-3	2
MN 673	Mining Engineering Laboratory – I	0-0-3	2
MN 674	Mining Engineering Laboratory – II	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

MN 681	Special Topics in Mining Engineering – I		3/4
MN 682	Special Topics in Mining Engineering – II		3/4
MN 683	Special Laboratory in Mining Engineering – I	0-0-3	2
MN 684	Special Laboratory in Mining Engineering – II	0-0-3	2
MN 685	Seminar & Technical Writing – I	0-0-3	2
MN 686	Seminar & Technical Writing – II	0-0-3	2
MN 687	Seminar & Technical Writing – III	0-0-3	2
MN 688	Seminar & Technical Writing – IV	0-0-3	2
MN 691	Summer Research / Industrial Project		4
MN 692	Comprehensive Viva Voce		4
MN 693	Research Project Work – I		20
MN 694	Research Project Work – II		20

B. CURRICULA OF M.Sc,INTEGRATED M.S.c, MA, MBA PROGRAMMES

Sl. No	Branch. Code	Branch Name	Page No.
1	CH	Chemistry	
2	LS	Life Science	
3	MA	Mathematics	
4	PH	Physics	
5	HS	MA in Development Studies (HUMANITIES & SOCIAL SCIENCES)	
6	SM	School of Management	

DEPARTMENT OF CHEMISTRY

Curriculum of M.Sc. (CHEMISTRY)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	CY 511	Stereochemistry and Reaction Mechanism	3-1-0	4
2	CY 521	Principles of Inorganic Chemistry	3-1-0	4
3	CY 531	Thermodynamics & Chemical Equlibria	3-1-0	4
4		Professional Elective – I	3-0-0	3
5		Open Elective - I	3-0-0	3
6	CY 571	Organic Chemistry Laboratory	0-0-9	6
7	CS 171	Computing Laboratory – I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	CY 512	Structure and Functions of Biomolecules	3-1-0	4
2	CY 522	Chemistry of Transition and Non-transition Elements	3-1-0	4
3	CY 532	Chemical Kinetics & Photochemistry	3-1-0	4
4		Professional Elective – II	3-0-0	3
5		Open Elective – II	3-0-0	3
6	CY 572	Inorganic Chemistry Laboratory	0-0-9	6
7	CS 172	Computing Laboratory – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	CY 533	Quantum Chemistry	3-1-0	4
2		Professional Elective - III	3-0-0	3
3		Professional Elective - IV	3-0-0	3
4		Open Elective - III	3-0-0	3
5	CY 573	Physical Chemistry Laboratory	0-0-9	6
6	CY 591	Research Project - I	0-0-6	4
7	CY 593	Seminar & Technical Writing - I	0-0-3	2
8	CY 595	Short term Industrial/ Research Experience	0-0-0	2
TOTAL				**27**

FOURTH SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	CY 514	Environmental Chemistry	3-1-0	4
2		Professional Elective V	3-0-0	3
3		Professional Elective VI	3-0-0	3
4		Open Elective - IV	3-0-0	3
5	CY 574	Environmental Chemistry Laboratory	0-0-9	6
6	CY 592	Research Project-II	0-0-9	6
7	CY 594	Seminar & Technical Writing-II	0-0-3	2
8	CY 596	Comprehensive Viva-Voce	0-0-0	2
TOTAL				**29**

Curriculum of Integrated M.Sc. (CHEMISTRY)

FIRST SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	MA 101	Mathematics – I	3-1-0	4
2	PH 101	Physics – I	3-1-0	4
3	CY 101	Chemistry	3-1-0	4
4	EE 100 EC 100	Basic Electrical Technology OR Basic Electronics Engineering	3-1-0	4
5	CE 100 CE 130	Engineering Mechanics OR Environmental and Safety Engineering	3-1-0	4
6	PH 170 CY 170	Physics Laboratory OR Chemistry Laboratory	0-0-3	2
7	CS 171	Computing Laboratory – I	0-0-3	2
8	CE 171	Engineering Drawing	0-0-3	2
9	WS 171	Workshop Practice – I	0-0-3	2
10		Extra Academic Activity – I	0-0-3	2
TOTAL			15-5-15	**30**

SECOND SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	MA 102	Mathematics – II	3-1-0	4
2	PH 102	Physics – II	3-1-0	4
3	CS 102	Data Structures and Algorithms	3-1-0	4
4	EC 100 EE 100	Basic Electronics Engineering OR Basic Electrical Technology	3-1-0	4
5	CE 130 CE 100	Environmental and Safety Engineering OR Engineering Mechanics	3-1-0	4
6	CY 170 PH 170	Chemistry Laboratory OR Physics Laboratory	0-0-3	2
7	CS 172	Computing Laboratory – II	0-0-3	2
8	ME 170	Machine Drawing and Solid Modeling	0-0-3	2
9	ME 172	Workshop Practice – II	0-0-3	2
10		Extra Academic Activity – I	0-0-3	2
TOTAL			15-5-15	**30**

THIRD SEMESTER

Sl.No	Sub.Code	Subjects	L-T- P	Credits
1.	CY 221	Chemistry of Industrial Materials	3-1-0	4
2.	CY 231	Basic Physical Chemistry – I	3-1-0	4
3.	PH 201	Thermodynamics	3-1-0	4
4.	MA 207	Introduction to Numerical Analysis	3-1-0	4
5.		HS & Open Elective – I	3-0-0	3
6.	MA 270	Numerical Methods Laboratory	0-0-3	2
7.	CY 271	UG Organic Chemistry Laboratory	0-0-3	2
8.	PH 271	Thermal Laboratory	0-0-3	2
TOTAL				**25**

FOURTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 214	Basic Organics Chemistry – I	3-1-0	4
2.	CY 234	Basic Physical Chemistry – II	3-1-0	4

3.	PH 202	Electricity and Magnetism	3-1-0	4
4.	MA 206	Introduction to Complex Analysis and Partial Differential Equations	3-1-0	4
5.		HS & Open Elective – II	3-0-0	3
6.	CY 273	UG Physical Chemistry Laboratory	0-0-3	2
7.	PH 272	Electricity and Magnetism Laboratory	0-0-3	2
8.	HS 270	Language Laboratory	0-0-3	2
		TOTAL		**25**

FIFTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 312	Basic Organic Chemistry – II	3-1-0	4
2.	CY 322	Basic Inorganic Chemistry – I	3-1-0	4
3.	MA 301	Group Theory	3-1-0	4
4.	PH 301	Waves and applications	3-1-0	4
5.		HS & Open Elective – III	3-0-0	3
6.	CY 375	Instrumentation Laboratory	0-0-3	2
7.	PH 371	Waves and Optics Laboratory	0-0-3	2
8.	MA 371	Lab works on Abstract Algebra	0-0-3	2
		TOTAL		**25**

SIXTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 313	Natural Products	3-1-0	4
2.	CY 323	Basic Inorganic Chemistry – II	3-1-0	4
3.	PH 302	Properties of Matter	3-1-0	4
4.	MA 332	Probality	3-1-0	4
5.		HS & Open Elective – IV	3-0-0	3
6.	CY 374	UG Inorganic Chemistry Laboratory	0-0-3	2
7.	PH 374	Properties of Matter Laboratory	0-0-3	2
8.	MA 372	Statistics Laboratory	0-0-3	2
		TOTAL		**25**

SEVENTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 511	Stereochemistry and Reaction Mechanism	3-1-0	4
2.	CY 521	Principles of Inorganic Chemistry	3-1-0	4
3.	CY 531	Thermodynamics & Chemical Equlibria	3-1-0	4
4.		Professional Elective – I	3-0-0	3
5.		HS & Open Elective – V	3-0-0	3
6.	CY 571	Organic Chemistry Laboratory	0-0-9	6
7.	CY 581	Research Project – I	0-0-6	4
		TOTAL		**25**

EIGHTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 512	Structure and Functions of Biomolecules	3-1-0	4
2.	CY 522	Chemistry of Transition and Non transition Elements	3-1-0	4
3.	CY 532	Chemical Kinetics and Photochemistry	3-1-0	4
4.		Professional Elective - II	3-0-0	3
5.		HS & Open Elective - VI	3-0-0	3

6.	CY 572	Inorganic Chemistry Laboratory	0-0-9	6
7.	CY 582	Research Project – II	0-0-6	4
		TOTAL		**28**

NINTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 533	Quantum Chemistry	3-1-0	4
2.		Professional Elective – III	3-0-0	3
3.		Professional Elective – IV	3-0-0	3
4.		HS & Open Elective – VII	3-0-0	3
5.	CY 573	Physical Chemistry Laboratory	0-0-9	6
6.	CY 583	Research Project – III	0-0-6	4
7.	CY 593	Seminar & Technical Writing - I	0-0-3	2
8.	CY 595	Short Term Industrial / Research Experience(SIRE)	0-0-0	2
		TOTAL		**27**

TENTH SEMESTER

Sl.No	Sub.Code	Subjects	L-T-P	Credits
1.	CY 514	Environmental Chemistry	3-1-0	4
2.		Professional Elective – V	3-0-0	3
3.		Professional Elective – VI	3-0-0	3
4.		HS & Open Elective - VIII	3-0-0	3
5.	CY 574	Environmental Chemistry Laboratory	0-0-9	6
6.	CY 584	Research Project – IV	0-0-9	6
7.	CY 594	Seminar & Technical Writing – II	0-0-3	2
8.	CY 596	Comprehensive Viva-Voce	0-0-0	2
		TOTAL		**27**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subjects	L-T- P	Credits	Offered To
1	CY 515	Spectroscopic Methods of Analysis	3-0-0	3	#
2	CY 516	Industrial Organic Chemistry	3-0-0	3	#
3	CY 517	Chemistry of Natural Products	3-1-0	4	#
4	CY 518	Polymer Chemistry	3-0-0	3	#
5	CY 519	Pericyclic Reactions and Photochemistry	3-0-0	3	#
6	CY 523	Industrial Inorganic Chemistry	3-0-0	3	#
7	CY 524	Group Theory and Molecular Orbitals	3-0-0	3	#
8	CY 525	Advanced Co-ordination Chemistry	3-0-0	3	#
9	CY 526	Bio-inorganic Chemistry	3-0-0	3	#
10	CY 527	Supramolecular Chemistry	3-0-0	3	#
11	CY 534	Principles of Heterogeneous Catalysis	3-0-0	3	#
12	CY 535	Electrochemistry	3-0-0	3	#
13	CY 536	Colloids and Surface Chemistry	3-0-0	3	#
14	CY 537	Advanced Solid State Chemistry	3-0-0	3	#
15	CY 538	Molecular Spectroscopy	3-0-0	3	#
16	CY 539	Biophysical Chemistry	3-0-0	3	#
17	CY 541	Chemistry of Heterocyclic Compounds	3-0-0	3	#
18	CY 542	Methods on Organic Synthesis	3-0-0	3	#
19	CY 543	Molecular Rearrangement	3-0-0	3	#
20	CY 544	Instrumental Methods of Analysis	3-0-0	3	#

21	CY 558	Organometallic Chemistry	3-0-0	3	#

Note: # - for both M.SC and Integrated M.Sc. courses

LIST OF OPEN ELECTIVES

Sl. No	Sub.Code	Subject	L-T-P	Credits	Non Eligible Branches
1	CY 211	Name Reactions & Rearrangements	3-0-0	3	-
2	CY 232	Chemical Kinetics	3-0-0	3	CH
3	CY 311	Concerted Reactions	3-0-0	3	-
4	CY 413	Spectroscopic Methods of Analysis.	3-0-0	3	-
5	CY 431	Chemistry of Nanomaterials	3-0-0	3	-
6	CY 432	Introduction to Nanobiotechnology	3-0-0	3	-

SUMMARY OF COURSES

Sub Discipline: Core Courses

CY 101	Chemistry	3-1-0	4

Sub Discipline: Organic Chemistry

CY 211	Name Reactions & Rearrangements	3-0-0	3
CY 214	Basic Organics Chemistry – I	3-1-0	4
CY 311	Concerted Reactions	3-0-0	3
CY 312	Basic Organics Chemistry – II	3-1-0	4
CY 313	Natural Products	3-1-0	4
CY 413	Spectroscopic Methods of Analysis	3-0-0	3
CY 511	Stereochemistry and Reaction Mechanism.	3-1-0	4
CY 512	Structure and Functions of Biomolecules	3-1-0	4
CY 514	Environmental Chemistry	3-1-0	4
CY 515	Spectroscopic Methods of Analysis	3-0-0	3
CY 516	Industrial Organic Chemistry	3-0-0	3
CY 517	Chemistry of Natural Products	3-0-0	3
CY 518	Polymer Chemistry	3-0-0	3
CY 519	Pericyclic Reactions and Photochemistry	3-0-0	3
CY 541	Chemistry of Heterocyclic Compounds	3-0-0	3
CY 542	Methods on Organic Synthesis	3-0-0	3
CY 543	Molecular Rearrangement	3-0-0	3
CY 544	Instrumental Methods of Analysis	3-0-0	3

Sub Discipline: Inorganic Chemistry

CY 221	Chemistry of Industrial Materials	3-1-0	4
CY 322	Basic Inorganic Chemistry – I	3-1-0	4
CY 323	Basic Inorganic Chemistry – II	3-1-0	4
CY 521	Principles of Inorganic Chemistry	3-1-0	4
CY 522	Chemistry of Transition and Non transition Elements	3-1-0	4
CY 523	Industrial Inorganic Chemistry	3-0-0	3
CY 524	Group Theory and Molecular Orbitals	3-0-0	3
CY 525	Advanced Co-ordination Chemistry	3-0-0	3
CY 526	Bio-Inorganic Chemistry	3-0-0	3
CY 527	Supramolecular Chemistry	3-0-0	3
CY 544	Industrial Methods of Analysis	3-0-0	3
CY 558	Organometallic Chemistry	3-0-0	3

Sub Discipline: Physical Chemistry

CY 231	Basic Physical Chemistry – I	3-1-0	4
CY 232	Chemical Kinetics	3-0-0	3
CY 234	Basic Physical Chemistry – II	3-1-0	4
CY 431	Chemistry of Nanomaterials	3-0-0	3
CY 432	Introduction to Nanobiotechnology	3-0-0	3
CY 531	Thermodynamics & Chemical Equilibria	3-1-0	4
CY 532	Chemical Kinetics & Photochemistry	3-1-0	4
CY 533	Quantum Chemistry	3-1-0	4
CY 534	Principles of Heterogeneous Catalysis	3-0-0	3
CY 535	Electrochemistry	3-0-0	3
CY 536	Colloids and Surface Chemistry	3-0-0	3
CY 537	Advanced Solid State Chemistry	3-0-0	3
CY 538	Molecular Spectroscopy	3-0-0	3
CY 539	Biophysical Chemistry	3-0-0	3

Sub Discipline: Laboratory Courses

CY 170	Chemistry Laboratory	0-0-3	2
CY 271	UG Organic Chemistry Laboratory	0-0-3	2
CY 273	Physical Chemistry Laboratory	0-0-3	2
CY 374	Inorganic Chemistry Laboratory	0-0-3	2
CY 375	Instrumentation Laboratory	0-0-3	2
CY 571	Organic Chemistry Laboratory	0-0-9	6
CY 572	Inorganic Chemistry Laboratory	0-0-9	6
CY 573	Physical Chemistry Laboratory	0-0-9	6
CY 574	Environmental Chemistry Laboratory	0-0-9	6

Sub Discipline: Project, Seminar and Special Courses

CY 491	Research Project – I	0-0-6	4
CY 492	Research Project – II	0-0-6	4
CY 581	Special Topics in Chemistry – I	3-1-0	4
CY 582	Special Topics in Chemistry – II	3-1-0	4
CY 583	Special Laboratory in Chemistry - I	0-0-3	2
CY 584	Special Laboratory in Chemistry - II	0-0-3	2
CY 591	Research Project – I	0-0-6	4
CY 592	Research Project – II	0-0-6	4
CY 593	Seminar & Technical Writing – I	0-0-3	2
CY 594	Seminar & Technical Writing – II	0-0-3	2
CY 595	Short Term Industrial / Research Experience	0-0-0	2
CY 596	Comprehensive Viva-Voce	0-0-0	2
CY 597	Research Project – III	0-0-6	4
CY 598	Research Project – IV	0-0-6	4

DEPARTMENT OF LIFE SCIENCE

Curriculum of M.Sc (LIFE SCIENCE)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	LS 401	Microbiology	3-1-0	4
2.	LS 402	Biochemistry	3-1-0	4
3.	LS 440	Physical Sciences and Instrumentation	3-1-0	4
4.		Professional Elective – I	3-1-0	4
5.		Open Elective – I	3-0-0	3
6.	LS 471	Microbiology Laboratory	0-0-3	2
7.	LS 472	Biochemistry Laboratory	0-0-3	2
8.	CS 171	Computing Laboratory - I	0-0-3	2
TOTAL				**25**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	LS 403	Immunology	3-1-0	4
2.	LS 404	Molecular Biology and Biotechnology	3-1-0	4
3.	LS 410	Food Science	3-1-0	4
4.		Professional Elective – II	3-1-0	4
5.		Open Elective – II	3-0-0	3
6.	LS 473	Biotechnology Laboratory	0-0-3	2
7.	LS 474	Molecular Biology Laboratory	0-0-3	2
8.	LS 475	Immunology Laboratory	0-0-3	2
TOTAL				**25**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	LS 420	Applied Bioinformatics	3-1-0	4
2.	LS 504	Environmental Sciences and Biostatistics	3-1-0	4
3.	LS 512	Developmental Biology	3-1-0	4
4.	LS 575	Applied Bioinformatics Lab.	0-0-3	2
5.	LS 591	Research Project – I	0-0-6	4
6.		Professional Elective - III	3-1-0	4
7.		Open Elective – III	3-0-0	3
8.	LS 593	Seminar and Technical Writing – I	0-0-3	2
9.	LS 595	Short-term Industrial/Research Experience (SIRE)	0-0-0	2
TOTAL				**29**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	LS 511	Genetics	3-1-0	4
2.	LS 592	Research Project – II	0-0-9	6
3.	LS 594	Seminar and Technical Writing – II	0-0-3	2
4.		Open Elective – IV	3-0-0	3
5.		Professional Elective – IV	3-1-0	4
6.	LS 596	Comprehensive Viva- Voce	0-0-0	2
TOTAL				**21**

TOTAL CREDITS: **25+25+29+21= 100**

LIST OF PROFESSIONAL ELECTIVES

Sl. No.	Sub.code	Subject	L-T-P	Credits
1.	LS 405	Cell biology	3-1-0	4
2.	LS 411	Biophysics	3-1-0	4
3.	LS 412	Advanced Microbial genetics	3-1-0	4
4.	LS 421	Radiation biology	3-1-0	4
5.	LS 422	Cell-cell Signaling	3-1-0	4
6.	LS 423	Advanced techniques	3-1-0	4
7.	LS 424	Genomics & Proteomics	3-1-0	4
8.	LS 502	Advances in Structural Biology	3-1-0	4
9.	LS 505	Food Processing technology	3-1-0	4
10.	LS 513	Enzymology and metabolism	3-1-0	4
11.	LS 530	Aquatic biology and marine biotechnology	3-1-0	4
12.	LS 531	Epigenetics	3-1-0	4
13.	LS 532	Molecular medicine	3-1-0	4
14.	LS 536	RNAi, Stem cells & Oncogenomics	3-1-0	4
15.	LS 581	Cancer Biology	3-1-0	4
16.	LS 583	Special Topics in Modern Biology – I	3-1-0	4
17.	LS 584	Special Topics in Modern Biology – II	3-1-0	4
18.	LS 585	Special Topics in Applied Life Science – I	3-1-0	4
19.	LS 586	Special Topics in Applied Life Science – II	3-1-0	4

LIST OF OPEN ELECTIVES

Sl. No	Sub.Code	Subject	L-T-P	Credits	Non Eligible Branches
1.	LS 406	Fundamentals of cell biology	3-0-0	3	HS, SM
2.	LS 413	Basic Biophysics	3-0-0	3	HS, SM
3.	LS 414	Microbial genetics	3-0-0	3	HS, SM
4.	LS 425	Introduction to Bioinformatics	3-0-0	3	HS, SM
5.	LS 427	Advanced Techniques	3-0-0	3	HS, SM
6.	LS 435	Microbial diversity and extremophiles	3-0-0	3	HS, SM
7.	LS 503	Recombinant DNA Technology	3-0-0	3	HS, SM
8.	LS 507	Structural Biology	3-0-0	3	HS, SM
9.	LS 509	Introduction to Proteomics	3-0-0	3	HS,SM
10.	LS 514	Fundamental of Genetics	3-0-0	3	HS, SM
11.	LS 533	Marine biotechnology	3-0-0	3	HS, SM
12.	LS 534	Introduction to Epigenetics	3-0-0	3	HS, SM
13.	LS 535	Basics in Molecular medicine	3-0-0	3	HS, SM
14.	LS 540	Research Methodology	3-0-0	3	HS, SM

SUMMARY OF COURSES

Sub Discipline: Foundation Courses

LS 401	Microbiology	3-1-0	4
LS 402	Biochemistry	3-1-0	4
LS 403	Immunology	3-1-0	4
LS 440	Physical Sciences and Instrumentation	3-1-0	4

Sub Discipline: Cell and Molecular Biology

LS 404	Molecular Biology and Biotechnology	3-1-0	4
LS 405	Cell biology	3-1-0	4
LS 406	Fundamentals of Cell Biology	3-0-0	3
LS 502	Advances in Structural Biology	3-1-0	4

LS 503	Recombinant DNA Technology	3-0-0	3
LS 507	Structural Biology	3-0-0	3

Sub Discipline: Topics in Modern Biology

LS 410	Food Science	3-1-0	4
LS 411	Biophysics	3-1-0	4
LS 412	Advanced Microbial genetics	3-1-0	4
LS 413	Basic Biophysics	3-0-0	3
LS 414	Microbial Genetics	3-0-0	3
LS 504	Environmental Sciences and Biostatistics	3-1-0	4
LS 511	Genetics	3-1-0	4
LS 512	Physical & Developmental Biology	3-1-0	4
LS 513	Enzymology & Metabolism	3-1-0	4
LS 514	Fundamental of Genetics	3-0-0	4

Sub Discipline: Advanced Courses

LS 420	Bioinformatics	3-1-0	4
LS 421	Radiation biology	3-1-0	4
LS 422	Cell- cell signaling	3-1-0	4
LS 424	Genomics and Proteomics	3-1-0	4
LS 425	Introduction to bioinformatics	3-0-0	3
LS 427	Advanced techniques	3-0-0	3
LS 509	Introduction to Proteomics	3-0-0	3

Sub Discipline: Specialized Courses

LS 435	Microbial diversity and extremophiles	3-0-0	3
LS 501	Ecology and Environmental Sciences	3-1-0	4
LS 505	Food Processing Technology	3-1-0	4
LS 530	Aquatic biology and marine biotechnology	3-1-0	4
LS 531	Epigenetics	3-1-0	4
LS 532	Molecular medicine	3-1-0	4
LS 533	Marine biotechnology	3-0-0	3
LS 534	Introduction to Epigenetics	3-0-0	3
LS 535	Basics in Molecular medicine	3-0-0	3
LS 536	RNAi, Stem cells and Oncogenomics	3-1-0	4
LS 581	Cancer Biology	3-1-0	4

Sub Discipline: Research Methodology

LS 540	Research Methodology	3-0-0	3

Sub Discipline: Laboratory Courses

CS 171	Computing Laboratory - I	0-0-3	2
LS 471	Microbiology Laboratory	0-0-3	2
LS 472	Biochemistry Laboratory	0-0-3	2
LS 473	Biotechnology Laboratory	0-0-3	2
LS 474	Molecular Biology Laboratory	0-0-3	2
LS 475	Immunology Laboratory	0-0-3	2
LS 571	Cell Biology Laboratory	0-0-3	2
LS 575	Applied Bioinformatics Lab	0-0-3	2

Sub Discipline: Project Seminar and Special Courses

LS 583	Special Topics in Modern Biology – I	3-1-0	4
LS 584	Special Topics in Modern Biology – II	3-1-0	4
LS 585	Special Topics in Applied Life Science – I	3-1-0	4
LS 586	Special Topics in Applied Life Science – II	3-1-0	4
LS 591	Research Project – I	0-0-6	4
LS 592	Research Project – II	0-0-9	6
LS 593	Seminar and Technical writing– I	0-0-3	2
LS 594	Seminar and Technical writing– II	0-0-3	2
LS 595	Short-term Industrial/Research Experience	0-0-3	2
LS 596	Comprehensive Viva- Voce	0-0-0	4

DEPARTMENT OF MATHEMATICS

Curriculum of M.Sc (MATHEMATICS)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 401	Real Analysis	3-1-0	4
2	MA 403	Linear Algebra	3-1-0	4
3	MA 405	Partial Differential Equations	3-1-0	4
4	MA 407	Topology	3-1-0	4
5		Open Elective – I	3-0-0	3
6	MA 471	Object Oriented Programming Practice Lab	0-0-3	2
7	MA 481	Departmental Seminar – I	0-0-3	2
TOTAL				**23**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 402	Measure Theory	3-1-0	4
2	MA 404	Functions of a Complex Variable	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Open Elective – II	3-0-0	3
6	MA 470	Lab works on Real Life Problems - I	0-0-3	2
7	MA 472	Research Paper Review	0-0-3	2
8	MA 482	Departmental Seminar – II	0-0-3	2
TOTAL				**25**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 501	Abstract Algebra	3-1-0	4
2		Professional Elective – III	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Open Elective – III	3-0-0	3
5	MA 571	Statistical Methods Laboratory	0-0-3	2
6	MA 591	Research Project – I	0-0-6	4
7	MA 593	Seminar and Technical Writing – I	0-0-3	2
8	MA 595	Short term Industrial/Research Experience	0-0-3	2
TOTAL				**25**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 502	Functional Analysis	3-1-0	4
2		Professional Elective – V	3-1-0	4
3		Professional Elective – VI	3-1-0	4
4		Open Elective – IV	3-0-0	3
5	MA 572	Lab Works on Real Life Problems - I	0-0-3	2
6	MA 592	Research Project – II	0-0-9	6
7	MA 594	Seminar and Technical Writing – II	0-0-3	2
8	MA 596	Comprehensive Viva Voce	0-0-3	2
TOTAL				**28**

Curriculum of Integrated M.Sc. (MATHEMATICS)

FIRST SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl. No.	Subject	Subject	L-T-P	Credit
1	MA 101	Mathematics-I	3-1-0	4
2	CY 101	Chemistry	3-1-0	4
3	PH 101	Physics-I	3-1-0	4
4	EE 100/ EC 100	Basic Electrical Technology/ Basic Electronics Engineering	3-1-0	4
5	CE 100/ CE 130	Engineering Mechanics/Environment Safety Engineering	3-1-0	4
6	PH 170/CY	Physics Laboratory/Chemistry Laboratory	0-0-3	2
7	CS 171	Computing Laboratory-I	0-0-3	2
8	CE 171	Engineering Drawing	0-0-3	2
9	WS 171	Workshop Practice-I	0-0-3	2
10		Extra Academic Activity-I	0-0-3	2
TOTAL				**30**

SECOND SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl. No	Subject	Subject	L-T-P	Credit
1	MA 102	Mathematics-II	3-1-0	4
2	PH 102	Physics-II	3-1-0	4
3	CS 102	Data Structures and Algorithm	3-1-0	4
4	EE 100 / EC 100	Basic Electrical Technology/ Basic Electronics Engineering	3-1-0	4
5	CE 100/ CE 130	Engineering Mechanics/Environment Safety Engineering	3-1-0	4
6	PH 170/CY 170	Physics Laboratory/Chemistry Laboratory	0-0-3	2
7	CS 172	Computing Laboratory-II	0-0-3	2
8	ME 170	Machine Drawing and Solid Modeling	0-0-3	2
9	WS 172	Workshop Practice-II	0-0-3	2
10		Extra Academic Activity-II	0-0-3	2
TOTAL				**30**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 205	Calculus	3-1-0	4
2	MA 207	Introduction to Numerical Analysis	3-1-0	4
3	CY 221	Chemistry of Industrial Materials	3-1-0	4
4	PH 201	Heat and Thermodynamics	3-1-0	4
5		Open Elective-I	3-0-0	3
6	CY 271	UG Organic Chemistry Laboratory	0-0-3	2
7	PH 271	Optics Laboratory	0-0-3	2
8	MA 270	Numerical Methods Laboratory	0-0-3	2
9	EE 270/ EC 270	Electrical Engineering Laboratory/Electronics Laboratory	0-0-3	2
TOTAL				**27**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 206	Introduction to Complex Analysis and Partial Differential Equations	3-1-0	4
2	MA 208	Analysis-I	3-1-0	4
3	CY 214	Basic Organic Chemistry-I	3-1-0	4
4	PH 202	Electricity and Magnetism	3-1-0	4
5		Open Elective-II	3-0-0	3
6	CY 273	Physical Chemistry Laboratory	0-0-3	2
7	PH 272	Electricity and Magnetism Laboratory	0-0-3	2
8	HS 270	Language Laboratory	0-0-3	2
		TOTAL		**25**

FIFTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	MA 301	Group Theory	3-1-0	4
2	MA 321	Discrete Mathematics	3-1-0	4
3	CY 321	Basic Physical Chemistry	3-1-0	4
4	PH 301	Waves and Applications	3-1-0	4
5		Open Elective-III	3-0-0	3
6	CY 375	Instrumentation Laboratory	0-0-3	2
7	PH 371	Thermal Laboratory	0-0-3	2
8	MA 373	Laboratory works on Latex and Matlab	0-0-3	2
		TOTAL		**25**

SIXTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credit
1	MA 322	Linear Programming	3-1-0	4
2	MA 332	Probability	3-1-0	4
3	CY 322	Basic Inorganic Chemistry-I	3-1-0	4
4	PH 302	Properties of Matter	3-1-0	4
5		Open Elective-IV	3-0-0	3
6	CY 374	Inorganic Chemistry Laboratory	0-0-3	2
7	MA 372	Statistical Laboratory	0-0-3	2
8	PH 374	Properties of Matter Laboratory	0-0-3	2
		TOTAL		**25**

SEVENTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 403	Linear Algebra	3-1-0	4
2	MA 413	Analysis-II	3-1-0	4
3	MA 405	Partial Differential Equations	3-1-0	4
4	MA 407	Topology	3-1-0	4
5		Open Elective-V	3-0-0	3
6	MA 471	Objective Oriented Programming Laboratory	0-0-3	2
7	MA 481	Departmental Seminar-I	0-0-3	2
		TOTAL		**23**

EIGHTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 402	Measure Theory	3-1-0	4
2	MA 404	Functions of Complex Variable	3-1-0	4
3		Professional Elective-I	3-1-0	4
4		Professional Elective-II	3-1-0	4

5		Open Elective-VI	3-0-0	3
6	MA 470	Lab works on Real Life Problems-I	0-0-3	2
7	MA 472	Research Paper Review	0-0-3	2
8	MA 482	Departmental Seminar-II	0-0-3	2
TOTAL				**25**

NINTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 503	Theory of Rings and Fields	3-1-0	4
2		Professional Elective-III	3-1-0	4
3		Professional Elective-IV	3-1-0	4
4		Open Elective-VII	3-0-0	3
5	MA 571	Statistics Laboratory	0-0-3	2
6	MA 591	Research Project-I	0-0-6	4
7	MA 593	Seminar and Technical Writing-I	0-0-3	2
8	MA 595	Short Term Industrial/Research Experience	0-0-0	2
TOTAL				**25**

TENTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 502	Functional Analysis	3-1-0	4
2	MA 504	Differential Geometry	3-1-0	4
3		Professional Elective-VI	3-1-0	4
4		Open Elective-VIII	3-0-0	3
5	MA 576	Laboratory Works on Real Life Problems-II	0-0-3	2
6	MA 592	Research Project-II	0-0-9	6
7	MA 594	Seminar and Technical Writing-II	0-0-3	2
8	MA 596	Comprehensive Viva Voce	0-0-3	2
TOTAL				**27**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Subject	Subject	L-T-P	Credit	Offered
1.	MA 438	Dynamical Systems	3-1-0	4	@
2.	MA 510	Calculus of Several Variables	3-1-0	4	#
2	MA 511	Differential Geometry	3-1-0	4	$
3.	MA 512	Fourier Analysis	3-1-0	4	#
4.	MA 513	Differential Topology	3-1-0	4	#
5.	MA 514	Rings and Module	3-1-0	4	#
6.	MA 515	Homotopy Theory	3-1-0	4	#
7.	MA 516	Operator Theory	3-1-0	4	#
8.	MA 517	Lie Algebra	3-1-0	4	#
9.	MA 518	Advanced Complex Analysis	3-1-0	4	#
10.	MA 519	Multi-Linear Algebra	3-1-0	4	#
11.	MA 520	Automata Theory	3-1-0	4	#
12.	MA 521	Combinatorics	3-1-0	4	#
13.	MA 522	Operations Research	3-1-0	4	#
14.	MA 523	Discrete Mathematics	3-1-0	4	#
15.	MA 524	Statistical Methods	3-1-0	4	#
16.	MA 525	Ergodic Theory	3-1-0	4	#
17.	MA 527	Fractals	3-1-0	4	#
18.	MA 529	Information Theory	3-1-0	4	#
19.	MA 531	Boundary Layer Theory	3-1-0	4	#
20.	MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4	#

21.	MA 533	Modern Theory of Partial Differential	3-1-0	4	@
22.	MA 534	Geometry of Robotics	3-1-0	4	#
23.	MA 535	Calculus of Variations and Integral	3-1-0	4	@
24.	MA 536	Numerical Method for Differential	3-1-0	4	@
25.	MA 537	Numerics of Singularly Perturbed	3-1-0	4	@
26.	MA 538	Fluid Dynamics	3-1-0	4	@
27.	MA 539	Scientific Computing	3-1-0	4	@
28.	MA 540	Singular Homology Theory	3-1-0	4	#
29.	MA 541	Commutative Algebra	3-1-0	4	@
30.	MA 542	Tensor Analysis	3-1-0	4	#
31.	MA 543	Complex Dynamics	3-1-0	4	@
32.	MA 544	Category Theory	3-1-0	4	#
33.	MA 545	Convex Analysis and Monotone	3-1-0	4	@
34.	MA 546	Differentiable Manifolds	3-1-0	4	#
35.	MA 547	Geometry of Normed Spaces	3-1-0	4	@
36.	MA 548	Field Theory	3-1-0	4	#
37.	MA 549	Algebraic Geometry	3-1-0	4	#
38.	MA 550	Coding Theory	3-1-0	4	#
39.	MA 551	Numerical Analysis	3-1-0	4	#
40.	MA 552	Fuzzy logic and Set Theory	3-1-0	4	#
41.	MA 553	Optimization Techniques	3-1-0	4	#
42.	MA 554	Graph Theory	3-1-0	4	#
43.	MA 555	Stochastic Processes	3-1-0	4	#
44.	MA 556	Number Theory	3-1-0	4	#
45.	MA 557	Statistical Inference	3-1-0	4	@
46.	MA 558	Sampling Techniques	3-1-0	4	#
47.	MA 559	Statistical Decision Theory	3-1-0	4	@
48.	MA 560	Mathematical Methods	3-1-0	4	#
49.	MA 561	Lie Groups & Applications to ODEs &	3-1-0	4	#
50.	MA 562	Finite Volume Methods for Hyperbolic	3-1-0	4	#
51.	MA 563	Wavelets and Applications	3-1-0	4	#
52.	MA 564	Integral and DiscreteTransforms	3-1-0	4	#
53.	MA 565	Fractional Order Models (a,b,d,f)	3-1-0	4	#
54.	MA 566	Fractional Differential Equations (c,e,g,h)	3-1-0	4	#
42	MA 567	Theory of Vibrations	3-1-0	4	#
56.	MA 568	Mathematics of Soft Computing	3-1-0	4	#
57.	MA 569	Perturbation Methods	3-1-0	4	@

Note: $- for M.Sc courses, @-for Integrated M.Sc courses, #- for both M.Sc and Integrated M.Sc courses

LIST OF PROFESSIONAL ELECTIVES OFFERED BY OTHER DEPARTMENTS

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1.	CS 414	Software Project, Process and Quality Management	3-1-0	4
2.	CS 418	Real Time Systems	3-1-0	4
3.	CS 425	Data Mining and Data Warehousing	3-1-0	4
4.	CS 427	Network Security	3-1-0	4
5.	CS 430	Information Theory and Coding	3-1-0	4
6.	CS 432	Distributed Operating Systems	3-1-0	4
7.	CS 438	Pattern Recognition	3-1-0	4
8.	CS 441	Advanced Computer Architecture	3-1-0	4

9.	CS 443	Embedded Systems	3-1-0	4
10.	CS 444	Cluster and Grid Computing	3-1-0	4
11.	CS 445	Parallel Algorithms	3-1-0	4
12.	CS 613	Combinatorial Optimization	3-1-0	4
13.	CS 617	Graph Theory and Network Algorithms	3-1-0	4
14.	CS 621	Cryptographic Foundations	3-1-0	4
15.	CS 630	Artificial Intelligence	3-1-0	4
16.	CS 631	Information Theory and Coding	3-1-0	4
17.	CS 633	Game Theory	3-1-0	4
18.	CS 635	Biometric Security	3-1-0	4
19.	CS 638	Image Processing	3-1-0	4
20.	CS 639	Soft Computing	3-1-0	4
21.	CS 673	Image Processing Laboratory	0-0-3	2
22.	CS 675	Soft Computing Laboratory	0-0-3	2
23.	CS 676	Cryptographic Laboratory	0-0-3	2
24.	CS 679	Biometric laboratory	0-0-3	2
25.	EC 641	Digital Signal Processing	3-1-0	4
26.	EC 644	Soft Computing	3-1-0	4

Note: all courses are common to both M.Sc and Integrated M.Sc

LIST OF OPEN ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credits	Non Eligible Branches
1.	MA 311	Linear Algebra	3-0-0	3	-
2.	MA 312	Real Analysis	3-0-0	3	-
3.	MA 411	Metric Spaces	3-0-0	3	-
4.	MA 423	Discrete Mathematics	3-1-0	4	-
5.	MA 424	Operations Research	3-0-0	3	-
6.	MA 426	Elementary Stochastic Processes with Applications	3-1-0	4	-

SUMMARY OF COURSES

Sub Discipline: Foundation Courses

MA 101	Differential Equations	3-1-0	4
MA 102	Matrix theory, Vector Calculus and Fourier Analysis	3-1-0	4
MA 201	Probability, Statistics and Numerical Methods	3-1-0	4
MA 202	Complex Analysis and Partial Differential Equations	3-1-0	4
MA 205	Calculus	3-1-0	4
MA 206	Introduction to Complex Analysis and Partial Differential Equations	3-1-0	4
MA 207	Introduction to Numerical Analysis	3-1-0	4
MA 208	Analysis-I	3-1-0	4
MA 301	Group Theory	3-1-0	4
MA 321	Discrete Mathematics	3-1-0	4
MA 322	Linear Programming	3-1-0	4
MA 401	Real Analysis	3-1-0	4
MA 402	Measure Theory	3-1-0	4
MA 403	Linear Algebra	3-1-0	4
MA 404	Functions of a Complex Variable	3-1-0	4
MA 405	Partial Differential Equations	3-1-0	4
MA 407	Topology	3-1-0	4

MA 413	Analysis-II	3-1-0	4
MA 501	Abstract Algebra	3-1-0	4
MA 502	Functional Analysis	3-1-0	4
MA 503	Theory of Rings and Fields	3-1-0	4
MA 504	Differential Geometry	3-1-0	4

Sub Discipline: Topology, Analysis and Algebra

MA 311	Linear Algebra	3-0-0	3
MA 312	Real Analysis	3-0-0	3
MA 313	Complex Analysis and Transforms Techniques	3-0-0	3
MA 510	Calculus of Several Variables	3-1-0	4
MA 511	Differential Geometry	3-1-0	4
MA 512	Fourier Analysis	3-1-0	4
MA 513	Differential Topology	3-1-0	4
MA 514	Rings and Modules	3-1-0	4
MA 515	Homotopy Theory	3-1-0	4
MA 516	Operator Theory	3-1-0	4
MA 517	Lie Algebra	3-1-0	4
MA 518	Advanced Complex Analysis	3-1-0	4
MA 519	Multi-Linear Algebra	3-1-0	4
MA 540	Singular Homology Theory	3-1-0	4
MA 541	Commutative Algebra	3-1-0	4
MA 542	Tensor Analysis	3-1-0	4
MA 543	Complex Dynamics	3-1-0	4
MA 544	Category Theory	3-1-0	4
MA 545	Convex Analysis and Monotone Operator	3-1-0	4
MA 546	Differentiable Manifolds	3-1-0	4
MA 547	Geometry of Normed Spaces	3-1-0	4
MA 548	Field Theory	3-1-0	4
MA 549	Algebraic Geometry	3-1-0	4

Sub Discipline: Statistics and Optimization

MA 423	Discrete Mathematics	3-1-0	4
MA 424	Operations Research	3-1-0	4
MA 425	Elementary Stochastic Processes with Applications	3-0-0	3
MA 520	Automata Theory	3-1-0	4
MA 521	Combinatorics	3-1-0	4
MA 522	Operations Research	3-1-0	4
MA 523	Discrete Mathematics	3-1-0	4
MA 524	Statistical Methods	3-1-0	4
MA 525	Ergodic Theory	3-1-0	4
MA 527	Fractals	3-1-0	4
MA 529	Information Theory	3-1-0	4
MA 550	Coding Theory	3-1-0	4
MA 551	Numerical Analysis	3-1-0	4
MA 552	Fuzzy logic and Set Theory	3-1-0	4
MA 553	Optimization Techniques	3-1-0	4
MA 554	Graph Theory	3-1-0	4
MA 555	Stochastic Processes	3-1-0	4
MA 556	Number Theory	3-1-0	4
MA 557	Statistical Inference	3-1-0	4
MA 558	Sampling Techniques	3-1-0	4
MA 559	Statistical Decision Theory	3-1-0	4

Sub Discipline: Applied Mathematics

MA 431	Mathematical Methods	3-0-0	3
MA 432	Finite Difference Methods	3-0-0	3
MA 433	Finite Element Methods	3-0-0	3
MA 438	Dynamical Systems	3-1-0	4
MA 531	Boundary Layer Theory	3-1-0	4
MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4
MA 533	Modern Theory of Partial Differential Equation	3-1-0	4
MA 534	Geometry of Robotics	3-1-0	4
MA 535	Calculus of Variations and Integral Equations	3-1-0	4
MA 536	Numerical Methods for Differential Equations	3-1-0	4
MA 537	Numerics of Singularly Perturbed Differential Equations	3-1-0	4
MA 538	Fluid Dynamics	3-1-0	4
MA 539	Scientific Computing	3-1-0	4
MA 560	Mathematical Methods	3-1-0	4
MA 561	Lie Groups & Applications to ODEs & PDEs	3-1-0	4
MA 562	Finite Volume Methods for Hyperbolic PDEs	3-1-0	4
MA 563	Wavelets and Applications	3-1-0	4
MA 564	Integral Transforms	3-1-0	4
MA 565	Fractional Order models (a,b,d,f)	3-1-0	4
MA 566	Fractional Differential Equations (c,e,g,h)	3-1-0	4
MA 567	Theory of Vibrations	3-1-0	4
MA 568	Mathematics of Soft Computing	3-1-0	4

Sub Discipline: Laboratory Courses

MA 270	Numerical Methods Laboratory	0-0-3	2
MA 372	Stastics Laboratory	0-0-3	2
MA 373	Laboratory Works onLatex and Matlab	0-0-3	2
MA 470	Lab works on Real Life Problems-I	0-0-3	2
MA 471	Object Oriented Programming Practice Laboratory	0-0-3	2
MA 571	Statistical Methods Lab.	0-0-3	2
MA 572	Lab. Works on Real Life Problems-II	0-0-3	2
MA 574	Laboratory Works on NSPDE	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

MA 472	Research Paper Review	0-0-3	2
MA 481	Departmental Seminar – I	0-0-3	2
MA 482	Departmental Seminar – II	0-0-3	2
MA 591	Research Project – I	0-0-6	4
MA 592	Research Project - II	0-0-9	6
MA 593	Seminar and Technical Writing – I	0-0-3	2
MA 594	Seminar and Technical Writing – II	0-0-3	2
MA 595	Short term Industrial/Research Experience	0-0-3	2
MA 596	Comprehensive Viva Voce	0-0-3	2

DEPARTMENT OF PHYSICS

Curriculum of M.Sc (Physics)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	PH 401	Mathematical Methods in Physics	3-1-0	4
2	PH 403	Classical Mechanics	3-1-0	4
3	PH 405	Statistical Mechanics	3-1-0	4
4	PH 407	Quantum Mechanics - I	3-1-0	4
5	EC 100	Basic Electronics Engineering	3-1-0	4
6	PH 471	General Physics Laboratory	0-0-3	2
7	PH 473	Spectroscopy Laboratory	0-0-3	2
8	CS 171	Computing Laboratory - I	0-0-3	2
TOTAL				**26**

SECOND SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	PH 402	Numerical Techniques in Physics	3-1-0	4
2	PH 404	Electrodynamics	3-1-0	4
3	PH 406	Condensed Matter Physics	3-1-0	4
4	PH 408	Quantum Mechanics - II	3-1-0	4
5		Open Elective - I	3-0-0	3
6	PH 472	SolidState Physics Laboratory	0-0-3	2
7	EC 270	Basic Electronics Laboratory	0-0-3	2
8	CS 172	Computing Laboratory - II	0-0-3	2
TOTAL				**25**

THIRD SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	PH 507	Nuclear & Particle Physics	3-1-0	4
2		Open Elective - II	3-0-0	3
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5	PH 571	Instrumentation Laboratory	0-0-3	2
6	PH 573	Computational Physics Laboratory	0-0-3	2
7	PH 591	Research Project – I	0-0-6	4
8	PH 593	Seminar & Technical Writing – I	0-0-3	2
9	PH 595	Short Term Industrial / Research Experience	0-0-0	2
TOTAL				**27**

FOURTH SEMESTER

Sl. No	Sub. Code	Subjects	L-T- P	Credits
1	PH 508	Atomic & Molecular Physics	3-1-0	4
2		Open Elective - III	3-0-0	3
3		Professional Elective - III	3-1-0	4
4		Professional Elective – IV	3-1-0	4
5	PH 572	Advanced Materials Synthesis Laboratory	0-0-3	2
6	PH 574	Advanced Characterization Techniques Laboratory	0-0-3	2
7	PH 592	Research Project – II	0-0-9	6
8	PH 594	Seminar & Technical Writing – II	0-0-3	2
9	PH 596	Comprehensive Viva - Voice	0-0-0	2
TOTAL				**29**

Curriculum of Integrated M.Sc. (PHYSICS)

FIRST SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	MA 101	Mathematics – I	3-1-0	4
2	PH 101	Physics – I	3-1-0	4
3	CY 101	Chemistry	3-1-0	4
4	EE 100 EC 100	Basic Electrical Technology OR Basic Electronics Engineering	3-1-0	4
5	CE 100 CE 130	Engineering Mechanics OR Environmental and Safety Engineering	3-1-0	4
6	PH 170 CY 170	Physics Laboratory OR Chemistry Laboratory	0-0-3	2
7	CS 171	Computing Laboratory – I	0-0-3	2
8	CE 171	Engineering Drawing	0-0-3	2
9	WS 171	Workshop Practice – I	0-0-3	2
10		Extra Academic Activity – I	0-0-3	2
TOTAL				**30**

SECOND SEMESTER(STRUCTURE COMMON TO ALL BRANCHES)

Sl.No	Sub. Code	Subjects	L-T- P	Credits
1	MA 102	Mathematics – II	3-1-0	4
2	PH 102	Physics – II	3-1-0	4
3	CS 102	Data Structures and Algorithms	3-1-0	4
4	EC 100 EE 100	Basic Electronics Engineering OR Basic Electrical Technology	3-1-0	4
5	CE 130 CE 100	Environmental and Safety Engineering OR Engineering Mechanics	3-1-0	4
6	CY 170 PH 170	Chemistry Laboratory OR Physics Laboratory	0-0-3	2
7	CS 172	Computing Laboratory – II	0-0-3	2
8	ME 170	Machine Drawing and Solid Modeling	0-0-3	2
9	WS 172	Workshop Practice – II	0-0-3	2
10		Extra Academic Activity – I	0-0-3	2
TOTAL				**30**

THIRD SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 201	Thermodynamics	3-1-0	4
2.	EC 201	Analog Electronics	3-1-0	4
3.	CY 221	Chemistry of Industrial Materials	3-1-0	4
4.	MA 207	Introduction to Numerical Analysis	3-1-0	4
5.		Open Elective - I	3-0-0	3
6.	PH 271	Thermal Laboratory	0-0-3	2
7.	CY 271	UG Organic Chemistry Laboratory	0-0-3	2
8.	MA 270	Numerical Methods Laboratory	0-0-3	2
TOTAL				**25**

FOURTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 202	Electricity & Magnetism	3-1-0	4
2.	EC 202	Digital Electronics	3-0-0	3
3.	CY 214	Basic Organic Chemistry - I	3-1-0	4
4.	MA 206	Introduction to Complex Analysis and Partial	3-1-0	4

		Differential Equations		
5.		Open Elective - II	3-0-0	3
6.	PH 272	Electricity & Magnetism Laboratory	0-0-3	2
7.	CY 273	UG Physical Chemistry Laboratory	0-0-3	2
8.	HS 270	Language Laboratory	0-0-3	2
TOTAL				**24**

FIFTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 301	Wave and Oscillations	3-1-0	4
2.	PH 303	Optics	3-1-0	4
3.	CY 231	Basic Physical Chemistry - I	3-1-0	4
4.	MA 301	Group Theory	3-1-0	4
5.		Open Electives - III	3-0-0	3
6.	PH 371	Waves and Optics Laboratory	0-0-3	2
7.	CY 375	Instrumental Laboratory	0-0-3	2
8.	MA 373	Laboratory Works on Latex and Matlab	0-0-3	2
TOTAL				**25**

SIXTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 302	Properties of Matter	3-1-0	4
2.	PH 304	Introduction to Mechanics	3-1-0	4
3.	CY 322	Basic Inorganic Chemistry - I	3-1-0	4
4.	MA 332	Probability	3-1-0	4
5.		Open Elective - IV	3-0-0	3
6.	PH 372	Properties of Matter Laboratory	0-0-3	2
7.	CY 374	UG Inorganics Chemistry Laboratory	0-0-3	2
8.	MA 372	Statistics Laboratory	0-0-3	2
TOTAL				**25**

SEVENTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 401	Mathematical Methods in Physics	3-1-0	4
2.	PH 403	Classical Mechanics	3-1-0	4
3.	PH 405	Statistical Mechanics	3-1-0	4
4.	PH 407	Quantum Mechanics – I	3-1-0	4
5.	PH 409	Introduction to Spectroscopy	3-1-0	4
6.	PH 471	General Physics Laboratory	0-0-3	2
7.	PH 473	Spectroscopy Laboratory	0-0-3	2
8.	PH 481	Research Project – I	0-0-6	4
TOTAL				**28**

EIGHTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 402	Numerical Techniques in Physics	3-1-0	4
2.	PH 404	Electrodynamics	3-1-0	4
3.	PH 408	Quantum Mechanics – II	3-1-0	4
4.	PH 406	Condensed Matter Physics	3-1-0	4
5.		Open Elective – V	3-0-0	3
6.	PH 472	Solid State Physics Laboratory	0-0-3	2
7.	EC 270	Basic Electronics Laboratory	0-0-3	2
8.	PH 482	Research Project – II	0-0-6	4
TOTAL				**27**

NINTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1.	PH 507	Nuclear & Particle Physics	3-1-0	4
2.		Professional Elective – I	3-1-0	4
3.		Professional Elective – II	3-1-0	4
4.	PH 571	Instrumentation Laboratory	0-0-3	2
5.	PH 573	Computational Physics Laboratory	0-0-3	2
6.	PH 581	Research Project – III	0-0-6	4
7.	PH 593	Seminar & Technical Writing – I	0-0-3	2
8.	PH 595	Short Term Industrial/Research Experience	0-0-0	2
TOTAL				**27**

TENTH SEMESTER

Sl.No	Sub. Code	Subjects	L-T-P	Credits
1	PH 508	Atomic & Molecular Physics	3-1-0	4
2		Professional Elective – III	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Open Elective – VII	3-0-0	3
5	PH 572	Advanced material synthesis Laboratory	0-0-3	2
6	PH 574	Advanced Characterization Techniques Laboratory	0-0-3	2
7	PH 582	Research Project – IV	0-0-9	6
8	PH 594	Seminar & Technical Writing - II	0-0-3	2
9	PH 596	Comprehensive Viva Voce	0-0-0	2
TOTAL				**29**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subjects	L-T-P	Credits	Offered to
1	PH 511	Advanced Quantum Mechanics	3-1-0	4	#
2	PH 512	Advanced Statistical Mechanics	3-1-0	4	#
3	PH 513	Density Functional Theory and its recent applications	3-1-0	4	#
4	PH 514	Advanced Condensed Matter Physics	3-1-0	4	#
5	PH 522	Physics of Semiconductors : From Bulk to Quantum Dots	3-1-0	4	#
6	PH 523	Semiconductor Spintronics & Quantum Computation	3-1-0	4	#
7	PH 524	Computational Condensed Matter Physics	3-1-0	4	#
8	PH 525	Electronic Structure of Disordered Alloys	3-1-0	4	#
9	PH 531	Non - linear dynamics, Chaos and its recent applications	3-1-0	4	#
10	PH 532	Physics of Macromolecules	3-1-0	4	#
11	PH 533	Synchronization and its recent applications in Chaotic systems	3-0-0	3	#
12	PH 535	LASER Physics	3-1-0	4	#
13	PH 541	Dielectric & Magnetic Properties of Materials	3-1-0	4	#
14	PH 542	Physics & Applications of Dielectric Materials	3-1-0	4	#
15	PH 543	Bio-Ceramic Materials & Applications	3-1-0	4	#
16	PH 544	Polymer Physics	3-1-0	4	#
17	PH 551	Crystal Symmetry & Crystal Physics	3-1-0	4	#
18	PH 553	Advanced X-rays structure Analysis	3-1-0	4	#
19	PH 554	Physics of Thin film Technology	3-1-0	4	#

20	PH 555	Physics of Material Synthesis and Characterization	3-1-0	4	#
21	PH 556	X-rays and Nano Science	3-1-0	4	#
22	PH 561	Physics of Microelectronic and Photonic Devices	3-1-0	4	#
23	PH 562	Super fluidity and Superconductivity	3-1-0	4	#
24	PH 563	Physical Phenomena at Low Temperature	3-1-0	4	#
25	PH-564	Magnetism – Principles & Applications	3-1-0	4	#
26	PH-565	Defects in Solids	3-1-0	4	#
27	PH 381	Special Topics in Physics – I	3-1-0	4	$
28	PH 382	Special Topics in Physics – II	3-1-0	4	$
29	PH 383	Special Laboratory in Physics - I	0-0-3	2	$
30	PH 384	Special Laboratory in Physics - II	0-0-3	2	$

Note: $- for only Integrated MSc Courses
#- for both MSc and Integrated MSc Courses

PROFESSIONAL ELECTIVES FROM OTHER DEPARTMENTS

1	CH 419	Computational Fluid Dynamics	3-1-0	4
2	CR 415	Bio-ceramics	3-0-0	3
3	CR 424	Composite Materials	3-0-0	3
4	CR 435	Functional Materials & Devices	3-0-0	3
5	CR 441	Electrical and Magnetic Ceramics	3-1-0	4
6	CR 446	Thin Film and Coating	3-0-0	3
7	CS 430	Information Theory and Coding	3-1-0	4
8	CS 434	Image Processing	3-0-0	3
9	CS 438	Pattern Recognition	3-1-0	4
10	CS 444	Cluster and Grid Computing	3-1-0	4
11	CS 445	Parallel Algorithms	3-1-0	4
12	EE 404	Renewable Energy Systems	3-0-0	3
13	MM 448	Composite Materials	3-1-0	4
14	MM 442	Advanced Materials	3-0-0	3
15	MM 449	Nanostructured Materials	3-0-0	3
16	EC 410	Antenna Engineering	3-0-0	3
17	EC 411	Coding Theory and Secure Communication	3-0-0	3
18	EC 412	Antenna Analysis and Synthesis	3-1-0	4
19	EC 414	Information Theory and Coding	3-1-0	4
20	CY 531	Spectroscopic Methods of Analysis	3-0-0	3
21	CY 532	Electrochemistry	3-0-0	3
22	CY 542	Group Theory and Molecular Orbitals	3-0-0	3
23	CY 563	Advanced Solid State Chemistry	3-0-0	3
24	CY 524	Molecular rearrangement	3-0-0	3
25	CY 554	Molecular Spectroscopy	3-0-0	3
26	CY 564	Instrumental Methods of Analysis	3-0-0	3
27	CY 533	Advanced Co-ordination Chemistry	3-0-0	3
28	MA 510	Calculus of Several Variables	3-1-0	4
29	MA 511	Differential Geometry	3-1-0	4
30	MA 512	Fourier Analysis	3-1-0	4
31	MA 513	Differential Topology	3-1-0	4
32	MA 514	Rings and Modules	3-1-0	4
33	MA 515	Homotopy Theory	3-1-0	4
34	MA 516	Operator Theory	3-1-0	4
35	MA 517	Lie Algebra	3-1-0	4
36	MA 518	Advanced Complex Analysis	3-1-0	4

37	MA 519	Multi-Linear Algebra	3-1-0	4
38	MA 520	Automata Theory	3-1-0	4
39	MA 521	Combinatorics	3-1-0	4
40	MA 522	Operations Research	3-1-0	4
41	MA 523	Discrete Mathematics	3-1-0	4
42	MA 524	Statistical Methods	3-1-0	4
43	MA 525	Ergodic Theory	3-1-0	4
44	MA 527	Fractals	3-1-0	4
45	MA 529	Information Theory	3-1-0	4
46	MA 530	Computational Methods in Boundary Value Problems	3-1-0	4
47	MA 531	Boundary Layer Theory	3-1-0	4
48	MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4
49	MA 534	Geometry of Robotics	3-1-0	4
50	MA 540	Singular Homology Theory	3-1-0	4
51	MA 542	Tensor Analysis	3-1-0	4
52	MA 544	Category Theory	3-1-0	4
53	MA 546	Differentiable Manifolds	3-1-0	4
54	MA 548	Field Theory	3-1-0	4
55	MA 549	Algebraic Geometry	3-1-0	4
56	MA 550	Coding Theory	3-1-0	4
57	MA 551	Numerical Analysis	3-1-0	4
58	MA 552	Fuzzy logic and Set Theory	3-1-0	4
59	MA 553	Optimization Techniques	3-1-0	4
60	MA 554	Graph Theory	3-1-0	4
61	MA 555	Stochastic Processes	3-1-0	4
62	MA 556	Number Theory	3-1-0	4
63	MA 558	Sampling Techniques	3-1-0	4

COURSES OFFERED AS OPEN ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credit	Non Eligible Branches
1	PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3	-
2	PH 312	Physics of Quantum World	3-0-0	3	-
3	PH 321	Physics of Semiconducting Materials	3-0-0	3	-
4	PH 331	World of LASERS	3-0-0	3	-
5	PH 332	Physics of the Universe	3-0-0	3	-
6	PH 341	Treatise of Einstein Work and Beyond	3-0-0	3	-
7	PH 351	Science of Nano-materials	3-0-0	3	-
8	PH 352	X-Ray techniques for Structure Evaluation	3-0-0	3	-
9	PH 422	Theory & Simulation of Nanostructures	3-0-0	3	-
10	PH 431	Non-linear systems & Chaos	3-0-0	3	-
11	PH 462	Vacuum Science and Applications	3-0-0	3	-

SUMMARY OF COURSES

Sub Discipline: Core Course

PH 101	Physics - I	3-1-0	4
PH 102	Physics - II	3-1-0	4
PH 201	Heat and Thermodynamics	3-1-0	4
PH 202	Electricity & Magnetism	3-1-0	4

PH 301	Wave and Oscillations	3-1-0	4
PH 302	Properties of Matter	3-1-0	4
PH 303	Optics	3-1-0	4
PH 304	Introduction to Mechanics	3-1-0	4
PH 401	Mathematical Methods in Physics	3-1-0	4
PH 402	Numerical Techniques in Physics	3-1-0	4
PH 403	Classical Mechanics	3-1-0	4
PH 404	Electrodynamics	3-1-0	4
PH 405	Statistical Mechanics	3-1-0	4
PH 406	Condensed Matter Physics	3-1-0	4
PH 407	Quantum Mechanics – I	3-1-0	4
PH 408	Quantum Mechanics – II	3-1-0	4
PH 409	Introduction to Spectroscopy	3-1-0	4
PH 507	Nuclear & Particle Physics	3-1-0	4
PH 508	Atomic & Molecular Physics	3-1-0	4

Sub Discipline: Condensed Matter Physics

PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3
PH 312	The Physics of Quantum World	3-0-0	3
PH 321	Physics of Semiconducting Materials	3-0-0	3
PH 422	Theory & Simulation of Nanostructures	3-0-0	3
PH 511	Advanced Quantum Mechanics	3-1-0	4
PH 512	Advanced Statistical Mechanics	3-1-0	4
PH 513	Density Functional Theory and its Recent Applications	3-1-0	4
PH 514	Advanced Condensed Matter Physics	3-1-0	4
PH 522	Physics of Semiconductors : From Bulk to Quantum Dots	3-1-0	4
PH 523	Semiconductor Spintronics & Quantum Computation	3-1-0	4
PH 524	Computational Condensed Matter Physics	3-1-0	4
PH 525	Electronic Structure of Disordered Alloys	3-1-0	4

Sub Discipline: Soft Condensed Matter Physics

PH 331	World of LASERS	3-0-0	3
PH 332	Physics of the Universe	3-0-0	3
PH 431	Non-linear systems & Chaos	3-0-0	3
PH 531	Non - linear dynamics, Chaos and its recent applications	3-1-0	4
PH 532	Physics of Macromolecules	3-1-0	4
PH 533	Synchronization and its recent applications in Chaotic Systems	3-0-0	3
PH 535	LASER Physics	3-1-0	4

Sub Discipline: Functional Materials

PH 341	Treatise of Einstein Work and Beyond	3-0-0	3
PH 541	Dielectric & Magnetic Properties of Materials	3-1-0	4
PH 542	Physics & Applications of Dielectric Materials	3-1-0	4
PH 543	Bio-Ceramic Materials & Applications	3-1-0	4
PH 544	Polymer Physics	3-1-0	4

Sub Discipline: Synthesis and Characterization

PH 351	Science of Nano materials	3-0-0	3
PH 352	X-Ray techniques for Structure Evaluation	3-1-0	4
PH 551	Crystal Symmetry & Crystal Physics	3-1-0	4

PH 553	Advanced X-rays structure analysis	3-1-0	4
PH 554	Physics of Thin Film Technology	3-1-0	4
PH 555	Physics of material synthesis & Charaterization	3-1-0	4
PH 556	X-rays and Nano-Science	3-1-0	4

Sub Discipline: Low Temperature Physics

PH 462	Vacuum Science and Applications	3-1-0	4
PH 561	Physics of Microelectronics and Photonic Devices	3-1-0	4
PH 562	Superfluidity and Superconductivity	3-1-0	4
PH 563	Physical Phenomena at Low Temperature	3-1-0	4
PH 564	Magnetism – Principles & Applications	3-1-0	4
PH 565	Defects in Solids	3-1-0	4

ub Discipline: Laboratory Courses

PH 170	Physics Laboratory	0-0-3	2
PH 271	Thermal Laboratory	0-0-3	2
PH 272	Electricity & Magnetism Laboratory	0-0-3	2
PH 371	Waves and Optics Laboratory	0-0-3	2
PH 372	Properties of Matter Laboratory	0-0-3	2
PH 471	General Physics Laboratory	0-0-3	2
PH 472	Solid State Physics Laboratory	0-0-3	2
PH 473	Spectroscopy Laboratory	0-0-3	2
PH 571	Instrumentation Laboratory	0-0-3	2
PH 572	Advanced material synthesis Laboratory	0-0-3	2
PH 573	Computational Physics Laboratory	0-0-3	2
PH 574	Advanced Characterization Techniques Laboratory	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

PH 481	Research Project – I	0-0-6	4
PH 482	Research Project – II	0-0-6	4
PH 538	Special Topics in Condensed Matter Physics - I	3-1-0	4
PH 539	Special Topics in Condensed Matter Physics - II	3-1-0	4
PH 558	Special Topics in Functional Materials – I	3-1-0	4
PH 559	Special Topics in Functional Materials – II	3-1-0	4
PH 568	Special Topics in Low Temperature Physics – I	3-1-0	4
PH 569	Special Topics in Low Temperature Physics – II	3-1-0	4
PH 381	Special Topics in Physics – I	3-1-0	4
PH 382	Special Topics in Physics – II	3-1-0	4
PH 383	Special Laboratory in Physics - I	0-0-3	2
PH 384	Special Laboratory in Physics - II	0-0-3	2
PH 581	Research Project – III	0-0-6	4
PH 582	Research Project – IV	0-0-9	6
PH 591	Research Project – I	0-0-6	4
PH 592	Research Project – II	0-0-9	6
PH 593	Seminar & Technical Writing – I	0-0-3	2
PH 594	Seminar & Technical Writing - II	0-0-3	2
PH 595	Short Term Industrial/Research Experience	0-0-0	2
PH 596	Comprehensive Viva Voce	0-0-0	2

DEPARTMENT OF HUMANITIES AND SOCIAL SCIENCES

Curriculum for MA (DEVELOPMENT STUDIES)

FIRST SEMESTER

Sl. No	Sub. Code	Subjects	L-T-P	Credits
1.	HS 511	Technical and Business Communication	3-1-0	4
2.	HS 522	Social Psychology and its Application	3-1-0	4
3.	HS 531	Social Institutions and Development	3-1-0	4
4.	HS 541	Economics of Development	3-1-0	4
5.	HS 543	Global Issues in Development	3-1-0	4
6.		Open Elective – I	3-0-0	3
7.	CS 171	Computing Laboratory - I	0-0-3	2
TOTAL				**25**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	HS 500	Research Methodology	3-1-0	4
2.	HS 532	Planning and Policy Issues in India	3-1-0	4
3.	HS 533	Development: Social, Anthropological and Political Perspectives	3-1-0	4
4.	HS 542	Measurement of Poverty, Inequality and Human Development	3-1-0	4
5.		Professional Elective – I	3-1-0	4
6.		Open Elective – II	3-0-0	3
7.	HS 572	Statistical Laboratory	0-0-3	2
TOTAL				**25**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	HS 535	Gender and Development	3-1-0	4
2.	HS 570	Advanced Language Laboratory	0-0-6	4
3.		Professional Elective – II	3-1-0	4
4.		Professional Elective – III	3-1-0	4
5.		Open Elective – III	3-0-0	3
6.	HS 591	Research Project – I	0-0-6	4
7.	HS 593	Seminar & Technical Writing – I	0-0-3	2
8.	HS 595	Short Term Industrial/Research Experience	0-0-3	2
TOTAL				**27**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	HS 534	Natural Resource Management and Sustainable Development	3-1-0	4
2	HS 544	Environment and Development	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Open Elective – IV	3-1-0	4
5	HS 592	Research Project – II	0-0-9	6
6	HS 594	Seminar & Technical Writing – II	0-0-3	2
7	HS 596	Comprehensive Viva -Voce	0-0-3	2
TOTAL				**26**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credits
1.	HS 501	Advanced Research Methodology	3-1-0	4
2.	HS 512	Literary Foundations: Methods and Genres	3-1-0	4
3.	HS 513	Post-Colonial Consciousness and Development	3-1-0	4
4.	HS 514	Mapping the Other: Theories for Alterity	3-1-0	4
5.	HS 515	History of Ideas: The Modern Period	3-1-0	4
6.	HS 523	Educational Psychology	3-1-0	4
7.	HS 524	Cognitive Development and Assessment	3-1-0	4
8.	HS 525	Psychometrics	3-1-0	4
9.	HS 526	Clinical Paradigms, Psychological Disorders and Therapeutic Interventions	3-1-0	4
10.	HS 527	Corporate Social Responsibility	3-1-0	4
11.	HS 536	Trends and Issues in Tribal Studies	3-1-0	4
12.	HS 537	Development Issues in Orissa	3-1-0	4
13.	HS 538	Urban Governance and Development	3-1-0	4
14.	HS 545	Indian Financial System	3-1-0	4
15.	HS 546	Population Dynamics and Development	3-1-0	4
16.	HS 548	Demographic Transition and Health Policies in Developing World	3-1-0	4
17.	HS 550	Special Topics in Development Studies – I		3/4
18.	HS 551	Special Topics in Development Studies – II		3/4
19.	HS 552	Special Topics in Development Studies – III		3/4
20.	HS 553	Special Topics in Development Studies – IV		3/4

SUMMARY OF COURSES

Sub Discipline: Research Methodology

HS 500	Research Methodology	3-1-0	4
HS 501	Advanced Research Methodology	3-1-0	4

Sub Discipline: English

HS 511	Technical and Business Communication	3-1-0	4
HS 512	Literary Foundations: Methods and Genres	3-1-0	4
HS 513	Post-Colonial Consciousness and Development	3-1-0	4
HS 514	Mapping the Other: Theories for Alterity	3-1-0	4
HS 515	History of Ideas: The Modern Period	3-1-0	4

Sub Discipline: Psychology

HS 522	Social Psychology and Its Application	3-1-0	4
HS 523	Educational Psychology	3-1-0	4
HS 524	Cognitive Development and Assessment	3-1-0	4
HS 525	Psychometrics	3-1-0	4
HS 526	Clinical Paradigms, Psychological Disorders and Therapeutic Interventions	3-1-0	4
HS 527	Corporate Social Responsibility	3-1-0	4

Sub Discipline: Sociology

HS 531	Social Institutions and Development	3-1-0	4
HS 532	Planning and Policy Issues in India	3-1-0	4
HS 533	Development: Social, Anthropological and Political Perspectives	3-1-0	4
HS 534	Natural Resource Management and Sustainable	3-1-0	4

	Development		
HS 535	Gender and Development	3-1-0	4
HS 536	Trends and Issues in Tribal Studies	3-1-0	4
HS 537	Development Issues in Orissa	3-1-0	4
HS 538	Urban Governance and Development	3-1-0	4

Sub Discipline: Economics

HS 541	Economics of Development	3-1-0	4
HS 542	Measurement of Poverty, Inequality and Human Development	3-1-0	4
HS 543	Global Issues in Development	3-1-0	4
HS 544	Environment and Development	3-1-0	4
HS 545	Indian Financial System	3-1-0	4
HS 546	Population Dynamics and Development	3-1-0	4
HS 548	Demographic Transition and Health Policies in Developing World	3-1-0	4

Sub Discipline: Laboratory Courses

CS 171	Computing Laboratory - I	0-0-3	2
HS 570	Advanced Language Laboratory	0-0-6	4
HS 572	Statistical Laboratory	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

HS 591	Research Project – I	0-0-6	4
HS 592	Research Project – II	0-0-9	6
HS 593	Seminar & Technical Writing – I	0-0-3	2
HS 594	Seminar & Technical Writing – II	0-0-3	2
HS 595	Short Term Industrial/Research Experience	0-0-3	2
HS 596	Comprehensive Viva -Voce	0-0-3	2

(For B.Tech Students)

SUMMARY OF COURSES

Sub Discipline: English

HS 311	Communicative English.	3-0-0	3
HS 317	Introduction to the Structure of Modern English	3-0-0	3
HS 410	Literary Foundations: Methods and Genres.	3-0-0	3
HS 418	Special Course in English	3-0-0	3

Sub Discipline: Psychology

HS 321	Organizational Behaviour.	3-0-0	3
HS 327	Special Course in Psychology	3-0-0	3
HS 420	Human Resource Management.	3-0-0	3
HS 428	Special Course in Psychology	3-0-0	3

Sub Discipline: Sociology

HS 330	Introduction to Indian Society and Development	3-0-0	3
HS 337	Special Course in Sociology	3-0-0	3
HS 431	Industrial Sociology	3-0-0	3
HS 438	Special Course in Sociology	3-0-0	3

Sub Discipline: Economics

HS 340	Environmental Economics	3-0-0	3
HS 347	Special Course in Economics	3-0-0	3

HS 441	Optimization Theory in Economics	3-0-0	3
HS 448	Health Economics and Policy	3-0-0	3

Sub Discipline: Laboratory Courses

HS 270	Language Laboratory	0-0-3	2

LIST OF OPEN ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credits	Non Eligible Branches
1.	HS 311	Communicative English	3-0-0	3	-
2.	HS 317	Introduction to the Structure of Modern English	3-0-0	3	-
3.	HS 321	Organizational Behaviour	3-0-0	3	-
4.	HS 327	Special Course in Psychology	3-0-0	3	-
5.	HS 330	Introduction to Indian Society and Development	3-0-0	3	-
6.	HS 340	Environment Economics	3-0-0	3	-
7.	HS 341	Managerial Economics	3-0-0	3	-
8.	HS 410	Literary Foundations: Methods and Genres	3-0-0	3	-
9.	HS 418	Special Course in English	3-0-0	3	-
10.	HS 420	Human Resource Management	3-0-0	3	-
11.	HS 428	Special Course in Psychology	3-0-0	3	-
12.	HS 430	Special Course in Sociology	3-0-0	3	-
13.	HS 440	Financial Markets and Institutions	3-0-0	3	-
14.	HS 441	Optimization Theory in Economics	3-0-0	3	-
15.	HS 448	Health Economics and Policy	3-0-0	3	-

COMPULSORY LAB COMPONENT (For B. Tech students)

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	HS 270	Language Laboratory	0-0-3	2

SCHOOL OF MANAGEMENT

Curriculum of MBA (Masters of Business Administration)

FIRST SEMESTER

Sl. No	Sub Code.	Subjects	L-T-P	Credits
1.	SM 501	Organizational Behaviour and Structure	3-0-0	3
2.	SM 503	Managerial Economics	3-0-0	3
3.	SM 505	Financial and Cost Accounting	3-0-0	3
4.	SM 507	Marketing Management	3-0-0	3
5.	SM 509	Research Methodology	3-0-0	3
6.	SM 511	Management Information System	3-0-0	3
		TOTAL		**18**

SECOND SEMESTER

Sl. No.	Sub Code.	Subjects	L-T-P	Credits
1.	SM 502	Human Resource Management	3-0-0	3
2.	SM 504	Production & Operations Management	3-0-0	3
3.	SM 506	Financial Management	3-0-0	3
4.	SM 508	Quantitative Techniques and Operations Research	3-0-0	3
5.	SM 510	Economic and Legal Environment	3-0-0	3
6.	SM 512	Technology and Innovation Management	3-0-0	3
		TOTAL		**18**

THIRD SEMESTER

Sl. No.	Sub Code.	Subjects	L-T-P	Credits
1.	SM 601	Strategic Management	3-0-0	3
2.		Professional Elective – I	3-0-0	3
3.		Professional Elective – II	3-0-0	3
4.		Professional Elective – III	3-0-0	3
5.		Professional Elective – IV	3-0-0	3
6.		Professional Elective – V	3-0-0	3
7.	SM 603	Internship	3-0-0	3
		TOTAL		**21**

FOURTH SEMESTER

Sl. No.	Sub Code.	Subjects	L-T-P	Credits
1.	SM 602	Business Ethics & Corporate Governance	3-0-0	3
2.		Professional Elective – I	3-0-0	3
3.		Professional Elective – II	3-0-0	3
4.		Professional Elective – III	3-0-0	3
5.		Professional Elective – IV	3-0-0	3
6.		Professional Elective – V	3-0-0	3
7.	SM 604	Presentation & Comprehensive Viva Voce	0-0-0	3
		TOTAL		**21**

LIST OF PROFESSIONAL ELECTIVES

Sl. No.	Sub Code.	Subjects	L-T-P	Credits
1.	SM 613	Consumer Behaviour and Marketing Research	3-0-0	3
2.	SM 614	Customer Relationship Management	3-0-0	3
3.	SM 615	Product and Brand Management	3-0-0	3
4.	SM 616	Retail Management	3-0-0	3
5.	SM 617	Sales and Distribution Management	3-0-0	3
6.	SM 618	Industrial and Services Marketing	3-0-0	3
7.	SM 619	Integrated Marketing Communication	3-0-0	3

8.	SM 620	International Marketing	3-0-0	3
9.	SM 621	Financial Institutions, Instruments and Markets	3-0-0	3
10.	SM 622	Financial Options, Futures and Swap	3-0-0	3
11.	SM 623	Commercial Banking	3-0-0	3
12.	SM 624	International finance	3-0-0	3
13.	SM 625	Financial Services	3-0-0	3
14.	SM 626	Mergers and Acquisitions	3-0-0	3
15.	SM 627	Security Analysis and Portfolio Management	3-0-0	3
16.	SM 628	Insurance and Risk Management	3-0-0	3
17.	SM 630	Project Planning and Appraisal	3-0-0	3
18.	SM 612	Customer Relationship Management	3-0-0	3
19.	SM 631	Employee Relations and Labour Legislations	3-0-0	3
20.	SM 632	Performance Management	3-0-0	3
21.	SM 633	Human Resource Planning	3-0-0	3
22.	SM 634	Organization Change and Development	3-0-0	3
23.	SM 635	Training and Development	3-0-0	3
24.	SM 636	Leadership for Corporate Excellence	3-0-0	3
25.	SM 637	Employee Compensation and Benefits Management	3-0-0	3
26.	SM 638	Strategic Human Resource Management	3-0-0	3
27.	SM 640	Knowledge Management	3-0-0	3
28.	SM 641	Materials Management	3-0-0	3
29.	SM 642	Reliability and Risk Management	3-0-0	**3**
30.	SM 643	Total Quality Management	3-0-0	3
31.	SM 644	Supply Network Management	3-0-0	3
32.	SM 645	Business Process Transformation	3-0-0	3
33.	SM 646	Operations Strategy	3-0-0	3
34.	SM 647	Project Planning, Scheduling and Monitoring	3-0-0	3
35.	SM 648	Decision Modeling and Simulation	3-0-0	3
36.	SM 651	Strategic Information System	3-0-0	3
37.	SM 652	Database Management System	3-0-0	3
38.	SM 653	E-Commerce	3-0-0	3
39.	SM 654	Software Project and Quality Management	3-0-0	3
40.	SM 655	Enterprise Resource Planning	3-0-0	3
41.	SM 656	IT Strategy	3-0-0	3
42.	SM 657	System Analysis and Design	3-0-0	3
43.	SM 658	Software Engineering	3-0-0	3

LIST OF LABORATORY COURSES

Sl. no	Sub Code.	Subjects	L-T-P	Credits
1.	SM 513	Basic Computer Lab	0-0-3	2
2.	SM 514	Statistics Lab	0-0-3	2
3.	SM 515	OB Lab	0-0-3	2
4.	SM 516	HR Lab	0-0-3	2
5.	SM 517	Business Simulation Lab	0-0-3	2
6.	SM 518	Management Games Lab	0-0-3	2
7.	SM 519	Seminar and Technical Writing - I	0-0-3	2
8.	SM 520	Seminar and Technical Writing - II	0-0-3	2
9.	SM 605	OR Lab	0-0-3	2
10.	SM 606	Banking Operations Lab	0-0-3	2
11.	SM 607	Leadership Lab	0-0-3	2
12.	SM 608	Project Lab	0-0-3	2

13.	SM 609	Language Lab	0-0-3	2
14.	SM 610	Marketing Lab	0-0-3	2
15.	SM 611	Seminar and Technical Writing - III	0-0-3	2
16.	SM 612	Seminar and Technical Writing - IV	0-0-3	2

SUMMARY OF COURSES

Sub Discipline: Marketing

SM 613	Consumer Behaviour and Marketing Research	3-0-0	3
SM 614	Customer Relationship Management	3-0-0	3
SM 615	Product and Brand Management	3-0-0	3
SM 616	Retail Management	3-0-0	3
SM 617	Sales and Distribution Management	3-0-0	3
SM 618	Industrial and Services Marketing	3-0-0	3
SM 619	Integrated Marketing Communication	3-0-0	3
SM 620	International Marketing	3-0-0	3
SM 653	E - Commerce	3-0-0	3

Sub Discipline: Finance

SM 621	Financial Institutions, Instruments and Markets	3-0-0	3
SM 622	Financial Options, Futures and Swap	3-0-0	3
SM 623	Commercial Banking	3-0-0	3
SM 624	International finance	3-0-0	3
SM 625	Financial Services	3-0-0	3
SM 626	Mergers and Acquisitions	3-0-0	3
SM 627	Security Analysis and Portfolio Management	3-0-0	3
SM 628	Insurance and Risk Management	3-0-0	3
SM 630	Project Planning and Appraisal	3-0-0	3

Sub Discipline: Human Resource

SM 631	Employee Relations and Labour Legislations	3-0-0	3
SM 632	Performance Management	3-0-0	3
SM 633	Human Resource Planning	3-0-0	3
SM 634	Organization Change and Development	3-0-0	3
SM 635	Training and Development	3-0-0	3
SM 636	Leadership for Corporate Excellence	3-0-0	3
SM 637	Employee Compensation and Benefits Management	3-0-0	3
SM 638	Strategic Human Resource Management	3-0-0	3
SM 640	Knowledge Management	3-0-0	3

Sub Discipline: Operations

SM 641	Materials Management	3-0-0	3
SM 642	Reliability and Risk Management	3-0-0	3
SM 643	Total Quality Management	3-0-0	3
SM 644	Supply Network Management	3-0-0	3
SM 645	Business Process Transformation	3-0-0	3
SM 646	Operations Strategy	3-0-0	3
SM 647	Project Planning, Scheduling and Monitoring	3-0-0	3
SM 648	Decision Modeling and Simulation	3-0-0	3

Sub Discipline: Systems & IT

SM 612	Customer Relationship Management	3-0-0	3
SM 640	Knowledge Management	3-0-0	3
SM 651	Strategic Information System	3-0-0	3

SM 652	Database Management System	3-0-0	3
SM 653	E- Commerce	3-0-0	3
SM 654	Software Project and Quality Management	3-0-0	3
SM 655	Enterprise Resource Planning	3-0-0	3
SM 656	IT Strategy	3-0-0	3
SM 657	System Analysis and Design	3-0-0	3
SM 658	Software Engineering	3-0-0	3

Sub Discipline: Project, Seminar and Special Courses

SM 519	Seminar and Technical Writing – I	0-0-3	2
SM 520	Seminar and Technical Writing – II	0-0-3	2
SM 603	Internship	0-0-0	3
SM 604	Presentation and Comprehensive Viva-voce	0-0-0	3
SM 611	Seminar and Technical Writing – III	0-0-3	2
SM 612	Seminar and Technical Writing – IV	0-0-3	2

Sub Discipline: Laboratory Courses

SM 513	Basic Computer Lab	0-0-3	2
SM 514	Statistics Lab	0-0-3	2
SM 515	OB Lab	0-0-3	2
SM 516	HR Lab	0-0-3	2
SM 517	Business Simulation Lab	0-0-3	2
SM 518	Management Games Lab	0-0-3	2
SM 605	OR Lab	0-0-3	2
SM 606	Banking Operations Lab	0-0-3	2
SM 607	Leadership Lab	0-0-3	2
SM 608	Project Lab	0-0-3	2
SM 609	Language Lab	0-0-3	2
SM 610	Marketing Lab	0-0-3	2

DEPARTMENT OF BIOTECHNOLOGY AND MEDICAL ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. code	Subject	L-T-P	Credits
BM 601	Quantitative Physiology	3-1-0	4
BM 603	Diagnostic Imaging and Radiation Biology	3-1-0	4
BM 611	Biomedical Signal Processing and Analysis	3-1-0	4
BM 612	Advanced Biomedical Instrumentation	3-1-0	4
BM 613	Safety consideration of Medical Devices	3-1-0	4
BM 614	Medical Image Processing	3-1-0	4
BM 616	BioMems and Biosensors	3-1-0	4
BM 621	Advanced Biomaterials	3-1-0	4
BM 622	Nanotechnology in Medical Application	3-1-0	4
BM 623	Advanced Tissue Engineering	3-1-0	4
BM 624	Surface Engineering of Medical Implants	3-1-0	4
BM 625	Nanobiotechnology	3-1-0	4
BM 626	Biomaterials and Tissue Characterization	3-1-0	4
BM 627	Cryo-Tissue Engineering	3-1-0	4
BM 628	Bioceramics and Biocomposites	3-1-0	4
BM 629	Regenerative medicine and stem cell	3-1-0	4
BM 631	Computational Methods in Biomedical Engineering	3-1-0	4
BM 632	Computational Fluid Dynamics in Bioengineering	3-1-0	4
BM 633	Artificial organ and Rehabilitative Engineering	3-1-0	4
BM 634	Advanced Biomechanics	3-1-0	4
BM 640	Fluorescence Techniques in Bioengineering	3-1-0	4
BM 641	Immunotechnology	3-1-0	4
BM 642	Biophysics & Structural Biology	3-1-0	4
BM 643	Advanced Protein Engineering	3-1-0	4
BM 644	Advanced Cell & Molecular Biology	3-1-0	4
BM 645	Cell and Protein Processing	3-1-0	4
BM 646	Molecular Biology of Cancer	3-1-0	4
BM 647	Advanced Bioinformatics	3-1-0	4
BM 648	Protein conformational diseases and therapy	3-1-0	4
BM 649	Recombinant DNA Technology	3-1-0	4
BM 651	Industrial Microbiology	3-1-0	4
BM 652	Advanced Biochemical Engineering	3-1-0	4
BM 653	Bioprocess and Plant Design	3-1-0	4
BM 654	Advanced Bioseparation	3-1-0	4
BM 656	Pharmaceutical Technology	3-1-0	4
BM 661	Biological Waste Treatment	3-1-0	4
BM 662	Nutritional Sciences and Plant Based Products	3-1-0	4
BM 670	Advanced Biochemical Engineering Laboratory	0-0-3	2
BM 671	Advanced Tissue Engineering Laboratory	0-0-3	2
BM 672	Advanced Bioseparation Laboratory	0-0-3	2
BM 673	Cell and Protein Processing Laboratory	0-0-3	2
BM 674	Advanced Biomedical Instrumentation Laboratory	0-0-3	2
BM 675	Advanced Biomedical Equipment Design Lab	0-0-3	2
BM 676	Biomedical Image Processing Laboratory	0-0-3	2
BM 677	Biomedical Signal Processing Laboratory	0-0-3	2

BM 601 QUANTITATIVE PHYSIOLOGY 4 credits [3-1-0]

Skeletal system: Classification of bones, joints and muscles, major muscles of limbs and their actions. Functional concept of the human body, bone and muscle physiology ; Nervous system& special senses: Brain and spinal cord, peripheral autonomic nervous system, nerve physiology, EEG, MEG & ECG. Eye & ear Cardio Vascular System: Structure & function of Heart & blood vessels. Special functional tissue of heart. E.C.G. Cardiac cycle. Blood – composition, Function, blood group, Blood clotting. Blood Pressure-regulation & controlling factors Respiratory system: Upper and lower respiratory tract, Structure and Function of respiratory membrane. Pulmonary circulation. Mechanics of breathing. Transport and control of gases. Lungs volume and capacities. Regulation of respiration . Pulmonary function tests. Endocrine Glands: types, location, description and functions, Digestive system: Parts of digestive system. Gastro intestinal tract and associated glands Urinary system: Parts and function of urinary system. Male and female reproductive system. Lymphatic system: Spleen, glands and lymph nodes.

Essential Reading

1. Richard S Snell, *Clinical Anatomy by Regions*: Lippincott Williams & Wilkins, 8th edition, 2007.
2. Richard Drake, A. Wayne Vogl, Adam W. M. Mitchell, and Richard Tibbitts, *Gray's Atlas of Anatomy:* Churchill Livingston, 1st edition, 2007.

Supplementary Reading

1. Kenneth Saladin, *Anatomy & Physiology: The Unity of Form and Function,* McGraw-Hill College, 2006
2. Gray's Anatomy for Students: Churchill Livingstone; 1 edition (October 19, 2004)

BM 603 DIAGNOSTIC IMAGING AND RADIATION BIOLOGY 4 credits [3-1-0]

Basic concepts, types, sources and characteristics of electromagnetic radiations and its influence on living beings with particular emphasis on human beings. Review of atomic structure and atomic particles : electrons, protons, neutrons, positrons, neutrinos, etc.; Classification of elements as per the periodic table; Atomic transitions - electron transitions and the generation of x-rays; Nuclear transitions and radioactive decay of nuclei. Characteristics of x-ray beams; Interaction with matter; Attenuation and interaction of x-rays in the human body; Films and fluoroscopic screens; CT Scan and its algorithm. Detrimental effects of radiation; Radiation safety and dosimetry; Overview of generation of radioisotopes. Radiopharmaceuticals, Radiotherapy, Physics of ultrasound imaging; Uses in diagnosis. Interaction of Ultrasound with tissue;Physics of Nuclear Magnetic Resonance and its application in the field of diagnostic medicine. Lasers, its classification, basic concept, types and their Biomedical Applications. Laser use in surgery, diagnosis and in promotion of healing. Safety with biomedical lasers.

Essential Reading

1. W.R.Hendee & E.R.Ritenour, *Medical Imaging Physics*,3rd editions, Mosbey Year-Book, Inc., 1992.
2. Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt Jr., and John M. Boone *the Essential Physics of Medical Imaging, 2nd* Edition, Lippincott Williams & Wilkins, 2001

Supplementary Reading

1. Dowsett, Kenny & Johnston, "*The Physics of Diagnostic Imaging*", Chapman & Hall Medical, Madras/London, 1998
2. Reiner Salzer; *Biomedical Imaging: Principles and Applications*; Wiley-Interscience; 2008

BM 611 BIOMEDICAL SIGNAL PROCESSING AND ANALYSIS 4 credits [3-1-0]

Short introduction- Discrete time systems and signals; Z-transform, Difference equation. Filter design by transformation - Impulse and step Invariant, Bi-linear Z-transform, matched Z-transform. Signal Model-AR, MA, ARMA, State Variable model, Lattice structures. FIR filter design, Frequency windowing technique, Equi ripple Chebyshev and Butterworth criterion. Filter performance and design in presence of noise, FIR filters banks-subband decomposition. Inverse filtering-Deconvolution and equalization techniques-Weiner, Linear prediction etc., Signal reconstruction.

Time frequency Analysis - STFT, WT, DSP hardware - Design methodologies, Popular architectures and overview of programming Application notes. Filter implementation: Topology, Scaling, Coefficient quantization, Signal quantization, Sensitivity analysis.

Essential Reading:

1. Oppenheim & Ronald W Schafer, *Digital Signal Processing,* Prentice Hall India, 2005
2. Wills J. Tompkins, *Biomedical digital signal processing*, Prentice Hall of India Pvt. Ltd.1993

Supplementary Reading:

1. Andreas Antoniou , *Digital Signal Processing*, McGraw Hill, 2005
2. Iefeachor, *Digital Signal Processing*, Prentice Hall, 2002
3. J.G. Prokis & D.G. Manolakis, *Digital Signal Processing: Principles, Algorithm and Applications,* PHI/Pearson Education, 1996

BM 612	**ADVANCED BIOMEDICAL INSTRUMENTATION**	**4 credits [3-1-0]**

Evolution of medical instrument, Explanation of generalized and biomedical instrumentation; Components of a medical instrumentation system, **Transducers**: Resistance type: Potentiometer, Strain gauge; inductive type: LVDT; Capacitive type: Differential pressure transmitter, Piezoelectric crystal; **Sensing elements**: Temperature sensing elements: RTD, Thermistor, Thermocouple, Semiconductor type (IC sensor); Pressure sensing elements: Manometers; Elastic elements: Bourdon tube, Bellows; Electrical type; Mcleod Gauge, Pirani Gauge; Flow sensing elements: Headmeters (Orifice, Venturi, Flow nozzle), Area meters (Rotameters), Electromagnetic flowmeter, Coriolis flowmeter. Instrumentation in Bioresearch: Principles, applications of Flowcytometer, PCR , Microplate Reader.

Essential Reading:

1.J. Bronzino, *Biomedical Engineering & Instrumentation*, PWS Engg. Boston.3rd Edn.
2.J. Enderle, *Bioinstrumentation*, Morgan & Claypool Publisher 2006.
3.R. S. Khandpur, *Handbook of Bio-Medical Instrumentation*, Tata McGraw Hill, 2003

Supplementary Reading:

1.Cromwell, Weibell & Pfeiffer, *Biomedical Instrumentation & Measurement*, Prentice Hall, India, 2nd Edn. 2003
2.J. Webster, *Bioinstrumentation*, Wiley & Sons.2004.

BM 613	**SAFETY CONSIDERATION OF MEDICAL DEVICES**	**4 credits [3-1-0]**

Safety in health care, mechanics & safety, electricity & safety, gas, fire & heat, measurement techniques, measurement methods & values, medical images, ventilation, parenteral administration of drugs, artificial organs & stimulators, tissues & calculi, computers in health care, responsibility, checklists.

Essential Reading:

1. Bertil Jacobson and Alan Murray, *Medical Devices: Use and Safety,* Publisher: Churchill Livingstone; 1 edition, ISBN-10: 0443102597, ISBN-13: 978-0443102592.
2. Shayne C. Gad and Marian G. McCord, *Safety Evaluation in the Development of Medical Devices and Combination Products,* Publisher: CRC; 3 edition, ISBN-10: 1420071645, ISBN-13: 978-1420071641

Supplementary Reading:

1. Jose Justiniano and Venky Gopalaswamy, *Practical Design Control Implementation for Medical Devices, Publisher: Informa Healthcare*; 1 edition, ISBN-10: 1574911279, ISBN-13: 978-1574911275.
2. Shayne C. Gad, *Safety Evaluation of Medical Devices,* Publisher: CRC; 2 edition, ISBN-10: 082470617X, ISBN-13: 978-0824706173.

BM 614 MEDICAL IMAGE PROCESSING 4 credits [3-1-0]

Digital image fundamentals: representation - elements of visual perception - simple image formation model - Image sampling and quantization - basic relationships between pixels - imaging geometry. Review of matrix theory results: Row and column ordering - Toeplitz, Circulant and Block matrices. Review of Image transforms: 2D-DFT, FFT, W alsh , Hadamard ,haar, DCT and W avelet transforms. Image enhancement: Spatial domain methods: point processing - intensity transformations, histogram processing, image subtraction, image averaging; Spatial filtering- smoothing filters, sharpening filters. Frequency domain methods: low pass filtering, high pass filtering, homomorphic filtering. Generation of spatial masks from frequency domain specifications. Image restoration: Degradation model - Diagonalization of circulant and Block circulant matrices - Algebraic approaches- Inverse filtering - W iener filter - Constrained Least squares restoration - Interactive restoration -Geometric transformations. Fundamentals of Colour image processing: colour models - RGB, CMY, YIQ, HIS - Pseudo color image processing - intensity slicing, gray level to color transformation. Image compression: fundamentals- redundancy: coding, inter pixel, psychovisual, fidelity criteria, Models, Elements of information theory, Error free compression- variable length, bit plane, lossless predictive, Lossy compression- lossy predictive, transform coding. Fundamentals of JPEG, MPEG, Fractals. Image segmentation: Detection of discontinuities - point, line and edge and combined detection ; Edge linking and boundary description - local and global processing using Hough transform Thresholding - Region oriented segmentation - basic formulation, region growing by pixel aggregation, region splitting and merging - Use of motion in segmentation. Fundamentals of Representation and Description.

Essential Reading :

1. R. C. Gonzalez, R. E. Woods, S. L. Eddins , *Digital Image Processing Using MATLAB(R) ,Course Technology,* 1 edition, 2004
2. A. K Jain, *Fundamentals of image processing*, prentice hall, Eagle cliffs, New Jersey, 1989

Supplementary Reading :

1. Chanda & Majumdar, *Digital image processing and analysis*, PHI, 2003
2. P. Suetens, *Fundamentals of image processing*, Cambridge University Press, 2002.
3. Gonzalez and Woods, *Digital image processing*, 2nd ed., Pearson, 2007

BM 616 BIOMEMS AND BIOSENSORS 4 credits [3-1-0]

Introduction to BioMEMS, Silicon Microfabrication, “Soft” Fabrication Techniques, Polymer Materials, Microfluidic Principles, Sensor Principles and Microsensors, Microactuators and Drug Delivery, Clinical Laboratory Medicine, Micro-Total-Analysis Systems, Detection and Measurement Methods, Genomics and DMA Microarrays, Proteomics and Protein Microarrays, Emerging BioMEMS Technology, Packing, Power, Data, and RF Safety, Biocompatibility.Biosensors based on antigen-antibody interactions, avidin-biotin mediated biosensors, functionalized electrodes as electrochemical biosensors, wired peroxidase based biosensors, electrochemical enzyme immunoassay, liposomes in immunodiagnostics, polyion sensors, piezoelectric immunosensors, SPV biosensors, SPR biosensors, dual electrode enzyme sensors.

Essential Reading:

1. *Handbook of Biosensors and Electronic Noses: Medicine, Food and the Environment*: CRC-Press; 1 edition;1996
2. Steven S. Saliterman, *Fundamentals of BioMEMS and Medical Microdevices* ,SPIE Press Monograph Vol. PM153, 2006

Supplementary Reading:

1. *Biosensors*: Oxford University Press, USA; 2 edition, 2004
   D. L. Wise, *Biosensors: Theory and Applications*, CRC Press,1993
2. Rao & Guha, *Principles of Medical Electronics & Biomedical Instrumentation*, Orient Longman.2001

BM 621 ADVANCED BIOMATERIALS 4 credits [3-1-0]

Introduction, biomaterials in medicine,Metallic implant materials: different types, Host tissue reaction with biometal, corrosion behavior and the importance of passive films for tissue adhesion. Hard tissue & Soft tissue replacement.Polymeric implant materials: Types and classification,Mechanical,Surface,Electrochemical, & Physiochemical properties of biopolymers. Biodegradable polymers for medical application. Synthetic polymeric membranes and their biological applications.Ceramic implant materials: Types of bioceramics, Importance of wear resistance and low fracture toughness. Host tissue reactions: importance of interfacial tissue reaction. Composite implant materials: Mechanics of improvement of properties by incorporating different elements. Composite theory of fiber reinforcement. Polymers filled with osteogenic fillers. Host tissue reactions.Testing of Biomaterials: biocompatibility, blood compatibility and tissue compatibility, Toxicity tests, sensitization, carcinogenicity, mutagenicity and special tests, In vitro and In vivo testing .Sterilisation of implants and device :ETO, gamma radiation, autoclaving. Effects of sterilization.

Essential Reading

1. Sujata V. Bhat, *Biomaterials,* **,** Springer, 2002.
2. Buddy D. Ratner, Fredrick J. Schoen, Allan S. Hoffman, Jack E. Lemons *"Biomaterials Science: An introduction to Materials in medicine*, Academic Press, 2004.

Supplementary Reading

1. Jonathan Black, Biological Performance of materials, Taylor & Francis,2006
2. C.P.Sharma & M.Szycher, Blood compatible materials and devices, Technomic Publishing Co. Ltd., 1991.

BM 622 NANOTECHNOLOGY IN MEDICAL APPLICATION 4 credits [3-1-0]

What is nanotechnology, examples of nanostructures, nanodefinitions, nanoscale, unique properties of nanoscale matrices, Nanoparticles - quantum dots, metal nanoparticles, magnetic nanoparticles, conjugation, fabrication, advantages and issues, Nanofibers – electrospin fibers, self assemble fibers, conjugation, fabrication, advantages and issues. Carbon nanotubes, Nanoporous materials – phase separation, hydro gels, Biomedical Applications – drug delivery, tissue regeneration, cancer detection, imaging and diagnostics, outlook for future.

Essential Reading :

1. C.N.R. Rao, A.Muller, A.K. Chutham. Vol 1 & Vol 2*:The Chemistry of Nanoparticles* (Synthesis, Properties and Applications) –WILEY-VCH
2. Challa Kumar *Nanomaterials for Medical Diagnosis and Therapy* – Vol 10, WILEY- VCH, 2007

Supplementary Reading :

1. William A. Goddard III, Donald W Brenner, Sergey E. Lyshevski, Gerald J. Iafrate: Handbook of Nanoscience, Engineering, and Technology, CRC Press Taylor and Francis Group, 2007
2. Bhushan:Springer Handbook of Nanotechnology –Springer,2007

BM 623 ADVANCED TISSUE ENGINEERING 4 credits [3-1-0]

Introduction, structural and organization of tissues: Epithelial, connective; vascularity and angiogenesis, basic wound healing, cell migration, current scope of development and use in therapeutic and in-vitro testing. Cell culture- Different cell types, progenitor cells and cell differentiations, different kind of matrix, cell-cell interaction. Aspect of cell culture: cell expansion, cell transfer, cell storage and cell characterization, Bioreactors ; Molecular biology aspect- Cell signaling molecules, growth factors, hormone and growth factor signaling, growth factor delivery in tissue engineering, cell attachment: differential cell adhesion, receptor-ligand binding,and Cellsurface markers.Scaffold and transplant-Engineering biomaterials, Degradable materials, porosity, mechanical strength, 3-D architecture and cell incorporation. Engineering tissues for replacing bone, cartilage, tendons, ligaments, skin and liver. Basic transplant immunology, stems cells ; Case study and regulatory issues-cell transplantation for liver, musculoskeletal, cardiovascular, neural, visceral tissue engineering. Ethical, FDA and regulatory issues.

Essential Reading

1. Bernhard Palsson, Sangeeta Bhatia, Tissue *Engineering*, Pearson Prentice Hall, 2003
2. Robert. P.Lanza, Robert Langer & William L. Chick*, Principles of tissue engineering*, Academic press,1997

Supplementary Reading

1. Joseph D., Bronzino *The Biomedical Engineering* –Handbook, CRC; 3rd edition , 2006

BM 624 SURFACE ENGINEERING OF MEDICAL IMPLANTS 4 credits [3-1-0]

Introduction to surface engineering, Need for surface engineering of Medical implants and equipment.Surface Modification of Biomaterials, Wettability in Biomaterials Science and Modification Techniques, Atomic Scale Machining of Surfaces.Anodization, Titanium Dioxide Coatings in Medical Device Applications, The Effect of Shape and Surface Modification on the Corrosion of Biomedical Nitinol Alloy Wires exposed to Saline Solution.Cardiovascular Interventional and Implantable Devices ; Surface Engineering Artificial Heart Valves to Improve Quality of Life and Lifetime using Modified Diamond-like Coatings, Diamond Surgical Tools, Dental Tool Technology. Nanocrystalline Diamond: Deposition Routes and Clinical Applications Advanced techniques of modifying implant material surfaces (like Laser Surface Treatmen, PVD, CVD, ion implantation etc.) Environmental Engineering Controls and Monitoring in Medical Device Manufacturing, Biomaterial-Cell-Tissue Interactions In Surface Engineered Carbon-Based Biomedical Implants and Devices, Machining Cancellous Bone Prior to Prosthetic Implantation, Bonelike Graft for Regenerative Bone Applications. Titanium and Titanium Alloy Applications in Medicine.

Essential Reading

1. Jürgen Breme, C. James Kirkpatrick, Roger Thull: *Metallic Biomaterial Interfaces*, Wiley-VCH; 1 edition, 2008
2. D.M. Brunette, P. Tengvall, M. Textor, P. Thomsen: *Titanium in Medicine: Material Science, Surface Science, Engineering, Biological Responses and Medical Applications*
; Springer; 1st edition ;2001;

Supplementary Reading

1. Jan Eirik Ellingsen, S. Petter Lyngstadaas: *Bio-Implant Interface: Improving Biomaterials and Tissue Reactions:* CRC Press, 2003:
2. Gerhard Rakhorst, Rutger Ploeg; *Biomaterials In Modern Medicine: The Groningen Perspective* **;**World Scientific Publishing Company; 1 edition 2008;

BM 625 NANOBIOTECHNOLOGY 4 credits [3-1-0]

Nanostructures in biological materials – Introduction, Mechanics of bulk nanostructures of bone like materials, Mechanics of surface nanostructure of gecko-like materials, Nano materials fabrication – top down and bottom up approaches. Nano materials for various applications: bone, cartilage applications, vascular applications, bladder application, neural applications. Rationale for nanomaterial – tissue interactions; Nanomaterial characterization for biological applications – ATR FTIR, XPS, Time of flight SIMS, Colorimetric methods, CD spectroscopy, AFM

Essential reading:

1. R. H. J. Hannink and A. J. Hill *“Nanostructure control of materials*”, Woodhead Publicating Limited, CRC Press 2006.

Supplementary reading:

1. Junbai Li (Ed.) *Nanostructured Biomaterials*, Springer Series: 1st edition 2010.

BM 626 BIOMATERIALS AND TISSUE CHARACTERIZATION 4 credits [3-1-0]

Materials characterization - definition ; importance and application, Principles and general methods of compositional and structural characterization, techniques of X-ray, electron and neutron diffraction, EDAX, Thermal methods - DTA, TGA, DSC, DMA, temperature dependent rheology. Microscopy - optical, electron (TEM, SEM), Atomic force microscopy, optical profilometer and confocal laser scanning microscopy, Spectroscopy – UV-visible, fluorescence & phosphorescence IR, Raman and NMR spectroscopy, ESCA and Auger spectroscopy.

Essential Reading

1. Joon Park and R.S. Lakes: Biomaterials: An Introduction, Third edition, Springer.
2. A. H. Beckett and J. B. Stenlake :Practical Pharmaceutical Chemistry (Part II), Fourth edition, Cbs Publishers & Distributors.

Supplementary Reading

1. Edith Mathiowitz :Encyclopedia of Controlled Drug Delivery John Wiley & Sons
2. Robert M. Silverstein, Francis X. Webster: Spectrometric Identification of Organic Compounds Seventh edition, John Wiley & Sons

BM 627 CRYO-TISSUE ENGINEERING 4 credits [3-1-0]

Introduction to Cryogenic Systems, Freezing Technology, Cryogenics, Refrigeration, Cryogenic Liquefaction, Temperature Measurement, Cryomicroscopy, Low temperature Properties of Cells and Tissues. Freezing of cells and Tissues, Cryopreservation of cells, Cryopreservation methods, Cryoprotectants, Viability assay, Optimization of Cryopreservation procedure, Cryopreservation of tissues and organs, Cryopreservation of organ, Tissue architecture, Penetration of Cryoprotectants, Mechanical damage from freezing, Tissue banking, Cryosurgery, Cryoinjury, Factor affecting Cryosurgical injury, Frostbite and Hypothermia, Application Of Cryopreservation Technology.

Essential Reading:

1. P. L. Steponkus, *Advances in low-temperature biology* Elsevier Science1997 ISBN: 0762301600
2. R. Fleck and B. Fuller*; Cell Preservation* John Wiley & Sons, Ltd 2007 ISBN: 9780470723791

Supplemental Reading:

1 . F. P. Miller, A. F. Vandome and J. McBrewster; *Cryopreservation;* VDM Publishing House Ltd. 2009; ISBN: 9786130268855
2. B. J. Fuller, E. E. Benson and N. Lane; *Life in the frozen state* CRC Press2004 ISBN: 9780415247009

BM 628 BIOCERAMICS AND BIOCOMPOSITES 4 credits [3-1-0]

Classification of bio-ceramic materials for medical applications. Alumina and zirconia in surgical implants, bioactive glasses and their clinical applications, A.W. machinable and phosphate glass ceramics. Dense and porous hydroxyl apatite calcium phosphate ceramics, coatings and resorbable ceramics. Carbon as an implant. CMC and PMC composites. Characterization of bio-ceramics. Regulation of medical devices ; Types of composites and their advantages. Reinforcement: Glass, boron, carbon, organic and ceramic fibers, their structure, properties and processing. Matrix materials: Polymers, metal and ceramic matrices, their structure, properties and processing. Wettability and interface bonding ; Polymer matrix composites: Lamina, laminate composites. Primary and Secondary manufacturing; Lay-up, Filament winding, pultrusion, compression moulding. Machining, drilling and routing, applications. Metal matrix composites: processing techniques and applications. Ceramic Matrix composites; processing techniques and applications. Introduction to Nanocomposites and applications Micromechanic: Mechanical properties, thermal properties and load transfer. Macromechanics: Elastic behavior, fracture behavior, fatigue behavior, creep behavior of composites. Tribological and electrical behavior of composites. Degradation of composites due to various environmental conditions, corrosion resistance of composite. Designing with composites Biological application of composites.

Essential Reading

1. Larry L. Hench and June Wilson :*An Introduction to Bioceramics* ;World Scientific Publishing Company; 1 edition 1993
2. Sharon Brown **,** Ian Clarke**,** Paul Williams ;*Bioceramics*; Trans Tech Publications, Ltd. 2002

Supplementary Reading

1. T. Kokubo: *Bioceramics and their clinical applications*;CRC; 1 edition, 2008
2. Joon Park; *Bioceramics: Properties, Characterizations, and Applications* : Springer; 1 Edition 2008

BM 629	REGENERATIVE MEDICINE AND STEM CELL	4 credits [3-1-0]

Regenerative medicine, regeneration, reparation. Cell therapy. Tissue engineering. Stem and progenitor cells – basic terms, characterization, biological behaviour, differentiation potential. Ethics and moral aspects of stem cell research. Embryonic stem cells. Tumour stem cells. Muscle-derived stem cells; muscle regeneration. Mesenchymal stem cells. Dental pulp stem cells. Separation techniques. Cellular interactions. Growth factors. Neural stem cells. Regeneration of the nervous tissue. Spinal cord injury. Haematopoietic stem cells Endothelial progenitor cells. Haematological applications, bone marrow transplantation. Scaffolds (2D, 3D) – natural, artificial. Encapsulation. Nanotechnology. Cellular migration. Cell differentiation. Cell transplantation. Tissue engineering of bones nd cartilages Orthopaedic applications.

Essential Reading:

1. A. Atala, R. Lanza and J. A. Thomson*, Principles of regenerative medicine*, Academic Press,2010 ISBN: 0123814227
2. D. L. Stocum and Science Direct, *Regenerative biology and medicine*; Elsevier Academic Press2006 ISBN: 0123693713

Supplemental Reading:

1. W. C. Low; *Stem cells and regenerative medicine* World Scientific Pub Co Inc, 2008 ISBN: 9812775765
2. M. P. Mattson and G. Van Zant *Stem cells: a cellular fountain of youth*; Elsevier;2002 ISBN: 0444507310

BM 631	COMPUTATIONAL METHODS IN BIOMEDICAL ENGINEERING	4 credits [3-1-0]

Overview of problems in Biomedical Engineering, Constructing Engineering Models, Numerical Algorithm and Errors: Round-off, truncation, Direct and Iterative Approaches for Solution of Linear and Nonlinear Biological Systems, Finite Difference Methods : Backward, Forward, and Central Differences; Interpolation, Differentiation, and Integration. The Lax-Richmyer equivalence theorem. Stability analysis: Von-Neumann stability criterion. Runge-Kutta Methods and Predictor-corrector Methods with Application to Biological Systems. Classification of PDEs. Formulation of PDEs for Diffusion Across Biological Membranes and Their Numerical Solution.

Essential Reading

1.Stanley Dunn, Alkis Constantinides, Prabhas V. Moghe, *Numerical Methods in Biomedical Engineering,* Academic Press, 2005.
2.S V Patankar, Numerical Heat Transfer and Fluid Flow, Taylor and Francis.
T J Chung, Computational Fluid Dynamics, Cambridge University Press, 2002.

BM 632	COMPUTATIONAL FLUID DYNAMICS IN BIOENGINEERING	4 credits [3-1-0]

An Overview of Fundamentals of Heat and Mass Transfer and Fluid Flow; Conservation Form of Governing Differential Equations; Classification of PDEs; Basic Discretization Techniques; An Overview of FEM, FDM, and FVM; Control Volume Formulation for Diffusion Type Problems; Solution of Systems of Discretized Equations; Formulation of Convection-diffusion Problems; Solution of Fluid Flow Equations; Formulation of Mathematical Model and Numerical Solution of Blood flow through arteries, Drug delivery, Phase Change Problems in Laser-tissue Interaction, Cryosurgery of a Tumor and Cryopreservation of a Cell, Flow Through Porous Medium, Oxygen Transport in Skeletal Muscle, Solute Transport in Biological Systems.

Essential Reading:

1. S V Patankar, *Numerical Heat Transfer and Fluid Flow*, Taylor and Francis, 1980.
2. J H Ferziger, M Peric, *Computational Methods for Fluid Dynamics*, Springer, 2002.

Supplementary Reading:

1. H. K. Versteeg, W. Malalasekera, *An Introduction to Computational Fluid Dynamics*, Longman scientific and Technical, 2007.
2. A. W. Date, *An Introduction to Computational Fluid Dynamics*, Cambridge University Press, 2005.
3. R L Fournier, *Basic Transport Phenomena in Biomedical Engineering*, Taylor & Francis, 2007

BM 633	ARTIFICIAL ORGAN AND REHABILITATIVE ENGINEERING	4 credits [3-1-0]

Introduction to artificial organs: Biomaterials used in artificial organs and prostheses,Rheological properties of blood, blood viscosity variation, Casson equation, flow properties of blood, problems associated with extracorporeal blood flow ; Artificial kidney: kidney filtration, artificial waste removal methods, hemodialysis, equation for artificial kidney and middle molecule hypothesis. Hemodialysers, mass transfer Analysis, regeneration of dialysate, membrane configuration, wearable artificial kidney machine, separation of antigens from blood in ESRD patients ; Artificial heart-lung machine: lungs gaseous exchange/ transport, artificial heart-lung devices. Oxygenators, Liver support system, artificial pancreas, blood and skin ; Audiometry: air conduction, bone conduction, masking, functional diagram of an audiometer. Hearing aids, Opthalmoscope, etinoscope, I.A.B.P principle and application ; Rehabilitation Engineering: Impairments, disabilities & handicaps, measurement & assessment, engineering concepts in sensory & motor rehabilitation. Engg. concept in communication disorders, Rehabs for locomotion, visual, speech & hearing, Artificial limb & hands, prosthetic heart valves,Externally powered & controlled orthotics & prosthetics, Myoelectric hand & arm prostheses, marcus intelligent hand prostheses, gait study, spinal rehabilitation.

Essential Reading

1. Gerald E Miller, *Artificial Organs,* Morgan & Claypool, 2006
2. Kondraske, G. V, *Rehabilitation Engineering*. CRC press 1995

Supplementary Reading

1. Bronzino Joseph, *Hand book of biomedical Engineering*, Springer, 2000
2. R. S.Khandpur*, Biomedical Instrumentation: Technology and Application,* McGraw-Hill Professional

BM 634	ADVANCED BIOMECHANICS	4 credits [3-1-0]

Scalar and vector quantities. Different operations on vector. Forces and moments, system of forces, resultant of system of forces in 3D and 2D. Equilibrium equations. Applications with example on human body. Work-energy equations: Applications to Biomedical system. Stress- strain diagram. Stress concentration. Mechanical properties of human bone. Mechanical properties of cortical bone, properties of cancellous bone, viscoelasticity, elastic model of bone. Mechanical testing of soft tissues ; Principle of continuum mechanics. Tensor treatment to explain elastic, viscoelaslicity, electric and electromechanical properties of bones, teeth and connective tissues. Wave propagation in extended and partly bound media and its application in analyzing the structural micro textural symmetry in calcified tissues. Theoretical models for bone as a hierarchical composite. Dental forces, implant-tissue biomechanics, Crack propagation in bones, dynamic models. Wolf's law and introduction to orthopedic biomechanics. Human body dynamics and locomotion analysis. Pressure sore biomechanics. Interaction between tissues and support surface. Mechanics of spinal distraction rods. Biomechanics of human motion and control interfaces with application to limb orthotics and prosthetics. Design of hip prosthesis. Automated driver's training programme. Sports biomechanics.

Essential Reading

1. Y C Fung, Biomechanics*: Mechanical Properties of Living Tissues*, springer, 2nd edition,1993.
2. Nihat Ozkaya and margarita nordin, *fundamentals of biomechanics-equilibrium, motion and deformation*, springer-verlag, 2nd edition 1999.

Supplementary Reading

1. John G Webster, *Medical instrumentation –Application and design*, John wiley and sons Inc. 3rd ed. 2003.
2. D. Dowson & V. Wright, An *introduction to Biomechanics of joints and joint replacements, Mechanical Engineering* Publications , 1980

BM 640	FLUORESCENCE TECHNIQUES IN BIOENGINEERING	4 credits [3-1-0]

Basic concepts in fluorescence; time resolved and steady state fluorescence; fluorescence lifetime measurements; Fluorescence quenching and its applications: static and dynamic quenching; Fluorescence Resonance Energy Transfer and its applications; Fluorescence anisotropy and its applications; Biochemical fluorophores: intrinsic and extrinsic fluorophores; Fluorescent proteins and their applications; Protein fluorescence; Fluorescence sensing; Fluorescence applications in DNA technology; Molecular beacons and their applications.

Essential Reading:

J. R. Lakowicz, *Principles of Fluorescence Spectroscopy*, Kluwer Academic/Plenum Publishers, 2nd Edition, 19999.
J. R. Lakowicz (Editor), *Topics in Fluorescence Spectroscopy*, Kluwer Academic/Plenum Publishers, Vol.-1-7, 1991 onwards.

BM 641	IMMUNOTECHNOLOGY	4 credits [3-1-0]

Characteristics of animal cells and their implication on process design Nutritional requirements and serum free culture of mammalian cells Kinetics of growth and product formation ; Reactor systems for large-scale production using animal cells ; Production of Polyclonal antibodies with different types of antigens: antigen preparation and modification, adjuvants does and rute of antigen administration, collection of sera, purification of antibodies ; Hybridoma technology. production and applications of monoclonal antibodies for diagnosis and therapy ; Production of virus vaccines, specific vaccines ; Production of cellular chemicals like Interferons, Interleukin etc.; Immunoassay procedures.

Essential Reading:

1.A Moran and J P. Gosling, *Immunotechnology: Principles, Concepts and Applications*, John Wiley & Sons, 2008.

Supplementary Reading:

1.D.P. Stites, J.D. Stobo, H.H. Fudenberg and J.V. Wells; Basic *and Clinical Immunology. Large medical publications*, 5th Edition, 1987

BM 642	BIOPHYSICS & STRUCTURAL BIOLOGY	4 credits [3-1-0]

Three dimensional conformations of proteins,Ramachandran plot, motifs, folds, mechanism of protein folding, fibrous proteins, membrane proteins and their structures. Hydrogen bonding, hydrophobic interactions, ionic interactions, disulphide bonds and their role in protein structure. Secondary structural elements and organisation of tertiary structure. Helix-coil transition and zipper model ; **Principles of Nucleic acid structures :** Nucleic acid structure and composition, supercoiling of DNA, denaturation and renaturation kinetics, nucleotide sequence composition: unique, middle and highly repetitive DNA ; **Methods of determination of biomolecular structures:** Macromolecular structure determination: X-ray crystallography, optical, UV and IR spectroscopy, luminescence, fluorescence, magnetic resonance and electron microscopy ; **Biomolecular interactions :** Protein-Proteininteractions,protein-carbohydrate interactions, Protein-DNA interactions. General features and thermodynamic aspects of protein folding, Detection of folding intermediates, Complex and folding kinetics.

Essential Reading :

1. D. L. Nelson and M.M. Cox, Lehninger *Principles of Biochemistry*, W. H. Freeman; Fourth Edition, 2004.
2. K.E van Holde, C.Johnson, and P.Shing Ho**,** *Principles of Physical Biochemistry*, Prentice Hall, Second edition, 2005.

Supplementary Reading :

1. P.R. Bergethon**,** The Physical Basis of Biochemistry: *The Foundations of Molecular Biophysics,* Springer, Corrected edition, 2000.

BM 643	**ADVANCED PROTEIN ENGINEERING**	**4 credits [3-1-0]**

Introduction: Design and construction of novel proteins and enzymes, Conformation of proteins in general and enzymes in particular, Effect of amino acids on structure of proteins, Energy status of a protein molecule, Structure function relations of enzymes, Physical methods such as x-ray crystallography for determination of protein structure, Site directed mutagenesis for specific protein function, Basic concepts for design of a new protein/enzyme molecule, Specific examples of enzyme engineering, -Tryesyl t RNAsynthetase, Dihydrofolate reductase, Subtilisin.

Essential Reading :

1. C.Köhrer and U.L. RajBhandary, *Protein Engineering (Nucleic Acids and Molecular Biology),* Springer, 1 edition.
2. J. L. Cleland and C.S. Craik, *Protein Engineering: Principles and Practice*, Wiley-Liss, 1 Edition.

Supplementary Reading:

1. S.Lutz and U.T.Bornscheuer*, Protein Engineering Handbook* , Wiley-VCH; New edition.

BM 644	**ADVANCED CELL & MOLECULAR BIOLOGY**	**4 credits [3-1-0]**

Organization of viral, prokaryotic and eukaryotic genomes: Cot curves, repetitive and unique sequences, kinetics and sequence complexities, satellite DNA, DNA melting and buoyant density ; Organelle genomes, Rearrangement and amplification of DNA in the genome, DNA replication models, DNA polymerases - mode of action, DNA damage, DNA repair and recombination., RNA polymerases and reverse transcriptase: structure and mechanism of action ; Enzymes involved in DNA modifications, methylases, demethylases, DNases, DNA gyrase, Topoisomerase, Organization structures and function of ribonucleoproteins, Protein synthesis: Genetic code, mechanism and regulation of protein synthesis, Development, Molecular basis of development in animals and plants, Homeobox gene expression and Pattern formation in development, DNA methylation, gene expression, chromosomal inactivation and sex determination , Oncogenes, proto-oncogenes and etiology of cancer.

Essential Reading :

1.B.Alberts, A.Johnson, J.Lewis and M.Raff, Molecular Biology of the Cell, Garland Science; 5th edition.

Supplementary Reading :

1.H. Lodish, A Berk, C.A. Kaiser and M.Krieger, Molecular Cell Biology, W. H. Freeman**,** 6th edition, 2007.

BM 645 CELL AND PROTEIN PROCESSING 4 credits [3-1-0]

Basics of cells and proteins, related processing steps, structural and dynamic properties of bulk and confined water, mechanism of protein stabilization during freeze drying, spray drying and storage, Freeze drying and spray drying fundamental issues, freezing and drying induced perturbations of protein structure and mechanism of stabilization, molecular mobility of freeze dried formulation and effect on storage stability, formulation characterization, freeze drying of biological standards, technical procedures for operation of sterilization-in-place process for production of freeze drying equipment, irradiation of freeze dried vaccine and other select biological products.

BM 646 MOLECULAR BIOLOGY OF CANCER 4 credits [3-1-0]

Carcinogenesis, cancer initiation, promotion, & progression, Cellular proto-oncogenes, oncogene activation, Growth factors, growth factor receptors, signal transduction, Transcription factors, Retroviral oncogenes, Tumor suppressor genes, Cancer cell cycles, DNA viruses/cell immortalization, Tumor suppressor gene pathways, DNA methylation, epigenetic silencing of suppressor genes, Genomic instability, Apoptosis, Free radicals, antioxidants, and cancer, Metabolic oxidative stress and cancer, Epidemiology of selected cancers, Gene rearrangements, detecting oncogene abnormalities in clinical specimens, Cell:cell interactions, cell adhesion, angiogenesis, invasion and metastasis. Strategies of anticancer chemotherapy, Strategies of anticancer gene therapy, Translating therapies from laboratory to clinic, Gene discovery in caner research, cancer genome anatomy project, Cancer immunity and strategies of anticancer, immunotherapy.

Essential Reading :

1.M.Khan and S.Pelengaris, The Molecular Biology of Cancer**,** First edition, Wiley- Blackwell, 2006.

Supplementary Reading :

1.L.Pecorino, Molecular Biology of Cancer: Mechanisms, Targets, and Therapeutics, 2nd edition, Oxford University Press, USA; 2008.

BM 647 ADVANCED BIOINFORMATICS 4 credits [3-1-0]

Scope of Bioinformatics, Elementary commands and protocols, ftp, telnet, http; Primer on information theory; Introduction to Homology (with special mention to Charles Darwin, Sir Richard Owen, Willie Henning and Alfred Russel Wallace); DNA mapping and sequencing; Map alignment; Large scale sequencing methods (Shotgun and Sanger method); Heuristic Alignment algorithms; Global sequence alignments-Neddleman-Wunsch Algorithm Smith-Waterman Algorithm-Local sequence alignments (Amino acid substitution Matrices (PAM, BLOSUM); Introduction to Biological databases; Organization and management of databases; Searching and retrieval of information from the World Wide Web; Structure databases-PDB (Protein Data Bank), Molecular Modeling Databases (MMDB); Primary Databases (NCBL, EMBL, DDBJ) ; Introduction to Secondary Databases Organization and management of databases (Swissprot, PIR, KEGG); Introduction to BioChemical databases-organization and Management of databases (KEGG, EXGESCY, BRENDA, WIT); Multiple sequence alignment and phylogenetic analysis.

Essential Reading :

1. H. H. Rashidi and L. K.Buehler, *Bioinformatics Basics. Applications in Biological Science and Medicine*, CAC Press, 2000.
2. D. Gusfiled , *Algorithms on Strings Trees and Sequences*, Cambridge University Press, 1997.

Supplementary Reading :

1. P. Baldi and S. Brunak, *Bioinformatics: A Machine Learning Approach*, MIT Press, 1988.
2. D. Mount, *Bioinformatics*, CSH Publications, 2000.

BM 648 PROTEIN CONFORMATIONAL DISEASES AND THERAPY 4 credits [3-1-0]

Introduction to Protein Architecture, Cooperative Transitions in Protein Molecules, Kinetics of Protein Folding and the Energy Landscape Model, Introduction to Misfolding, Aggregation, and Disease, Thermodynamics of protein folding, misfolding and aggregation; Neurodegenerative disorders, Alzeimer's disease, Parkinson's disease, Prion disease, polyglutamine diseases, Amyloidosis. Other protein misfolding disorders: Cystic fibrosis, alpha-antitrypsisn deficiency, Fabry disease, cancer ; Various Experimental Models in diseases. Disease mechanism, Genetic mutation in diseases,Dysfunction of proteasome in diseases.Role of chaperones in various pathogenesis ; Study of Disordered Proteins and Aggregation, Intrinsically Disordered Proteins ; Current therapy; chemicals drugs, chaperone-based therapy in neurodegeneration, Proteasome inhibitors, Gene therapy etc.

Essential Reading :

1.V.N. Uversky and V. N. Uversky, A.Fink, *Protein Misfolding, Aggregation and Conformational Diseases (Protein Reviews),* First edition, Springer, 2007.

2.H. J.Smith, C.Simons, and R.D. E. Sewell*, Protein Misfolding in Neurodegenerative Diseases: Mechanisms and Therapeutic Strategies (Enzyme Inhibitors*), First edition, CRC, 2007.

Supplementary Reading :

1.J.Ovádi and F.Orosz, Protein folding and misfolding: neurodegenerative diseases (Focus on Structural Biology), First edition, Springer, 2009.

BM 649 RECOMBINANT DNA TECHNOLOGY 4 credits [3-1-0]

Tools of recombinant DNA: restriction endonucleases and other enzymes; vecors; plasmid; Bacteriophage and other viral vectors, cosmids, Ti plasmid, yeast artificial chromosome. c-DNA and genomic DNA library, gene isolation, gene cloning, expression of cloned gene, DNA labeling by radioactive and non radioactive methods ; DNA sequencing, Chemical cleavage and dideoxy methods; oligonucleotide synthesis; polymerase chain reaction ; Southern and Northern blotting, in situ hybridization. DNA markers: restriction fragment length polymorphism, random amplified ploymorphic DNA, DNA finger printing, and their applications ; Site-specific and oligonucleotide directed mutagenesis, antisense and ribozyme technology; genetic diagonosis, gene transfer technologies; transgenics; gene therapy.

Essential Reading :

1.O.S. Reddi, *Recombinant DNA Technology*, Allied Publishers Pvt. Ltd. 2000.

Supplementary Reading :

1.A.Prokop, R.K. Bajpai, and C.S. Ho*, Recombinant DNA Technology and Applications*, Mcgraw-Hill, 1991.

BM 651 INDUSTRIAL MICROBIOLOGY 4 credits [3-1-0]

Chemical composition of food; Structure, properties, chemical and biochemical function of food constituent water, protein, fats, carbohydrates; enzymes, vitamins and minerals; pigments, colour and flavourings; Food additives and contaminants. Chemical changes during food processing, Chemical spoilage of food. Introduction to food microorganisms, Morphology and charactristics of bacteria, yeasts and molds, Factors affecting microbial growth and decay. Microbial growth and death kinetics. Food poisoning, intoxicating and infective organism. Microbial spoilage of foods.

Essential Reading :

1. M.J. Waites, N. L. Morgan, J.S. Rockey, and G.Higton*, Industrial Microbiology: An Introduction*, Wiley-Blackwell, ISBN-13: 978-0632053070, 2001.

Supplementary Reading :

1. Samuel and Dunn, C.Prescott, *Industrial Microbiology*, McGraw Hill; 3Rev Ed edition (1959); ISBN-13: 978-0070507487.

BM 652 ADVANCED BIOCHEMICAL ENGINEERING 4 credits [3-1-0]

Kinetics of cell growth; Mathematical models for substrate uptake and product formation; Plasmid stability in recombinant cell cultures; Kinetics of enzyme-catalyzed reactions; Media and air sterilization; Cell cultivation strategies; Novel bioreactor designs; Developments in aeration & agitation in bioractors; immobilized whole cell and immobilized enzyme reactors; RTD and mixing in bioreactors; Dynamics of mixed cultures; Scale-up and scale down of bioreactors.

Essential Reading :

1. M.L. Shuler and F.Kargi, *Bioprocess Engineering: Basic Concepts* ,. Prentice Hall PTR; 2 edition, 2001.

Supplementary Reading :

1. J.E. Bailey and D.F. Ollis*, Biochemical Engineering Fundamentals*, McGraw Hill Higher Education, 2nd edition, 1986.

BM 653 BIOPROCESS AND PLANT DESIGN 4 credits [3-1-0]

Introduction; General design information; Mass and energy balance; Flowsheeting; Piping and instrumentation ; Materials of construction for bioprocess plant; Mechanical design of process equipment; Vessels for biotechnology application; Design of bioreactors ; Design considerations for maintaining sterility of process streams and process equipment; Selection and specification of major equipment used in bioprocess industries ; Utilities for biotechnology production plants; Process economics ; Bioprocess validation; Safety considerations; Case studies.

Essential Reading :

1. B. K. Lydersen, N.A. D'Elia, and K. L. Nelson, *Bioprocess Engineering*, Wiley- Interscience; 1st edition, 1994.

Supplementary Reading :

1.P.M. Doran, Bioprocess *Engineering Principles*, Academic Press; 1st edition, 1995.

BM 654 ADVANCED BIOSEPARATION 4 credits [3-1-0]

Introduction; An overview of bioseparation. Filtration: Separation of cells and other insolubles from fermented broth. Centrifugation (batch, continuous, basket). Cell disintegration: Physical methods (osmotic shock, grinding with abrasives, solid shear, liquid shear), Chemical methods (alkali, detergents), Enzymatic methods ; Products isolation: Liquid-liquid Extraction and adsorption method, precipitation (ammonium sulphate. Organic solvents, high molecular weight polymers), chromatographic separation; affinity, size exclusion, Thin layer, ion exchange chromatography. Modern separation: ultrafiltration, Reverse Osmosis, Electrophoretic separation ; Products polishing: Crystallization and drying.

Essential Reading:

1. PA Belter, EL Cussler and WS Hu, Bioseparations: *Downstream Processing for Biotechnology*, John Wiley and Sons, 1988.

Supplementary Reading :

1. R Ghosh, *Principles of Bioseparation Engineering*, World Scientific Pte. Ltd, 2006.
2. RG Harrison, PW Todd, SR Rudge. D Petrides, DP Petrides, *Bioseparations Science and Engineering*, Oxford University Press, 2002.

BM 656 PHARMACEUTICAL TECHNOLOGY 4 credits [3-1-0]

Tablet: Types, definition, preparation ; Tablet coating: Coating processes, film testings and film defects ; Capsules: Method of capsule production ; Parenteral products: Route of administration; selection of vehicles; added substances; containers; suspension and emulsion for injections; production-facilities, environmental control, personel, cleaning of containers and closures, sterilization of equipment, compounding the product, filtration of solutions, filling and sealing procedures, sterilization of products; various quality control test for parenteral products. Opthalmic products: eye drops, eye lotions, eye ointments, formulation, additives, preparation, sterilizing, packaging, contact lens solutions ; Aerosols: mode of operations, propellants, containers, valves, actuators and buttons, diptubes, packing, application and testing ; Liposomes: fundamentals of manufacturing, evaluation, advantages & limitations, application. Niosomes & their fundamentals ; Iontophoresis & sonophoresis: fundamentals, evaluation & applications ; Protein, peptide & gene deliveries: Their basics, success, limitation and application ; Other Important delivery systems: Microcapsules, nanoparticles, mucoadhesives, buccal and sublingual preparations, transdermal patches & other topical products, multiple emulsion and solid dispersion.

Essential Reading :

1. H. A. Lieberman, L. Lachman and J. B. Schwartz*, Pharmaceutical Dosage forms (Vol 1, 2 and 3),* Second edition, Informa Health Care.
2. Mathiowitz Edith, *Encyclopedia of Controlled Drug Delivery* , John Wiley & Sons

Supplementary Reading :

1. Binghe Wang, Teruna J. Siahaan, Richard A. Soltero , *Drug Delivery: Principles and Applications* , John Wiley & Sons.
2. T. Scheper , *Gene Therapy and Gene Delivery Systems (Advances in Biochemical Engineering / Biotechnology),* Springer.

BM 661 BIOLOGICAL WASTE TREATMENT 4 credits [3-1-0]

Qualitative and quantitative characterization of wastes; Waste disposal norms and regulations; Indian regulations; Principles of biological treatment; Aerobic and anaerobic biological wastewater treatment systems; Suspended and attached cell biological wastewater treatment systems; Biological nutrient removal; Treatment plant design calculations; Treatment and disposal of sludges; biological means for stabilization and disposal of solid wastes; Treatment of hazardous and toxic wastes; Degradation of xenobiotic compounds; bioremediation.

BM 662 NUTRITIONAL SCIENCES AND PLANT BASED PRODUCTS 4 credits [3-1-0]

Chemical nature, physiology, metabolism and biochemical/molecular mode of action of nutrients; assessment of nutrition status (anthropometric, biochemical and dietary) and requirements of nutrients for different physiological groups; functional significance of nutrition - physical work, psychosocial development, immunity, reproductive performance, drug utilisation; nutritional deficiency disorders-clinical manifestations and diagnosis; diet and degenerative diseases-role of functional foods (nutraceuticals-plants based products); food toxicities; reaching nutrients to the community-food fortification, food processing, nutrition intervention programmes, dietary diversification.

Essential Reading :

1. M. J Chrispeels, *Plants, Genes, and Crop Biotechnology,* Jones and Bartlett Publishers, Inc., 2 Sub edition, 2002.

BM 670 ADVANCED BIOCHEMICAL ENGINEERING LABORATORY 4 credits [3-1-0]

Isolation of useful microorganisms from natural samples. Growth of microorganisms, estimation of Monod parameters. Temperature effect on growth-estimation of energy of activation and Arrhenius. Constant for microorganisms. Study of growth kinetics of bacteria in shake flask. Separation of protein using sucrose gradient method. Separation of proteins using Electrophoresis methods. Separation of DNA using Electrophoresis method. Separation of protein using reverse osmosis. Study of growth kinetics saccharomyces cerevisiae in shake flask. Estimation of dry cell mass. Study of growth kinetics of bacteria in bioreactor. Death kinetics of saccharomyces cerevisiae.

BM 671 BIOMOLECULAR INTERACTION LABORATORY 4 credits [3-1-0]

Estimation the extent of folding of a protein in vivo.Study the process of Protein misfolding and aggregation in vitro.Study the process of amyloid formation of a protein in-vitro.Study the thermodynamics of protein folding, misfolding.Monitoring Protein-DNA interaction.Calculation of Hydrophobicity of macromolecules by online software.Estimation secondary and tertiary structure of proteins by online software.Study Protein, DNA and various metallic nanoparticle interactions.Study the folding behaviour of proteins by the action of Chaperones.Small ligand docking. Protein-protein docking.Protein-Protein, Protein-DNA interaction study by Chromatography.Protein-Protein interaction study by Isothermal titration calorimetry.

BM 672 ADVANCED BIOSEPARATION LABORATORY 4 credits [3-1-0]

Introduction; An overview of bioseparation. Separation of cells and other insolubles from fermented broth. Filtration and microfiltration, centrifugation (batch, continuous, basket). Cell disruption: Physical methods (osmotic shock, grinding with abrasives, solid shear, liquid shear), Chemical methods (alkali, detergents), Enzymatic methods ; Products isolation: Solvent Extraction and adsorption method, precipitation (ammonium sulphate. Organic solvents, high molecular weight polymers), chromatographic separation; affinity, size exclusion, Thin layer, ion exchange chromatography. ultrafiltration, Reverse Osmosis, Electrophoretic separation ; Products polishing: Crystallization and drying.

BM 673 CELL AND PROTEIN PROCESSING LABORATORY 4 credits [3-1-0]

Introduction to cells and proteins, their sensitivity to different processing exercises. Differential scanning calorimetric properties of proteins and cells in the presence and absence of excipients. Study of processing caused changes/damages in proteins and cell membrane using Infrared Spectrometry. Cell counting, cell separation using Flow Cytometer.Studies on cell death using Flow Cytometer. Use of fluorescent tag and tagged antibody for identification of proteins and cells using fluorescent spectrometry. Biostabilization of cells and proteins using freeze drying technique. Biostabilization of cells using Spray drying technique. Biostabilizationof cells and proteins using spray drying technique.

BM 674 ADVANCED BIOMEDICAL INSTRUMENTATION LABORATORY 4 credits [3-1-0]

Build a program to add two numbers.Build a program to add four numbers using two adders and also using compound arithmetic function.Build a program to add, subtract, multiply and divide two numbers simultaneously.Build a program to convert temperature in degree Celsius to Fahrenheit.(F=C*1.8+32).Build a program to find acceleration given Mass and Force.(F=M*A).Build a program which performs Addition, subtraction, ultiplication and division as per the selected function. (Multiple Case Structure)Build a program to generate random numbers between 0 and 1 using "Run Continuous" button.Build a program to generate random numbers between 0 and 1 using While Loop.Build a program to generate random numbers between 0 and 1 using For LoopBuild a program which generates random numbers between 1 and 100. The program has to stop executing once the number 5 is generated.Build a program to generate random numbers between 0 and 1 using While Loop and Store the numbers generated.Modify the above program such that the while loop stops after 10 sec.Modify the above program such that the while loop stops either after the end of 10 sec or when the user wishes it to stop.Build a program to generate random numbers between 0 and 1 using For Loop and Store the numbers generated.Build a program to generate a Sine wave and display it in a Graph.Build a program to generate a Sine wave. Also provide the controls to control amplitude and frequency of the waveform.Build a program to generate Sine, Square, and Triangle waves with an option to select the desired waveform during the execution of the program.Execute the above program by using hybrid programming.Build a program to observe the Spectrum of the generated waveform.Build a program using Express VI to generate a Sine wave. Also provide the controls to control amplitude and frequency of the waveform.Use Mathscript node to generate the signal given by the formula **y = sin(2*pi*50*t) + 2*sin(2*pi*120*t)**. The time information for the signal is given by t = (0:0.001:1). Use Mathscript to generate a sawtooth signal with following characteristics. fs = 10000; t = 0:1/fs:1.5; x = sawtooth(2*pi*50*t).Use Mathscript to generate a square signal with following characteristics. fs = 10000; t = 0:1/fs:1.5; x = square(2*pi*50*t).Use Mathscript to generate a chirp signal with following characteristics. t = 0:1/1000:1;y = chirp(t,0,1,150);Use Mathscript to generate a chirp signal with following characteristics. t = 0:1/1000:1;y = chirp(t,150,1,0);Use Mathscript to generate a chirp signal with following characteristics. t = 0:1/1000:2; y = chirp(t,0,1,150);Use Matlab script to generate a pulse trains. (T = 0:1/50E3:10E-3; D = [0:1/1E3:10E-3;0.8.^(0:10)]'; Y = pulstran(T,D,'gauspuls',10E3,0.5);Generate a sound of 400 hz. t=0:1/8000:1; x=cos(2*pi*400*t); sound(x,8000)Generate a noise sound. Find convolution of x and y. x=[1,1,1] and y=[1,1,1].Find the convolution of two signals x and y.Generate impulse function. Using hybrid-programming, prove the commutative, distributive and associative properties of convolution. Use Express VI palette for spectral measurements.Build a program to filter the Noisy Sine Wave.Extract the sine wave using filtering technique.Prove that the periodic signals (e. g. square wave, sawtooth wave, triangular wave) are a combination of various sinusoids.Modulate signals as per the given mathematical equation. Find out the spectral components present in the resultant waveform.Extract the various frequency components of a modulated signal (as per a given mathematical) using LPF, HPF, BPF and Notch filter.Determine the Tone of a given sinusoidal wave.Determine the frequency response of a given filter by using dual channel spectral measurement.To perform the various voltage measurements of a given signal.Compute the histogram of a given signal.Display the given signal in an array. Save the array in a xl file.Display the maximum and minimum values in an array.Sort a given array in ascending and descending order.Search an element in a given array.Replace an element or subarray in an array at a specified point.Insert an element or subarray in an array at a specified point.Delete an element or subarray in an array at a specified point.Split an 1-D array into two sub-arrays.Merge two or more signals and view in a waveform graph. Save the signal in a file.Split merged signals.View selected waveforms from a merged signal.Extract a portion of the given signal.Collect input signals and show the most recent data, up to the specified maximum number of samples per channel.Signal acquisition using a sound-port of a computer.Implementation of a peak detector.Implementation of FIR and IIR filters and study their characteristics.Designing of notch filter to eliminate 50 Hz noise. Designing of comb filter to eliminate 50 Hz noise and its harmonics.Implementation of an adaptive filter for noise cancellation.Introduction to JTFA → The need for JTFA.Implementation of wavelet-based peak detection.Wavelet based data compression.Implementation of an ECG R-peak detector.Implementation of a program for monitoring Heart Rate.Implementation of a program to drive a demand pacemaker.Implementation of a program for designing a biofeedback system.Implementation of a program to drive demand pacemaker.Implementation of a program to drive DC motor using EMG signal.HRV analysis from raw ECG signal using biomedical startup kit.Introduction to joint time-frequency analysis tools.Introduction to feature extraction and signal classification.Online signal processing of digitized analog signals.Introduction to hybrid programming.

BM 675 ADVANCED BIOMEDICAL EQUIPMENT DESIGN LAB 4 credits [3-1-0]

Mechanical Design of Hospital Beds, Wheel Chairs, Prosthesis and orthotics, Stents, Nails, Plates, Electrical safety and precaution in hospital setting, Electrical design of AC/DC defibrillator, Centrifuge, Autoclave and Hot Air Oven, Incubators, CAD/CAM in Hospital equipment design, Ergonomics in equipment design, Simulation in the Hospital equipment design.

BM 676 BIOMEDICAL IMAGE PROCESSING LABORATORY 4 credits [3-1-0]

Implementation of the below Algorithms.Algorithms for low Pass filter, High Pass Filter, Median filter.Prewitt Edge, quich Edge detector.Miller's Algorith.Cooley- Turkey Algorithm.Numerical Implementation of the TWO Dimensional F.F.T.Reconstruction Algorithm for Parallel Projections.Reconstruction Algorithm for Fan Beam Projections.Re-sorting Algorithm.Back Projection Algorithm.Algebric Reconstruction Techniques (A.R.T.).Simultaneous Algebric Reconstruction Technique (S.A.R.T.).Simultaneous Iterative Reconstruction Technique

BM 677	BIOMEDICAL SIGNAL PROCESSING LABORATORY	4 credits [3-1-0]

Use of DSP processor 6X and 2X series for a. Sine wave generation using C.
b. Linear and circular convolution
c. Finding DFT and IDFT of a given density d. Realization of FIR and IIR filters
e. Plotting the power spectral density

Designing an FIR filter using MATLAB and DSP Kit. Designing an IIR filter using MATLAB and DSP Kit. Fourier analysis of periodic signal.Time frequency domain properties of different windows using MATLAB. Implementation of the Double-Precision Complex FFT for ECG signal. Design of Notch filter for elimination of 50Hz from ECG signal. EMG processing using MATLAB –Rectification and Signal Averaging. Signal Averaging Improvement in the SNR using coherent and incoherent Averaging Data Polishing: Mean and Trend Removal.PSD Estimation. LMS based Algorithm for Adative Noise Canceling. Data Compression Techniques: AZTEC, TP, CORTES, KL TRANSFORM. Classification of EEG waves.

DEPARTMENT OF CIVIL ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
CE 601	Material Technology	3-1-0	4
CE 602	Optimization Methods &Its Application In Civil Engineering	3-1-0	4
CE 604	Finite Element Method	3-1-0	4
CE 610	Structural Dynamics and Earthquake Engineering	3-1-0	4
CE 611	Matrix Method of Structural Analysis	3-1-0	4
CE 612	Stability of Structures	3-1-0	4
CE 613	Analysis & Design of Plates & Shells	3-1-0	4
CE 614	Advanced Reinforced Concrete Design	3-1-0	4
CE 615	Applied Elasticity and Plasticity	3-1-0	4
CE 616	Advanced Steel Design	3-1-0	4
CE 617	Bridge Engineering	3-1-0	4
CE 618	Pre Stressed Concrete	3-1-0	4
CE 619	Composite Structures	3-1-0	4
CE 620	Ground Improvement Techniques	3-1-0	4
CE 621	Advanced Soil Mechanics	3-1-0	4
CE 622	Stability Analysis of Slopes, Dams and Embankments	3-1-0	4
CE 623	Soil-Structure Interaction	3-1-0	4
CE 624	Ground Water & Flow through Porous Media	3-1-0	4
CE 625	Soil Exploration and Analysis of Foundations	3-1-0	4
CE 626	Rock Mechanics	3-1-0	4
CE 627	Dynamics of Soils and Foundations	3-1-0	4
CE 628	Earth Retaining Structures	3-1-0	4
CE 629	Earthquake Geotechnical Engineering	3-1-0	4
CE 630	Advanced Wastewater Treatment	3-1-0	4
CE 631	Principles of Environmental Management	3-1-0	4
CE 632	Advanced Air Quality Management	3-1-0	4
CE 633	Water and Wastewater Engineering	3-1-0	4
CE 634	Industrial Pollution Prevention & Clean Technologies	3-1-0	4
CE 635	Environmental Impact & Risk Assessment	3-1-0	4
CE 636	Water Resources Engineering Design Practice	0-0-3	2
CE 638	Environmental Legislation & Policy	3-1-0	4
CE 640	Analysis and Structural Design of Pavements	3-1-0	4
CE 641	Transportation Systems Planning	3-1-0	4
CE 642	Traffic Engineering and Traffic Flow	3-1-0	4
CE 643	Highway and Airport Pavement Materials	3-1-0	4
CE 644	Planning & Design of Airports	3-1-0	4
CE 645	Geometric Design of Highways	3-1-0	4
CE 646	Evaluation and Strengthening of Pavements	3-1-0	4
CE 647	Transportation and Environment	3-1-0	4
CE 648	TransportationSystems, Analysis & Modelling	3-1-0	4
CE 649	Advanced Railway Engineering	3-1-0	4
CE 650	Hydrology and Hydraulics of Surface and Sub-Surface Water	3-1-0	4
CE 651	Hydrologic Element and Analysis	3-1-0	4
CE 652	Open Channel Flow	3-1-0	4
CE 653	Advanced Fluid Mechanics	3-1-0	4

CE 654	Water Resources Management	3-1-0	4
CE 655	Computational Fluid Dynamics	3-1-0	4
CE 656	Ground Water Resources Assessment and Management	3-1-0	4
CE 657	Water Quality Modeling & Management	3-1-0	4
CE 659	Water Resources Management	3-1-0	4
CE 660	High Rise Structures	3-1-0	4
CE 661	Strength & Deformation Behaviour of Soil	3-1-0	4
CE 662	Environmental Geotechnics	3-1-0	4
CE 663	Mass Transit Systems	3-1-0	4
CE 664	Advances in Remote Sensing and GIS	3-1-0	4
CE 665	Ground Water Assessment & Development	3-1-0	4
CE 668	Special Topic in Civil Engineering – I	3-1-0	4
CE 669	Special Topic in Civil Engineering – II	3-1-0	4
CE 670	Structural Engineering Design Practice	0-0-3	2
CE 671	Structural Engineering Laboratory	0-0-3	2
CE 672	Geotechnical Engineering Design Practice	0-0-3	2
CE 673	Geotechnical Engineering Laboratory	0-0-3	2
CE 675	Hydraulics and Hydrologic Engineering Laboratory	0-0-3	2
CE 676	Traffic & Transportation Engineering Design Practice	0-0-3	2
CE 677	Transportation Engineering Laboratory	0-0-3	2
CE 678	Environmental Engineering Design Practice	0-0-3	2
CE 679	Environmental Engineering Laboratory	0-0-3	2
CE 680	Computational Laboratory-II	0-0-3	2
CE 681	Computational Laboratory		
CE 682	Computer Aided Foundation Engineering Design Practice	0-0-3	2
CE 684	Computer Application in Water Resources Engineering	0-0-3	2
CE 685	Seminar & Technical Writing – I	0-0-3	2
CE 686	Seminar & Technical Writing – II	0-0-3	2
CE 687	Seminar & Technical Writing – III	3-1-0	2
CE 688	Seminar & Technical Writing – IV	0-0-3	2
CE 689	Special Laboratory in Civil Engineering – I	0-0-3	2
CE 690	Special Laboratory in Civil Engineering – II	0-0-3	2
CE 691	Summer Research/Industrial Project	0-0-3	2
CE 692	Comprehensive Viva Voce	0-0-3	2
CE 693	Research Project Work – I	0-0-6	4
CE 694	Research Project Work – II	0-0-0	4
CE 704	Remote Sensing & GIS Laboratory	0-0-3	2

CE 601 MATERIAL TECHNOLOGY 4 Credits [3-1-0]

Cement and Concrete: Portland cement: chemical composition, hydration of cement, structure of hydrated cement, mechanical strength of cement gel, water held in hydrated cement paste and heat of hydration. Cements of different types. Factors affecting the strength of concrete. Elasticity, shrinkage and creep of concrete ; Durability of concrete: Permeability of concrete. Chemical attack of concrete, air-entrained concrete and thermal properties of concrete. The mechanical test of hardened concrete .Light weight and high density concrete. Mix design. Statistical quality control; Biaxial strength of concrete, Fibre reinforced concrete ; Metals: Behaviour of common constructional metals in tension and compression. True stress-strain curve for mild steel in simple tension. Theories of failure and yield surfaces ; Fatigue properties: Nature of fatigue failure, fatigue strength for completely reversed stresses, fatigue strength with super imposed static stress and factors influencing fatigue strength ; Temperature and Creep properties: Low temperature properties ,high temperature properties, creep-stress-time-temperature relations for simple tension, mechanics of creep in tension. Structure of materials and their imperfections. Deformation of crystals and theory of dislocations.

Essential Reading:

1. A.M. Neville, J.J. Brooks,*Concrete Technology*, Low Priced Edition, Pearson Education, 2004.
2. A J Martin, *Mechanical behavior of engineering materials.*

Supplementary Reading:

1. S P Timoshenko,*Strength of materials- Part II*
2. M. S. Shetty, *Concrete technology- Theory & Practice*, S.Chand & Company New Delhi, 2005

CE 602	OPTIMIZATION METHODS AND ITS APPLICATIONS IN CIVIL ENGINEERING	4 Credits [3-1-0]

Introduction: Need for engineering optimal design, Optimum design formulation: Design variable, objective function and constraints ; Unconstrained optimization methodsSingle variable optimization methods: Region elimination method – Golden section search, Interval halving method; Gradient based method – Newton-Raphson, bisection and secant method. Multi variable optimization methods: Direct search method: Hooke-Jeeve pattern search, simplex reflection search, Powell's conjugate direction search. Gradient Based methods: Cauchy's steeped descent, Newton's method, Levenberg-Marquardt's method, Fletcher- Reeve method ; Constrained optimization methods Kuhn Tucker condition, Penalty function method, Augmented Lagrangian method, sequential unconstrained minimization, cutting plane method ; Introduction to Evolutionary algorithms: Need for evolutionary algorithms, Type of evolutionary methods, Introduction to Genetic algorithm (GA), Difference and similarities between GA and traditional methods. Basic operations of GA: reproduction, crossover, mutation and elitism. Binary coded and Real coded GA ; Application of Optimization techniques: Water resource planning management, Structural Optimization, Transportation planning and Management, Slope stability and optimal dimensioning of foundations. multi-objective optimization models.

Essential Reading:

1. J.S. Arora, *Introduction to Optimum Design*, Elsevier, 2nd Edition, 2004.
2. K. Deb, *Optimization for Engineering. Design: Algorithms & Examples*, Prentice Hall India, 2006

Supplementary Reading:

1. S.S. Rao, *Engineering Optimization: Theory & Practice,* New Age International (P) Ltd, 3rd Edition, 1996, Reprint : June, 2008
2. K. Deb,*Multi-Objective Optimization Using Evolutionary Algorithms*, John Wiley, 2003

CE 604	FINITE ELEMENT METHOD	4 Credits [3-1-0]

Basic Principles of Structural Mechanics: Equations of equilibrium, Strain displacement relations, Stress strain relations, Plane stress and Plane strain problems, Boundary Conditions. Basics of Finite Element Method: Different steps involved in finite element method(FEM), Different approaches of FEM, Direct method, Variational Principle & Weighted Residual method. Element Properties: Displacement models, Shape functions, Stiffness matrices, One dimensional bar element, two dimensional truss elements, three dimensional truss elements, two dimensional beam elements, three dimensional beam elements, analysis of framed structures using truss and beam elements, Lagrangian interpolation, Pascal's triangle, Convergence criteria. Plane Stress and Plane Strain Problems: Analysis of plates using triangular CST elements, Rectangular elements, axy-symmetric elements. Isoparametric Elements: four node, eight node elements, Numerical integration, Bending of plates by rectangular elements, triangular elements and quadrilateral elements, Concept of 3D modeling. Vibration and buckling analysis of structures using Finite element method.

Essential Reading:

1. R. D. Cook, *Concepts and Applications of Finite Element Analysis*, John Wiley& Sons, New York
2. C. S. Krishnamoorthy, *Finite Element analysis-Theory and Programming*, Tata McGraw Hill.
3. O. C. Zienkiewicz and R. L. Taylor, *The Finite Element Method*, McGraw Hill Publishing Company

Supplementary Reading:

1. J. N. Reddy, *An introduction to Finite Element Method*, Tata-Mc Graw Hill, New Delhi.
2. M. Petyt, *Introduction to finite element vibration analysis*, Cambridge University Press, UK.
3. T. R. Chandrupatla & A. D. Belegundu, *Introduction to Finite Elements in Engineering*, Prentice Hall of India Pvt. Ltd., New Delhi.

CE 610	STRUCTURAL DYNAMICS AND EARTHQUAKE ENGINEERING	4 Credits [3-1-0]

Single degree of freedom system: Equation of motion, Damped and undamped free vibration, Response to harmonic, periodic, impulse load and general dynamic load, Duhamel's integral; Multi-degrees of freedom system: Equation of motion, Free vibration analysis, Dynamic response and modal analysis; Free and Forced vibration of distributed mass system: Beam

Essential Reading:

1. R. W. Clough and J Penzien, *Dynamics of structures* , McGraw-Hill, Inc,
2. A K Chopra, *Dynamics of Structures: Theory and Applications to Earthquake Engineering*, Prentice Hall of India

Supplementary Reading:

1. M. Paz, *Structural Dynamics - Theory and Computation*, Van Nostrand, 1985.
2. *IS: 1893 - 2002 Criteria for Earthquake Resistant Design of Structures*.
3. L. Meirovitch, *Elements of Vibration Analysis*, 2nd Ed., McGraw-Hill, 1986.

CE 611	MATRIX METHOD OF STRUCTURAL ANALYSIS	4 Credits [3-1-0]

Matrix, Vector, Matrix Operations, Rank of a Matrix, Eigenvalues and Eigenvectors; Matrix Analysis of Structures, Coordinate Systems, Transformation Matrices, Stiffness Matrix, Flexibility Matrix, Stiffness and Flexibility Methods; Stiffness and Flexibility Matrices for a Truss Element, Plane Trusses, Space Trusses; Stiffness Method Applied to Beams, Flexibility Method Applied to Beams, Analysis of Grids, Stiffness and Flexibility Method Applied to Plane Frames

Essential Reading:

1. D. Menon, *Advanced Structural Analysis*, Narosa Publishing House.
2. M B Kanchi, *Matrix Methods of Structural Analysis*, New Age International.
3. G. S. Pandit and S. P. Gupta, *Structural Analysis: A Matrix Approach*, Tata McGraw-Hill.

Supplementary Reading:

1. W. Weaver Jr. and J.M Gere, *Matrix analysis of Frames and Structures,* CBS Pub and Distributors.

CE 612	STABILITY OF STRUCTURES	4 Credits [3-1-0]

Torsion of thin walled open sections, warping displacements under pure torsion,-Warping constants for rolled steel section. Strain energy in bending and torsion of members of thin walled open section including the effects of warping. Torsional buckling including the effects of Wagner's effect, flexural torsional buckling (with centroid and shear centres coincident) ; Lateral buckling of beams under pure bending central point load through centre of gravity of the section. Cantilever beams with point load at the free end, Application of Rayleigh-Ritz method ; Beam-columns on rigid supports-concentrated and continuous lateral loads with simply supported and built in-ends. Continuous beam with as axial loads. Application of trigonometric series. Inplane buckling of bars ; Approximate calculation of critical loads for bar structures by energy method- a bar on elastic foundation, a bar with intermediate compressive forces, bar under distributed axial loads, a bar with changes in cross section ; Effects of shearing force on the critical load. Buckling of built-up columns. In-elastic in-plane buckling of columns. Tangent and reduced modulus concept, Shanley's contribution, elastic critical loads for rigid frames and triangulated structures, stability functions. Bending of thin plate. Buckling of thin rectangular plates in compression, shear and bending.

Essential Reading:

1. S.P. Timoshenko and J. M. Gere, *Theory of Elastic Stability* , MC Graw Hill,
2. A. Kumar, *Stability of Structures*, Allied Publishers Ltd., New Delhi, 1998

Supplementary Reading:

1. M.R.Horns and W.Merchang, *The stability of frames*, Porgamon press, 1965.
2. M.Gregory, *Elastic Instability*, spon's Civil Engineering series, 1967.
3. F.Bleich, *Buckling strength of Metal structures*,Mc Graw Hill Book co.,1952
4. T.V Galambos, *Structural members and frames*, Prentice-Hall INC, 1968

CE 613	ANALYSIS & DESIGN OF PLATES AND SHELLS	4 Credits [3-1-0]

Pure Bending of Plates: Slope & curvature of slightly bent plates, Relations between bending moments and curvature in pure bending of plates, Strain energy in Pure bending of plates ; Symmetrical bending of Circular plates: Differential equation for symmetrical bending of laterally loaded circular plates, uniformly loaded circular plates, Circular plates with circular hole at center, circular plate concentrically loaded ; Small deflections of laterally loaded plates : Differential equation of the deflection surface, Boundary conditions, Simply supported rectangular plates under sinusoidal load, Navier solution for simply supported rectangular plates, Further applications of the Navier solution, Alternate solution for simply supported and uniformly loaded rectangular plates, Concentrated load on simply supported rectangular plates. Classification of shell structures, importance of membrane theory of shells, shells in the form of a surface of revolution and loaded un-symmetrically with respect to their axes, spherical dome, conical shells, cylindrical shells, Elliptic paraboloid, hyperbolic parabolod and conoids ; General theory of cylindrical shells : Circular cylindrical shell loaded symmetrically with respect to its axis, particular cases of symmetrical deformations of circular cylindrical shells, cylindrical tanks of uniform wall thickness.
Design of spherical domes with/without lanterns at top.

Essential Reading:

1. S. P. Timoshenko and Woinowsky-Kriegar, *Theory of plates and shells*, Mc Graw Hill International , New Delhi
2. G. S. Ramaswamy, *Design and construction of concrete shells Roofs*, CBS Publishers, Delhi

Supplementary Reading:

1. D. P. Billington, *Thin shell concrete structures*, Mc Graw Hill international, New York
2. W. T. Marshall, *Design of cylindrical shell roofs*, E& FN SPON, London

CE 614	ADVANCED REINFORCED CONCRETE DESIGN	4 Credits [3-1-0]

Estimation of crack width and deflection of reinforced concrete beams. Analysis and design of building frames subjected to wind load; Earthquake forces and structural response. Ductile detailing of RCC frames, Design of beam-column joints, Design of deep beam. Design of shear walls

Essential Reading:

1. R. Park and T. Pauley, *Reinforced concrete structures*, John Wiley and sons
2. A. K. Jain, *Reinforced Concrete: Limit State design*, NemChand and Bros. 1999.

Supplementary Reading:

1. J. Krishna and OP Jain, *Plain and Reinforced Concrete*, Vol. I I, Roorkee, Nem Chand and Bros.
2. H. Nilson, D. Darwin and C. W. Dolar, *Design of Concrete structures*, Tata McGraw Hill
3. T. Paulay and M.J.N. Priestley , *Seismic Design of Reinforced Concrete and Masonry Buildings*,John Wiley & Sons Inc

CE 615	APPLIED ELASTICITY AND PLASTICITY	4 Credits [3-1-0]

Analysis of Stress: State of stress at a point, Stress components at an arbitrary plane, Principal stresses, Stress invariants, Construction of Mohr's circle for three dimensional state of stress, Planes of maximum shear. State of pure shear, Octahedral Stresses, Plane stress problem, Differential equation of equilibrium, Equilibrium equations for plane stress problem, Boundary conditions, Equation of equilibrium in cylindrical coordinates; Analysis of Strain: State of strain at a point, Principal axes of strains and Principal strains, Plane strain problem, Plane strain in polar coordinates, Compatibility conditions, Strain deviator and its invariants; Stress-strain relations for isotropic materials: Modulus of rigidity, Bulk modulus, Young's modulus and Poisson's ratio, Relations between elastic constants, Displacement equations of equilibrium; Two Dimensional Problems in Elasticity: Stress function. Solution by polynomials, Saint-Venant's Principle, Pure bending of curved bar, Effect of circular holes on stress distribution of a plate, Concentrated force at a point of straight boundary, Force acting on the end of a Wedge, Concentrated force acting on a beam, Thick-walled cylinder subjected to internal and external pressure, Rotating disks of uniform thickness; Torsion: Torsion of general prismatic bars, Torsion of circular and elliptical bars, Torsion of equilateral triangular bars, Torsion of rectangular bars, Membrane analogy, Torsion of a thin-walled tubes, Torsion of a thin-walled multiple-cell closed section, Torsion or rolled sections, Centre of twist and flexural centre; Theories of failure, Criterion of yielding, Strain-hardening postulates, Rule of plastic flow, Total strain theory, Theorems of limit analysis, Elasto-plastic bending and torsion, Plastic analysis of beams and frames, Theory of the Slipline field, Steady and non-steady problems in plane strain.

Essential Reading:

1. S P Timoshenko and J N Goodier, *Theory of Elasticity* –McGraw Hill.
2. J. Chakrabarty, *Theory of Plasticity* – Elsevier Butterworth-Heinemann.

Supplementary Reading:

1. L S Srinath, *Advanced Mechanics of Solids* –Tata McGraw-Hill.

CE 616	ADVANCED STEEL DESIGN	4 Credits [3-1-0]

Design for tension and compression members, connections, design of plate girders, crane girders and trusses. Multi-storyed buildings. Silos, bins and hoppers. Design of steel tanks and staging. Design of bridges, trusses, lateral bracings, sway brackens and stress reversals. Design of continuous beams and frames by plastic theory; Use of reference books and relevant codes of practice are permitted in the examination.

Essential Reading:

1. K.Mukhanov, *Design of Metal structures*, University Press Of The Pacific
2. N. Subramanian, *Design of Steel structures*, Oxford University Press

Supplementary Reading:

1. P Dayaratnam, *Design of Steel Structures*, S. Chand Group
2. B Bresler, T Y Lin and J B Scalzi, *Design of Steel structures*, John Wiley & Sons

CE 617	BRIDGE ENGINEERING	4 Credits [3-1-0]

Introduction, historical review, engineering and aesthetic requirements in bridge design. Introduction to bridge codes. Economic evaluation of a bridge project. Site investigation and planning;. Scour - factors affecting and evaluation. Bridge foundations - open, pile, well and caisson.

Piers, abutments and approach structures; Superstructure - analysis and design of right, skew and curved slabs. Girder bridges - types, load distribution, design. Orthotropic plate analysis of bridge decks. Introduction to long span bridges - cantilever, arch, cable stayed and suspension bridges. Methods of construction of R.C Bridges, Prestressed concrete bridges and steel bridges Fabrication, Lounching & creation. Design and construction of construction joints (use of relevant codes of practice are permitted in the examination).

Essential Reading:

1. V. K. Raina, *Concrete Bridges Practice – Analysis, Design and Economics*, Shroff Publications, New Delhi 2nd Ed. 2005.
2. Vazirani, Ratwani and Aswani, *Design of Concrete Bridges*, Khanna Publishers, 2nd Ed. 2008.

Supplementary Reading:

1. *IRC codes for Road bridges- IRS Sec –I , II, III*
2. *IRS Codes of Practice for Railway bridges.*
3. B. M. Das, *Principles of Foundation Engineering,* Thomson, Indian Edition, 2003.

CE 618	PRE-STRESSED CONCRETE	4 Credits [3-1-0]

Different systems of prestressing, Characteristics of concrete and steel, Other suitable design of section for flexure, shear and torsion. Design of compressive member. Limit state design as per IS code. Comparision of design with respect to British, Australian and American code. Partial prestressing.Stress distribution in end-block of post tensioned section. Magnel's method, Guyen's method, Rowe's method and IS code method. Deflection of prestressed structures- short term as well as long term deflections of uncracked and cracked members.Indeterminate structures- Principles of design of prismatic continuous beams of two and three equal, unequal spans with variable moments of inertia, Cap cable, Jaeques Muller's theorem. Prestressing of rigid frames. Composite construction of prestressed and in-situ concrete ; Design of special structures- Circular tanks, Pipes, Mast, and materials, Losses in prestress. Analysis of Railway sleepers.

Essential Reading:

1. Y. Guyen, *Prestressed concrete Vol-I & Vol.-II,* John Willey & Sons, New York-1960.
2. N. Krishnaraju, *Prestressed concrete,* Tata McGraw-Hill, New Delhi-2004.

Supplementary Reading:

1. T. Y. Lin and H. Burns Ned, *Design of Prestressed concrete structures*, John Willey & Sons, New York-1982.
2. S. K. Mallik and A. P. Gupta, *Prestressed concrete,* Oxford & IBH, New Delhi-1982.
3. E. W. Bennet, *Prestressed concrete theory & design,* Chapman & Hall, London-1962.

CE 619	COMPOSITE STRUCTURES	4 Credits [3-1-0]

Introduction: definition, Classification and characteristics of Composite materials, advantages and limitations, Current Status and Future Prospects ; Basic Concepts and characteristics: Homogeneity and Heterogeneity, Isotropy, Orthotropy and Anisotropy; Characteristics and configurations of lamina, laminate, micromechanics and macromechanics. Constituent materials and properties ; Elastic behavior of unidirectional lamina: Anisotropic, separately orthotropic and transversely isotropic materials, stress-strain relations for thin lamina, transformation of stress and strain, transformation of elastic parameters ; Strength of unidirectional lamina: Macromechanical failure theories- Maximum stress theory, maximum strain theory, Deviatoric strain energy theory (Tsai-Hill), Interactive tensor polynomial theory (Tsai-Wu) ; Elastic Behavior of multidirectional laminates: Basic assumptions, Stress-strain relations, load deformation relations, symmetric and balanced laminates, laminate engineering properties ; Bending and vibration of laminated plates: Governing equations, Deflection of simply supported rectangular symmetric angle-ply, specially orthotropic, anti-symmetric cross-ply laminates ; Recent advances: Functionally graded materials, Smart materials.

Essential Reading:

1. R.M. Jones, *Mechanics of Composite materials*, Taylor and Francis, 1999.
2. I. M. Daniel and O. Ishai, *Engineering mechanics of Composite materials*, Oxford university press, 1999

Supplementary Reading:

1. P.K. Mallick, *Fiber-reinforced Composites*, Marcel Dekker Inc, 1988.
2. D. Hull and T. W. Clyne, *An introduction to composite materials*, Cambridge university press, Second Edition, 1996.
3. J.N. Reddy, *Mechanics of laminated composite plates and shells-Theory and Analysis*, CRC Press, Boca Raton, Second Edition, 2003.

CE 620	GROUND IMPROVEMENT TECHNIQUES	4 Credits [3-1-0]

Introduction: Engineering properties of soft, week and compressible deposits, Natural on land, off-shore and Man-made deposits. Role of ground improvement in foundation engineering, methods of ground improvement, Selection of suitable ground improvement techniques ; In-situ treatments methods: In-situ densification soils, Dynamic compaction and consolidation, Vibrofloation ,Sand pile compaction, Preloading with sand drains and fabric drains, Granular columns, Micro piles, Soil nailing, Ground Anchors, Lime piles, Injections, Thermal, Electrical and Chemical methods, Electro osmosis, Soil freezing ; Reinforced Soil: The Mechanism, Reinforcement materials, Reinforcement - Soil Interactions, Geosynthetics, Principles, Analysis and Design of Reinforced Retaining Structures, Embankments and Slopes ; Ground Improvement Techniques for Geotechnical Earthquake Engineering, Case studies on ground improvement techniques.

Essential Reading:

1. R. M. Korner, *Design with Geosynthetics*, Prentice Hall, New Jersy, 3rd Edn. 2002
2. P. Purushothama Raj, *Ground Improvement Techniques*, Tata McGrawHill, New Delhi, 1995.

Supplementary Reading:

1. B. M. Das, *Principles of Foundation Engineering,* Thomson, Indian Edition, 2003.
2. G. V. Rao and G. V. S. Rao, *Text Book On Engineering with Geotextiles*, Tata McGraw Hill
3. T. S. Ingold and K. S. Miller, *Geotextile Hand Book*, Thomas Telfrod, London
4. N. V. Nayak, *Foundation Design Manual*, Dhanpat Rai and Sons, Delhi.

CE 621	ADVANCED SOIL MECHANICS	4 Credits [3-1-0]

Introduction: Origin of soil and its types, mineralogy and structure of clay minerals, X-ray and Differential Thermal Analysis; structure of coarse grained soil, behavior of granular and cohesive soils with respect to their water content ; Consolidation: Steady State flow, 2D and 3D seepage, transient flow; Compressibility and rate of consolidation, one, two, and three dimensional consolidation theories; Sand drains ; Critical state soil mechanics: Critical State Line, Hvorslev Surface, Yield Surfaces: Modified Cam-clay and Original Cam-clay ; Elastic and plastic analysis of soil:-Constitutive relationships of soil; failure theories. Limit analysis-Upper bound theorems, lower bound theorems, limit equilibrium methods ; Soil Stabilization: Classification of stabilizing agents and stabilization processes. Nature and surface characteristics of soil particles. Concepts of surface area and contact points. Inorganic stabilizing agents. Strength improvement characteristic of soft and sensitive clay, Marine clay and waste material.

Essential Reading:

1. B M Das, *Advanced Soil Mechanics*, Taylor and Francis
2. R F Scott, *Principles of Soil Mechanics*, Addison & Wesley.

Supplementary Reading:

1. R.O. Davis and A.P.S. Selvadurai, *Elasticity and Geomechanics*, Cambridge University Press, New York.
2. Mitchell, James K, *Fundamentals of Soil Behaviour*, John Wiley and Sons
3. D.M. Wood, *Soil Behaviour and Critical State Soil Mechanics,* University of Glasgow

CE 622	STABILITY ANALYSIS OF SLOPES, EMBANKMENTS AND DAMS	4 Credits [3-1-0]

Landslide phenomenon: Types and causes of slope failures, Practical applications ; Stability analysis of infinite slopes with or without water pressures ; Stability analysis of finite and Infinite slopes: concept of factor of safety, pore pressure coefficients, Mass analysis, Wedge methods, friction circle method ; Method of slices, Bishop's method, Janbu's method ; Effect of seepage, submerged and sudden draw down conditions ; Design of slopes in cutting, Embankments and Earth dams ; Site Investigation: Reconnaissance, Preliminary and detailed investigation, Investigation for foundations ; Advances in stability analysis of slopes

Essential Reading:
1. L. W Abramson, T. S Lee, S Sharma and G M Boyce, *Slope Stability and Stabilization Methods*, Willey Interscience publications
2. B M Das, *Principles of Geotechnical Engineering*, Thomson Brooks/Cole

Supplementary Reading:
1. T W. Lambe and R V Whitman, *Soil Mechanics*, John Wiley & sons
2. V N S Murthy, *Principles of Soil Mechanics and Foundation Engineering*, UBS Publishers Private Ltd.

CE 623	SOIL-STRUCTURE INTERACTION	4 Credits [3-1-0]

Soil-Foundation Interaction: Introduction to soil-foundation interaction problems, Soil behaviour, Foundation behaviour, Interface behaviour, Scope of soil foundation interaction analysis, soil response models, Winkler, Elastic continuum, Two parameter elastic models, Elastic plastic behaviour, Time dependent behavior ; Beam on Elastic Foundation- Soil Models: Infinite beam, Two parameters, Isotropic elastic half space, Analysis of beams of finite length, Classification of finite beams in relation to their stiffness. Plate on Elastic Medium: Thin and thick plates, Analysis of finite plates, Numerical analysis of finite plates, simple solutions ; Elastic Analysis of Pile: Elastic analysis of single pile, Theoretical solutions for settlement and load distributions, Analysis of pile group, Interaction analysis, Load distribution in groups with rigid cap ; Laterally Loaded Pile: Load deflection prediction for laterally loaded piles, Subgrade reaction and elastic analysis, Interaction analysis, Pile-raft system, Solutions through influence charts.

Essential Reading:
1. N.P. Kurien, *Design of Foundation Sytems : Principles& Practices*, Narosa, New Delhi 1992,
2. E.S. Melerski, *Design Analysis of Beams, Circular Plates and Cylindrical Tanks on Elastic Foundation*, Taylor and Francis, 2006.

Supplementary Reading:
1. L.C. Reese, *Single piles and pile groups under lateral loading*, Taylor & Francis, 2000
2. G. Jones, *Analysis of Beams on Elastic foundation*, Thomas Telford, 1997.

CE 624	GROUND WATER AND FLOW THROUGH POROUS MEDIA	4 Credits [3-1-0]

Soil Water: Modes of occurrence of water in soils. Adsorbed water, capillary water, Capillary potential, Capillary tension and soil suction. Effective and Neutral pressures in soil ; Flow through porous Media: Darcy's law and measurement of permeability in laboratory and field. Steady State flow solutions of LaPlace's equation, Plane problems, 3-dimensional problems, Partial cut-offs, uplift pressure, consolidation theory –one and three dimensional consolidation .Secondary consolidation ; Ground water Hydraulics: Water table in regular materials, Geophysical exploration for locating water table. Confined water, Equilibrium conditions, Non-equilibrium conditions, Water withdrawal from streams, Method of ground water imageing.

Essential Reading:

1. D.K.Todd, *Groundwater Hydrology*, John wiley and Sons
2. H.M. Raghunath, *Ground Water*, Willy Eastern Ltd.

Supplementary Reading:

1. C. Fitts, *Ground Water Science*, Elsevier Publications, U. S. A.
2. P. P. Raj, *Geotechnical Engineering*, Tata McGraw-Hill
3. A. Jumikis, *Soil Mechanics*, East West Press Pvt Ltd.

CE 625	SOIL EXPLORATION AND ANALYSIS OF FOUNDATIONS	4 Credits [3-1-0]

Introduction: Planning of Geotechnical exploration, methods of boring, types of samples & sampling, field tests, Geophysical exploration ; standard penetration test, plate load test, cyclic plate load test, static and dynamic cone penetration test, pressure meter tests, dilatometer tests, in-situ permeability tests ; Presentation and processing of soil exploration data and its interpretation ; Shallow foundations: Bearing capacity of foundation based on in-situ tests. Bearing capacity for foundation on slope, mat foundations including floating raft, settlement calculations for footings on cohesive and cohesionless soil based on in-situ tests. Deep foundations: mechanics of load transfer in piles, load carrying capacity, pile load test, design of pile groups including settlement calculations; well foundation- Design of well foundation based on bore log data ; Advanced topics on in-situ soil testing

Essential Reading:

1. B. M Das, *Principles of Foundation Engineering*, Thomson Brooks/Cole
2. J. E. Bowles, *Foundation Analysis and Design*, McGraw-Hill Book Company

Supplementary Reading:

1. N.P. Kurien, *Design of Foundation Systems : Principles& Practices*, Narosa, New Delhi 1992
2. G.Ranjan and A S R Rao, *Basic and Applied Soil Mechanics*, New Age international Publishers.
3. H. F. Winterkorn and H Y Fang, *Foundation Engineering Hand Book*, Galgotia Booksource

CE 626	ROCK MECHANICS	4 Credits [3-1-0]

Rock:Formation of rocks, Physical properties, Classification of rocks and rock masses**,** Static Elastic constants of rock ; Rock Testing: Laboratory and Field tests ; Discontinuities in Rock Masses: Discontinuity orientation,Effect of discontinuities on strength of rock ; Strength Behaviour: Compression, Tension and Shear, Stress-Strain relationships, Rheological behavior ; Strength/ Failure Criterion: Coulomb, Mohr, Griffith theory of brittle strength and other strength criteria. Stresses in rock near underground openings ; Application of rock mechanics in Civil Engineering: Rock tunneling, rock slope stability, bolting, blasting, grouting and rock foundation design.

Essential Reading:

1. W. Farmer, *Engineering Behavior of Rocks*, Chapman and Hall Ltd.
2. R. E. Goodman, *Introduction to Rock Mechanics*
3. P.R. Sheorey, *Empirical Rock Failure Criteria*, Balkema, Rotterdam, 1997

Supplementary Reading:

1. V.S. Vutukuri and R D Lama, *Hand Book on Mechanical Properties of Rocks*
2. B.P Verma, *Rock Mechanics for Engineers*

CE 627	DYNAMICS OF SOILS AND FOUNDATIONS	4 Credits [3-1-0]

Vibration of elementary systems, Analysis of systems with Single degree and multi-degree of freedom. Natural frequencies of continuous systems ; Elastic Constants of soil and their experimental determination. Effect of vibration on soil properties ; Bearing capacity of dynamically loaded foundations ; Principles of Machine foundation design, Experimental and analytical determination of design parameters ; Design of foundations for turbines, vertical and horizontal reciprocating engines, forge hammers, Effect of machine foundation on adjoining structures, vibration isolation.

Essential Reading:

1. S. Saran, *Soil Dynamics and Machine Foundations*, Galgotia Publications Private Ltd.1999
2. N. S. V. Kameswara Rao, *Vibration Analysis and Foundation Dynamics*, Wiley New Delhi, 1998

Supplementary Reading:

1. B M Das, *Principles of Soil Dynamics*, Thomsons Engineering, 1992
2. K.G. Bhatia, *Foundations For Industrial Machines*, D-CAD Publishers , 2008
3. A Major, *Vibration Analysis and Design of Foundations for Machines and Turbines: Dynamical Problems in Civil Engineering*, Akademiai Kiado Budapest Collets Holding Ltd., 1962

CE 628	EARTH RETAINING STRUCTURES	4 Credits [3-1-0]

Earth Pressure: Fundamental relationships between the lateral pressures and the strain with a back fill. Rankine and Coulomb theories, Active, passive and pressure at rest ; Backfill with broken surface, wall with broken back, concentrated surcharge above the back fill, earth pressure due to uniform surcharge, earth pressure of stratified backfills, saturated and partially saturated backfill. Passive earth pressure in engineering practice. Assumption and conditions, point of application of passive earth pressures ; Bulkheads: Definition and assumptions, conditions of end supports and distribution of active earth pressure and bulkheads, bulkheads with free and fixed earth supports, equivalent beam method, Improvements suggested by Rowe, Tschebotarioff's method, Anchorage of bulkheads and resistance of anchor walls, spacing between bulkheads and anchor walls, resistance of anchor plates, Consideration of effects of ground water, seepage, surcharge loading together with possibility of shallow and deep sliding failures on retaining structure ; Sheet Pile wall: Free earth system, fixed earth system, Dead man ; Tunnel and Conduit: Stress distribution around tunnels, Types of conduits, Load on projecting conduits ; Arching and Open Cuts: Arching in soils, Braced excavations, Earth pressure against bracings in cuts, Heave of the bottom of cut in soft clays ; Reinforced earth retaining structures- Design of earth embankments and slopes ; Recent advances in Earth retaining structures.

Essential Reading:

1. B. M. Das, *Principles of Foundation Engineering,* Thomson, Indian Edition, 2003.
2. J. Bowel, *Foundation Engineering* , Analysis and Design. McGrwHill

Supplementary Reading:

1. P. Raj, *Geotechnical Engineering*, Tata McGraw Hill
2. R F Craig, *Soil Mechanics,* Chapman and Hall(ELBS)

CE 629	EARTHQUAKE GEOTECHNICAL ENGINEERING	4 Credits [3-1-0]

Earthquakes: Causes and characteristics (magnitude, intensity, accelarograms), response spectra, attenuation of ground motion. Estimation of seismic hazards (deterministic and probabilistic); Introduction to vibratory motion:Waves in Elastic Medium**;** Dynamics of Discrete: Systems , Vibration of single and multiple degree of freedom systems. Free and forced vibrations (regular and irregular excitation) ; Dynamic properties of soils: Determination of site characteristics, local geology and soil condition, site investigation and soil test, Laboratory and in-situ tests; Site response to earthquake. Seismic Microzonation ; Liquefaction of soils: Fundamental concept of liquefaction, assessment of liquefaction susceptibly from SPT and CPT ; Seismic response of soil structure system, seismic bearing capacity of shallow foundation, design of pile foundation in liquefiable ground.

Pseudo-static analysis and design of earth retaining structures and soil slopes. Estimation of earthquake-induced deformation.

Essential Reading:

1. S.L. Kramer, *Geotechnical Earthquake Engineering*, Pentice Hall, international series, Pearson Education (Singapore) Pvt. Ltd., 2004.
2. S.Saran, *Soil Dynamics and Machine Foundation*, Galgotia publications Pvt. Ltd., New Delhi 1999.

Supplementary Reading:

1. A. Ansal, *Recent Advances in Earthquake Geotechnical Engineering and Microzonation*, Springer, 2006.
2. I. Towhata, *Geotechnical Earthquake Engineering*, Springer, 2008.

CE 630	ADVANCED WASTE WATER TREATMENT	4 Credits [3-1-0]

Microbiological concepts; cells, classification and characteristics of living organisms, charaterisation techniques, reproduction, metabolism, microbial growth kinetics and kinetics of biochemical operations; Modelling of suspended growth systems, techniques for evaluation of kinetic and stoichiometric parameters. Optimal selection of water and waste water treatment chain, Engineered systems, concepts and principles of carbon oxidation, nitrification, denitrification, methanogenasis. Biological nutrient removal ; Anaerobic treatment (process options, components of anaerobic reactions that influence process design); Attached growth reactors (process description, design and applications). Decentralised wastewater treatment systems; Low cost options, constructed wetlands. Reliability and cost effectiveness of wastewater systems.

Essential Reading:

1. M. J. Hammer, *Water and Wastewater Technology*, Prentice Hall, 6th edition, 2007.
2. G. Tchobanoglous, L. Franklin, Burton, H. D. Stensel, Metcalf & Eddy Inc., *Wastewater Engineering: Treatment and Reuse*, McGraw-Hill Higher Education; 4th edition, 2002.

Supplementary Reading:

1. G. M. Fair, J. C. Geyer, D. A. Okun, *Elements of Water Supply and Wastewater Disposal*, John Wiley and Sons Inc.,
2. J. McGhee, *Water Supply and Sewerage*, Terence, McGraw Hill Book Co..

CE 631	PRINCIPLES OF ENVIRONMENTAL MANAGEMENT	4 Credits [3-1-0]

Environmental regulations and policies; Environmental protection laws and acts; Corporate and international charters and protocols; Environment Risk assessment; Industrial ecology, Pollution prevention and Waste minimization; Sustainable development. Life cycle assessment; Environmental auditing; Eco-labelling of products; Performance indicators. Environmental management systems particularly IS 14000 series. Successful Case Studies.

Essential Reading:

1. R.Welford, *Corporate Environmental Management*, Earthscan Publications Limited, London, 2002.
2. D. Sayre, *Inside ISO 14000 : Competitive Advantage of Environmental Management*, St. Louis Press, Florida, 2000.

Supplementary Reading:

1. T.E. Graedel, and B.R.Allenby, *Industrial Ecology*, Englewood Cliffs: Prentice Hall, New Jersey, 1995.
2. A. Rosencranz, S. Divan and M.L. Noble, *Environmental Law and Policy in India : Cases, Materials and Statutes*, Tripathi Pvt. Ltd, Bombay, 1992.

CE 632 ADVANCED AIR QUALITY MANAGEMENT 4 Credits [3-1-0]

Air pollutants, Sources, Classifications, Effects, Atmospheric diffusion of pollutants and their analysis, Transport, transformation and deposition of air contaminants on a global scale, Air sampling and pollution measurement methods, principles and instruments; Particulate Pollutant Control: Settling chambers; Filtration; Impaction; Convective diffusion; Collection of particles; Electrostatic precipitation; Electrical migration velocity; Cyclones; Wet collectors; Efficiency and dimensions of particle control devices ; Aerosol Dynamics : Discrete and continuous aerosol size distributions; Thermodynamics of atmospheric aerosols; Homogeneous and heterogeneous nucleation; Coagulation and coagulation kernels; Condensation/evaporation, saturation vapour pressure corrections; Sedimentation and dry deposition; Chemical equilibria; Heterogeneous reactions in aerosol- and aqueous-phase; Aerosol-cloud interactions. Aerosols and Global Climate: Trends in anthropogenic emissions and troposphere composition; Solar and terrestrial radiation; Radiation scattering by aerosols and clouds ; Gaseous Pollutant Control: Gas absorption in tray and packed towers; Stage efficiency; Liquid/gas rates; Equilibrium number of stages/packed height; Absorption with/without chemical reaction; Removal of SO2; Adsorption in fixed beds; Breakthrough; Wet scrubbers. Integrated air pollution control systems; Effect of process parameters on performance of control systems.

Essential Reading:

1. S.K. Friedlander, *Smoke, Dust and Haze: Fundamentals of Aerosol Dynamics*, Oxford University Press, New York, 2000.
2. Noel de Nevers, *Air Pollution Control Engg.*, McGraw-Hill Inc, 2000.

Supplementary Reading:

1. M.Z. Jacobson, *Fundamentals of Atmospheric Modelling*, Cambridge University Press, New York, 1999.
2. J.H.Seinfeld, and S.N.Pandis, *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, Wiley-Interscience, New York, 1998.
3. K.Willeke and P.A. Baron, *Aerosol Measurement: Principles, Techniques and Applications*, van Nostrand-Reinhold, New York, 1993.
4. C. S. Rao, *Environmental Pollution Control Engg*, Wiley Eastern Ltd, 1995.

CE 633 WATER AND WASTE WATER ENGINEERING 4 Credits [3-1-0]

Water Quality, Physical, chemical and biological parameters of water, Water Quality requirement. Potable water standards, In-stream standards, Wastewater Effluent standards. Water quality indices. Water purification systems in natural systems ; physical processes, chemical processes and biological processes. Primary, Secondary and tertiary treatment. Unit operations, unit processes. Aeration and gas transfer Sedimentation, different types of settling, sedimentation tank design Coagulation and flocculation, coagulation processes, stability of colloids, destabilization of colloids, destabilization in water and wastewater treatment, transport of colloidal particles. Filtration: filtration processes, Hydraulics of flow through porous media, Rate control patterns and methods, Filter effluent quality parameters,

Mathematical model for deep granular filters, slow sand filtration, rapid sand filtration, precoat filtration Adsorption, adsorption equilibria and adsorption isotherm, rates of adsorption, Sorption kinetics in batch reactors, continuous reactors, factors affecting adsorption Ion Exchange-processes, materials and reactions, methods of operation, Application Membrane Processes, Reverse osmosis, Ultrafiltration, Electrodyalisis, Disinfection Water and Wastewater Treatment Processes.

Essential Reading:

1. G.Tchobanoglous, *Wastewater Engineering: Treatment and Reuse*, Tata-McGraw-Hill Science/Engineering, 2002.
2. MWH, *Water Treatment: Principles and Design*, Wiley, 2005.

Supplementary Reading:

1. *Manual on Sewerage and Sewage Treatment*, 2nd Edition, Ministry of Urban Development, New Delhi, 1993.
2. *Manual on Water Supply and Treatment*, 3rd Edition, Ministry of Urban Development, New Delhi, 1991.
3. T.M.Walski, J. Gessler, and J.W.Sjostorm, *Water Distribution Systems: Simulation and Sizing*, Lewis Publisher, Michigan, 1990.
4. H. S.Peavy, D. R.Rowe and G. Tchobanoglous, *Environmental Engineering*, McGraw Hill Book Company, Singapore, 1985.
5. L.D. Benefield, J.F. Judkins, and A.D. Parr, *Treatment Plant Hydraulics for Environmental Engineers*, Prentice-Hall Inc, New Jersey, 1984.

CE 634	INDUSTRIAL POLLUTION PREVENTION AND CLEAN TECHNOLOGIES	4 Credits [3-1-0]

Principles and techniques for industrial pollution prevention and waste minimization; Nature and characteristics of industrial wastes; Prevention versus control of industrial pollution; Source reduction tools and techniques: raw material substitution, toxic use reduction and elimination, process modification and procedural changes; Recycling and reuse; Opportunities and barriers to cleaner technologies; Pollution prevention economics ; Waste audits, emission inventories and waste management hierarchy for process industries; Material balance approach; Material and process mapping approach; Emission sources; Estimation of fugitive emissions; Environmental impact of VOCs; Energy and resource (material and water) audits for efficient usage and conservation. Unit operations in separation technology; Pollution prevention for unit operations: Boilers and Heat Exchangers; Storage tanks; Distillation columns; Application of separation technologies for pollution prevention; Process optimization for cleaner industrial processes: Flow sheet analysis: qualitative and quantitative approaches using mass exchange networks ; Thermodynamic constraints to waste minimization;Holistic and critical technology assessment; Environmental performance indicators; Concept of industrial ecology and symbiosis of eco-parks. Case studies on industrial applications of cleaner technologies in chemical, metallurgical, pulp and paper, textile, electroplating, leather, dairy, cement and other industries.

Essential Reading:

1. P.E. Bishop, *Pollution Prevention: Fundamentals and Practice*, McGraw Hill, 2000.
2. H. M. Freeman, *Industrial Pollution Prevention Handbook*, McGraw Hill, 1995.

Supplementary Reading:

1. D.T.Allen and K.S.Rosselot, *Pollution Prevention for Chemical Processes*, John Wiley, 1997.
2. D.T.Allen, N. Bakshani and K.S.Rosselot, *Pollution Prevention: Homework and Design Problems for Engineering Curricula*, American Institute for Pollution Prevention. Johansson, A., Clean Technology, Lewis Publishers, 1992.
3. L. Theodore and Y. C.McGuinn, *Pollution prevention*, Van Nostrand Reinhold, New York, 1992.

CE 635	ENVIRONMENTAL IMPACT AND RISK ASSESSMENT	4 Credits [3-1-0]

Evolution of EIA; EIA at project; Regional and policy levels; Strategic EIA; EIA process; Screening and scoping criteria; Rapid and comprehensive EIA; Specialised areas like environmental health impact assessment; Environmental risk analysis; Economic valuation methods; Cost-benefit analysis; Expert system and GIS applications; Uncertainties. Legislative and environmental clearance procedures in India and other countries, Siting criteria; CRZ; Public participation; Resettlement and rehabilitation. Practical applications of EIA; EIA methodologies; Baseline data collection; Prediction and assessment of impacts on physical, biological and socio-economic environment; Environmental management plan; Post project monitoring, EIA report and EIS; Review process. Case studies on project, regional and sectoral EIA. Risk assessment fundamentals and methodology, case studies.

Essential reading:

1. A.Chadwick, *Introduction to Environmental Impact Assessment*, Taylor & Francis, 2007.
2. Larry, W. Canter, *Environmental Impact Assessment*, McGraw Hill Inc. Singapore, 1996.

Supplementary Reading:

1. R.Therirvel, E. Wilson, S. Hompson, D. Heaney, D.Pritchard, *Strategic Environmental Assessment Earthscan*, London, 1992.
2. A.Gilpin, *Environmental Impact Assessment-Cutting edge for the 21st century*, CUP, London, 1994.
3. Paul, A Erickson, *A Practical Guide to Environmental Impact Assessment,* Academic Press, 1994.

CE 638	ENVIRONMENTAL LEGISLATION AND POLICY	4 Credits [3-1-0]

Models of environmental management; Incentives; Context; Theories of corporate strategy and environmental policy; Environmental guidelines and charters; Auditing, Monitoring; Reporting, economics and accounting; Local economic development and environmental management; Role of government; National and International trends, changes in global perspective, International treaties. Legal provisions for environmental protection; various Acts, Rules and Regulations. Notifications issued under various Acts and Rules. Environmental standards, Criteria for standard setting. Public Liability Insurance Act and Acts relating to hazardous and toxic substances. Law and policies beyond environmentalism; Sustainability issues; Role of government and non-government organizations and citizens.

Essential Reading:

1. P.Portney and R.N. Stavins, *Public Policies for Environmental Protection*, RFF Press2000.
2. N.J. Vig and M.E. Kraft, *Environmental Policy: New Directions For the Twenty-First Century*, CQ Press, 2005
3. *EP Act*, Ministry of Environment & Forests, Govt of India. 2004.

Supplementary Reading:

1. P. Hawken, *Ecology and Commerce*, Harper Business, New York, 1993.
2. R. Welford, *Corporate Environmental Management*, Earthscan Publications Ltd., London, 1988.

CE 640	ANALYSIS AND STRUCTURAL DESIGN OF PAVEMENTS	4 Credits [3-1-0]

Theories of pavement design, Factors affecting pavement design; Methods of flexible pavement design- applications of CBR, Burmister, Asphalt Institute, AASHTO and IRC methods; Load and temperature stresses in rigid pavements- Westergaard's, Bradburry's and Picket's concepts; Design of rigid pavements by PCA, AASHTO and IRC methods; Design of joints in rigid pavements; Evaluation of pavement distress; Design aspects of flexible and rigid overlays.

Essential Reading:

1. Yoder and Witzack, *Principles of Pavement Design*, John Willey and Sons, October 1975
2. Yang H. Huang*, Pavement Analysis and Design*, PH,2nd Edition, 2004

Supplementary Reading:

1. *Relevant IRC, ASTM, AASHTO and other Codes*, Manuals and Specifications
2. D. Croney & P. Croney, *The Design and Performance of Road Pavements*, Mc Graw Hill Professional, 3rd Edition. 1998
3. Richard J Salter,*Highway design and construction*, Palgrave Macmillan,1988

CE 641 TRANSPORTATION SYSTEMS PLANNING 4 credits [3-1-0]

Brief Description of urban and regional transportation systems, Definition of a system ; System analysis: scope and limitations, Transportation planning based upon system analysis, Survey and analysis of existing conditions, Models for trip generation, trip distribution, traffic assignment and modal split ; Analysis of future conditions, Plan synthesis and evaluation.

Essential Reading:

1. L.R. Kadiyalli, *Traffic Engineering and Transport Planning*, Khanna Publishers, 7th edition, 2008
2. C. S. Papacostas, P. D. Prevedouros, *Transportation Engineering and Planning*,PHI Publication, 3rd edition , 2002.

Supplementary Reading:

1. M.J. Bruton*, Introduction to Transportation Planning (Built Environment)*, Routledge, 1992.
2. J.D. Fricker and R. K. Whitford, *Fundamentals of Transportation Engineering*: *A Multimodal System Approach*, *Pearson Education*, PH, 2005
3. Ortuzar & Willumsen, *Modeling Transport*, John Wiley, 1990

CE 642 TRAFFIC ENGINEERING AND TRAFFIC FLOW 4 credits [3-1-0]

Traffic surveys: Speed, volume, delay, origin and destination, parking ; Traffic controls: Traffic signs, signals, road marking and other traffic control aids ; Traffic safety: Accidents, causes and prevention ; Traffic flow theory: Light hill and Witham's theory, the queuing theory and its application to traffic engineering problems, car flow theory ; Simulations of traffic: scanning technique

Essential Reading:

1. L.R. Kadiyalli, *Traffic Engineering and Transport Planning*, Khanna Publishers, 7th edition, 2008.
2. C.A.O'Flaherty, *Transport Planning and Traffic Engineering*, Arnold, 1997

Supplementary Reading:

1. R. P. Roess, E. S. Prassas, &W.R. Mc Shane, *Traffic Engineering*, Prentice Hall, 3rd Edition, 2004
2. May, *Traffic Flow Fundamentals*, Prentice Hall, 1989
3. F. L. Mannering,*Principles of Highway Engineering and Traffic Analysis*, 4th Edition, 2008, John Wiley.

CE 643 HIGHWAY AND AIRPORT PAVEMENT MATERIALS 4 credits [3-1-0]

Soil in subgrade, subbase and unstabilised base: Basic engineering properties; Soil stabilization: different methods; Use of geosynthetics ; Conventional aggregates used in paving and their evaluation ; Bituminous binders: Properties, testing and applications; Superpave concept ; Bituminous mixes: Design, testing and evaluation; Superpave method ; Material Characterisation of bituminous binders and bituminous mixes. ; Materials for cement concrete and semi-rigid pavements, Design of mixes for stabilized roads; Non-conventional and new pavement materials-their application and limitations.

Essential Reading:

1. Atkins & Harold**,** *Highway Materials, Soils, and Concretes*, Prentice Hall – Pearson, 4th Ed**.,** 2003
2. Y. Richard Kim, *Modeling of Asphalt Concrete*, 2008, McGraw Hill Professional.

Supplementary Reading:

1. *Relevant IRC, ASTM, AASHTO and other Codes*, Manuals and Specifications
2. P.G. Lavin, *Asphalt Pavements*, Taylor and Francis, 1st Ed. 2007

CE 644 PLANNING AND DESIGN OF AIRPORTS 4 credits [3-1-0]

Classification of airports- ICAO standards ; Planning for airport- Airport components- Zoning laws ; Runways- orientation and geometric design- Runway patterns ; Taxiways- alignment- geometry and turning radius- exit taxiways ; Aprons- planning and design ; Design principles of critical, semi-critical, non-critical airport pavements- FAA and PCA methods ; Airport hangars- their planning and design criteria ; Airport landscaping, grading and drainage- general aspects ; Airport terminal and amenities ; Airport lighting and marking.

Essential Reading:

1. N.J. Ashford, P.H. Wright,*Airport Engineering*, 3rd Edition, 1992, John Wiley
2. R.M. Horonjeff, F.X. Mc Kelvey, W.J Sproule, *Seth Young, Planning and Design of Airports*, *TMH International Publishers*, Fifth Edition, 2009

Supplementary Reading:

1. Khanna, Arora and Jain, *Planning and Design of Airports*, Nemchand Bros., 2001
2. Wells, Alexander; Young, Seth, *Airport Planning & Management*, McGraw Hill,5th Edition, July,2009
3. De N. Richard, & Odoni, *Airport Systems: Planning, Design, and Management*, McGraw Hill Amedeo, 1st Edition, 2004.

CE 645 GEOMETRIC DESIGN OF HIGHWAYS 4 credits [3-1-0]

Highway capacities and speeds on rural and urban roads, Special aspects of horizontal and vertical alignments, Interrelationships between geometric elements in rural and urban roads, Variations in geometric standards between plains and hilly regions, Special curves, Design aspects of intersections and grade separations, Traffic rotaries, Flyovers and cloverleaf junctions.

Essential Reading:

1. C. S. Papacostas, P. D. Prevedouros, *Transportation Engineering and Planning*,PHI Publication, 3rd edition , 2002
2. L.R. Kadiyalli, *Traffic Engineering and Transport Planning*, Khanna Publishers, 7th edition, 2008.

Supplementary Reading:

1. P.H. Wright, K.K. Dixon, *Highway Engineering*, John Willey, 2004
2. C.J. Khisty and B. Lall, *Transportation Engineering*, PHI Publication, 3 ed., 2006 Relevant IRC and other Codes and specifications
3. J.G. Schoon, *Geometric Design Projects for Highways: An Introduction, American Society of Civil Engineers* (ASCE Press), 2nd Edition, 2002

CE 646 EVALUATION AND STRENGTHENING OF PAVEMENTS 4 credits [3-1-0]

Factors affecting pavement performance; Failure and distresses: their nature; Evaluation Techniques for monitoring the nature and magnitude of distress in flexible and rigid pavements- devices adopted; Measurement of profile: tolerance standards in quality control- waves and deformations; Measurements: rebound deflection- roughness index- effect of traffic, fuel, chemicals and environmental conditions; Assessing structural strength of highway and airport pavements; Serviceability, structural number and energy concepts: need for conditioning and strengthening; Overlays: their types- general construction features, Design of overlays over existing flexible and rigid Pavements: IRC, AASHTO and other methods- their comparison

Essential Reading:

1. Yoder and Witzack, *Principles of Pavement Design*, John Willey and Sons.,1975
2. Yang H. Huang*, Pavement Analysis and Design*, PH,2nd Edition, 2004

Supplementary Reading:

1. *Relevant IRC and other Codes and Specifications.*

2. D. Croney & P. Croney, *The Design and Performance of Road Pavements*, McGraw Hill Professional, 3rd Edition, 1998.
3. Yang, *Design of Functional Pavement*, Mc. Graw Hill,1972

CE 647	TRANSPORTATION AND ENVIRONMENT	4 credits [3-1-0]

The Road Environment**:** human factors in road user behavior, vehicle characteristics, driver, road and environment. Environmental Factors**:** impacts and mitigation measures of air quality, noise, severance, visual intrusion, impact on water quality, use of limited resources, impact on flora & fauna, vibration, dust ; Transport related pollution; Technology Vision-2020; Urban and non-urban traffic noise sources, Noise pollution; Energy related aspects of different transport technologies. Traffic calming, Measures, Road transport related air pollution, sources of air pollution, effects of weather conditions, Vehicular emission parameters, pollution standards, measurement and analysis of vehicular emission; Imitative measures; EIA requirements of Highways projects, Procedure; MOEF World Bank/EC/UK guidelines ; EIA practices in India.

Essential Reading:

1. K. Wark, C.F. Warner, & W.T. Davis, *Air Pollution: Its Origin and Control*, Prentice Hall. 3rd Ed. 1997.
2. R.W. Boubel, *Fundamentals of Air Pollution*, Academic Press, 4th Ed. 2007.

Supplementary Reading:

1. D. Vallero, *Fundamentals of Air Pollution*, Academic Press, 4th Ed. 2007.
2. L. Canter, *Environmental Impact Assessment*, McGraw-Hill International, 2nd Ed. 1995.

CE 648	TRANSPORTATION SYSTEMS, ANALYSIS AND MODELLING	4 credits [3-1-0]

Systems modeling- definitions ; Transport models, Model building kit, Mathematical modeling and its calibration, Data collection and application of models ; Land use and transportation interaction ; Future forecasts using models ; Evaluation and analysis of transportation systems

Essential Reading:

1. P.H. Wright, N.J. Ashford, R.J. Stammer, *Transportation Engineering: Planning and Design*, 4th Edition, December 1997
2. Fred. Mannering, *Principles of Highway Engineering and Traffic Analysis*, John Wiley & Sons, 3rd Ed., 2004.

Supplementary Reading:

1. M.D. Meyer and E.J. Miller, *Urban Transportation Planning. Urban Transportation Planning*: *A Decision-Oriented Approach*, 2nd edition, McGraw-Hill, 2001
2. B.G. Hutchinson, *Urban Transportation Planning*, Mc. Graw Hill, 1974

CE 649	ADVANCED RAILWAY ENGINEERING	4 credits [3-1-0]

Track and track stresses, Train resistances and hauling power of locomotives ; Railway track components: Important features, Railway curves, Superelevation, Gradients and grade compensation, Points and crossing and their design approaches. ; Construction and maintenance of railway track, Control of train movements; Signals and interlocking, Modernisation of railways and future trends; Track standards and track rehabilitation.

Essential Reading:

1. J.S. Mundrey, *Railway Track Engineering*, Tata McGraw Hill Co. Ltd., 3rd Edition, 2000.
2. M.M. Agarwal, *Railway Track Engineering*, Standard Publishers, 1st Ed. 2005.

Supplementary Reading:

1. S. Chandra and Aqarwal,*Railway Engineering*, Oxford University Press, 1st Ed. Feb 2008.

2. A.D. Kerr, *Fundamentals of Railway Track Engineering*, Simmons Boardman Pub Co (December 30, 2003)

CE 650	HYDROLOGY AND HYDRAULICS OF SURFACE AND SUB SURFACE WATER	4 credits [3-1-0]

Hydraulics of alluvial rivers: regimes and morphology. Critical tractive force and resistance relations. Suspended, Bed and Total loads. Meandering, Braiding, Aggradation and Degradation. Routing of floods – reservoir and channel routing. Determination of reservoir capacity and height of dam. Sub-surface water flows. Aquifers and their properties. Estimation of ground water flows. Well hydraulics and quality of ground water.

Essential Reading:
1. H. Rouse, *Engineering Hydraulics* by John Wiley and sons
2. M.S. Stephenson, *River Engineering*, Prentice Hall, New Delhi.

Supplementary Reading:
1. H. Rouse, *Engineering Hydraulics*, John Wiley and Sons.

CE 651	HYDROLOGIC ELEMENTS AND ANALYSIS	4 credits [3-1-0]

Importance and application, water budget, catchments, hydraulics cycle and water budget. Hydrologic cycle. Measurement of rainfall, infiltration, evaporation and runoff. Hydrologic frequency analysis. Peak flow using frequency analysis and catchment area formulae. PMP, PMF and SPF. Unit hydrograph, Synthetic unit hydrograph, S-hydrograph and watershed dynamics simulation models. Flood hydrograph. Flood Routing, Reservoir routing and channel routing, Flood estimation and flood frequency studies. ; Erosion and sediment yield. Application of remotely sensed information in water resources engineering. hydrologic process; Measurements and networks for rainfall, stream flow. Statistical analysis of discrete Hydrologic data: Statistical analysis; Correlation & Regression analysis. ; Time series analysis and its applications. Synthetic data generation of hydrologic variables. Multivariate stream flow model. Models for long and short term forecasting; Depth duration and frequency analysis. Catchment characteristics; Mathematical models for deterministic, stochastic, conceptual and empirical models. Stochastic processes, stationary and non-stationary processes, discrete linear processes, Parameter estimation.

Essential Reading:
1. K.C. Patra, *Hydrology and Water resources Engineering*, by Narosa publishing house, New Delhi
2. K. Subramanya,*Engineering Hydrology*, Tata McGraw Hill Book Company

Supplementary Reading:
1. V. P. Singh, "*Elementary Hydrology*", Prentice Hall of India, Pvt. Ltd., New Delhi.
2. V.T. Chow, *Hand book of Applied Hydrology*, Mc Graw-Hill Publishing Company, New York.
3. M.A. Kohlar, J.L.H. Pauluhus, R.K. Linsely, *Hydrology for Engineers*, Tata Mc Graw Hill, New Delhi.

CE 652	OPEN CHANNEL FLOW	4 credits [3-1-0]

Energy and Momentum of flow; Critical flow; Channel Control and Transitions; Discharge measurement methods; Uniform flow and Flow resistance; Composite roughness and Compound channels; Gradually varied flow; Classifications and Computations of Free surface profiles; Spatially varied flow; Supercritical flows and Oblique flows. Rapidly varied flow; Hydraulic jump ; Unsteady flow in bounded systems, Quasi- steady flow, unsteady flow in open channel flow. Finite difference representation of depth dependent-discharge, Simulation of unsteady flow channels and ducts. Development of St. Venant equation of continuity and motion, Continuity and Dynamic equations of Unsteady flow; Wave propagation and Surge; Method of Characteristics; Dam-break problem; Density current; Flow in Channel bends.

Essential Reading:

1. V.T.Chow, *Open Channel Flow*, By McGraw- Hill Book Co.,
2. H. Chanson, *The Hydraulics of Open Channel Flow:* An Introduction by Elsevier

Supplementary Reading:

1. K. Subramanya, *Flow in Open Channel*,Tata Mc Graw hill, New Delhi
2. R.J. Garde and K.G. Rangaraju, *Mechanics of Sediment Transport and Alluvial Stream.*
3. K.G. R. Raju, *Flow Through Open Channels Problems*.

CE 653 ADVANCED FLUID MECHANICS 4 credits [3-1-0]

Dynamic of Fluid Flow, One-Dimensional method, The Nervier Stokes Equation, Limiting Case, applications ; Boundary Layer Theory for low and high Viscosity, Boundary Layer thickness, Prandtl's Equation, Momentum Integral Equation, Pressure Distribution in boundary layer. ; Dimension analysis and similarities, Buckingham ⍰ theorem, types of similarities, forces influencing hydraulic phenomenon, significance of dimensionless numbers, distorted model, and model proto type similarity law. ; Ideal Fluid Flow, Circulation and Vortices, Source and sink, combining flow field by super position, combined flow field for engineering importance. ; Doublet in rectilinear flow and Doublet with Circulation. Flow past a cylinder curved flow and with circulation and their different combinations ; Real-Fluid Flow: Viscous incompressible flow; Navier-Stokes equations, Laminar and Turbulent boundary layer, Turbulence and Coherent structure of flow; Reynolds stresses; Skin friction; Form drag and Lift.

Essential Reading:

1. K. Subramanya, *Theory and application of Fluid Mechanics*, Tata Mc Graw hill, New Delhi.
2. V.L. Streeter, *Fluid Mechanics*, 1971, New York, McGraw-Hill Book, New York.

Supplementary Reading:

1. J.F. Douglas, J.M. Gasiorek, J.A. Swaffield, *Fluid Mechanics*, Person Education.
2. S.K. Som and G. Biswas, *Introduction to Fluid Mechanics*, Tata McGraw Hill Book Company.
3. K.C. Patra, *Engineering Fluid Mechanics and Hydraulic Machines*, Narosa publishing house, New Delhi.

CE 654 WATER RESOURCES MANAGEMENT 4 credits [3-1-0]

Managing our water resources, Erosion control and watershed development: their benefit towards conservation of national water wealth. Rain water harnessing and recharge of ground water: role of society and People's participation for sustainable water resource development. Mitigation strategies for flood damage: structural and non-structural measures.

Essential Reading:

1. A.S. Goodman, *Principles of Water Resources Planning*, Prentice Hall Inc., New Jercy, 1984.
2. L.D. James, and R.R. Lee, *Economics of Water Resources Planning*, Mc Graw Hill, 1971.

Supplementary Reading:

1. L. W. Meyer- *Water Resources Hand Book*, Mc Graw Hill
2. C.C. Warnic, *Hydropower Engineering*, Prentice Hall Inc., New Jersey, 1984

CE 655 COMPUTATIONAL FLUID DYNAMICS 4 credits [3-1-0]

Introduction, overview of the numerical simulation of flood flows in river channels, governing equations in flood flows in river channels. Finite difference approach, Explicit finite difference schemes, Implicit finite difference schemes, significance of model boundary conditions, Hydraulic structures,hydraulic structures affect flow conditions within river channels and structures within numerical models, data requirements for numerical models of flood flows in river channels, Model calibration , understanding of the data checks necessary to ensure correct representation of the river geometry in a numerical model, calibrating numerical models of flood flows in river channels, Conveyance Estimation, prediction of conveyance within river channels, new Conveyance Estimation System (CES).

Essential Reading:

1. M.B. Abbot. *Computational Hydraulics*. (1979)
2. M.B. Abbott and D.R. Basco, *Computational Fluid Dynamics*. (1989).

Supplementary Reading:

1. C.B. Vreugdenhill, *Computational Hydraulics* (1989).
2. P.S. Huyakern and G. F. Pinder, *Computational Methods in sub-surface flows*, academic Press, 1983.

CE 657	WATER QUALITY MODELLING AND MANAGEMENT	4 credits [3-1-0]

Water quality description, various characteristics of water, water quality criteria and standards, elements of reaction kinetics, spatial and temporal aspects of contaminant transport, transport mechanism-advection, diffusion, dispersion. River and streams, convective diffusion equation and its application. Estuaries, Estuarine hydraulics, Estuarine water quality models. Lakes and reservoirs, eutrophication. Contaminant transport in unsaturated flows, solute transport models for conservative species, solute transport in in spatially variable soils. Contaminant transports in ground water advection, dispersion, one dimensional transport with linear adsorption, dual porosity models, numerical models, bio degradation reaction. Water quality management, socio-economic aspects of water quality management, management alternatives for water quality control, waste load allocation process, lake quality management, ground water remediation.

Essential Reading:

1. Thomann and Muller, *Principles of surface water quality modeling and control*
2. Chapra, *Surface water quality modeling*

Supplementary Reading:

1. Schnoor, *Environmental Modelling*
2. Thomann, *Systems Analysis and Water Quality Management*.

CE 660	HIGH RISE STRUCTURES	4 Credits [3-1-0]

Analysis of tall building frames, Lateral load analysis, multi bay frames, gravity loads, settlement of foundation. Analysis of shear walls - plane shear walls, infilled frames, coupled frames, frames with shear walls. Principle of three dimensional analysis of tall buildings; Perforated cores, pure torsion in thin tubes, bending and warping of perforated cores. Analysis of floor system in tall buildings, Vierendal girders, diagrid floors. Elastic and inelastic stability of frames and shear walls. Analysis of thermal stresses.

Essential Reading:

1. B S Smith & A Coull, *Tall Building Structures:* - John Wiley & Sons.
2. W. Schueller, *High Rise Building Structures*: John Wiley & Sons.

CE 661	STRENGTH AND DEFORMATION BEHAVIOUR OF SOIL	4 Credits [3-1-0]

Introduction: Physico-Chemical aspects, Failure theories, Yield criteria, Elastic and Plastic analysis of soil, Mohr’s diagram. ; Stresses in Soil: Description of state of stress and strain at a point, stress distribution problems in elastic half pace. Boussinessqu, Westergard Mindlin and Kelvin problems. Distribution of contact pressure. Analysis of Elastic settlement. ; Soil Plasticity. ; Shear Strength of Soils: Experimental determination of shear strength, Types of tests based on drainage conditions and their practical significance, Skempton’s and Henkel’s pore water pressure coefficients, Stress path, Shear strength of unsaturated soils, Row’s stress dilatancy theory. Constitutive Models: Constitutive

Models in Soil Mechanics: Isotropic Elastic, Anisotropic Plasticity and Viscous Models. Representing Soil Behaviour using these Models. ; Advances in Constitutive models.

Essential Reading:

1. A.P.S. Selvadurai, *Plasticity& Geomechanics*, Cambridge University Press, 2002
2. W.F. Chen, *Limit Analysis & Soil Plasticity*, Elsevier Scientific, 1975.

Supplementary Reading:

1. C. S. Desai and J. T. Christian, *Numerical Methods in Geotechnical Engineering*, McGrew Hill, New York.
2. R. F. Scott, *Principles of Soil Mechanics*, Addison & Wesley

CE 662	**ENVIRONMENTAL GEOTECHINICS**	**4 Credits [3-1-0]**

Introduction: Forms of waste, engineering properties (determination and typical values), subsurface contamination. ; Selection of waste disposal sites: Site selection – selection criteria and rating; Solid waste disposal: Ash Disposal facilities- Dry disposal, waste disposal, Design of ash containment system, Stability of ash dykes; Contaminant transport through porous media: mechanisms- addective and dispersion; Municipal and hazardous waste landfill: Types- Dry cell, wet cell, bioreactor, Design- clay liners, geosynthetic clay liners for waste containment, cover and gas collection system. ; Remediation: Principle- planning, source control, soil washing, bioremediation.

Essential Readings:

1. K. R. Reddy and H D Sharma, *“Geoenvironmental Engineering: Site Remediation, waste containment, and emerging waste management technologies”*, John Willey, 2004.
2. R N. Yong, *“Geo Environmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation”*, Thomson Telford, 2000.

Suggested Readings:

1. L N Reddy and H.I. Inyang, *“Geoenvironmental Engineering: Principles and Applications”*, Marcel Dek, 2000

CE 663	**MASS TRANSIT SYSTEMS**	**4 credits [3-1-0]**

Mass Transit concepts- Trip interchanges and assignments ; Urban transportation problems, Modes of mass transit- their planning, construction and operation, Case studies of existing mass transit systems ; Technical and economic evaluation of mass transit projects

Essential Readings:

1. C. S. Papacostas, P. D. Prevedouros, *Transportation Engineering and Planning*,PHI Publication, 3rd edition, 2002
2. S. Grava, *Urban Transportation Systems*, Mc. Graw Hill Professional, 1st Ed. 2002

Supplementary Readings:

1. J.D. Fricker, & R.K. Whitford, *Fundamentals of Transportation Engineering*, Pearson, PH, 2004
2. V.R. Vuchic, *Urban Transit Systems and Technology*, John Wiley & Sons, February 2007
3. C.A. O'Flaherty, *Transport Planning and Traffic Engineering*, Arnold, 1997
4. J. E. Anderson, *Transit Systems Theory*, Lexinton Books, USA

CE 665	**GROUND WATER ASSESSMENT AND DEVELOPMENT**	**4 credits [3-1-0]**

Importance of GW, available water on earth, Hydrologic cycle, types of aquifer, storage coefficients, ground water basins, Darcy’s law, permeability, well hydraulics, pumping test, water wells, test holes and well loss, Methods of Drilling of deep wells, cable tool drilling method, rotary method, pumps. ; Surface investigation of ground water, remote sensing, geo-physical exploration, electrical resistivity method, seismic refraction method, gravity and magnetic methods, water witching, sub surface investigation of ground water: test drilling, geologic logging, geophysical logging, resistivity logging, artificial recharge of ground water, conjunctive use of water.

Essential Reading:

1. *Ground Water Manuals, A water resources technical Publications*, Scientific Publishers, Jodhpur
2. L. Harvil and F. G. Bell, *Ground Water Resources and Development*, Butterworths, London.

Supplementary Reading:

1. H.M. Raghunath, *Ground Water*, New Age International Pvt. Ltd.
2. F. W. Schwartz & H. Zhang, *Fundamental of Ground Water*, John Willey & Sons.

CE 670	STRUCTURAL ENGINEERING DESIGN PRACTICE	2 Credits [0-0-3]

Analysis and design of Multi-storey building frames using STAAD. Pro. SAP ; Analysis and design of Elevated Water Tank using STAAD-Pro., SAP ; Analysis and design of bridg e decks and other structures using STAAD-Pro., SAP ; Analysis and design of steel trusses using STAAD-Pro., SAP ; Dynamic response of structures using PULSE software.

CE 671	STRUCTURAL ENGINEERING LABORATORY	2 credits [0-0-3]

Mix design of concrete of different grades & using admixtures ; Tensile and Flexural strength of concrete of different grades ; Tensile strength of different types of steel rebars, rolled steel sections ; Testing of simply supported RCC beams for flexural failure ; Testing of simply supported RCC beams for shear failure ; Testing of RCC column ; Non-destructive testing of concrete including rebound hammer and ultrasonic pulse method ; Permeability of concrete ; Vibration analysis of beams and plates ; Buckling load of struts.

Essential Reading:

1. A.M. Neville & J.J. Brooks, *Concrete Technology*, Pearson Education, Delhi, 2004.
2. A.R. Santhakumar, *Concrete Technology*, Oxford University Press, 2007, New Delhi

Supplementary Reading:

1. *Structural Engineering laboratory manual.*
2. *Relevant BIS Codes of practice for mix design*, rebar testing, concrete design etc.

CE 672	GEOTECHNICAL ENGINEERING DESIGN PRACTICE	2 Credits [0-0-3]

Standard Penetration test ; Field vane shear test ; Cone penetration tests ; Plate load test ; Pile load tests ; Nondestructive testing of piles ; Pressure meter test ; Geophysical Exploration ; Field Visit

CE 673	GEOTECHNICAL ENGINEERING LABORATORY	2 Credits [0-0-3]

Standard and Modified Proctor Compaction Test ; Permeability of fine grained soil ; Direct Shear Test ; Triaxial Shear Test (CU, CD, UU) ; C.B.R (Unsoaked& soaked) ; Consolidation Test ; Mechanical properties of geosynthetics/ geogrid

CE 674	WATER RESOURCES ENGINEERING DESIGN	2 credits [0-0-3]

Computing average unit hydrographs, Flood routing, estimation and design of flood, computation of yields series. ; Design of earth and gravity dams.

CE 675	HYDRAULIC AND HYDROLOGIC ENGINEERING LABORATORY	2 credits [0-0-3]

Measurement of velocity profile in straight and meandering open channel; Experiments on velocity distribution and Boundary shear in rough and smooth channels, Discharge measurement by weir; Measurement of Shear stress using Preston Tube and from velocity distribution obtained from Acoustics Doppler Velocity meter (ADV). Measurement of rainfall, evaporation, infiltration, laboratory and field tests.

CE 676	TRAFFIC & TRANSPORTATION ENGINEERING LABORATORY	2 credits [0-0-3]

Traffic volume studies ; Spot speed studies ; Accident and Parking studies ; Design of Traffic rotaries and Intersections ; Traffic simulation modeling ; Road safety audit ; Use of software for geometric design and alignment of highways

CE 677	TRANSPORTATION ENGINEERING LABORATORY	2 credits [0-0-3]

Penetration Ratio and Penetration Viscosity Number of Bituminous binders ; 10% Fines Test for aggregates ; CBR Test for subgrade and subbase material ; Moisture sensitivity test for bitumen adhesion ; Temperature susceptibilty for Bituminous binders ; Rheological properties of Bituminous binders ; Design of Bituminous mixes ; Indirect Tensile Test

CE 678	ENVIRONMENTAL ENGINEERING DESIGN PRACTICE	2credits [0-0-3]

Design of Water Supply Systems: Selection of site for the source of water supply. Design of units for sedimentation, cogulation, flocculation, granular media filtaration, disinfectation, water softening, advanced tertiary treatment, design of city water supply pumping and distribution systems ; Design of Wastewater Treatment Units: Screening chamber, septic tank and soak pits, activated sludge process and filtration units ; Design of air pollution control units: Design of stacks and chimneys, design fo air pollution control equipments.

CE 679	ENVIRONMENTAL ENGINEERING LABORATORY	2 credits [0-0-3]

Complete physical, chemical, and bacteriological analysis of water ; Complete physical, chemical, and bacteriological analysis of wastewater ; Ambient air quality analysis (NOx, SO2, PM10, SPM) ; Ambient Noise Quality Analysis ; Solid waste Analysis ; Ambient Noise Quality Monitoring

CE 680	COMPUTATIONAL LABORATORY - II	2 credits [0-0-3]

Development of Finite Element Programming for analysis of beams, trusses, frames. ; Analysis of plates and shells using commercial softwares.

CE 681	COMPUTATIONAL LABORATORY	2 credits [3-1-0]

Computer programming in C^{++}. ; Development of computer programs to solve problems related to civil engineering using matrix method.

CE 682	COMPUTER AIDED FOUNDATION ENGINEERING DESIGN PRACTICE	2 credits [0-0-3]

Computer aided design of: Design of footing for compression, bending and uplift ; Design of sheet pile, bracing ; Design of Pile foundation ; Design of Retaining wall ; Design of Well foundation ; Design of slopes and embankments ; Design of foundation subjected to dynamic load ; Design of reinforced earth works

CE 684	COMPUTER APPLICATION IN WATER RESOURCES ENGINEERING	2 credits [0-0-3]

The numerical simulation of flood flows in river channels, governing equations in flood flows in river channels. Finite difference approach, explicit finite difference schemes, implicit finite difference schemes, significance of model boundary conditions, computer application for velocity distribution, boundary shear study and conveyance estimation to open channel flow and prediction of conveyance within river channels.

CE 704	REMOTE SENSING AND GIS LABORATORY	2credits [0-0-3]

Review of target Recognition Concepts; Non Photographic Imagery; Introduction to Digital Image Analysis; Image Exploration; Image Corretion/ Recrification; Unsupervised Classification; Supervised Classification; Verification.

DEPARTMENT OF CHEMICAL ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
CH 611	Advanced Fluid Dynamics	3-1-0	4
CH 612	Computational Transport Phenomena	3-1-0	4
CH 613	Advanced Mass Transfer	3-1-0	4
CH 614	Advanced Separation Technology	3-1-0	4
CH 615	Advanced Heat Transfer	3-1-0	4
CH 616	Advanced Fluidization Engineering	3-1-0	4
CH 620	Pinch Technology	3-1-0	4
CH 621	Bioenergy Engineering	3-1-0	4
CH 622	Membrane Science & Technology	3-1-0	4
CH 623	Environmental Management System	3-1-0	4
CH 624	Advanced Thermodynamics	3-1-0	4
CH 625	Bioprocess Engineering	3-1-0	4
CH 626	Nano Science & Technology	3-1-0	4
CH 628	Advanced Environmental Biotechnology	3-1-0	4
CH 629	Interfacial Science and Engineering	3-1-0	4
CH 631	Process Plant Simulation	3-1-0	4
CH 632	Advanced Process Control	3-1-0	4
CH 634	Chemical Engineering analysis: Application of mathematical and statistical methods	3-1-0	4
CH 636	Evolutionary Computation	3-1-0	4
CH 638	Advanced Reaction Engineering & Reactor Design	3-1-0	4
CH 670	Chemical Engineering Lab – III	0-0-3	2
CH 671	Chemical Engineering Lab – I	0-0-3	2
CH 672	Chemical Engineering Lab – IV	0-0-3	2
CH 673	Chemical Engineering Lab – II	0-0-3	2
CH 681	Special Topics in Chemical Engineering – I		3/4
CH 682	Special Topics in Chemical Engineering – II		3/4
CH 683	Special Laboratory in Chemical Engineering – I	0-0-3	2
CH 684	Special Laboratory in Chemical Engineering – II	0-0-3	2
CH 687	Seminar & Technical Writing – III	0-0-3	2
CH 688	Seminar & Technical Writing – IV	0-0-3	2
CH 691	Summer Research/Industrial Project	0-0-0	4
CH 692	Comprehensive Viva Voce	0-0-0	4
CH 693	Research Project – III	0-0-15	10
CH 694	Research Project Work – IV	0-0-30	20

CH 611 ADVANCED FLUID DYNAMICS 4 credits [3-1-0]

Professor-in-Charge: Prof. H. M. Jena.

Properties of fluids and multiphase flow, fluids and fluid properties, Kinematics: Motion, streamlines, pathlines and streaklines, Newtonian, non- Newtonian and non-viscous fluids, Continuity equation in Cartesian, cylindrical and spherical coordinates, Derivation of general momentum equation for Newtonian fluids in Cartesian coordinates, Eulers equation, principles of rotational and irrotational flow, velocity potential, Bernoulli's equation, Laplace equations, stream function, vorticity, Cauchy – Rieman equation, Analytical solutions for simple two dimensional incompressible, irrotational fluid flows: flow along two inclined plates, point source or sink in an infinite fluid. Stokes law of viscosity, Navier-stokes equation, creeping flow around a solid sphere, expression for total drag, Turbulent flow: Transition to turbulence, Prandtl's mixing length, Turbulence models. Boundary layer on immersed bodies, two dimensional boundary layer equation, laminar boundary layer on flat plate (Blasius' exact solution), Von-Karmann's integral momentum equation, boundary layer separation flow and pressure drag, Flow of compressible fluids, thermodynamic considerations, continuity and momentum equation for one dimensional compressible flow, one dimensional normal shock, flow through fluidized beds. Navier-Stokes equation and various approaches of simulation (stream velocity, primitive variable).

Essential Reading:

Supplementary Reading:

1. R.W. Fox, A.T. Mc Donald, P.J. Pritchard, *Introduction to Fluid Mechanics*, Willey, 6th edition.
2. J.G. Knudsen and D.L. Katz, *Fluid Dynamics and Heat Transfer*, McGraw Hill, New York, 1958.
3. R.B. Bird, W.E. Stewart, and E.N. Lightfoot, *Transport Phenomena*, Second edition, John Wiley and Sons, 2002.

Pre-requisite: Knowledge in under graduate 'Fluid Mechanics'

CH 612	COMPUTATIONAL TRANSPORT PHENOMENA	4 credits [3-1-0]

Professor-In-Charge: Dr. B. Munshi.
Explicit and Implicit scheme to solve heat and fluid flow problems, Simulation of fluid flow problems using both stream function and primitive variable approach. Understanding Staggered Grid concept and its application to simulate fluid flow problems, Application of 1st order and 2nd order Upwind Scheme, Application of SIMPLE, SIMPLER and MAC algorithm to solve fluid flow problems, Simulation of coupled heat and momentum transfer problem, Concepts of boundary layer theory and its simulation algorithm, Study on Grid generation and Stability criterion, QUICK and exponential scheme. Orthogonal Collocation for Finite Elements, Galerkin finite element technique. Variational methods, Finite Element Method for heat and momentum transfer problems. A few case studies, Preliminary concepts Finite Volume Method. Simulation of CFD problems using Fluent.

Essential Reading:

Supplementary Reading:

1. P.S. Ghosdastidar, *Computer Aimulation of Flow and Heat Transfer*, Tata McGraw-Hill, New Delhi.
2. K. Muralidhar, and T. Sundararajan, "*Computational Fluid Flow and Heat Transfer*", Narosa Publishing. House, 2nd Edition, 1995.
3. J.N. Reddy, "*An Introduction to the Finite Element Method*", Tata Mc-Graw-Hill, 3rd Edition, 2005.
4. S.V. Patankar. "*Numerical Heat Transfer and Fluid Flow*", Taylor and Francis, 1978.
5. S K. Gupta. "*Numerical Methods for Engineers*", New Age Publishers, 2nd Edition, 1995.

Pre-requisite: Knowledge in under graduate "Transport phenomena"

CH 613	ADVANCED MASS TRANSFER	4 credits [3-1-0]

Professor-In-Charge: Dr. S. Paria & Dr. B. Munshi
Characteristic of Equilibrium stage and Flash calculations, Study of different types of equilibrium cascade configurations and its degrees of freedom analysis, Algebraic method to determine the number of equilibrium stages, Calculation of stage efficiency, tray diameter, pressure drop and mass transfer, Rate based method to design a packed column, Scale up of a column from laboratory data, Estimation of distillation column efficiency using performance data and to develop its empirical correlation, Scale up of distillation column, Rate based method for packed distillation column, Approximate methods for Multicomponent, multistage separations, Use of residue curve for the conceptual design of distillation columns, Pressure swing and azeotropic distillation, Rate based models for distillation, Modeling of batch distillation, Modeling and simulation of absorption and

leaching processes. Diffusion in non-ideal system and development of generalized Maxwell-Stefan formulation, Study of Generalized Fick's law, Estimation of binary and multicomponent Diffusion Coefficients, Study of interphase mass and energy transfer.

Essential Reading:

Supplementary Reading:

1. J.D Seader, E. J. Henly, "*Separation Processes and principles*", John Willey, 2nd edition, 2006.
2. R. Taylor, R. Krishna. "*Multicomponent Mass Transfer*", John Wiley, 1993.
3. J. Bendaitez "*Principles and Modern Applications of Mass Transfer Operations*", Willey, 2002.
4. A.K. Datta, "*Biological and Bioenvironmental Heat and Mass Transfer*", C R C Press, 2002.
5. N Hallale, "*Supertargeting for Mass Exchange Networks*", American Institute of Chemical Engineers, 1998.

Pre-requisite: Knowledge in under graduate "Mass Transfer"

CH 615	**ADVANCED HEAT TRANSFER**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. S. K. Agarwal and Dr. S. Khanam

Conduction: Steady and unsteady state heat conduction, Unsteady state heating and cooling of solid objects: Transient heat conduction in bodies with finite internal and surface resistance, Transient heat conduction charts, Insulation design and selection. ; Convection: Heat transfer coefficient, Dimensional analysis in convective heat transfer, Heat transfer during laminar and turbulent flow in closed conduits, empirical correlation, Heat transfer in laminar and turbulent flow over a flat plate, Heat transfer in liquid metals, Analogy between momentum and heat transfer, Heat transfer with phase change: Boiling and condensation heat transfer. ; Recent developments in heat exchangers: Heat Transfer Augmentation, Recent developments in the design of compact heat exchangers: Features of Plat Fin and Tube Fin heat exchangers, Construction, Heat transfer and pressure drop, Analysis of plate fin and tube fin heat exchangers.

Essential Reading:

Supplementary Reading:

1. C.P. Gupta and R. Prakash, *Engineering Heat Transfer*, Nem Chand & Bros., Roorkee, 6^{th} Edn, 1994.
2. B.K. Dutta, *Heat Transfer: Principles and Applications*, Prentice Hall of India Pvt. Ltd. New Delhi, 2001.
3. S.K. Das and A.R. Balakrishan, ***Process Heat Transfer*,** Alpha Science International Ltd., 2005.
4. J.P. Holman, *Heat Transfer*, McGraw-Hill Science/Engineering/Math, 2001.

Pre-requisite: Knowledge in under graduate "Heat Transfer"

CH 616	**ADVANCED FLUIDIZATION ENGINEERING**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. A. Sahoo

Gross behaviour of fluidized beds, Minimum fluidizing velocity and pressure drops; Voidage, transport disengaging height; Bubbles in dense beds, Davidson Model, stream of bubbles, bubbling bed models, Emulsion phase, Turn-over rate of solids, residence time distribution diffusion model of solids movement, interchange coefficient into and out of wake; Diffusion model for gas flow; two region models, evaluation of interchange coefficients. Mass and heat transfer between fluids and solid from bubbling bed model; Catalytic conversion from bubbling bed model; contacting efficiency; application to successive reactions; Theories and bed-wall heat transfer; comparison of theories; Entrainment and elutrition, application of entrainment model; Residence time distribution and size distribution of solids in fluidized beds, particles of changing size; Circulation rates of solids, flow of high and low bulk density mixtures; Design for catalytic reactors; Design for noncatalytic gas-solid reactors.

Essential Reading:

Supplementary Reading:

1. J.F. Davidson and D. Harrison, *Fludization*, Academic Press, 1971.
2. D. Kunil and O. Levenspiel, *Fludization Engineering*, John Wiley, 1969.
3. F.A. Zenz and D.F. Othmer, *Fludization and Fluid Particles Systems*, Reinhold Publishing, 1960.

CH 620	PINCH TECHNOLOGY	4 credits [3-1-0]

Professor-In-Charge: Dr. S. Khanam

Process Integration and its Building Blocks: Definition of Process Integration (PI), School of thoughts, Areas of application and Techniques available for PI, Onion diagram. ; Pinch Technology – An Overview: Introduction, Basic concept, How it is different than energy auditing, Role of thermodynamic laws, Problem addressed by Pinch technology. ; Key Steps of Pinch Technology: Data extraction, Targeting, Designing, Optimization- Supertargteing. ; Basic Elements of Pinch Technology: Grid diagram, Composite curve, Problem table algorithm, Grand composite curve. ; Targeting of Heat Exchanger Network (HEN): Energy targeting, Area targeting, Number of units targeting, Shell targeting, cost targeting. ; Designing of HEN: Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER), Design of multiple utilities and pinches, Design for threshold problem, Loops and Paths. ; Heat Integration of Equipments: Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Drier, Refrigeration systems. ; Heat and Power Integration: Co-generation, Steam turbine, Gas turbine.

Essential Reading:

Supplementary Reading:

1. V.U. Sheno, *Heat Exchanger network synthesis*, Gulf Publishing Co, USA, 1995
2. J.M. Douglas, *Conceptual Design of Chemical Process*, McGraw Hill, New York, 1988.
3. B. Linnhoff, D.W.Townsend, D. Boland, G.F. Hewitt, B.E.A. Thomas, A.R. Guy and R.H. Marsland, "*A User's guide on process integration for the efficient use of energy*", Inst of Chemical Engineers, London (1982).
4. R. Smith, "*Chemical Process Design*", McGraw Hill (1995).

CH 621	BIOENERGY ENGINEERING	4 credits [3-1-0]

Professor-In-Charge: Dr. A. Sahoo

Biomass Sources and classification, Characteristics & preparation, Chemical composition and properties of different biomass materials and bio-fuels, Sugar cane molasses and other sources for fermentation ethanol, Sources and processing of oils and fats for liquid fuels, Energy plantations, Preparation of woody biomass: Size reduction, Briquette of loose biomass, drying, storage and handling of biomass. ; Biogas Technology: Feedstock for biogas production, Aqueous wastes containing biodegradable organic matter, animal residues, Microbial and biochemical aspects-Operating parameters for biogas production, kinetics and mechanism, Dry and wet fermentation, Digesters for rural application, High rate digesters for industrial waste water treatment. ; Bio-ethanol and Bio-diesel technology: Production of fuel ethanol by fermentation of sugars. Gasohol as a substitute for leaded petrol, trans-esterification of oils to produce Bio-diesel. ; Pyrolysis and gasification of biomass: Thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, - Pyrolysis of biomass, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles: effect of pressure, temperature and introduction of steam and oxygen, Design and operation of fixed and fluidized bed gasifiers. ; Combustion of biomass and cogeneration systems: Combustion of woody biomass: Theory, calculations and design of equipments. Cogeneration in biomass processing industries. Case Studies: Combustion of rice husk, Use of bagasse for cogeneration.

Essential Reading:

Supplementary Reading:

1. A.Chakraverthy, *Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes*, Oxford & IBH publishing Co., New Delhi, 1989.
2. K.M. Mital, *Biogas Systems: Principles and Applications*, New Age International Publishers (p) Ltd., 1996.
3. P.V. Ramana and S.N.Srinivas, *Biomass Energy Systems*, Tata Energy Research Institute, New Delhi, 1996.
4. D.L. Klass and G.M. Emert, "*Fuels from Biomass and Wastes*", Ann Arbor Science publ. Inc. Michigan, 1985.
5. K.C. Khandelwal and Mahdi, *Bio-gas Technology*, Tata McGraw-Hill pub. Co. Ltd., New Delhi
6. O.P. Chawla, *Advances in bio-gas Technology*. I.C.A.R., New Delhi. 1970.

CH 623	**ENVIRONMENTAL MANAGEMENT SYSTEM**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. S. Mishra

Introduction to air water and air pollutants and solid wastws; Sampling and analysis techniques; Impact assessment. National and International regulations. ISO series. Conventional and non-conventional energy resources, life cycle analysis. Environmental audit. Sustainable development. Case studies.

Essential Reading:

Supplementary Reading:

1. Deneves, *"Air Pollution Control Engineering"*, Mc .Graw hill, 1999.
2. Jr. W.C. Blackman, *"Basic Hazardous Waste Management"*, CRC Press.
3. K.L. Mulholland, J.A. Dye, "*Pollution Prevention: Methodology, Technologies and Practices*", Wiley.
4. T.K. Das, "*Toward Zero Discharge: Innovative Methodology and Techniques for Process pollution*", Wiley-VCH, 2005.
5. S. Alan, "*Environmental Biotechnology*", Oxford University, 2005.

CH 624	**ADVANCED THERMODYNAMICS**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. M. Kundu

Review of Basic Postulates, Maxwell's relations, Legendre Transformation, Pure Component properties, Theory of corresponding states, real fluids Equilibrium, Phase Rule, Single component phase diagrams, Introduction to Multicomponent Multiphase equilibrium, introduction to Classical Mechanics, quantum Mechanics, Canonical Ensemble, Microcanonical Ensemble, Grand Canonical Ensemble, Boltzmann, Fermi-dirac and Bose Einstein Statistics, Fluctuations, Monoatomic and Diatomic Gases, introduction to Classical Statistical Mechanics, phase space, liouville equation, Crystals, Intermolecular forces and potential energy functions, imperfect Monoatomic Gases, Molecular theory of corresponding states, introduction to Molecular Simulations, Mixtures, partial molar properties, Gibbs Duhems equations, fugacity and activity coefficients, Ideal and non-ideal solutions, Molecular theories of activity coefficients, lattice models, multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Chemical Equilibrium and Combined phase and reaction equilibria. Thermodynamics of irreversible processes. Exergy analysis of Chemical Engg Processes.

Essential Reading:

Supplementary Reading:

1. D.A. McQuarrie, *Statistical Mechanics*, Viva Books Private Limited, 2003.
2. H. Terrel, *An Introduction to Statistical Thermodynamics*, Dover, 1960.
3. M. P. Allen, DJ Tildesley, *Computer simulation of liquids*, Oxford, 1989.

4. H. B. Callen, *Thermodynamics and an Introduction to Thermostatics*, 2nd Edition, John Wiley and Sons, 1985.
5. J.M. Prausnitz, R.M. Lichtenthaler and E.G. Azevedo, *Molecular thermodynamics of fluid-phase* Equilibria (3rd edition), Prentice Hall Inc., New Jersey, 1996.
6. J.M. Smith. H.C.V. Ness and M.M. Abott, *"Introduction to Chemical Engineering Thermodynamics"* McGraw Hill International edition (5th ed.). 1996.

Pre-requisite: Knowledge in under graduate "Engineering Thermodynamics" and "Chemical Engineering Thermodynamics"

CH 625	**BIOPROCESS ENGINEERING**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. S. Mishra

Bioprocess principles; kinetics of biomass production, substrate utilization and product formation; Batch and Continuous culture, Fed batch culture. ; Introduction: Fermentation Processes General requirements of fermentation processes, An overview of aerobic and anaerobic fermentation processes and their application in industry, Medium requirements for fermentation processes, examples of simple and complex media Design and usage of commercial media for industrial fermentation, Thermal death kinetics of micro-organisms, Heat Sterilization of liquid media, Filter sterilization of liquid media and air. ; Enzyme Technology, Microbial metabolism enzymes: Classification and properties, Applied enzyme catalysis - Kinetics of enzyme catalytic reactions, Metabolic pathways, Protein synthesis in cells. ; Bioreactor design & operations, Selection, scale-up, operation of bioreactors, Mass transfer in heterogeneous biochemical reaction systems; Oxygen transfer in submerged fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer, Heat transfer processes in biological systems, Recovery and purification of products. ; Introduction to instrumentation and process control in bioprocesses: measurement of physical and chemical parameters in bioreactors, Monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter. Bioprocess patenting and economics

Essential Reading:

Supplementary Reading:

1. M.L. Shuler and F. Kargi, "*Bio-process Engineering*", 2nd Edition, Prentice Hall of India, New Delhi. 2002.
2. Rajiv Dutta, "*Fundamentals of Biochemical Engineering*", 1st Edition, Springer, 2008.
3. J.E. Bailey and D.F. Ollis, *"Biochemical Engineering Fundamentals"*, 2nd Edn, McGraw Hill, Publishing Co. New York, 1986.

CH 626	**NANO SCIENCE & TECHNOLOGY**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. S. Paria

Introduction to nanotechnology, definition, history. What makes the nanoscale so different from the other lengthscales by considering the underpinning science (*i.e.* nanoscience) and some key examples of nanotechnology. ; Properties in nanoscale: Extensive and Intensive properties, change in physical properties like color, melting point, electrical, magnetic, and mechanical. Quantum mechanical approach to explain the properties change in nanoscale. Theory of size dependent melting point, effect of grain size and grain boundary on mechanical properties of nanomaterials. ; Methods of synthesis of nanometerials fabrication-"Top-down" vs. "bottom-up" approaches. Equipment and processes needed to fabricate nanodevices and structures. ; Focous on different nanomaterials: Carbon nanotubes (discovery, preparation, properties, applications), Inorganic nanowires, Biological and bio-inspired materials, Metallic nanomaterials, Different shape nanomaterials. ; Nanomaterial based biosensors: biofunctionalization of nanomaterials, advantages over other sensors, Field effect transistor based biosensors. Application in cholesterol, blood sugar, single virus detection. ; Semiconductor nanoparticles, and Quantum dots. Application of quantum dots. Application of nanoparticles in catalysis. ; Characterization of nano particles by Scanning probe microscopes (Atomic Force Microscopy, Scanning Tunneling Microscopy), Transmission Electron Microscopy, Scanning Electron Microscopy.

Essential Reading:

Supplementary Reading:

1. T. Zikang and S. Ping, *Nano science and technology: novel structures and phenomena*, Taylor and Francis, 2003.
2. B. Rogers, S. Pennathur, J. Adams, *Nanotechnology: Understanding small systems*, Taylor and Francis, 2008.
3. M. Rieth, *Nano-Engineering in Science and Technology: An Introduction to the World of Nano design,*World Scientific, 2003
4. R. Kelsall, I. Hamley and M. Geoghegan, *Nanoscale Science and Technology*, (Eds.), Wiley, 2005.
5. M.Di Ventra, S.Evoy and Jr. J. R. Heflin, *Introduction to Nanoscale Science and Technology*, (Eds.), Springer, 2004.
6. Jr. C. P. Poole, F. J. Owens, *Introduction to Nanotechnology*, Wiley, 2003.

CH 628	ADVANCED ENVIRONMENTAL BIOTECHNOLOGY	4 credits [3-1-0]

Professor-In-Charge: Dr. S. Mishra

General effluent treatment – nature of sewers, sewage; Methods adopted in effluent treatment; Legal Consideration – Royal Commissions. Current situation in laying of charging ownership, regulations, legislation; Activated sludge process equipment, plant kinetics, CSTR modeling. PFR modeling, recycle stability, washout; Advanced Process – Trickling fitter, moving medium system; Biology of effluent treatment process: Roles of bacteria, fungi and protozoa. Extracellular Polymers, films, flocs, Analysis of effluent; Nutrition, Carbon removal, influences of loading ratio, retention times, season on kinetics and performance, Nitrogen and Phosphorous requirement for adequate plant performance. Nitrification and De-nitrification Anoxic process, extended aeration, high rate process; Sludge disposal methods; Anaerobic processes. Sludge digestion (contact digester), Management of digester sludge. Aerobic effluent treatment. Gas production and utilization, related problem.

Essential Reading:

1. M.J. Waites, N.L. Morgan, J.S. Rockey, and G. Higton , *Industrial Microbiology,* Wiley Blackwel, 2001

Suggested Reading:

1. W. Grueger and A. Crueger, *Biotechnology a Text book of Industrial Microbiology*, Mc Graw Hill, 1990
2. J E Bailey and D F Ollis, *Biochemical Engineering Fundamentals*, Mc Graw-Hill, 2005

CH 629	INTERFACIAL SCIENCE AND ENGINEERING	4 credits [3-1-0]

Professor-In-Charge: Dr. S. Paria

General introduction of colloids, interfaces, surfactants, and micellization. Intermolecular forces, Van der Waals forces (Keesom, Debye, and London interactions), Colloidal systems and colloidal stability (van der Waals attraction and potential energy curves), Brownian motion and Brownian flocculation. Surface and interfacial tension and surface free energy, Surface tension for curved interfaces, Surface excess and Gibbs equation. Theory of surface tension and contact angle, and wetting. Thermodynamics of interfaces, thermodynamics of micelle and mixed micellar formation. Electrical phenomena at interfaces (Electrokinetic phenomena, Electrical double layer). Emulsion and micro-emulsion; Application: General applications, Enhanced petroleum recovery, Super hydrophobic and self cleaning surfaces, Novel fabrication of nanostructured particles ; Measurement techniques of surface tension, Contact angle, Zetapotential, Particle size.

Essential Reading:

Supplementary Reading:

1. P.C. Hiemenz, and R. Rajagopalan*, Principles of Colloid and Surface Chemistry*, 3rd Edition, Marcel Dekker, N.Y., 1997.
2. M.J. Rosen, *Surfactants and Interfacial Phenomena*, Wiley-Interscience Publication, New York, 2004.
3. A.W. Adamson, A. P. Gast, *Physical Chemistry of Surfaces*, Wiley-Interscience, New York, 1997.
4. J. Israelachvili, *Intermolecular and Surface Forces*, Academic Press, New York, 1992
5. D.J. Shaw, *Colloid & Surface Chemistry*, Butterworth Heinemann, Oxford, 1991.

CH 631	PROCESS PLANT SIMULATION	4 credits [3-1-0]

Professor-In-Charge: Dr. M. Kundu

Introduction and fundamentals of process modeling and simulation, Models in chemical engineering; Simulation of steady state lumped systems including simultaneous solution, modular solution, nested inside-out algorithms, partitioning and tearing with reference to chemical process equipments like reactors; distillation, absorption, extraction columns; evaporators; furnaces; heat exchangers; flash vessels etc. Unsteady state lumped systems and dynamic simulation; Introduction to application of advanced Artificial intelligence based modeling methods using Artificial Neural Networks, Traditional and non-traditional optimization techniques. Case study using professional software packages.

Essential Reading:

Supplementary Reading:

1. B.V. Babu, *"Process Plant Simulation*", OUP, India, 2004.
2. Seinfeld and Lapidus, *"Mathematical methods in Chemical Engineering"* Prentice-Hall-International, Inc., 1978
3. B. Wayne Bequette, *"Process Dynamics Modeling, Analysis, and Simulation",* Prentice-Hall-International, Inc., 1998.
4. O.T. Hanna and O.C. Sandall, "*Computational Methods in Chemical Engineering*", Prentice-Hall-International, Inc., 1998.
5. B. Roffel, B. Betlem, *"Process Dynamics & Control: Modeling for control and prediction*. John Wiley & Sons Ltd., 2006

CH 632	ADVANCED PROCESS CONTROL	4 credits [3-1-0]

Professor-In-Charge: Dr. M. Kundu

A brief review on preliminary concepts of process control, Modeling of a few complicated systems, Understanding of first and second order systems and PID controllers, State space and transfer function matrix models, Stability criterion of transfer function matrix models, Development of empirical model from process data, Identifying Discrete-Time models from experimental data, Design of Feedforward and Ration control, Study of Cascade Control system, Digital Sampling, Filtering, and Control: Sampling period, Analog and digital filters, z-transform, use of SIMULINK, design of digital controller, Multiloop Control: Calculation of extent of interaction and pairing of controlled and manipulated variable, Implementation of real time optimization in computer control, Study of Model Predictive Control (MPC), Concepts of Statistical process control,. Study on Kalman Filter.

Essential Reading:

Supplementary Reading:

1. S. Edgar, Mellichamp, *Process Dynamics and control*, John Willey, 2nd Edn, 2004.

2. W.H. Ray, B.A. Ogunnaike. "*Process Dynamics, Modeling, and Control*", Oxford University Press, 1994.
3. B.W. Bequette. "*Process Control: Modeling, Design, and Simulation*", Prentice Hall Internation Series, 1998.
4. M. Chidambaram. "*Computer Control of Processes*", Narosa Publishing House, 2002.
5. D.R. Coughnowr, *Process System Analysis and Control,* 2nd Edn., McGraw ill,NewYork,1991.
6. C.A. Smith and A.B. Corripio, *Principles and Practice of Automotive Process Control*, John Wiley, New York, 1976.
7. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp. "*Process Dynamics & Control*", 2 nd Edition, John Wiley & Sons Ltd., 2004.

Pre-requisite: Knowledge in under graduate "Process Control"

CH 634	CHEMICAL ENGINEERING ANALYSIS: APPLICATION OF MATHEMATICAL AND STATISTICAL METHODS	4 credits [3-1-0]

Professor-In-Charge: Dr. B. Munshi

Models in Chemical Engg.: Modeling, Simulation, Types of Equation, Linear algebraic Equation ODE, IVP, Non Self adjoint systems, Gram-Schmidt Ortho-normalization. Matrices, Operators & Transformations (Matrices, Eigenvalues, Eigen vectors, Rayleigh's Quotient) for solving process models in chemical Engg., Partial Differential Equation: Classification of PDE, boundary conditions, Developing PDE in Chemical Engg. Systems. Application of Sturm-Louiville Theory, Green's function in solving ODES and PDES of chemical Engineering processes. Uniqueness condition for linear and non-linear systems: Maximum principles, Energy methods, Fredholm alternative, Steady State analysis of a Nonlinear dynamic System: application of method of continuation and homotopy continuation, Linear stability & limit cycles: Linear stability of a dynamic system, Bifurcation theory, Maps, e.g., application in stability analysis of reactive distillation system. Secondary bifurcations and Chaos: Landau-Hopf Scenario, Period -Doubling cascades, Ruelle- Takens Scenario, Characteristic of trajectories, application in non linear dynamic systems, bioprocess modeling. ; Probability concepts and distributions, random variables, error analysis, point estimation and confidence intervals, hypothesis testing, development of empirical chemical engineering models using regression techniques, design of experiments, process monitoring based on statistical quality control techniques. Case studies.

Essential Reading:

Supplementary Reading:

1. S. Pushpavanam, "*Mathematical Methods in Chemical Engineering*," Prentice-Hall-India, 1998.
2. B. Wayne Bequette, "*Process Dynamics Modeling, Analysis, and Simulation*," Prentice-Hall-International, Inc., 1998.
3. Owen T. Hanna and Orville C. Sandall, "*Computational Methods in Chemical Engineering*," Prentice-Hall-International, Inc., 1998.
4. B.V. Babu, "*Process Plant Simulation*", OUP, India, 2004.
5. Seinfeld and Lapidus, "*Mathematical methods in Chemical Engineering*" Prentice-Hall-International, Inc., 1978

CH 636	EVOLUTIONARY COMPUTATION	4 credits [3-1-0]

Professor-In-Charge: Dr. M. Kundu

Introduction to Optimal problem formulation, Single variable optimization algorithms, multi variable optimization algorithms, constrained optimization algorithms including Khun-Tucker conditions, transformation methods; direct search methods; liberalized search techniques; feasible direction method, Specialized algorithms including Integer programming; geometric programming, Nontraditional optimization techniques; population based search algorithms; evolutionary strategies; evolutionary programming; simulated annealing; genetic algorithms; differential evolution; different strategies of differential evolution; Memetic algorithms; scatter search; ant colony optimization; self-organizing migrating algorithm; Engineering applications involving highly non-linear processes with many constraints, multi-objective optimization problems with pareto optimal solutions, NSGA II (non dominated sorting genetic algorithm II).

Essential Reading:

Supplementary Reading:

1. G. C. Onwubolu, & B. V. Babu, *New Optimization Techniques in Engineering*, Springer-Verlag Publication, Germany, 2003.
2. B.V. Babu, *Process Plant Simulation*, OUP, India, 2004.
3. K. Deb, *Multi-Objective Optimization Using Evolutionary Algorithms*, John Wiley & Sons, 2001.
4. K. Deb, *Optimization for Engineering Design-Algorithms and examples*, PHI, 2003
5. S.S. Rao, *Engineering Optimization Theory & Practice*, John Wiley & Sons Inc, 1996.

Pre-requisite: Knowledge in under graduate "Engineering Optimization"

CH 638	**ADVANCED REACTION ENGINEERING & REACTOR DESIGN**	**4 credits [3-1-0]**

Professor-In-Charge: Dr. R. K. Singh

Homogeneous reactor design and analysis-I: Ideal reactors, Review of isothermal design for batch, semi-batch and flow reactors, multiple reactions and reaction networks: Yield-selectivity concepts, Wei-Prater analysis for first order networks, reaction networks of general order, Reactor energy balance and its applications to reactor design and analysis. ; Homogeneous reactor design and analysis-II: Non-ideal reactors- Review of the basic concepts of residence time distributions, single parameter models for real reactor behavior, macromixing and micromixing, segregated flow model and Zweitering's analysis of maximum mixedness, IEM and other models for micromixing. ; Heterogeneous reactors-I: Gas-solid systems- Review of kinetics of gas-solid catalytic reactions with and without diffusion limitations, Reactor design for fixed and fluidized bed reactors, Selected case studies, Non-catalytic gas-solid reactions: review of kinetics; reactor design case studies. ; Heterogeneous reactors-II: Gas-liquid systems- Basic theories of mass transfer with chemical reaction model systems and model reactors, Reactor design for mechanically agitated and bubble column reactors. Selected case studies.

Essential Reading:

Supplementary Reading:

1. F.G.Froment, and K.B. Bischoff, *Chemical Reactor Analysis and Design*, Wiley, 1990.
2. J.B. Rawlings, and J.G. Ekerdt, *Chemical Reactor Analysis and Design Fundamentals*, Nob Hill, 2002.
3. J.J. Carberry, *Chemical and Catalytic Reaction Engineering*, McGraw Hill, 1976.
4. O. Levenspiel, *Chemical Reaction Engineering*, Third edition, Wiley, 1999.
5. J.M. Smith, *Chemical Engineering Kinetics*, McGraw Hill, 1981.
6. L.K. Doraiswamy, and M.M. Sharma, *Heterogeneous Reactions*, Vol. I and II, Wiley, 1984.
7. P.V. Danckwerts, *Gas-Liquid Reactions*, McGraw Hill, 1970.

Pre-requisite: Knowledge in under graduate "Reaction kinetics" and Ideal "Reactor Design".

CH 670	**CHEMICAL ENGINEERING LAB- III (PROCESS DEVELOPMENT LAB)**	**2 credits [0-0-3]**

Scope: The course demands development of new methodology, experimental setup, and related theoretical background.

CH 671	**CHEMICAL ENGINEERING LAB- I (PROCESS**	**2 credits [0-0-3]**

	DEVELOPMENT LAB)	

Scope: This course demands performing experiments on existing setup.

CH 672	**CHEMICAL ENGINEERING LAB- IV (PROCESS DEVELOPMENT LAB)**	**2 credits [0-0-3]**

Professor-In-Charge: Dr. B. Munshi

Scope:

1. Simulation of steady state and Dynamic processes using ASPEN PLUS
2. Simulation of mass transfer processes using Fluent.

CH 673	**CHEMICAL ENGINEERING LAB- II (COMPUTATION LAB)**	**2 credits [0-0-3]**

Professor-In-Charge: Dr. M. Kundu

Scope: Solving linear and non-linear algebraic equations, matrix operations, differential equations, land parameter estimation by linear and non-linear regression methods using ‘C’ language and MATLAB.

DEPARTMENT OF CERAMIC ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
CR 610	Advanced Refractories	3-1-0	4
CR 611	Industrial Furnace Technology	3-1-0	4
CR 612	Refractories for Metallurgical & Allied Processes	3-1-0	4
CR 614	Monolithic Refractories	3-1-0	4
CR 620	Industrial Glass Making	3-1-0	4
CR622	Glass and Glass Ceramic for Technical Application	3-1-0	4
CR 624	Advanced Glasses	3-1-0	4
CR 631	Industrial Ceramic Processing	3-1-0	4
CR 635	Whiteware Production and Practices	3-1-0	4
CR 645	Design and Modeling of Industrial Ceramics	3-1-0	4
CR 647	Advanced Composites	3-1-0	4
CR 652	Applications of Phase Diagrams in Ceramic Industries	3-1-0	4
CR 653	Manufacturing Technology of Electroceramics	3-1-0	4
CR 654	Sintering and Microstructure	3-1-0	4
CR 661	Technical Ceramics	3-1-0	4
CR 662	Ceramics in Energy Sector	3-1-0	4
CR 663	Testing and Characterization of Ceramics	3-1-0	4
CR 664	Ferrite Technology	3-1-0	4
CR 681	Special Topic in Ceramic Engineering - I	3-1-0	4
CR 682	Special Topic in Ceramic Engineering - II	3-1-0	4
CR 683	Special Laboratory in Ceramic Engineering - I	0-0-3	2
CR 684	Special Laboratory in Ceramic Engineering - II	0-0-3	2
CR 685	Seminar & Technical Writing - I	0-0-3	2
CR 686	Seminar & Technical Writing - II	0-0-3	2
CR 687	Seminar & Technical Writing - III	0-0-3	2
CR 688	Seminar & Technical Writing - IV	0-0-3	2
CR 691	Summer Research/ Industrial Project	0-0-0	4
CR 692	Comprehensive Viva Voce	0-0-0	4
CR 693	Research Project – I	0-0-0	20
CR 694	Research Project – II	0-0-0	20

CR 610 ADVANCED REFRACTORIES 4 credits [3-1-0]

Refractories – General Classification, Properties and process flow diagram for fabrication of both shaped and unshaped refractories, particle size distribution, manufacturing techniques of shaped and unshaped refractories, Brief details of various shaped and unshaped refractories.
Comparison between conventional and advanced refractories, examples of various advanced refractories and refractory systems like, ceramic cup for blast furnace, trough refractories, porous plug, slide gate refractories, continuous casting refractories, lance pipes, ceramic filters, etc, their applications, application specific critical properties, oxides and non-oxide components, binders system, manufacturing techniques, detailed properties.
Latest development and trends of refractories in application industries, like iron & steel, glass, cement, etc. global trend of refractories and refractory research, status of refractory industries and research in India, new refractory products and commercialization aspects of new developments. Standards and testing, non-destructive testing for Life Prediction.

Essential Reading:

1. J. H. Chesters, Refractories- Production and Properties, The Iron and Steel Institute, London, 1973.
2. 1. C. A. Schacht, Refractories Handbook, CRC Press. , NY, 2004.

3. S. Banerjee, Monolithic Refractories: A Comprehensive Handbook, Wiley-American Ceramic Society, 1998.

Supplementary Reading:

1. P. P. Budnikov, The Technology of Ceramics and Refractories, Translated by Scripta Technica, Edward Arnold, The MIT Press, 4th Ed, 2003.
2. C. A. Schacht, Refractory Linings: Thermo-mechanical Design and Applications, CRC Press, 1995.
3. M. Rigaud and C. Allaire, Advances in Refractories for the Metallurgical Industries IV, Canadian Institute of Mining, Metallurgy and Petroleum, 2004

CR 611	**INDUSTRIAL FURNACE TECHNOLOGY**	**4 credits [3-1-0]**

Classification of Industrial furnace: Continuous, batch, heat source, fuel, recirculation, heat recovery. Combustion and heat transfer modeling in furnace. Heat transfer: conduction, convection, radiation, electrical. Resistance heating, induction heating, Heating Capacity of batch furnace and continuous furnace. Furnace construction. Furnace Design method. Thermal consideration in Furnace Design. Temperature Modeling for Proper Refractory Selection Materials in furnace construction. Combustion process. Fuels for furnaces. Flames and burners for furnaces. Furnace control and safety. Process control and Instrumentation. Furnace efficiency design. Design and construction of rotary kiln, tunnel kiln, shaft kiln, shuttle kiln. Temperature gradient furnace.

Essential Reading:

1. Peter Mullinger, Barrie Jenkins:Industrial and Process Furnaces: Principles, Design and Operation,Butterworth-Heinemann;2008
2. W. Trinks, M. H. Mawhinney, R. A. Shannon and R. J. Reed,Industrial Furnaces , Wiley-Interscience; 2003

Supplementary reading:

Charles E. Baukal Jr,Heat Transfer in Industrial Combustion,CRC Press; 2000
Samir Sarkar, Fuels and Combustion, CRC Press; 2010

CR 612	**REFRACTORIES FOR METALLURGICAL & ALLIED PROCESSES**	**4 credits [3-1-0]**

Review of metallurgical processes; Iron and steel making principles, Refractory linings for primary and secondary steel making operations, Refractories used in the coke oven, blast furnace, properties and problems, Refractories for hot metal handling, steel refining and secondary steel making. Continuous casting refractories: materials, production, properties and future trends. Hot repairing – Materials, Repairing techniques; Ladle refractories, Direct bonded mag-chrome aggregates, New generation slide gate refractories with improved performance; Principles of extraction of non-ferrous metals of commercial importance especially Cu, Zn and Al. Types of furnaces and refractories used. Factors affecting the performance of refractories; Refractories used in Glass production, Cement industries, Lime calcinations, regenerators, Pottery industries and allied industries. Standardization, testing – including non – destructive testing. Plant trial performance of non shaped and advanced refractories developed using surface chemistry, thermo-mechanical considerations for refractory linings, refractories for the refineries and circulating fluid beds, plasma processing of refractory aggregates, coating techniques for improving the oxidation resistance of graphite. Use of non-oxide ceramic materials in ferrous and non-ferrous industries. Future trends in utilization of refractories. Recent advances in this area.

Essential Reading:

1. J. H. Chesters, *Refractories- Production and Properties*, The Iron and Steel Institute, London.
2. R. Amavis (ed.), *Refractories for the Steel Industry*, Elsevier Applied Science, 1990.

Supplementary Reading:

1. S. C. Caniglia and G. L. Barna, *Handbook of Industrial Refractories Technology*, William Andrews Publishing, NY, 1992.

2. S. Banerjee, *The Changing Refractories Industry: New Tech.,, Materials and Markets*, Business Communication Co, 1999.

CR 614	MONOLITHIC REFRACTORIES	4 credits [3-1-0]

Introduction to monolithic refractories, advantages and disadvantages; classifications based on application techniques, chemical constituents and purity; raw materials and their selection, particles size distribution, discrete and continuous particle size distribution, Furnas, Andreassen-Andersen and Dinger-Funk model; different bonding systems, CaO-Al2O3 system, hydration of calcium aluminates, bonding mechanism of different binders, various additive systems; refractory castable and details of CCC, LCC, ULCC, NCC, SFC; other monolithics, like mortar, gunning mass, spraying mass, ramming mass, etc; machinery and equipments for making unshaped refractories, batch preparation, mixing, processing and manufacturing techniques; installation techniques and application; properties and specialties of different castable systems, like alumina, alumina - magnesia, alumina spinel, magnesia, magnesia carbon, etc

Essential Reading:

1. C. A. Schacht, *Refractories Handbook*, CRC Press, 2004.
2. S. Banerjee, *Monolithic Refractories: A Comprehensive Handbook*, Wiley-American Ceramic Society, 1998.
3. Subrata Banerjee, Thomas Abraham, The changing refractory industry: new technologies, materials, and markets, Business Communications Co., 1999.

Supplementary Reading:

1. Stephen C. Carniglia, Hand book of industrial refractories technology, Principles, Types, Properties and Applications Noyes Publications USA 1992 .
2. Hiemenz PC. Principles of Colloid and Surface Chemistry. 2d ed. New York: Marcel Dekker, 1986.

CR 620	INDUSTRIAL GLASS MAKING	4 credits [3-1-0]

TTT diagram for glass making. Batch materials handling equipments. Process Control for Glass Furnaces Operation, various stages and Statistical Inspection. Design for Energy Saving in Glass Furnaces and Recovery in Heat Regenerator. Thermal consideration in Furnace Design.Temperature Modeling for Proper Refractory Selection. Flux line corrosion: Mechanism and prevention. Oxy Fuel Furnace. Instrumentation: Semsors, Automatic control, Controlling Devices. Gasses in Glass. Glass moulds. Redox and Electrochemical Behavior, Transport Phenomena, Viscosity variation, Surface Tension, Density, Heat Capacity, Heat Transfer in Molten Glass. Electrical Melting. Phase Separation. Design for controlling glass strength. Annealing and Strengthening: Mechanism and Process. Industrial Surface treatment.. Inspection procedure. Quality control in glass Industry and defect analysis. Dimensional and capacity tolerance. Float Glass manufacturing: Stress Distribution profile. Testing methods Pot melting. Day Tank, Float glasss, Container glass, Danner processes. Glass Fiber.

Essential Reading:

1. P.J. Doyle, Glass Making Today, Cbls\Ceramic Books & Literature, 2000
2. L. David Pye, Angelo Montenero, Innocent Joseph Properties of Glass-Forming Melts, CRC Press, 2005
3. Dagmar Hülsenberg, Alf Harnisch, Alexander Bismarck, Microstructuring of Glasses, Springer, 2010

Supplementary Reading:

1. Eric Le Bourhis , Glass: Mechanics and Technology, Wiley-VCH; 2007
2. K.J. Rao, Structural Chemistry of Glasses,Elsevier Science; 2002

CR 622	GLASS AND GLASS CERAMICS FOR TECHNICAL APPLICATION	4 credits [3-1-0]

Glass design based on mechanical, optical and electrical properties. Chemical resistant glass, heat resistance glass, Neutral glass, Glass electrodes, Low dielectric loss glass, Eutectic glass. Optical Glass. Glasses for Plasma Display Panels: LCD, LED and CRT glass. Infrared transmitting glasses.

Chalcogenide, Halide, Oxynitride,oxy-halide glasses. Photonic Glass. Laser glasses. Processing of Optical fiber. Fiber Gratings. Glass Fibers for High Power Lasers. Nonlinear optical glass. Gel glass, Bioglass. Glasses for solar energy application. Digital coloring in glasses. Microstructure and property correlation in glass ceramics. Glass ceramic used in Radome, Photosensetaitve materials, Machinable glass ceramics, Magnetic Memory Disk. Household application of glass ceramics. reflective optics, laser gyroscopes, light weight mirrors, Radiation stability technology, Refractory glass ceramics, Glass and Glass ceramics in biomedical application. Transparent glass ceramics

Essential Reading:

1. Yamane, Glasses for Photonics, Chembridge University Press 2000.
2. W. Holand, Glass Ceramic Technology, The American Ceramic Society, 2002

Supplementary Reading:

1. Paul, Chemistry of Glasses, Chapman and Hall, 2nd Ed., 1990.
2. P. W. McMillan, *Glass Ceramics*, Academic Press, 2nd Ed., NY, 1979.

H. Bachs and D. Krause, *Low Thermal Expansion Glass Ceramics*, Springer, 2005

CR 624	**ADVANCED GLASSES**	**4 credits [3-1-0]**

Metallic glass. Commercial Glass fiber, Glass ceramic. Large Casting. High-Strength Glass Fibers. Mechanics of glass making. Designing Energy-Friendly Glass Fibers, Glass Fibers for Printed Circuit Boards. Designing New Energy-Friendly Glass Compositions. Plasma Melting Technology and Applications. Microwave melting of glass. Designing optical glass. Geometrical Microstructuring of glass. Mechanical Structuring Processes. Micromachining. Ultrasonic Machining. Powder Blasting. Chemical and Complex Structuring. Pull Extrusion. Electrochemical Discharge Machining. Embossing and Press Forming. Laser Processing. Photostructuring. Joining Methods.Glass sealing. Lapping and polishing. Contact resistance of glasses. Aging of glasses. Self healing of glasses. Self cleaning glass manufacturing. Production control of residual stress. Optical fiber design and manufacturing. Glass design based on thermal expansion.

Essential Reading:

1. Dagmar Hülsenberg, Alf Harnisch, Alexander Bismarck, Microstructuring of Glasses, Springer, 2010
2. Eric Le Bourhis , Glass: Mechanics and Technology, Wiley-VCH; 2007

Supplementary Reading:

1. H. Bachs and D. Krause, *Low Thermal Expansion Glass Ceramics*, Springer, 2005
2. L. David Pye, Angelo Montenero, Innocent Joseph Properties of Glass-Forming Melts, CRC Press, 2005

CR 631	**INDUSTRIAL CERAMIC PROCESSING**	**4 credits [3-1-0]**

Unit operations in ceramic fabrication, particle size reduction, particle size distribution, jaw crusher, hammer mill, high impact roller crusher, ball mill, jet mill, particle classification technologies, screening, cyclone separation, centrifuge, filtration, washing; Colloidal Processing: basic surface forces, stabilization of colloidal suspensions, electrostatic stabilization, electrical double layer theory, zeta potential, steric stabilization, plasticizers, foaming and antifoaming agents, rheology of colloidal suspension; Forming of Ceramics: particle packing, additives in ceramic forming, dry and semi-dry pressing, isostatic compaction, slip casting, pressure casting, gel casting, tape casting, EPD, extrusion, injection moulding; Drying of Ceramics: drying of layers and solids, binder removal, drying defects, drying shrinkage, advanced drying technologies; Sintering: Basics of sintering, driving forces, sintering variables, solid state and liquid phase sintering; Industrial Firing Technologies: batch and continuous furnaces, design and operation of furnaces, fuel economy, thermal efficiency, Sankey diagram, regenerators and recuperators, chimney design, pyrometry, energy balance calculations.

Essential Reading:

1. W. L. McCabe, J. C. Smith and P. Harriot, Unit Operations of Chemical Engineering, 7 th Ed., McGraw-Hill Professional 2005.
2. M. N. Rahaman, Ceramic Processing and Sintering, CRC Press, 2003
3. J.S. Reed, Introduction to the Principles of Ceramic Processing, 2nd Ed., John Wiley & Sons. 1995.

Supplementary Reading:

1. D. W. Richerson, *Modern Ceramic Engineering: Properties, Processing, and Use in Design*, 3rd ed, CRC Press, 2006.
2. D. A. Brosan and G. C. Robinson, *Introduction to Drying of Ceramics*, The American Ceramic Society, Ohio, USA, 2003.
3. H. Mehrer, *Diffusion in Solids: Fundamentals, Methods, Materials, Diffusion Controlled Processes*, Springer, 2007.

CR 635	WHITEWARE PRODUCTION AND PRACTICES	4 credits [3-1-0]

General definition and classification, Raw materials, clay water system, rheology, viscosity, whiteware manufacturing techniques like slip casting, wheel, extrusion, jiggering & jolleying, turning, pressing, etc, drying & firing. Glazing and decoration, properties of whitewares.Tiles technology: description and classification, detailed raw materials, manufacturing techniques and flow diagram, properties and specifications, Sanitaryware technology: , Raw materials, manufacturing techniques and flow diagram, body preparation, properties and specifications, Insulator technology: Essential properties for insulator, specifications, manufacturing techniques and flow diagram,Pottery and bone china technology: description and classification, raw materials, process details and flow diagram, properties and specifications,

Essential Reading:

1. Industrial ceramics – singer and Singer
2. Fine ceramic – F. H. Norton
3. Whitewares: Production, Properties and Quality Control - W. Ryan and C. Radford, Pergamon Press, Oxford, 1987.

Supplementary Reading:

1. Ceramic Whiteware - Sudhir Sen
2. Science of Whitewares, - V. E. Henkes, George Y. Onoda, W. M. Carty

CR 645	DESIGN AND MODELING OF INDUSTRIAL CERAMICS	4 credits [3-1-0]

Concepts and Principles of Engineering Design, Materials Selection Methodology. Statistical Design, Use of Computers in Design of Ceramic Bodies and Processes, Developing a Design Protocol for Load-Bearing Applications. Role of Thermal Expansion and Conductivity in Design Designing for Severe Thermal Stresses, Thermal Protection Design, Designing Glass Fibers, Designing Whitewares, Design of an Orthopedic Joint, Design Optimization of Ceramic-to-Metal Joints. Designing for Thermochemical Applications, Designing with Piezoelectric Devices. Integrated Process Design .

Essential Reading:

1. David E. Clark, Diane C. Folz and Thomas D. McGee (Edited) An Introduction to Ceramic Engineering Design Wiley-Blackwell (2002)
2. D. Raabe, *Computational Materials Science:The Simulation of Materials Microstructure and Properties*, Wiley-VCH, 1998

Supplementary Reading:

1. M. Meyer and V. Pontikis, *Computer Simulation in Materials Science: Inter-atomic Potentials, Simulation, Techniques and Applications*, Kluwer Academic, 1991

K. Ohno, K. Esfarjani and Y. Kawazoe, *Introduction to Computational Material Science: from ab initio to Monte Carlo methods*, Springer-Verlag, 1999

CR 647	ADVANCED COMPOSITE	4 credits [3-1-0]

Composites- Definition, Classification, matrices and their properties. Importance of glass, ceramic and carbon fibres, polyster, epoxies, thermosetting and thermoplastic materials. Fabrication, structure, properties and application; Common ceramic matrix composite material and their properties, interfaces in composites, interaction at the interface. Types of reinforcement: continuous fiber, short fiber, whisker, glass fiber, carbon/graphite fiber, natural fiber, boron carbide silicon carbide fiber; Ceramic Matrix composites: Fabrication, properties, and uses, interface reaction, toughness; Specific examples - Alumina silicon carbide, Mullite- Zirconia, polymer-PZT composites, Processing and application; Mechanics of properties of composites: Density, Mechanical properties, mechanism of load transfer from matrix to fiber, variation of lamina properties with orientation, tensile and compressive strength of unidirectional fiber composite, fracture in composites, debonding, fiber pull out, delamination fracture; Qualty and testing; material testing, mechanical testing, thermal and environmental testing, flamibility testing, non-destructive testing; Composite design; stress type, lamination theory, modeling and finite element analysis. Recent advances in this area.

Essential Reading:

1. G. F. Carter and D. F. Paul, *Materials Science and Engineering*, ASM International, 1991.
2. J. F. Shackelford and M. Meier, *Introduction to Materials Science for Engineers*, Prentice Hall PTR, 2005.

Supplementary Reading:

1. F. L. Matthews and R. D. Rawlings, *Composite Materials: Engineering and Science*, Chapman and Hall, 1994.
2. K. K. Chawla, *Composite Materials: Science and Engineering*, Springer- Verlag, 1987.
3. W. Krenkel (Editor) *Ceramic Matrix Composites: Fiber Reinforced Materials and their Applications,* Wiley-VCH, 2008.

CR 652	APPLICATIONS OF PHASE DIAGRAMS IN CERAMIC INDUSTRY	4 credits [3-1-0]

Use of Phase Diagrams: in Alumino-silicate refractory; Al2O3-SiO2, Al2O3-SiO2-K2O/Fe2O3, In Silica Brick; CaO-SiO2, Fe2O3-SiO2, SiO2-CaO-Al2O3, In Basic Refractories; MgO-FeO/Fe2O3, MgO-CaO-SiO2, In Spinel bonded Refractory; MgO-MgAl2O4, MgO-MgCr2O4, In Dolomite-C brick; CaO-MgO-Fe2O3/FeO. In Fusion-cast refractory. Application in Cement Chemistry; CaO-SiO2, CaO-Al2O3, CaO-SiO2-Al2O3, In Extraction Metallurgy; Blast Furnace Slag, Metallurgical Slag, In Sintering of Ceramics; WC-Co, Porcelain Transparent Yttria, Alumina and Magnesium Aluminate Lead-lanthanum-zirconium-titanate (PLZT), preparation and application of phase diagram: Y2O3-La2O3, Y203-AI203, Al2O3-MgO, Al2O3-MgAl2O4, MgAl2O4-MgO etc. Fe-C Phase diagram, In ZrO2 Stabilization, etc.

Essential Reading:

1. W. D. Kingery, H. K. Bowen and D. R. Uhlmann, *Introduction to Ceramics*, 2nd Ed. John Wiley & Sons, Singapore, 1991.
2. F. A. Hummel, *Introduction to Phase Equilibrium in Ceramic Systems*, First Edition, CRC Press, 1984.
3. Allen M. Alper, Phase Diagrams, Materials Science and Technology, Vol-II, 1970 ACADEMIC PRESS, INC
4. Allen M. Alper, Phase Diagrams in Advanced Ceramics, 1995 by ACADEMIC PRESS, INC

Supplementary Reading:

1. G. Smith, R. S. Roth, T. Negas, L. P. Cook, *Phase Diagrams for Ceramists*, American Ceramic Society, 1983

CR 653 MANUFACTURING TECHNOLOGY OF ELECTROCERAMICS 4 credits [3-1-0]

Electrical and electronic conduction in ceramics, defect chemistry, ionic conductivity, ceramic electrolytes and fast ion conductors, ceramic insulators; Ceramic Capacitors, piezoelectric, ferroelectric and electro optic ceramics - material systems, processing and fabrication; Origin of magnetism in solids, classification of magnetic materials, soft ferrite, hard ferrite, spinel ferrite, hexagonal ferrite, garnet ferrite-processing, properties and applications; Ceramic Sensors and resistors- classification, materials systems, processing and applications. Positive temperature coefficient and negative temperature coefficient ceramics – thermistor, gas sensor, humidity sensor, pressure sensors, ZnO-varistors technology, varistor microstructure and fabrication, mechanism, equivalent circuit. Varistor application, ceramic thick film technology, materials and processing. Electro ceramic thin film technology, materials and deposition methods, application of thin films in microelectronics and micro systems; Multilayer ceramic technology – Sequential, laminated MLC processes, processing of multi layer ceramics, sintering of multilayer structure. Low temperature co-fired glass ceramics. Recent advances in this area.

Essential Reading:

1. R. C. Buchanan (Edt.), *Ceramic Materials for Electronics*, 3rd edition Marcel Dekker, NY, 2004.
2. L. M. Levinson, *Electronic Ceramics*, Marcel Dekker, NY, 1988.

Supplementary Reading:

1. A. J. Moulson and J. M. Herbert, *Electroceramics: Materials, Properties and Applications*, Wiley; 2nd edition, 2003.
2. B. Jaffe, W. R. Cook, H. Jaffe and H. L. C. Jaffe, *Piezoelectric Ceramics*, R.A.N Publishers, 1990.

CR 654 SINTERING AND MICROSTRUCTURE 4 credits [3-1-0]

Fundamentals, defects and defect chemistry, intrinsic, extrinsic defects, defect reactions, diffusion and defects, mechanisms of diffusion, types of diffusion co-efficients, chemical potentials of different systems, diffusional flux equation, ambipolar diffusion, driving force for sintering; Solid state and viscous sintering, theoretical analysis, Herrings-Scaling law; sintering models and sintering diagrams, intial, intermediate, final stage sintering models. Sintering with an externally applied pressure – Hot Pressing and Hot Isostatic Pressing, stress in densifiction factor and sintering stress; Grain growth and Ostwald ripening. Normal and exaggerated grain growth, grain growth in dense and porous solid, grain growth kinetics, pore-grain boundary interactions, densification and coarsening, simultaneous densification and grain growth; Liquid phase sintering, mechanism, stages and microstructure of liquid phase sintering. Pressure assisted liquid phase sintering, activated sintering, vitrification Advanced techniques: Microwave sintering and spark plasma sintering Problems of sintering: Constrained sintering; Sintering of thin films; Sintering with a chemical reaction. Recent advances in this area.

Essential Reading:

1. J. Reed, *Introduction to the Principles of Ceramic Processing*, 2nd Ed., John Wiley & Sons. 1995.
2. M. N. Rahaman, *Sintering of Ceramics*, CRC Press, 2008.
3. C. Kittel, *Introduction to Solid State Physics*, 8th Ed. John Wiley & Sons Pvt. Ltd, 2004.

Supplementary Reading:

1. D.W. Richerson, *Modern Ceramic Engineering: Properties, Processing, and Use in Design,* 3rd Ed, CRC Press, 2006.
2. P. G. Shewmon, *Diffusion in Solids,* McGraw Hill, NY, 2nd edition, February 1998.
3. S. Somiya and Y. Moriyoshi Eds., *Sintering Key Papers,* Elsevier Applied Science, London, 1990.

CR 661 TECHNICAL CERAMICS 4 credits [3-1-0]

Introduction and classification of Technical Ceramics, Brief review of Griffith theory of fracture, toughness, statistical nature of strength. Alumina and alumina ceramics Crystal structure, phases, types of alumina, properties and its relation to microstructure, importance and application. Zirconia Ceramics Crystal structure and polymorphic modifications, Transformation Toughening; different system in zirconia. Composites: strengthening and toughening mechanisms, composite fabrication. Composites of some oxides and nonoxides.Classification of non-oxide ceramics, silicon carbide, silicon nitride Sialon, Tungsten Carbide, Boron Carbide, Boron Nitride, Carbon and Graphite, phase diagrams, processing, sintering and properties. Abrasives; natural and synthetic; properties, applications in Aerospace, Automotive, Household Applications, Electronics, Industrial Equipment, Medical, Power Generation & Distribution, Security and DefenceSemiconductor, electronic, ionic conductors and fast ion conductors; defects in fluoride type and perovskite oxides; conduction process and transference number; electronic conduction in oxides; semiconductor - metal transition; Ionic conduction in oxides; fast –ion conductors;resistors and varistors; ceramic capacitors; Ceramic in Electronic Packaging; Piezoelectric materials, properties and its Industrial applications; electro-optic ceramics; Super conductivity: basic principles; materials; synthesis and Industrial applications; Magnetic Ceramics: Introduction; magnetic Materials: soft and hard; synthesis; characterization and applications,

Essential Reading:

1. W. E. Lee and W. M. Rainforth, *Ceramic Microstructures: Property Control by Processing*, Springer, 1994.
2. J. B. Wachtman Jr., *Structural Ceramics*, Treatise on Materials Science & Technology Vo l- 29, Academic Press, New York, 1989.
3. J. Moulson and J. M. Herbert, *Electroceramics: Materials, Properties and Applications*, 2^{nd} Edition, John Wiley & Sons Ltd, 2003.
4. Mechanical Properties of Ceramics, JOHN B. WACHTMAN, W. ROGER CANNON, M. JOHN MATTHEWSON, 2^{nd} Edition, John Wiley & Sons Inc, 2009

Supplementary Reading:

1. E. Dorre and H. Hubner, *Alumina: Processing, Properties and Applications*, Springer- Verlag, Berlin Heidelberg, 1984.
2. R. C. Buchanan, *Ceramic Materials for Electronics: Processing, properties and applications*, Marcel Dekker, 1986

CR 662 CERAMICS IN ENERGY SECTORS 4 credits [3-1-0]

Refractory for energy saving application. Li-Battery Technologies and Energy Storage. Fuel Cells and Solid Oxide Fuel Cells (SOFC). Design of Fuel Cell. Cathode materials. Anode Materials. Electrolyte.Interconnect. Glass ceramic seals. Ceramic based Membrane for fuel Cell. Ceramic capacitor. Light-Emitting Diode. Thermal design of ceramic packages for high power light-emitting diodes. White Light Generation. Phosphor. Upconversion and downconversion phosphor. Rare earth phosphor. Transparent glass ceramics. Transparent alumina. Solar Energy and Photovoltaic Energy. Ceramic substrate for solar cell. Thin film solar Cell. ITO thin film. Nuclear Energy.

Essential Reading:

1. S.C. Singhal, K. Kendall High-temperature Solid Oxide Fuel Cells: Fundamentals, Design and Applications, Elsevier Science; 2003

CR 663 TESTING AND CERAMIC CHARACTERIZATION 4 credits [3-1-0]

Thermal analysis methods- principles, instrumentation, data analysis and applications in ceramics; X-ray diffraction and Bragg Law, Diffraction under ideal and non-ideal condition, X-ray scattering and structure factor, X-ray diffractometer, X-ray data file analysis, Chemical analysis by x-ray fluorescence, Auger Electron Spectroscopy, X-ray Photoelectron Spectroscopy, Electron loss energy spectroscopy; Scanning Electron Microscopy – basic principle, instrumentation, electron specimen interaction, topographical and atomic number contrast. Transmission Electron Microscopy; practical aspect of microscopy, amplitude and phase contrast imaging, kinematical theory of image contrast, electron diffraction. Atomic Force Microscopy- basic principles, Atomic Force Microscopy modes, phase imaging, face curve, application of Atomic Force Microscopy; Infrared, Raman and Nuclear magnetic resonance spectroscopy: field ion microscopy, Basic principles, Instrumentation, Infra red and Raman active bonds, data analysis, applications, surface analysis and chromatography techniques for material characterization.

Essential Reading:

1. R. F. Speyer, *Thermal Analysis of Materials*, Marcel Dekker Inc., 1994.
2. B. D. Cullity, *Elements of X-ray Diffraction*, Addison Wesley Publishing Company; 2nd edition,1978.
3. P.J. Goodhew, J. Humphreys, R. Beanland, *Electron Microscopy and Analysis*, Third Edition, Taylor & Francis, 2001.

Supplementary Reading:

H. P. Klug and L. E. Alexander, *X-ray Diffraction procedures for Polycrystalline and Amorphous Materials*, 2nd Edition, John Wiley, 1974.

1. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental Analysis*, 5th Ed., Hartcourt College Publishers, 1998.

CR 664	FERRITE TECHNOLOGY	4 credits [3-1-0]

Basics of Magnetism, Magnetization in domains and bulk materials, AC properties of ferrites; Hysteresis, Eddy Current loss, Permeability, Core loss, Microwave properties. Crystal structure of ferrites. Chemical and Microstructural aspect of ferrites. Ferrite processing and application. Physical, Mechanical and thermal aspects of ferrites, Magnetic measurements on ferrite materials and components. Ferrites for permanent Magnetic application, Inductors and Transformer for low power and high power applications, Pot core, Low Level Transformer, Power Transformer, Inverters, Converters, MLC Indictor, LC Filter, Ferrite for EMI suppression, Ferrites for Radio and TV applications, Deflection Yokes, Antennas, Ferrites for magnetic recording, Recording media, heads, Magnetoresistive heads. Microwave applications. Magnetostrictive Transducers, Sensors. Ferrofluids.

Essential Reading:

1. Alex Goldman, Modern Ferrite Technology, Springer, 2006.
2. Smit, J. and Wijn, H.P. Ferrites, New Yourk, John Wiley and Sons, 1959.
3. B. D. Cullity, C. D. Graham, Introduction to Magnetic Materials, Wiley, 2008

Supplementary Reading:

1. Nicola A. Spaldin, Magnetic Materials: Fundamentals and Applications, Cambridge University Press, 2011.
2. J. M. D. Coey, Magnetism and Magnetic Materials, Cambridge University Press, 2009.
3. Robert C. O'Handley Modern Magnetic Materials: Principles and Applications, John Wiley and Sons, 2000.

CR 671	PROCESS CERAMICS LABORATORY	2 credits [0-0-3]

1. Determination of particle size and particle size distribution by Andreasen Pipette and Centrifuge.
2. Effect of milling time on the surface area and phase transformation of ceramic powder.
3. Effect of additives on the rheological properties of oxide ceramic slurries.
4. Slip casting of oxide ceramics and study of casting process.
5. Effect of processing parameter on the properties of slip cast bodies.

6. Effect of binder type and amount on the green strength of dry-pressed article.
7. Effect of relative humidity on the green density of dry pressed bodies.
8. Study of compaction behaviour of ceramic powder.
9. Effect of powder and pressing properties on the generation of various defects in dry pressed articles.
10. Effect of different drying conditions on the properties of dried articles prepared by slip casting.

CR 672 REFRACTORY LABORATORY 2 credits [0-0-3]

1. Determination of packing density of mono component and multi component systems.
2. Effect of size ratio on the on the packing density in multi component systems.
3. Effect of weight ratio of different sizes on the packing density of multi component system.
4. Selection of multi component system for making refractory shape.
5. Green binder preparation and shape making.
6. Effect of pressing pressure on the green density and optimization of the same.
7. Drying and firing study of the prepared refractory shapes.
8. Characterization of fired refractory shapes for various physical properties.
9. Measurement of PLCR of the prepared refractory shapes.
10. Measurement of mechanical properties, both at ambient and elevated temperatures.
11. Batch calculation, preparation and making of unshaped refractory.
12. Casting and shaping of the prepared unshaped refractory batch.
13. Drying and firing at different temperatures of the prepared unshaped refractory.
14. Characterization for physical properties of the unshaped refractory batch.
15. Characterization for mechanical properties, at ambient and elevated temperatures of the unshaped refractory batch.

CR 673 WHITEWARE CHARACTERIZATION LAB 2 credits [0-0-3]

1. Study the effect of clay composition on whiteware body
2. Study the effect of different fluxes on whiteware body
3. Study the effect of different anti shrinkage agent on white ware body
4. Preparation of tiles by uniaxial pressing methods
5. Study of effect of solid loading on the rheological properties of slip
6. Effect of firing on steatite, cordierite and bone china body
7. Preparation of colored and transparent glaze
8. Preparation of white ware body by extrusion method
9. Preparation of white ware body by turning method
10. Study of chemical resistance properties of whiteware body
11. Study of crazing behavior of whiteware body
12. Study of mechanical properties of whiteware body

CR 674 GLASS LABORATORY 2 credits [0-0-3]

1. Different Optical Glass Processing
2. Sol gel synthesis of monolithic glass
3. Defect analysis of glass
4. Glass Ceramic Processing
5. Viscosity measurement of glass
6. Effect of heat treatment on glass ceramic properties
7. Mechanical Property testing of glass and glass ceramic
8. Spectral analysis of different coloring ions of glass and glass ceramic
9. Thin film coating on glass by spin coating
10. Thin film coating on glass by dip coating
11. AFM analysis of glass surface
12. Microstructural characterization of glass ceramics

CR 681	**SPECIAL TOPIC IN CERAMIC ENGINEERING - I**	**3-1-0**	**4**
CR 682	**SPECIAL TOPIC IN CERAMIC ENGINEERING - II**	**3-1-0**	**4**
CR 683	**SPECIAL LABORATORY IN CERAMIC ENGINEERING - I**	**0-0-3**	**2**
CR 684	**SPECIAL LABORATORY IN CERAMIC ENGINEERING - II**	**0-0-3**	**2**
CR 685	**SEMINAR & TECHNICAL WRITING - I**	**0-0-3**	**2**
CR 686	**SEMINAR & TECHNICAL WRITING - II**	**0-0-3**	**2**
CR 687	**SEMINAR & TECHNICAL WRITING - III**	**0-0-3**	**2**
CR 688	**SEMINAR & TECHNICAL WRITING - IV**	**0-0-3**	**2**
CR 691	**SUMMER RESEARCH/ INDUSTRIAL PROJECT**	**0-0-0**	**4**
CR 692	**COMPREHENSIVE VIVA VOCE**	**0-0-0**	**4**
CR 693	**RESEARCH PROJECT – I (INDUSTRIAL BASED)**	**0-0-0**	**20**
CR 694	**RESEARCH PROJECT – II (INDUSTRIAL BASED)**	**0-0-0**	**20**

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
CS 610	Software Design	3-1-0	4
CS 611	Foundations of E-Commerce	3-1-0	4
CS 612	Software Engineering	3-1-0	4
CS 613	Combinatorial Optimization	3-1-0	4
CS 614	Software Project, Process and Quality Management	3-1-0	4
CS 615	Software Testing	3-1-0	4
CS 616	Algorithm Design	3-1-0	4
CS 617	Graph Theory and Network Algorithms	3-1-0	4
CS 618	Real Time Systems Design	3-1-0	4
CS 619	Software Engineering Requirements, and Modeling	3-1-0	4
CS 620	Software Testing	3-1-0	4
CS 621	Cryptographic Foundations	3-1-0	4
CS 622	Design of Computer Networks	3-1-0	4
CS 623	Ad-hoc and Wireless Networks	3-1-0	4
CS 624	Database Engineering	3-1-0	4
CS 625	Data Mining and Data Warehousing	3-1-0	4
CS 626	Intrusion Detection Systems	3-1-0	4
CS 627	Wireless Network Security	3-1-0	4
CS 628	Wireless Sensor Networks	3-1-0	4
CS 629	Network Security	3-1-0	4
CS 630	Artificial Intelligence	3-1-0	4
CS 631	Information Theory and Coding	3-1-0	4
CS 632	Distributed Operating Systems	3-1-0	4
CS 633	Game Theory	3-1-0	4
CS 634	Bioinformatics	3-1-0	4
CS 635	Biometric Security	3-1-0	4
CS 636	Image Processing	3-1-0	4
CS 637	Digital Signal Processing	3-1-0	4
CS 638	Pattern Recognition	3-1-0	4
CS 639	Soft Computing	3-1-0	4
CS 640	Requirements Engineering	3-1-0	4
CS 641	Advanced Computer Architecture	3-1-0	4
CS 642	Cluster and Grid Computing	3-1-0	4
CS 643	Embedded Systems	3-1-0	4
CS 644	Fault Tolerant Computing	3-1-0	4
CS 645	Parallel Algorithms	3-1-0	4
CS 646	Parallel and Distributed Computing	3-1-0	4
CS 647	Performance Evaluation of Computer Systems and Networks	3-1-0	4
CS 648	Security and Fault Tolerance in Distributed System	3-1-0	4
CS 649	VLSI System Design	3-1-0	4
CS 650	Software Metrics	3-1-0	4
CS 651	Software Reliability	3-1-0	4
CS 652	Software Architecture	3-1-0	4
CS 653	Software Processes	3-1-0	4
CS 656	Software Configuration Management	3-1-0	4
CS 657	Principles of Management	3-1-0	4

CS 666	Software Design Laboratory	0-0-3	2
CS 670	Programming Laboratory – I	0-0-3	2
CS 671	Programming Laboratory – II	0-0-3	2
CS 672	Software Engineering Laboratory	0-0-3	2
CS 673	Image Processing Laboratory	0-0-3	2
CS 674	Network Simulation Laboratory	0-0-3	2
CS 675	Soft Computing Laboratory	0-0-3	2
CS 676	Cryptography Laboratory	0-0-3	2
CS 678	OS and Database Security Laboratory	0-0-3	2
CS 679	Biometrics Laboratory	0-0-3	2
CS 680	Cryptography Laboratory - II	0-0-3	2

CS 611 FOUNDATION OF E- COMMERCE 4 Credits [3-1-0]

Introduction to Business/Network Concepts, Technology and business integration*. The Hardware of E commerce:* Introduction to networks, Introduction to the, business server, *Electronic Business Structure:* Protocols, The WebPages, Portals of Business, Web salesmanship, Introduction to the client machine and OS. Business *servers:* Mail, Applications, Proxy, Entertainment, ISP, Banking. *Advertising on the Network:* Web software infrastructure, personalization and tracking, Web Billboards, The 'Hit' Theory, Intellectual property for sale, 'Bots'. Business *Netiquette:* Dos and Don't of WebPages, Client service, Personnel ,Technical support, Network services ,Accounting and statistics, integration of catalogs and other trading information. Business *Security:* The Credit card on the Net, Secure transmission , Internal security of telephony, E mail security, auctions and trading mechanisms, safe exchange, payment mechanisms and protocols, searching hyperlink structures, data mining, copy right protection and security. Special topics in E-Commerce.

Essential Readings:
1. W. Hanson, *Principles of Internet Marketing*, South Western Publishing, 2004.
2. K. K. Bajaj & D. Nag, *E Commerce*, Tata McGraw Hill, 2006.

Supplementary Readings:
1. R. Kalakola and A. B. Whiston, *Frontiers of Electronic Commerce*, Addison-Wesley, 1996.
2. Greensein, Feinman, *Electronic Commerce Security,* Risk management and Control, Tata McGraw Hill, 2000.
3. *Green Stein*, *Electronic Commerce*, Tata McGraw Hill, 2007.

CS 612 SOFTWARE ENGINEERING 4 Credits [3-1-0]

Software Life Cycle Models, Managing software projects, Project management concepts, Software process and Project metrics, Software Project Planning, Risk Analysis and Management, Project scheduling and tracking, Software Quality Assurance, Software Configuration Management. Conventional methods for software engineering, System Engineering, Requirements Analysis and Specifications, Analysis Modeling, Design Concepts and principles, Architectural design, User Interface Design, Component level Design, Software Testing Techniques, Software testing Strategies, Software Reliability, Technical metrics for software, CASE tools, Software Maintenance, Software Reusability. Object Oriented software engineering: Object Oriented Concepts and principles, Object Oriented analysis, Object Oriented Design, and Object Oriented testing, Technical metrics for Object Oriented Systems. Special topics in Software Engineering.

Essential Readings:
1. R. S. Pressman, *Software Engineering A Practitioner's Approach*, McGraw Hill Publications, 2006.
2. R. Mall, *Fundamentals of Software Engineering*, Prentice Hall of India, 2nd Ed, 2006.

Supplementary Readings:

1. I Sommerville, *Software Engineering*, Pearson Education, Asia, 2006.
2. P. Jalote, *An Integrated Approach to Software Engineering*, Narosa, 3rd reprint, 2006.
3. A. Behferooz & F. J. Hudson, *Software Engineering Fundamentals*, Oxford Univ. Press, 2000.
4. Baude, *Object Oriented Software Engineering*, Wiley, 2006.

CS 613	**COMBINATORIAL OPTIMIZATION**	**4 Credits [3-1-0]**

Optimization Problem: Global and Local optima; Convex sets and functions; Convex programing problem; Simplex algorithm: Forms of linear programming problem; Geometry of linear program; Duality: Dual of a linear program in general form; shortest path problem and its dual; Dual simplex algorithm; Primal dual algorithm: Shortest path problem, max flow; Algorithms and complexity: Computability; time bound; analysis of algorithm; polynomial time algorithm; Algorithm for matching; weighted matching. Special topics in Combinatorial Optimization

Essential Reading:
1. C. H. Papadimitriou, K. Steiglitz, *Combinatorial optimization: algorithm and Complexity*, Prentice Hall of India, 2006.
2. D. Knuth, *Art of Computer Programming*, Vol. IV, Addison Wesley, 1st ed. 2008.

Supplementary Reading:
1. C. H. Papadimitriou, *Computational Complexity*, Addison Wesley, 1st ed. 2002.

CS 614	**SOFTWARE PROJECT, PROCESS AND QUALITY MANAGEMENT**	**4 Credits [3-1-0]**

Introduction to S/W project management, S/W project management competencies, responsibilities of a software project manager, Software process, S/W process models, project planning, organization of project team, S/W size estimation, estimation of effort & duration, Halstead’s software Science, models, dependency & scheduling, staffing, Organizing a software engineering project, S/W configuration management, monitoring & controlling S/W projects, developing requirements, risk management, project tracking & control, communication & negotiating, S/W quality, S/W quality engineering, defining quality requirements, quality standards, practices & conventions, ISO 9000, ISO 9001, S/W quality matrices, managerial and organization issues, defect prevention, reviews & audits, SEI capability maturity model, PSP, six sigma. Special topics in process and quality management.

Essential Reading:
1. B. Hughes, M. Cotterell, *Software Project Management*, McGraw Hill, 4th ed, 2005.
2. R. Walker, *Software Project Management*, Pearson, 2003.

Supplementary Reading:
1. R. H. Thayer, *Software Engineering Project management*, IEEE CS Press, 2nd Ed, 1988.
2. R. Pressman, *Software Engineering A Practitioner’s approach*, McGraw Hill, 4th Ed, 2005.

CS 615	**SOFTWARE TESTING**	**4 Credits [3-1-0]**

Introduction, Basic concepts, discrete mathematics for testers, Graph theory for testers, Black box testing: Boundary value testing, Equivalence class testing, White box testing: statement coverage, Branch coverage, condition coverage, path coverage, Mc Cabe’s cyclomatic complexity; Decision Table based testing, Data flow based testing, Integration testing, System testing, Interaction testing, Performance testing, Mutation testing, Regression testing, error seeding , object oriented testing: issues in object oriented testing , Test case design by object oriented software, Fault based testing, test cases and class hierarchy, Scenario based Test design, Testing surface structure and deep structure, Class testing: Random testing for object oriented classes, Partition testing at the class level; Inter class test case design: multiple class testing, tests derived from behavior models, Test case generation using UML diagrams, GUI testing, object oriented system testing. Special topics in software testing.

Essential Reading:

1. C. J. Paul, *Software testing: A craftsmen's approach*, CRC Press, 2nd Ed, 2002.
2. R. Gopalswamy, *Software testing*, Pearson, 2005.

Supplementary Reading:

1. G. J. Myers, *The art of software testing*, Wiley Interscience New York, 2005.
2. R. S. Pressman, *Software Engineering A Practitioner's approach*, McGraw Hill, 4th Ed, 1982.
3. R. Mall, *Fundamentals of Software Engineering*, Prentice Hall of India, 2nd Ed, 2003.

CS 616 ALGORITHMS DESIGNS 4 Credits [3-1-0]

Measuring Algorithm Efficiency: Implementation independent measurement of algorithm efficiency, time and space resources, growth in terms of input size, polynomial vs. exponential growth algorithms, worst and average case efficiency, big Oh notation, algorithm efficiency vs. inherent problem (any algorithm) complexity, deterministic and non deterministic algorithms, algorithm analysis techniques, amortization, standards and implementation dependent resource measurement. Algorithm Design Paradigms: Characterization of algorithm design paradigms, Utilization of design paradigms for problems across application areas of sorting, selection, computer arithmetic and algebraic computation, graphs and networks, computational geometry. Computation Models and Complexity: NP Complete Problems, NP hard problems, Proving of problem to NP Complete, different NP complete problem. Approximation Algorithms, Randomized Algorithms: Some Complexity Classes, Computing π, Numerical Integration, Primality Testing, Randomize Algorithm for Majority Element, Graph Algorithms, Lower Bound Techniques, Nature Inspired Algorithms: Genetic algorithm; Ant Colony Optimization, DNA algorithms, Parallel Algorithms: Memory Multiprocessor. Special topics in algorithms design.

Essential Reading:

1. S. K. Bose, *Design Methods and Analysis of algorithms*, Prentice Hall of India, 2005.
2. A. Levitin, *Introduction to the design & analysis of Algorithms*, Pearson, 2003.

Supplementary Reading:

1. M. A. Weiss, *Data Structures and Algorithm Analysis in Java*, Pearson, 2003.
2. T. H. Cormen, C. E. Leiserso, and Ronald L. Rivest, *Introduction to Algorithms*, Prentice Hall of India, 2005.
3. Baase and Gelder, *Computer Algorithms, Introduction to design & Analysis*, Pearson, 2000.

CS 617 GRAPH THEORY AND NETWORK ALGORITHMS 4 Credits [3-1-0]

Introduction: Graphs, Isomorphism, Walks, Paths, Circuits, Trees, Properties of Trees, Cotrees and Fundamental Circuits, Cut Sets, Fundamental Cut Sets and Cut Vertices, Planar and Dual Graphs, Metric Representation of Graphs, Coloring and covering and partitioning of a graph, chromatic number, chromatic partitioning, chromatic polynomials, matching, covering, four color problem, Directed graphs, some type of directed graphs, Directed paths, and connectedness, Euler digraphs, trees with directed edges, fundamental circuits in digraph, matrices A, B and C of digraphs adjacency matrix of a digraph,, enumeration, types of enumeration, counting of labeled and unlabeled trees, polya's theorem, graph enumeration with polya's theorem; **Graph Algorithms**: Elementary Graph Algorithms, Representations of graphs, Breadth-first search, Depth-first search, Topological sort, strongly connected components; **Minimum Spanning Trees:** Growing a minimum spanning tree, The algorithms of Kruskal and Prim, **Single-Source Shortest Paths:** Shortest paths and relaxation, Dijkstra's algorithm, The Bellman-Ford algorithm, Single-source shortest paths in directed acyclic graphs, Difference constraints and shortest paths, **All-Pairs Shortest Paths:** Shortest paths and matrix multiplication, The Floyd-Warshall algorithm, Johnson's algorithm for sparse graphs, and A general framework for solving path problems in directed graphs; **Maximum Flow:** Flow networks, The Ford-Fulkerson method, Maximum bipartite matching, Preflow-push algorithms, The lift-to-front algorithm. Special topics in graph theory and network algorithms.

Essential Reading:

1. T. H. Cormen, C. E. Leiserson and R. L. Rivest, *Introduction to Algorithms*, Prentice Hall of India, 3rd ed, 2006.
2. N. Deo, *Graph Theory with Applications to Engineering and Computer Science*, Prentice Hall of India, 2004.

Supplementary Reading:

1. D. B. West, *Introduction to Graph Theory*, 2nd Ed, Prentice Hall of India, 2007.
2. R. Diestel, *Advanced Graph Theory*, Springer Verlag Heidelberg, New York, 2005.
3. M. T. Goodrich and R. Tamassia, *Algorithm Design: Foundations, Analysis, and Internet Examples*, Wiley, 1st ed, 2001.

CS 618	REAL TIME SYSTEMS DESIGNS	4 Credits [3-1-0]

Introduction to Real Time systems, applications of Real Time systems, basic model of Real Time systems, characteristics of Real Time systems, types of Real Time systems: hard, firm, soft, timing constraints, modeling timing constraints, Real Time task scheduling: basic concepts, clock driven scheduling, table driven scheduling, cyclic, schedulers, hybrid schedulers, event driven scheduling, EDF Scheduling, RMA, DMA, resource sharing among RT tasks, Priority inversion, Priority Inheritance Protocol, Highest Locker Protocol, Priority Ceiling Protocol, Scheduling Real Time tasks in multiprocessor and distributed systems, Fault tolerant scheduling of tasks, clocks in distributed Real Time systems, Commercial Real Time Operating Systems, timers, UNIX and Windows as RT OS, POSIX, PSOS, VRTX, QNX, RT Linux, Lynx, other RT OS, benchmarking RT OS, RT communications, QoS framework, models, Real Time Communication in a LAN, IEEE 802.4, RETHER, Communication over Packet Switched Networks, Routing algorithms, RSVP, rate control, RT databases, Applications, characteristics of temporal data, Concurrency control, Commercial RT databases. Special topics in real time systems.

Essential Reading:

1. J. W. S. Liu, *Real time Systems, Pearson Education*, 6th impression, 2008.
2. R. Mall, *Real Time Systems*, Pearson, 2007.

Supplementary Reading:

1. C. M. Krishna and K. G. Shin, *Real Time Systems*, McGraw Hill, reprinted 2004.
2. P. A. Laplante, *Real Time Systems Design & Analysis*, Willey, 3rd Ed, 2004.

CS 621	CRYPTOGRAPHIC FOUNDATIONS	4 Credits [3-1-0]

Introduction to cryptography: Attacks, Services, and Mechanisms, Security Attacks, Security Services, A Model for Inter network Security. Conventional Encryption: Classical and Modern Techniques, Conventional Encryption: Algorithms Triple DES, International Data Encryption Algorithm, Blowfish, RC5, CAST, RC2, Characteristics of Advanced Symmetric Block Ciphers. Confidentiality Using Conventional Encryption: Placement of Encryption Function, Traffic Confidentiality, Key Distribution, Random Number Generation.; Public Key Cryptography Principles of Public Key Cryptosystems, The RSA Algorithm, Key Management, Diffie Hellman Key Exchange, Elliptic Curve Cryptography, Message Authentication and Hash Functions: Authentication Requirements, Authentication Functions, Message Authentication Codes, Hash Functions, Security of Hash Functions and MACs. Hash and Mac Algorithms (MD5 Message Digest Algorithm, Secure Hash Algorithm (SHA l), RIPEMD, HMAC), Digital Signatures and Authentication Protocols and Web Security. Special topics in cryptographic foundations.

Essential Reading:

1. R. E. Smith, *Internet Cryptography*, AWL.

2. A. J. Menezes, *Handbook of Applied Cryptography*, CRC Press.

Supplementary Reading:
1. J. Hershey, *Cryptography Demystified*, McGraw Hill.
2. J. Knudsen, *Java Cryptography*, O'Reilly.

CS 622	DESIGN OF COMPUTER NETWORKS	4 Credits [3-1-0]

Introduction to computer networks; telephone networks, networking principles; multiple access, multiplexing FDM, TDM, SM; local area networks Ethernet, token ring, FDDI; switching circuit switching, packet switching, multicasting; scheduling performance bounds, best effort disciplines, naming and addressing, protocol stack, SONET/SDH; ATM networks AAL, virtual circuits, SSCOP; Internet addressing, routing, end point control; Internet protocols IP, TCP, UDP, ICMP, HTTP; traffic management models, classes, scheduling; control of networks QoS, static and dynamic routing, Markov chains, queuing models, Bellman Ford and Dijkstra's algorithms, window and rate congestion control, large deviations of a queue and network, open and closed loop flow control, control of ATM networks. Mobile IP, Voice over IP (VoIP), VPNs, Network Security. Congestion Control: Control vs. Avoidance, Overview of Algorithms, Congestion in the Internet. Management: Quality of Service (QoS), network vs. distributed systems management, Protocols, web based management. Special topics in design of computer networks.

Essential Reading:
1. J. Walrand and P. Varaya, *High Performance Communication Networks*, Harcourt Asia (Morgan Kaufmann), 2000.
2. S. Keshav, *An Engineering Approach to Computer Networking*, Pearson Education, 2004

Supplementary Reading:
1. L. Garcia and I. Widjaja, *Communication Networks: Fundamental Concepts and Key Architectures*, Tata McGraw Hill, 2000.
2. J. F. Kurose and K. W. Ross, *Computer Networking:A Top Down Approach Featuring the Internet*, Pearson Education, 2001.

CS 623	AD- HOC AND WIRELESS NETWORKS	4 Credits [3-1-0]

Ad Hoc Wireless Networks: Issues in Ad Hoc Wireless Networks, Ad Hoc Wireless Internet; MAC Protocols for Ad Hoc Wireless Networks: Issues in Designing a MAC Protocol for Ad Hoc Wireless Networks, Classifications of MAC Protocols; Routing Protocols for Ad Hoc Wireless Networks: Issues in Designing a Routing Protocol for Ad Hoc Wireless Networks, Classifications of Routing Protocols, Power Aware Routing Protocols; Multi cast routing in Ad Hoc Wireless Networks: Issues in Designing a Multicast Routing Protocol, Classifications of Multicast Routing Protocols, Energy Efficient Multicasting, Multicasting with Quality of Service Guarantees, Application Dependent Multicast Routing; Security Protocols for Ad Hoc Wireless Networks: Security in Ad Hoc Wireless Networks. Network Security Requirements. Issues and Challenges in Security Provisioning. Network Security Attacks. Key Management. Secure Routing in Ad Hoc Wireless Networks; Energy Management in Ad Hoc Wireless Networks: Classification of Energy Management Schemes, Transmission Power Management Schemes, System Power Management Schemes. Special topics in Ad-hoc and wireless networks.

Essential Reading:
1. C S. Ram Murthy, B. S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*, Prentice Hall of India, 2nd ed. 2005.
2. R. Hekmat, *Ad hoc Networks: Fundamental Properties and Network Topologies*, Springer, 1st ed. 2006.

Supplementary Reading:
1. B. Tavli and W. Heinzelman, *Mobile Ad Hoc Networks: Energy Efficient Real Time Data Communications*, Springer, 1st ed. 2006.

2. G. Anastasi, E. Ancillotti, R. Bernasconi, and E. S. Biagioni, *Multi Hop Ad Hoc Newtorks from Theory to Reality*, Nova Science Publishers, 2008

CS 624 DATABASE ENGINEERING 4 Credits [3-1-0]

Introduction to Database systems: Data Independence, Data Models, levels of abstraction, structure of DBMS, Relational Model, Integrity constraints, Relational Languages, Query Languages: SQL, QUEL, QBE, Aggregate operators, Embedded and Dynamic SQL. File Organization: Storage, Buffer management, Record and page formats, File organization techniques, Indexing. Query optimization: Query processing on various operations, Translating SQL queries, estimating the cost. Database design: E R Model, Functional dependencies, normalization, multi valued dependencies. Concurrency control and recovery: transaction, schedules, Lock based concurrency, Lock management, Concurrency control without locking, Crash recovery log, check pointing, media recoveries. Database Security, Distributed databases design, Object Oriented database design & its implementation, Introduction to recent advances in database technology. Special topics in database engineering.

Essential Reading:

1. J. D. Ullman, *Principles of Data Base Systems, Galgotia Publisher*, New Delhi, 2nd Ed, 2003.
2. Silberschatz, H. F. Korth & A. Sudarshan, *Database system Concepts*, McGraw Hill,

Supplementary Reading:

1. B. Desai, *An Introduction to database system*, Galgotia, 1997.
2. C. J. Date: *An introduction to Data Base Systems*, Addison Wesley, 1995.
3. R. Elmasri, S. Navathe, S. B. Navathe, R. Sunderraman, *Fundamentals of Database Systems*, Addison Wesley, 2nd ed, 2005.
4. R. R. Krishnan, *Database Management Systems*, McGraw Hill, reprint 2007

CS 625 DATA MINING & DATA WAREHOUSING 4 Credits [3-1-0]

Introduction to Data mining: Motivation for Data Mining, its importance, Role Data in Data Mining, Data Mining functionalities, patterns in data mining, Type of patterns, Classification of Data Mining Systems, Major issues in Data Mining; Data Warehousing and OLTP technology for Data Mining, Data Mining Languages, and System Architectures, Concept Description: Characterization and Comparison, Mining Association Rules in Large Databases, Classification and Prediction, Cluster Analysis, Mining Complex Data, Applications and Trends in Data Mining Characteristics of data warehouse, Data Mart, Online Analytical Processing, OLAP tools, Data warehouse Architecture, Organizational Issuer, Tools for Data warehousing, Performance consideration, case studies. Special topics in data mining and data ware housing.

Essential Reading:

1. J. Han & M. Kamber, *Data Mining: Concepts and Techniques*, Morgan Kaufmann, 2nd Ed, 2006.
2. M. J. A. Berry and G. Linoff, *Mastering Data Mining: The Art and Science of Customer Relationship Management*, Wiley Computer Publishing, 2000.

Supplementary Reading:

1. P. Adriaans & D. Zantinge, *Data Mining*, Addison Wesley, 1996.
2. R. Mattison, *Data Warehousing: Strategies, Tools and Techniques*, McGraw Hill, 1996.
3. P. Ponniah, *Data Warehousing Fundamentals: A Comprehensive Guide for IT Professionals*, Wiley, 2001.

CS 626 INTRUSION DETECTION SYSTEMS 4 Credits [3-1-0]

Introduction to data and methodologies of computer intrusion detection, statistical & machine approaches to detection of attacks on computers, techniques for studying the Internet & estimating the number & severity of attacks, network based attacks such as probes & denial of service attacks, host based attacks such as buffer overflows and race conditions, malicious codes such as virus and worms, statistical pattern recognition for detection & classification of attacks, techniques for visualizing networked data etc. Special topics in intrusion detection systems.

Essential Reading:

1. S. McClure, S.Shah, *Shreeraj.Shah,We Hacking*, Pearson Press.
2. D. Litchfield, C. Anley et. al., *Database Hacker's handbook*, Wiley Publishers.

Supplementary Reading:

1. S. McClure, J. Scambray, G. Kurtz, *Hacking Exposed*, TMH.

CS 627	WIRELESS NETWORK SECURITY	4 Credits [3-1-0]

Wired/wireless networks, effect of mobility on networks & systems, impact on IP stack from MAC layer and up. Ad hoc and sensor networks, wireless broadcasts, IP broadcasts, satellite broadcasts, issues of information capacity, distinction between wired & wireless from information theory, issues of securities in wireless, issues of 802.11 protocols, routing in wireless networks, design of secure protocols, key distribution for access control, source authentication of transmissions and non repudiation, power management & selfishness issues, attacks in wireless networks, DOS & DDOS attacks, reaction to attacks, information processing for sensor networks. Special topics in wireless network security.

Supplementary Reading:

1. J. R. Vacca, Guide *to Wireless Network Security*, Springer Verlag,2006.
2. Tara M. Swaminatha, C. R.Elden*, Wireless Security & Privacy*, Pearson Press, 2007.

CS 628	WIRELESS SENSOR NETWORKS	4 Credits [3-1-0]

Introduction to wireless sensor network: Application and Motivation, Network Performance objective, Development of Wireless Sensor Network; Canonical Problem Localization and Tracking: Tracking Multiple Objects, State space decomposition, Data association, Sensor Models, Performance Comparison and Metrics; Networking Sensors: The S MAC Protocol,IEEE 802.15.4 Standard and ZigBee , Routing in sensor network; Infrastructure Establishment: Topology Control, Clustering, Time Synchronization, Clocks and Communication Delays, Sensor Tasking and Control; Sensor Network Databases: Sensor Database Challenges, Querying The Physical Environment, Query Interfaces, Cougar sensor database and abstract data types, Probabilistic queries, High level Database Organization, In Network Aggregation, Query propagation and aggregation, TinyDB query processing, Query processing scheduling and optimization, Data Centric Storage. Special topics in wireless sensor networks.

Essential Reading:

1. F. Zhao and L. Guibas, *Wireless Sensor Network: Information Processing Approach,* Elsevier.
2. E. H. Callaway, Jr. E. H. Callaway, *Wireless Sensor Networks Architecture and Protocols*: CRC Press.

Supplementary Reading:

1. A. Hac, *Wireless Sensor Network Designs*, John Wiley & Sons

CS 629	NETWORK SECURITY	4 Credits [3-1-0]

Network architecture, attacks, covert channels, Security at the Application Layer (PGP and S/MIME), email, PGP, S/MIME, MIME, S/MIME. Security at the Transport Layer (SSL and TLS): SSL architecture, Protocols : Handshake, changecipherspec, alert, record, SSL Message format, Transport Layer Security. Security at the Network Layer(IPSec): Modes, Two security protocols, Security association, security policy, Internet key exchange, ISAKMP. Recent trends in network security.

Essential Reading:

1. B. A. Forouzan, *Cryptography & Network Security*, McGraw Hill, Special Indian Edition, 2007.
2. W. Stallings, *Cryptography and Network Security*, Pearson Education, 3rd Ed, 2006.

Supplementary Reading:

1. N. Krawety, *Introduction to Network Security*, Thompson, Special India Ed, 2007.

CS 630	**ARTIFICIAL INTELLIGENCE**	**4 Credits [3-1-0]**

AI Techniques, Production systems, State space representation and search methods, A * and AO * algorithms, game tree, Knowledge representation: predicate calculus, semantics nets, conceptual dependency, frames and scripts, perception and knowledge acquisition. Introduction to Natural language processing, Expert systems, Non monotonic reasoning, Man Machine interface, Question answering, Computer vision etc., Simple Case Study. Special topics in artificial intelligence.

Essential Reading:

1. E. Rich and K. Knight : *Artificial Intelligence* , Tata Mc Grawhill,
2. N.J. Nilsson : *Principles of Artificial Intelligence* , Narosa,

Supplementary Reading:

1. G. F. Luger Wa Stubblefield : *Artificial Intelligence*, Addison Wisley
2. S. L. Tanimotto: *The Elements of Artificial Intelligence*, Computer Science Press.

CS 631	**INFORMATION THEORY AND CODING**	**4 Credits [3-1-0]**

Introduction to information Theory, Information and entropy, properties of entropy of a binary memory less source, Measure of Information, Source Coding, Shannon Fano coding, Huffman coding, Lempel Ziv coding, channel coding, Channel capacity, noisy channel coding theorem for DMC. Linear block codes, generator matrices, parity check matrices, encoder syndrome and error detection minimum distance, error correction and error detection capabilities, cyclic codes, coding and decoding. Coding convolutional codes, encoder, generator matrix, transform domain representation state diagram, distance properties, maximum likelihood decoding, Viterbi decoding, sequential decoding, interleaved convolutional codes. Special topics in information theory and coding.

Essential Reading:

1. R. Bose*, Information Theory Coding and Cryptography,* Tata McGraw Hill, 2003.
2. F. J. MacWilliams, N. J. A. Sloane*, The Theory of Error Correcting Codes*, Elsevier, 1977.

Supplementary Reading:

1. S. Roman, *Coding and Information Theory*, Springer, 1992.
2. R. J. McEliece, *The Theory of Information and Coding*, Cambridge Uinv Press, 2004.
3. T. M. Cover, J. A. Thomas*, Elements of Information Theory*, Wiley, 1991.

CS 632	**DISTRIBUTED OPERATING SYSTEMS**	**4 Credits [3-1-0]**

Introduction to parallel Computing, Solving problems in parallel, Structures of parallel computers, Instruction level parallel processing, Parallel Algorithms, Parallel programming, Operating Systems for parallel computers, Performance Evaluation of parallel computers.

Characterization of distributed systems, Design goals, Communication and computer networks, Distributed processing, Distributed operating systems, Client Server Communications, Remote Procedure calls, File Service, Name Service, Distributed transactions and concurrency control, fault tolerance and security. Synchronization & Coordination, Distributed Algorithms, research issues. Special topics in distributed operating systems.

Essential Reading:

1. G. Coulororis, J. Dollimore & T. Kindberg, *Distributed Systems: Concepts and Design*, Addison-Wesley, 3rd ed, 2001.
2. M. Singhal & N. G. Shivaratri, *Advanced Concepts in Operating Systems*, McGraw Hill, 1994.

Supplementary Reading:

1. P. K. Sinha, *Distributed Operating Systems*, IEEE Press, 1997.
2. H. F. Jordan, *Fundamentals of Parallel Processing*, Pearson, 2004.
3. C. Hughes & T, Hughes, *Parallel and Distributed Programming Using C++*, Pearson, 1st Ed, 2004.
4. W. Buchanan, *Distributed Systems and Networks*, Tata McGraw Hill, 2004.
5. P. S. Pacheco, *Parallel Programming with MPI*, Morgan Kaufmann, 1997.

CS 633	**GAME THEORY**	**4 Credits [3-1-0]**

Basic Solution concepts and computational issues: Games, Old and New; Games Strategies, Costs and Payoff,; Basic Solution Concepts; Finding equilibria and Learning in Games. Refinement of Nash: Games with Turns and Sub game Perfect Equilibrium: Cooperative games, markets and their Algorithmic Issues. The Complexity of finding Nash Equilibria: Introduction, Is Lemke Howson algorithm, succinct representation of games. Graphical Games: Computing Nash equilibria in Tree Graphical Games, Graphical Games and correlated Equilibria, Cryptography and Game theory: Cryptographic notation and settings, game theory notation and settings, cryptographic influence on game theory and Game theoretic influence on cryptography. Distributed algorithmic mechanism design : two examples of DAMD, Interdomain routing Cost sharing. Incentive and Pricing in Communication Networks Large network Competitive model, Pricing and Resource allocation Game theoretic model Incentive and Information security: Misaligned incentive Informational Asymmetries, Complex network and topology. Special topics in game theory.

Essential Reading:

1. M. J. Osborne & A. Rubinstein, *A Course in Game Theory*, MIT Press, 2001.
2. M. J. Osborne, *An Introduction to Game Theory*, Oxford University Press, 2004.

Supplementary Reading:

1. N. Nisan, T. Rougharden, E. Tardos & V. V. Vazirani, *Algorithmic Game Theory*, Cambridge University Press, 2004.
2. K. Binmore, *Fun and Games: A text on Game theory*, AIBS publisher, 2004.

CS 634	**BIOINFORMATICS**	**4 Credits [3-1-0]**

Pre requisite Knowledge on following is necessary:

1. Genetics
2. Cell and Molecular Biology
3. Biochemistry

Introduction; Databases mapping, sequence, structure, non redundant; Sequence alignment pair wise and multiple; phylogenetics; Structure prediction methods homology, threading, abinitio; Sequence analysis class and secondary structure prediction; motifs PROSITE; detecting functional sites in DNA; OR Finder; Computer science perspective pattern recognition, hidden Markov models; Data Mining using Soft computing Techniques. Special topics in bioinformtatics.

Essential Reading:

1. A. D. Baxevanis & B. F. F. Ouellette, *Bioinformatics*, Wiley Interscience, 1998.
2. A. M. Lesk, *Introduction to bioinformatics*, OXFORD University Press, 1st Ed, 2003.

Supplementary Reading:

1. S. L. Salzberg, D. B. Searls and S.Kasif eds, *Computational methods in molecular biology*, Elsevier, 1998.

2. R. F. Doolittle, *Computer methods for macromolecular sequence analysis*, Academic Press, 1996.
3. M. Bishop, *Guide to human genome computing*, Academic Press.

CS 635 BIOMETRIC SECURITY 4 Credits [3-1-0]

Security via biometrics, space domain based biometrics and recognition techniques. Correlation based biometric filters, Basic theory of correlation filters, Design of advanced correlation filters that offer tolerance to expected impairments, methods to implement digital correlation, applications of correlation filters. Special topics in biometric security.

Essential Reading:

1. P. Reid, *Biometrics for Network Security*, Pearson Press.
2. J. D. Woodward, N.M.Orlans, P.T.Higgins, *Biometrics*, Dreamtech Publishers.

Supplementary Reading:

1. S. Nanavati, M. Thieme, R. Nanavati, *Biometrics*, Wiley Publishers.

CS 636 IMAGE PROCESSING 4 Credits [3-1-0]

The DFT and Digital Convolution: The DFT and its relationship to other transforms, properties of the DFT, FFT, DIT and DIF FFT algorithms, prime factor FFT algorithms, Analysis and Design of discrete time systems in the frequency domains, Frequency domain characteristics of LTI systems, LTI frequency selective filters, linear filtering method based on DFT , the Goertzel algorithm and chirp Z transform algorithm. Inverse systems and Deconvolutions, Realisation of discrete systems: Design of digital filters, Quantization effects in Digital Signal Process, Power Spectrum Estimation, Adaptive Filters. Recent advances in signal processing applications.

Essential Reading:

1. J. G. Proakis and D. G. Manolkis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall of India, 3rd Ed, 1996, reprint 2005.

Supplementary Reading:

1. V. Oppenheim & R. W. Schafer, *Digital Signal Processing*, Prentice Hall of India, 8th Ed, 2002.
2. S. W. Smith, *Digital Signal Processing: A Practical Guide for Engineers and Scientists*, Newness – Elsevier Science, 1st Ed, 2002.

CS 637 DIGITAL SIGNAL PROCESSING 4 Credits [3-1-0]

Two Dimensional Systems & Mathematical Preliminaries: Linear Systems and Shift Invariance; the Fourier Transform; Optical and Modulation Transfer Functions; Matrix Theory Results; Block Matrices and Kronecker Products; Random Signals; Discrete Random Fields; the Spectral Density Function; Some results from information theory. Image Perception, Image Sampling and Quantization, Image Transforms, Image Enhancement, Image Filtering and Restoration, Image Analysis and Computer Vision Spatial Feature Extraction; Transform Features; Edge Detection; Boundary extraction; Boundary, Region, Moment Representation; Structure; Shape Features; Texture; Scene Matching and Detection; Image Segmentation; Classification Techniques; Image Understanding. Image Reconstruction from Projections, Image Data Compression. Recent advances in image processing.

Essential Reading:

1. R. C. Gonzalez & R. E. Woods, *Digital Image Processing*, Prentice Hall, 3rd ed, 2008.
2. A. K. Jain, *Fundamentals of Digital Image Processing*, Prentice Hall of India, 2002.

Supplementary Reading:

1. W. K. Pratt, *Digital Image Processing,* Wiley Interscience, 4th ed, 2007.

2. Rosenfled & A. C. Kak, Vol.I, *Digital Picture Processing*, Academic Press, 1976.

CS 638 PATTERN RECOGNITION 4 Credits [3-1-0]

Introduction to pattern recognition, statistical pattern recognition, decision trees, classification using decision trees, obtaining Prules from decision trees, missing attribute values, error rates on recall sets, pruning decision trees, obtaining Prules by evolution, Bayes classification, estimation of probabilities, nearest neighbor classification, performance issues of a nearest neighbor classifier, Neural classifier, training of neural classifier, clustering, Agglomerative hierarchical clustering, K means clustering, syntactic pattern recognition. Recent advances in pattern recognition.

Essential Reading:
1. Rajjan Shighal, *Pattern Recognition: Techniques and Applications*, Oxford University Press, 1st ed, 2006.
2. Christopher M. Bishop, *Neural Networks for Pattern Recognition,* Oxford University Press, 1st ed, 2003.

Supplementary Reading:
1. W. Gibson, *Pattern Recognition*, Berkley Press, 1st Ed, 2005.
2. C. M. Bishop, *Pattern Recognition and Machine Learning,* Springer, 1st Ed, 2007.

CS 639 SOFT COMPUTING 4 Credits [3-1-0]

Introduction to Neorofuzzy and Soft Computing, Fuzzy set theory, Fuzzy Rules, Fuzzy Reasoning, Fuzzy inference System, Neural Networks; Radial basis and recurrent neural networks, Hopfield Networks, Comparision of RBF and MLP Network, Running Algorithms, NeuroFuzzy Modeling, Applications of Soft Computing to Signal Processing, Image Processing, Forecasting, XOR Problem traveling salesman problem, Image compression suing MLPs character retrieval using Hopfield networks, Introduction to Genetic Algorithm hybrid systems etc. Recent advances in soft computing applications.

Essential Reading:
1. V. Kecman, *Learning and Soft Computing*, Pearson, 1st Ed, 2001.
2. D. E. Goldberg, *Genetic Algorithms in Search Optimization and Machine Learning*, Addison Wesley, 3rd Ed.

Supplementary Reading:
1. B. Kosko, *Neural Network and fuzzy systems*, Prentice Hall of India, 2006.
2. S. Goonatilake & S. Khebbal, *Intelligent Hybrid Systems*, Wiley, 1995.

CS 641 ADVANCE COMPUTER ARCHITECTURE 4 Credits [3-1-0]

Metrics for computer performance: clock rate, MIPS, CPI; Strength and weakness of performance metrics; role of Amdalh's in computer performance; Classification of computer architecture: SIMD, MIMD, SISD and MISD; Processing unit design: Data path implementation, Microprogrammed execution. Instruction pipelining and parallel processing, Instruction level parallelism: VLIW, Vector processor, Multithreaded processor, Superscalar architecture; branch prediction; Prefetching; Speculative execution; Principles of pipelining and vector processing: Pipelining, Instruction and Arithmetic Pipelines, Principles of Designing Pipelined Processor, Vector Processing Requirements. Structure and Algorithms for array processors: SIMD Array Processors, SIMD Interconnection Networks, Parallel Algorithms for array Processors, Associative Array Processing. Multiprocessor architecture and programming: Inter processor Communication Mechanisms, System Deadlocks and Protection, Multiprocessor Scheduling Strategies, Parallel Algorithm for Multiprocessor. Multiprocessor architecture. Recent advances in computer architecture.

Essential Reading:

1. K. Hwang and F. A. Briggs, *Computer Architecture and Parallel Processing*, McGraw Hill, 2001.
2. N. Carter, *Computer Architecture*, Tata McGraw Hill, 3rd ed. 2008.

Supplementary Reading:

1. J. L. Heressy and D. A. Pattersan, *Computer Architecture A Quantitative approach*, Elsevier, 3rd ed. 2006.
2. Kai Hwang, *Advanced Computer Architecture: Parallelism, Scalability, Programmability*, Tata McGraw Hill, 2004.

CS 642	CLUSTER AND GRID COMPUTING	4 Credits [3-1-0]

Introduction: High Performance Computing (HPC), Grand Challenge Problems Computational and communication intensive, Parallel Architectures Classifications SMP, MPP, NUMA, Clusters and Components of a Parallel Machine, Conventional Supercomputers and it's limitations, Multi processor and Multi Computer based Distributed Systems. Cluster and Grids: Cluster Components Processor/machine, High Speed Interconnections goals, topology, latency, bandwidth, Example Interconnect: Myrinet, Inifiniband, QsNet, Fast Ethernet, Gigabit Ethernet, Light weight Messaging system/Light weight communication Protocols, Cluster Middleware Job/Resource Management System, Load balancing, Scheduling of parallel processes, Enforcing policies, GUI, Introduction to programming tools such as PVM, MPI, Cluster Operating Systems Examples: Linux, MOSIX, CONDOR, Characteristics of Grid, Computational services, Computational Grids, Data grids/Storage grids, management and applications, Different components of Grid Grid fabric, Grid middleware, Grid applications and portal, Globus toolkit Ver.2.4, web services, MDS,GRAM, Grid Security – Cryptography, Authentication, Integrity, Digital Signature, Digital Certificates, Certificate Authority, MD 5, RSA, GSI,GSSAPI, Directory Service, LDAP,GRID FTP,GASS Fault Tolerance: Fault detection and diagnosis of Clusters and Grids. Recent advances in cluster and grid computing.

Essential Reading:

1. D. Janakiram, *Grid Computing,* Tata Mcgraw Hill, 2005.
2. R. K. Buyya, *High Performance Cluster Computing: Programming and Applications, Vol 2*, PHI, NJ, USA, 1999.

Supplementary Reading:

1. P. Jalote, *Fault Tolerance in Distributed Systems*, Prentice Hall, 1994.
2. J. J. Jos & R. K. Buyya, *High Performance Cluster Computing: Architecture and Systems*, Vol 1, PHI, NJ, USA, 1999.
3. R. K. Buyya & C. Szyperski, *Cluster Computing*, Nova Science, New York, USA, 2001.
4. R. K. Buyya & K. Bubendorfer, *Market oriented Grid and Utility Computing*, Wiley, 2008.
5. J. Jaseph & C. Fellenstein, *Grid Computing*, Pearson, 1st Wd, 2004.

CS 643	EMBEDDED SYSTEMS	4 Credits [3-1-0]

Introduction: Embedded system, Processor, hardware units, software embedding, SOC, NOC, VLSI circuit; Device and Device drivers, I/O devices, timer and counting devices, serial communication using IC, LAN and advanced I/O buses between the networked multiple devices, Host system, parallel communication using ISA, PCI, PCI X, and advanced buses, device drivers, parallel port device drivers in a system, serial port device drivers. Interrupt service handling mechanism; Software and programming concepts: processor and memory selection for embedded system, embedded programming in C++, Java and UML, multiple processes and applications, problem of sharing data by multiple tasks and routines, interprocess communication; Real time OS: OS services, I/O subsystem, Network OS, Real time Embedded system, Need of well tested and debugged RTOS, Introduction to C/OS II. Case Studies of programming with RTOS: Smart card embedded system, Hardware and Software co design: specification and design of an embedded system, use of software tools for development of an embedded system. Recent advances in embedded applications.

Essential Readings:

1. R. Kamal, *Embedded System Architecture, Programming and Design*, Tata McGraw Hill, 2005.
2. R. Niemann, *Hardware Software Codesign of Embedded System*, Kulwer Academic, 2006.

Supplementary Readings:

1. S. V. Iyer & P. Gupat, *Embedded Real Time System Programming*, Tata McGraw Hill, 2004.
2. W. Wolf, *Computer as Components: Principles of Embedded Computer System Design*, Elsevier, 2005.
3. S. Heath, *Embedded System Design*, 2nd ed, Elsevier, 2005.
4. R. Mall, *Real Time Systems Theory and Practice*, Pearson, 2008.
5. F. Vahid & T. Givargis, *Embedded Ssytem design: A unified Hardware/Software approach*, Wiley, 2007.
6. G. D. Michelli & L. Benin, *Network on Chip*, Morgan & Kaufman Publication, 2004.

CS 644	**FAULT TOLERANT COMPUTING**	**4 Credits [3-1-0]**

Introduction to Fault Tolerant Computing. Basic concepts and overview of the course; Faults and their manifestations, Fault/error modeling, Reliability, availability and maintainability analysis, System evaluation, performance reliability trade offs. System level fault diagnosis, Hardware and software redundancy techniques. Fault tolerant system design methods, Mobile computing and Mobile communication environment, Fault injection methods, Software fault tolerance, Design and test of defect free integrated circuits, fault modeling, built in self test, data compression, error correcting codes, simulation software/hardware, fault tolerant system design, CAD tools for design for testability. Information Redundancy and Error Correcting Codes, Software Problem. Software Reliability Models and Robust Coding Techniques, Reliability in Computer Networks Time redundancy. Re execution in SMT, CMP Architectures, Fault Tolerant Distributed Systems, Data replication. Case Studies in FTC: ROC, HP Non Stop Server. Case studies of fault tolerant systems and current research issues.

Essential Readings:

1. D. K. Pradhan, editor, *Fault Tolerant Computer System Design*, Prentice Hall, 1996.
2. I. Koren*. Fault Tolerant System*s, Morgan Kauffman 2007.

Supplementary Readings:

1. L. L. Pullum, *Software Fault Tolerance Techniques and Implementation*, Artech House Computer Security Series, 2001.
2. M. L. Shooman, *Reliability of Computer Systems and Networks Fault Tolerance Analysis and Design*, Wiley, 2002

CS 645	**PARALLEL ALGORITHMS**	**4 Credits [3-1-0]**

Modeling; Synchronous Network Model, Leader Election in a Synchronous Ring, Algorithms in General Synchronous Networks, Distributed Consensus with Link Failures, Distributed Consensus with Process Failures, More Consensus Problems, Asynchronous System Model, Asynchronous Shared Memory model, Mutual Exclusion, Resource Allocation, Consensus, Atomic Objects, Asynchronous Network Model, Basic Asynchronous Network Algorithms, Synchronizers, Shared Memory versus Networks, Logical Time Global Snapshots and stable properties, Network Resource allocation, Asynchronous Networks with Process Failures, Data Link Protocols, Partially Synchronous Models, Mutual Exclusion with Partial Synchrony, Consensus with Partial Synchrony. Recent advances in parallel algorithms.

Essential Reading:

1. B. Wilkinson & M. Allen, *Parallel Programming*, Pearson, 2nd ed, 2005.
2. M. J. Quinn, *Parallel Programming in C with MPI and OpenMP*, Tata McGraw Hill, 2003.

Supplementary Reading:

1. W. Groop, E. Lusk & A. Skjellum, *Using MPI: Portable Parallel Programming with the Message passing Interface*, MIT Press, 1999.
2. H. F. Jordan and G. Alaghband, *Fundamentals of Parallel Processing*, Pearson, 1^{st} Ed, 2003.
3. G. V. Wilson & G. Wilson, *Practical Parallel Programming*, MIT Press, 1995.

CS 646	PARALLEL AND DISTRIBUTED COMPUTING	4 Credits [3-1-0]

Introduction to parallel Computing, Solving problems in parallel, Structures of parallel computers, Instruction level parallel processing, Parallel Algorithms, Parallel programming, Operating Systems for parallel computers, Performance Evaluation of parallel computers; Characterization of distributed systems, Design goals, Communication and computer networks, Distributed processing, Distributed operating systems, Client Server Communications, Remote Procedure calls, File Service, Name Service, Distributed transactions and concurrency control, fault tolerance and security. Synchronization & Coordination, Distributed Algorithms, research issues.

Essential Reading:

1. G. Coulororis, J. Dollimore & T. Kindberg, *Distributed Systems: Concepts and Design*, Addison Wesley, 3^{rd} ed, 2001.
2. M. Singhal & N. G. Shivaratri, *Advanced Concepts in Operating Systems*, McGraw Hill, 1994.

Supplementary Reading:

1. P. K. Sinha *Distributed Operating Systems*, IEEE Press, 1997.
2. H. F. Jordan, *Fundamentals of Parallel Processing*, Pearson, 2004.
3. C. Hughes and T. Hughes, *Parallel and Distributed Programming Using C++*, Pearson, 1^{st} ed, 2004.
4. W. Buchanan, *Distributed Systems and Networks*, Tata McGraw Hill, 2004.
5. P. S. Pacheco, *Parallel Programming with MPI*, Morgan Kaufmann, 1997.

CS 647	PERFORMANCE EVALUATION OF COMPUTER SYSTEMS	4 Credits [3-1-0]

Introduction to Probability Refresher: Bayes theorem, Conditional probability, Total probability, Discrete and Continous Random variables, Common distributions, Probability Generating Functions(PGF) and Laplace Transforms(LST), Numerous examples from computer networking, Stochastic processes, Discrete time Markov chains (DTMC), Continous time Markov chains (CTMC), Queueing systems (M/M/1, M/M/c/k, M/G/1), Queueing networks, Statistical analysis of simulations, Specific topics: Introduction to performance measures, basic probability review, Markov chains, basic queueing models, introduction to simulation modeling, some advanced queueing models, basic queueing networks, examples from recent research papers.

Essential Reading:

1. Kishor Trivedi, *Probability and Statistics with Reliability, Queueing and Computer Science Applications,* PHI, 2005.
2. Law and Kelton, *Simulation Modeling and Analysis*, 2nd Ed., McGraw Hill, 1991.
3. D. Gross and C. M Harris, *Fundamentals of Queueing Theory*, John Wiley and Sons, 1974.
4. L. Kleinrock, *Queueing Systems Vol. I & II*, John Wiley and Sons, 1975.

Supplementary Reading:

1. For a primer in Probability, this On Line Book from Dartmouth College can be referenced.
2. A gentle introduction to some basic queuing concepts, by William Stallings, PHI.
3. Quantitative Systems Performance, an on line version of the book on queueing networks by Edward D. Lazowska, John Zahorjan, G. Scott Graham, Kenneth C. Sevcik.

CS 648 SECURITY AND FAULT TOLERANCE IN DISTRIBUTING SYSTEM 4 Credits [3-1-0]

Introduction: High Performance Computing (HPC), Grand Challenge Problems Computational and communication intensive, Parallel Architectures Classifications SMP,MPP,NUMA,Clusters and Components of a Parallel Machine, Conventional Supercomputers and it's limitations, Multi processor and Multi Computer based Distributed Systems, Introduction to Clusters and Grids. Fault Tolerance: Classification of faults , Fault detection, fault diagnosis, fault model, hardware and software redundancy Masking/Non masking –Group and Hierarchical masking, Reliability and availability, Code protection/data protection (RAID LEVEL 0 5), Dependable Clusters high availability and high performance clusters. Dependability Concepts, Quorums, Consensus and Broadcast, View synchronous Group Communication, Distributed Cryptography, Byzantine Agreement, Service Replication, Data Storage. System Level diagnosis: Diagnosis and Diagnosability Theory, Testing Assignment, Syndrome Collection, Centralized vs. Distributed Diagnosis, Static Vs. Dynamic Fault Environment, System and Fault Model, Classification of Diagnosis Algorithms, Evaluation Metric such as Time and Space Complexity, Bounded Correctness, Applications to Distributed Embedded System, Internet, DSNs, MANETs, PVN. Fault Tolerant Networks: Meausers of Resilence, Graph Theoretic Meausers, Computer Network Measures, Regular Networks, Adhoc Point to point Networks. Fault Detection in Cryptographic Systems: Overview of Ciphers, Symmetric Ciphers, Public Key Ciphers, Security Attacks Through Fault Injection, Fault Attacks on Symmetric/Asymetric Key Ciphers, Counter Meausres: Spatial and Temporal Duplication, Error Detecting Codes. Recent advances in security and fault tolerance in distributing system.

Essential Reading:

1. P. Jalote, *Fault Tolerance in Distributed Systems*, Prentice Hall, 1994.
2. J. Joseph & C. Fellenstein*, Grid Computing,* Pearson Education, 1st Ed, 2004.

Supplementary Reading:

1. H. Attiya and J. Welch, *Distributed Computing: Fundamentals, Simulations and advanced Topics*. Wiley, 2nd edition, 2004
2. G. Coulororis, J. Dollimore, and T. Kindberg. *Distributed Systems: Concepts and Design*. Addison Wesley, 3rd edition, 2001.
3. S. Koren, C. M. Krishna, *Fault Tolerant systems*, Morgan Kaufman Publishers, 2007.

CS 649 VLSI SYSTEM DESIGN 4 Credits [3-1-0]

Deep sub micron digital IC design; Transistors and Devices: MOS transistors; Bipolar transistors and circuits; Fabrication: IC fabrication technology; Simulation: Modeling the MOS transistor for Circuit Simulation; Silicon on Insulator technology; MOS Inverter circuits: Voltage transfer characteristics; Noise margin definitions; NMOS transistors as load devices; COMS inverter. Static MOS Gate circuits: CMOS gate circuits; Complex CMOS Gates; XOR and XNOR Gates; Flip Flops and Latches; Semiconductor memory design: MOS decoder; Static RAM cell design; RAM column I/O circuitry; Power Grid and Clock design: Power distribution design; clocking and timing issues; Phase locked loop/Delayed locked loop. Recent advances in VLSI design.

Essential Reading:

1. D. A. Hodges, H. G. Jackson & R. A. Saleh, *Analysis and Design of Digital Integrated circuits*, Tata McGraw Hill, 3rd ed. 2008.
2. D. A. Pucknell & K. Eshraghian, *Basic VLSI Design,* Prentice Hall of India, 3rd ed. 2001.

Supplementary Reading:

1. W. H. Wolf, *Modern VLSI Design System on chip design*, Prentice Hall of India, 3rd ed. 2004.
2. C. Mead & L. Conway, *Introduction to VLSI system*, Addison Wesley, 2004.

CS 650 SOFTWARE METRICS 4 Credits [3-1-0]

Basics of measurement: scope of software metrics, representational theory of measurement, measurement and models, measurement scales, meaningfulness in measurement, goal-based framework for software, measurement, Software-metrics data collection and analysis: What is good data, how to define the data, how to collect the data, how to store and extract data, analyzing software-measurement data, frequency distributions, various statistical techniques. Measuring internal product attributes: Measuring external product attributes: Modeling software quality, measuring aspects of software quality, software reliability, basics of software reliability, software reliability problem, parametric reliability growth models, predictive accuracy, recalibration of software-reliability growth predictions, importance of operational environment, wider aspects of software reliability. Metrics for object-oriented systems: The intent of object-oriented metrics, distinguishing characteristics of object-oriented metrics, various object-oriented metric suites – LK suite, CK suite and MOOD metrics. Metrics for component-based systems: The intent of component-based metrics, distinguishing characteristics of component-based metrics, various component-based metrics. Resource measurement: Measuring productivity, teams, tools, and methods.

Essential Reading:

1. N.E. Fenton and S.L. Pfleeger; *Software Metrics – A Rigorous and Practical Approach,* Thomson Asia Pte., Ltd, Singapore.
2. S.H. Kan; *Metrics and Models in Software Quality Engineering*, Addison Wesley, New York.

Supplementary Reading:

1. K. H. Möller and D. J. Paulish; *Software Metrics - A Practitioner's Guide to Improved Product Development*, Chapman and Hall, London.
2. M. Lorenz and J. Kidd; *Object-Oriented Software Metrics*, Prentice Hall, New York.

CS 651 SOFTWARE RELIABILITY 4 Credits [3-1-0]

Software Reliability: Basic Ideas of Software Reliability, Computation of software reliability, Classes of software reliability Models. Time Dependent Software Reliability Models: Time between failure reliability Models, Fault Counting Reliability Models. Time Independent Software Reliability Models: Fault injection model of Software Reliability, Input Domain Reliability Model, Orthogonal defect classification, Software availability Models. Software Reliability Modeling: A general procedure for reliability modeling.

Essential Reading:

1. H. Pham, *Software Reliability*, Springer Verlag, New York.
2. J.D. Musa, *Software Reliability Engineered Testing*, McGraw Hill, New York.

Supplementary Reading:

1. D. Reled, *Software Reliability Methods*, Springer Verlag, New York
2. R. Ramakumar, *Reliability Engineering: Fundamentals and Applications*, Prentice Hall, New Delhi.

CS 652 SOFTWARE ARCHITECTURE 4 Credits [3-1-0]

Architectural styles, Pipes and Filters, Data abstraction and object oriented organization, Event based, implicit invocation, Layered systems, Repositories, Interpreters, Process Control, Other familiar architectures, Heterogeneous architectures, Shared information systems, Database Integration, Integration in Software Development Environments, Integration in the design of buildings, Architectural Structures for Shared Information Systems , Guidance for user interface architectures, The quantified Design space, The value of architectural formalism, Formalizing the architecture of a specific system, Formalizing an architecture Style, Toward a theory of Software Architecture, **Z** Notation used, Requirements for Architectural description Languages, First Class Connectors, Adding Implicit Invocation to Traditional Programming Languages. ; Unicon: A Universal

Connector Language, Exploiting style in Architectural Design Environments, Beyond Definition/Use: Architectural Interconnection.

Essential Reading:

1. C. Paul, K. Rick and K. Mark, *Evaluating Software Architecture: Methods and Case Studies*, Pearson Education, 2007.
2. Sreve and B. Paul, *Patterns for Effective Use Cases*, Pearson Education, 2006.

Supplementary Reading:

1. Baroca L, and P. Hall, Software Architecture: Advances and Applications, Springer Verlag, 2000.
2. M.Shaw and D.Garlan; *Software Architecture: perspectives on an emerging discipline*, Eastern Economy Edition.
3. Bosch. J, *Design and Use of Software Architectures*, Addision-Wisley, 2000.

CS 653	**SOFTWARE PROCESS**	**4 Credits [3-1-0]**

Identifying process issues, Selecting and defining measures , Integrating measures with the software process ; Principal tasks, Specifics of collecting software process data, Reviewing and Assessing Collected data, Retaining data, Tools for understanding your data, Separating signals from noise, Evaluating process stability, Control chart basics, Control charts for variables or discrete data , Control charts for attributes data, Anomalous process behavior patterns, Rational sampling and homogeneity of subgroups, Rational sub grouping, The problem of insufficient granularity in recorded values, Aggregation and decomposition of process performance data, Process capability, Process capability analysis, Improving the process, Improvement and investment.

Essential Reading:

1. W.A. Florac and A.D. Carleton, *Measuring theSoftware Process: Statistical process control for software process improvement*, Pearson Education, 2007.
2. Card David N. and Glass, Robert L., *Measuring Software Design Quality*, Englewood Cliffs, NJ, PH, 1990.

Supplementary Reading:

1. Austin, Robert D, *Measuring and managing Performance in Organizations*, New York, Dorset House Publishing Company, 1996.

CS 656	**SOFTWARE CONFIGURATION MANAGEMENT**	**4 Credits [3-1-0]**

Introduction : Evolution in the Software Life Cycle , Configuration Management as a Controlling Tool , Configuration Management Process as a Visibility Tool, Configuration Management as a Cost Saving Tool, Requirements for the Success of Configuration Management. Maintaining Product Integrity: Indentifying Configuration Items, Establishing Baselines, Naming Configuration Items. Change Management: Types of change, Configuration Control Boards. Version Control: The Simultaneous Update Problem, Version Trees, Tools for Version Control , System Description Languages, Metrics**.** Configuration Management Planning**:** Content of Configuration Management Plans, Characteristics of Personnel.

Essential Readings:

1. E.H. Bersoff, V.D.Hendersom, and S.G. Siegel. *Software Configuration Management*, Englewood Cliffs, N.J., Prentice- Hall 1980.
2. W. A. Babich, *Software Configuration Management*, Addision-Wisley, 2006.

Supplementary Reading:

1. R.C. Gunther, *Management Technology for software product engineering*, New York, John Wiley, 2005.

CS 657 PRINCIPLES OF MANAGEMENT 4 Credits [3-1-0]

Introduction to Management: Management as a Science or Art, Management and Administration; Management thought: Classical, Neo-classical, and Modern; Functions of Management: planning, organizing, directing, coordinating and controlling; Decision-making: Types, Process, Effective Decision-making, Rationality and Decision-making; Business Forecasting: Process, Forecasting Techniques, Factors Affecting; Organizational Design: Organization Structure, Formal & Informal Organization, Span of Management, Centralization & Decentralization; Authority & Responsibility: Power and Authority, Sources of Authority, Line and Staff, Delegation of Authority; Objectives: Objective Setting, Prerequisites, Management by Objectives; Business Environment: Business System, Objectives of Modern Business, Changing Business Environment and Management Challenges, Essentials of Successful Business, Social and Ethical Issues in Management; Managerial Roles and Skills: Skills for Professional Manager - Technical and Managerial, Tasks and Roles of Effective Manager; Leadership: Types, Theories, Transformational Leadership; Employee Motivation: Issues, Theories, Elements of Sound Motivation; Conflict and Change Management: Causes of Conflict, Conflict Resolution Technique, Planned Vs. Reactive Change, Process of Initiating Change; Group Dynamics: Groups, Teams, Group Cohesiveness, Effective Teams; Organizational Effectiveness: Employee Empowerment and Involvement, Employee Engagement. Organizational Climate and Culture, Quality of work life, Learning organization and Knowledge management, approaches to effectiveness, factors affecting effectiveness and Likert's model of effectiveness.

Essential Reading:

1. H. Weihrich, M. V. Cannice and H. Koontz; *Management: A Global and Entrepreneurial Perspective)*, TMH, 12/e, 2008.
2. J.A.F. Stoner, R. E. Freeman and Daniel R. Gilbert, Jr., *Management*, PHI, 6/e, 1995.

Supplementary Reading:

1. L. M. Prasad, *Principles and Practice of Management*, Sultan Chand & Sons, 6/e, 2004.
2. R. D. Agarwal, *Organization and Management*, TMH, 29th Reprint, 2007.

CS 670 PROGRAMMING LABORATORY - I 2 Credits [0-0-3]

No Description

CS 671 PROGRAMMING LABORATORY - II 2 Credits [0-0-3]

To be assigned by the professor in charge of the lab keeping in view the subjects taught in the semester.

CS 672 SOFTWARE ENGINEERING LABORATORY 2 Credits [0-0-3]

For Questions 1 – 8, do the followings:
Prepare the SRS document. You should identify the appropriate requirements for each problem; Draw the Use Case diagrams, Domain Models, and Class Diagrams using Rational Rose. ; Draw the Sequence Diagrams and Collaboration Diagrams for each Use Case, using Rational Rose; Draw the State Chart Diagrams and Activity Diagrams using Rational Rose, wherever necessary; Develop the corresponding software using Java with an interactive GUI and appropriate Database ; Develop software to automate the bookkeeping activities of a 5 star hotel ; The local newspaper and magazine delivery agency wants to automate the various clerical activities associated with its business. Develop a software for this ; A small automobile spare parts shop sells the spare parts for vehicles of several makes and models. Each spare part is typically manufactured by several small industries. To streamline the sales and supply ordering, the shop owner wants to automate the activities associated with his business. Develop a software for this ; Develop software for the automation of the dispensary of NIT, Rourkela ; Develop a software for automating various activities of the Estate Office of NIT, Rourkela ; Develop a word processing software with some limited

number of facilities such as making bold, italics, underline, cut, copy and paste etc ; Develop a graphics editor software package, using which one can create / modify several common types of graphics entities ; Develop a software for automating various activities of the department offices of NIT, Rourkela ; Write a C function for searching an integer value from a large sorted sequence of integer values stored in array of size 100, using the binary search method. Build the control flow graph of this function using any compiler writing tool. Write a program in Java to determine its cyclomatic complexity ; Write a program in Java to determine the number of defects still remaining after testing, using error seeding methodology.

CS 673 IMAGE PROCESSING LABORATORY 2 Credits [0-0-3]

Understanding the image formation ; Exercise on image transformations ; Assignments on image enhancement by point processing ; Image enhancement in frequency domain ; Understanding the concept of image degradation ; Realizing different approaches of restoration ; Implementation of different image compression techniques ; Detection of discontinuity, edge linking, boundary detection ; Region oriented segmentation ; Thematically oriented project for the entire duration of the course for individual students or group of students. Laboratory works are to be done in C or MatLab.

CS 674 NETWORK SIMULATION LABORATORY 2 Credits [0-0-3]

Installation and configuration of NS2 ; Creating a network: nodes, links and queues ; Creating connections, traffic and computing routers ; Insertion of errors and analysis of trace file ; Simple project on NS2 – wired, wireless and combination of wired and wireless ; Implementation of new protocols in NS2

CS 675 SOFT COMPUTING LABORATORY 2 Credits [0-0-3]

Implementation of selected soft-computing methods presented during the lecture ; Implementation of various learning strategies ; Realization of MLP, RBF, Hopfield networks etc ; Solving optimization problems ; Understanding and realizing Fuzzy Logic and Fuzzy inference ; Programming Genetic Algorithms ; Understanding probabilistic reasoning, rough sets, chaos ; Realization of hybrid approaches

CS 676 CRYPTOGRAPHY LABORATORY 2 Credits [0-0-3]

Simulation of the following experiments

1. Ciphers : Polyalphabetic, Monoalphabetic
2. DES
3. AES
4. RSA
5. Diffie – Hellmann
6. ECC
7. DSA using RSA and ECC
8. Blind Signatures
9. E – Voting
10. Smartcard

CS 678 OS AND DATABASE SECURITY LABORATORY 2 Credits [0-0-3]

Installation of Oracle with administration features ; Study of Administration skills of any operating system ; Study of commands related to OS security and oracle security ; Study of File permissions in UNIX, Windows ; Implementation of Access control mechanisms ; Write a pair of programs in C or shell script to send and receive a message by a covert channel in UNIX ; Simulation of k Anonymity, l diversity and t closeness algorithms ; Developing a simple intrusion detection system to protect masquarading attacks ; Study of SQL Injection attacks and simulation of control strategies ; Other assignments suggested by the instructor

CS 679	BIOMETRICS LABORATORY	2 Credits [0-0-3]

No Description

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
EC 600	Architecture of DSP	3-1-0	4
EC 611	Digital Communication	3-1-0	4
EC 612	Antenna Analysis and Synthesis	3-1-0	4
EC 613	Optical Communication	3-1-0	4
EC 614	Information Theory and Coding	3-1-0	4
EC 615	Mobile Communication	3-1-0	4
EC 616	Microwave Engineering	3-1-0	4
EC 617	Satellite Communication	3-1-0	4
EC 619	Computer Communication Network	3-1-0	4
EC 620	Modeling and Circuit Simulators for VLSI Systems	3-1-0	4
EC 621	Digital VLSI Design	3-1-0	4
EC 622	Design of Analog and Mixed Mode VLSI Circuits	3-1-0	4
EC 623	HDL and High Level VLSI Design	3-1-0	4
EC 624	Embedded Computing System	3-1-0	4
EC 626	Low Power VLSI Design	3-1-0	4
EC 627	VLSI Fabrication Technology	3-1-0	4
EC 628	VLSI Signal Processing	3-1-0	4
EC 629	VLSI Testing and Testability	3-0-0	3
EC 630	Industrial Electronics & Instrumentation	3-1-0	4
EC 631	Analytical Instrumentation	3-1-0	4
EC 633	PC Based Instrumentation	3-1-0	4
EC 637	Medical Instrumentation	3-0-0	3
EC 639	Advanced Process Control	3-1-0	4
EC 640	Pattern Recognition Application	3-1-0	4
EC 641	Digital Signal Processing	3-1-0	4
EC 642	Advanced Techniques in Digital Signal Processing	3-1-0	4
EC 643	Digital Image Processing	3-1-0	4
EC 644	Soft Computing	3-1-0	4
EC 646	Adaptive Signal Processing	3-1-0	4
EC 648	Evolutionary Computing Techniques	3-1-0	4
EC 670	Mobile Communication Laboratory	0-0-3	2
EC 671	Digital Signal Processing Laboratory	0-0-3	2
EC 672	Advanced Techniques in DSP Laboratory	0-0-3	2
EC 673	Advanced Communication Laboratory	0-0-3	2
EC 674	Soft Computing Laboratory	0-0-3	2
EC 675	High Level VLSI Design Laboratory	0-0-3	2
EC 676	Analog and Mixed Signal IC Lab	0-0-3	2
EC 677	VLSI Design Laboratory	0-0-3	2
EC 678	Embedded Computing System Lab	0-0-3	2
EC 679	Antenna Design & Simulation Laboratory	0-0-3	2
EC 681	Special Topic in Electronics & Communication Engg - I		3/4
EC 682	Special Topic in Electronics & Communication Engg – II		3/4
EC 683	Special Lab. in Electronics & Communication Engg - I	0-0-3	2
EC 684	Special Lab. in Electronics & Communication Engg - II	0-0-3	2
EC 685	Seminar Technical Writing – I	0-0-3	2
EC 686	Seminar Technical Writing – II	0-0-3	2
EC 687	Seminar Technical Writing – III	0-0-3	2

EC 688	Seminar Technical Writing – IV	0-0-3	2
EC 691	Summer Research / Industrial Project	0-0-0	4
EC 692	Comprehensive Viva Voce	0-0-0	4
EC 693	Research Project – I	0-0-0	20
EC 694	Research Project – II	0-0-0	20
EC 700	High-Vacuum Technology & Application	3-1-0	4
EC 701	Optical Engineering and Laser Instrumentation	3-1-0	4
EC 702	Instrumentation for Energy Conservation & Management	3-1-0	4
EC 704	Digital Design of Instrumentation	3-1-0	4
EC 705	Safety & Reliability	3-1-0	4
EC 707	Micro controller & Application	3-1-0	4
EC 708	Micro-system Materials, Processes & Devices	3-1-0	4
EC 709	Micro-Electronic Devices & Application	3-1-0	4
EC 710	Digital Control System	3-1-0	4
EC 771	Digital Communication Lab	0-0-3	2
EC 772	DSP Hardware Lab	0-0-3	2
EC 773	Advanced Instrumentation Laboratory	0-0-3	2
EC 774	Image Processing Laboratory	0-0-3	2
EC 776	Advanced Process Control Laboratory	0-0-3	2
EC 777	Digital Filter Design Lab	0-0-3	2
EC 778	Adaptive Signal Processing Laboratory	0-0-3	2
EC 779	Video Signal Processing Lab	0-0-3	2
EC 781	Special Topic in Signal & Image Processing – I/ Special Topic in VLSI Design and Embedded System– I/ Special Topic in Electronics and Instrumentation – I/ Special Topic in Communication and Networks – I		3/4
EC 782	Special Topic in Signal & Image Processing – II/ Special Topic in VLSI Design and Embedded System– II/ Special Topic in Electronics and Instrumentation – II/ Special Topic in Communication and Networks – II		3/4
EC 783	Special Laboratory in Signal & Image Processing – I/ Special Laboratory in VLSI Design and Embedded System– I/ Special Laboratory in Electronics and Instrumentation – I/ Special Laboratory in Communication and Networks – I	0-0-3	2
EC 784	Special Laboratory in Signal & Image Processing – II/ Special Laboratory in VLSI Design and Embedded System–II/ Special Laboratory in Electronics and Instrumentation – II/ Special Laboratory in Communication and Networks – II	0-0-3	2
EC 785	Transform Domain Signal Processing Lab	0-0-3	2
EC 786	Biomedical Signal Processing Lab	0-0-3	2
EC 787	Speech Processing Lab	0-0-3	2
EC 788	Multimedia Signal Processing Lab	0-0-3	2
EC 791	Microwave Lab	0-0-3	2
EC 792	Sensor Lab	0-0-3	2
EC 793	Communication Networks Lab	0-0-3	2

EC 600 ARCHITECTURE OF DSP 4 Credits [3-1-0]

INTORODUCTION TO DIGITAL SIGNAL PROCESING: Introduction, Analysis and Design tool for DSP Systems, DSP using MATLAB. ; **COMPUTATIONAL ACCURACY IN DSP IMPLEMENTATIONS:** Number formats for signals and coefficients in DSP systems, Dynamic Range and Precision, Sources of error in DSP implementations, A/D Conversion errors, DSP Computational errors, D/A Conversion Errors, Compensating filter. ; **ARCHITECTURES FOR PROGRAMMABLE DSP DEVICES:** The Programmable DSP

Architecture, Top-Down Design of Dedicated DSPs. A Library-Based Systems Design Environment An Abstract Computing Machine, DSP Computational Building Blocks, Bus Architecture and Memory, Data Addressing Capabilities, Address Generation Unit, Programmability and Program Execution, Speed Issues, Features for External interfacing. Optimization of Performance, Interconnection between Functional Units, A Multi-level Classification. SISC Architectures, Addressing Modes, External Interface Units. The SISC Processor, Pipeline Control in SISCs, Superscalar Processors. ; **EXECUTION CONTROL AND PIPELINING:** Hardware looping, Interrupts, Stacks, Relative Branch support, Pipelining and Performance, Pipeline Depth, Interlocking, Branching effects, Interrupt effects, Pipeline Programming models. ; **PROGRAMMABLE DIGITAL SIGNAL PROCESSORS :** Commercial Digital signal-processing Devices, Data Addressing modes, Memory space, instructions and Programming, On-Chip Peripherals, Pipeline Operation of Commercial DSP Processor ; **IMPLEMENTATIONS OF BASIC DSP ALGORITHMS :** The Q-notation, FIR Filters, IIR Filters, Interpolation Filters, Decimation Filters, PID Controller, Adaptive Filters, 2-D Signal Processing. An FFT Algorithm for DFT Computation, A Butterfly Computation, Overflow and scaling, Bit-Reversed index generation, Computation of the signal spectrum. ; **INTERFACING MEMORY AND I/O PERIPHERALS TO PROGRAMMABLE DSP DEVICES :**Memory space organization, External bus interfacing signals, Memory interface, Parallel I/O interface, Programmed I/O, Interrupts and I/O, Direct memory access (DMA). A Multichannel buffered serial port (McBSP), McBSP Programming, a CODEC interface circuit, CODEC programming, A CODEC-DSP interface example.

Essential Reading:

1. B. Venkata Ramani and M. Bhaskar,*Digital Signal Processors*, Architecture, Programming and Applications –TMH, 2004.

Supplementary Reading:

1. Jonatham Stein,*Digital Signal Processing*, John Wiley, 2005.
2. Avtar Singh and S. Srinivasan,*Digital Signal Processing* –Thomson Publications, 2004.
3. Vijay K. Madisetti, *"VLSI Digital Signal Processors – An Introduction to Rapid Prototyping and Design Synthesis"*, IEEE Press, 1999.
4. Richard J. Higgins, *"Digital Signal Processing in VLSI"*, Prentice Hall, 1990

EC 611	**DIGITAL COMMUNICATION**	**4 credits [3-1-0]**

DIGITAL MODULATION TECHNIQUES:BPSK, BFSK and DPSK, QPSK, M-ary PSK, MSK, M-ary FSK, GMSK.**OPTIMUM RECEIVERS FOR AWGN CHANNEL**: Optimum receiver for signals corrupted by AWGN, performance of optimum receiver for memory less modulation, optimum receiver for CPM signals, optimum receiver for signals with random phase in AWGN channel. **CARRIER AND SYMBOL SYNCHRONIZATION:** Signal Parameter estimation, carrier phase estimation, symbol timing estimation, Joint estimation. **CHANNEL CAPACITY AND CODING**: Channel models and channel capacity, Block codes – coding and decoding, cyclic codes, algebraic codes, Reed-Solomon Code, Convolutional codes; **SPREAD SPECTRUM SIGNALS FOR DIGITAL COMMUNICATION:** Direct sequence (DS) spread spectrum and its applications, frequency hopping (FH) spread spectrum, synchronization of spread spectrum systems.

Essential Reading:

1. H. Taub and D.L. Schilling, *Principle of Communication Systems*, 2^{nd} Ed., McGraw Hill, 1986.
2. J.G. Proakis, *Digital Communication,* McGraw-Hill Publications, 2000.

Supplementary Reading:

1. B. Sklar, *Digital Communications*, Pearson Education, India, 2001
2. J.G. Proakis, M. Salehi,*Communication Systems Engineering*, Pearson Education International, 2002
3. Lee & Moseschmitt, *Digital Communication,*Springer, 2004.

EC 612	**ANTENNA ANALYSIS & SYNTHESIS**	**4 credits [3-1-0]**

Design of short wire antenna, Calculation of field pattern for odd and even Half- wavelengths. Antenna Array, Linear array, Phased array; Array synthesis: Prediction of antenna array from radiation pattern, Detailed theoretical analysis of: Yagi-Uda array; Theory of: Horn antenna, Parabolic antenna, satellite antenna; Design of Microstrip antenna (Rectangular & square patches); Idea about Transmission Line Model; Brief idea about Active Integrated antenna

Essential Reading:

1. C.A. Balanis, *Antenna Analysis.*

Supplementary Reading:

1. Jordan & Balmain, *Electromagnetic Waves and Radiating Systems.*
2. J. D. Kraus,*Antenna Theory*.

EC 613	OPTICAL COMMUNICATION	4 credits [3-1-0]

Introduction to optical communication: Characteristics of optical transmission media, optical fibres-preparation and transmission characteristics, loss and dispersion mechanisms; **Optical sources:** principles of operation, modulation characteristics and driver circuits,LED, laser diodes, light source linearity, modal, and partition and reflection noise**; Power Launching and Coupling:**Source to fibre power launching, lensing schemes for coupling improvement, fibre to fibre joints, couplers, multiplexers and splices;**Photo detectors**: principles of operation, circuits and performance,preamplifiers and post-detection amplifiers; **Optical Fiber systems**: intensity modulation/direct detection system, link budget using direct detection, coherent system,wavelength converters, coherent and WDM systems,Photonic switching.

Essential Reading:

1. G. Keiser, *Optical Fibre Communications*, McGraw Hill, 2008.
2. John M. Senior, *Optical Fiber Communications: Principles and Practice*, PHI, 2008.

Supplementary Reading:

1. Jones, W.B. Jones, *Introduction to Optical Fiber Communications Systems*, Oxford University Press (1995)
2. A. J. Rogers, *Understanding Optical Fiber Communications*,Artech House (2001)
3. J. C. Palais, Fiber optic communication, 5th edition, Prentice Hall, 2004

EC 614	INFORMATION THEORY AND CODING	4 credits [3-1-0]

Introduction: Entropy and mutual information, source coding, variable length coding, discrete memory less channels, capacity cost functions, channel coding, linear block codes, and cyclic codes. Convolution codes, sequential and probabilistic decoding, majority logic decoding, burst error-correcting codes, turbo codes and low-density-parity-check codes; rate distortion theory: rate distortion function. **Cryptography**: basic concepts on cryptography and cryptoanalysis, security issues; private-key encryption algorithms-stream ciphers, block ciphers, Shannon's theory; introduction to number theory - modular arithmetic, exponentiation and discrete logarithms in Galois field; public-key encryption algorithms-Diffie-Hellman public-key distribution scheme, RSA public-key cryptosystem; Message authentication, hashing functions, digital signatures.

Essential Reading:

1. S. Haykin, *Communication Systems*, 4th Ed, John Wiley & Sons, New York, 2001.
2. L. Hanzo, T.H. Liew and B.L. Yeap, *Turbo coding, turbo equalization and space-time coding for transmission over fading channels*, John Wiley &Sons, 2002.

Supplementary Reading:

1. W. Trappe, L. C. Washington, *Introduction to Cryptography with Coding Theory*, Second edition, Prentice-Hall, Inc. NJ, USA.
2. R. Bose, *Information Theory, Coding and Cryptography*, Tata McGraw-Hill, 2002.

3. B.P. Lathi, *Modern Digital and Analog communications,* Third Edition, Oxford University Press
4. D. R. Stinson, Cryptography*: Theory and Practice*, Third Edition, Champmen & Hall/ CRC

EC 615	**MOBILE COMMUNICATION**	**4 credits [3-1-0]**

Evolution Mobile Systems around the World, Example of the mobile radio systems, recent trends, Frequency reuse, Channel assignment, hand off process, Interference. Path less:– Radio wave propagation, diffraction, Scattering, link budget; Outdoor and indoor propagation models; Principle of multi path propagation, Impulse response model of channels, parameters for mobile multi path channels, concept of fading, Rayleigh and Ricean fading; simulation of fading channels. Modulations techniques for mobile communication:- Linear Modulation techniques, constant envelop modulation, QPSK, MSK, GMSK, spread spectrum modulation techniques. Equalization:- Fundamentals, General adaptive equalizer, Linear and non-linear equalizers, diversity techniques, RAKE receivers. Basic concept of coding. Multiple access techniques: - Introduction, FDMA, TDMA, CDMA, Space division multiple access, capacity of cellular systems. Introduction to OFDM and wireless LAN.

Essential Reading:

1. T.S. Rappaport, *Wireless Communications – Principles and Practice*, Prentice Hall of India/ Pearson Education India, 2002.
2. W C Y Lee; *Mobile Communication Engineering*, Tata McGraw Hill, India, 2008

Supplementary Reading:

1. W.C.Y. Lee, *Digital Cellular Systems*, Mc Graw Hill, 2000.
2. G. Stuber; *Principles of Mobile Communication*, 2001, Springer

EC 616	**MICROWAVE ENGINEERING**	**4 credits [3-1-0]**

Introduction: Microwave frequencies, Standard frequency bands, behavior of circuits at conventional & microwave frequencies, Microwave Applications, Review of Maxwell's equations. Wave guides: Over view of wave guided waves; TE, TM & TEM modes, circular wave guide, choice of types of wave guide dimensions, waveguide dimensions, waveguide problems; Microwave Components & Devices: Scattering Matrix and its properties, coupling probes, Coupling loops, Windows, Waveguide Tuners, Termination, E-plane Tee, H-plane Tee, Magic Tee, Phase Shifter, attenuators, Directional Couplers, Gunn Diodes, Microwave Transistors, MASER, Resonator & Circulators. Microwave Generators: Transit Time Effect, Limitations of conventional Tubes, Two-cavity and Multi-cavity Klystron, Reflex Klystron, TWT and Magnetrons. Microwave Measurements: Power Measurement; Calorimeter method, bolometer bridge method, thermocouples, impedance measurement, Measurement of frequency and wavelength, Measurement of unknown loads, Measurement of reflection coefficient. VSWR and Noise, Microwave Test bench.

Essential Reading:

1. D M Pozar, *Microwave Engineering*, John Wiley & Sons, 2004
2. S Lio, *Microwave Devices & circuits*, Prentice halls, India, 2004

Supplementary Reading:

1. Herbert J. Reich, *Microwave Principles.*
2. R Chatterjee, *Elements of Microwave Engg.*

EC 617	**SATELLITE COMMUNICATION**	**4 credits [3-1-0]**

Introduction: Original Satellite Communications, History, Current State, Overview of Satellite System Engineering; **Orbital Aspects of Satellite Communication:** Orbital mechanism, look angle determination, orbit determination, orbit effects on Communication, System performance; **Satellite Link Budget:** Basic transmission theory, system noise and G/T ratio, down link design, satellite system using small earth station, up-link design; **Modulation Multiplexing Techniques:** Analog telephone transmission, Television transmission, Digital transmission, Digital TV and bandwidth Compression, time division multiplexing; **Multiple Access Techniques:** Frequency division multiple access, time division multiple access, code division multiple access, practical demand access systems, random access, multiple access with on-board processing; **Satellite Earth Solution Techniques:** Earth solution design, tracking, small earth station antennas, Equipment for the Earth station.

Essential Reading:

1. T. Pratt and W. Boston, *Satellite Communications,* John Wiley & Sons, 2004.
2. William W Wu, Elements of Digital Satellite Communication, Vol. 1, Computer Science Press 2006.

Supplementary Reading:

1. T.T. Ha, *Digital Satellite Communications,* McGraw Hill, U.S.A., 2004.
2. G.D. Gordon, W.L. Morgan, *Principles of Communication Satellite,* John Wiley & Sons, U.S.A., 2005.

EC 619	COMPUTER COMMUNICATION NETWORKS	4 credits [3-1-0]

Communication Model, Data Communications, Computer Communication Architecture, Standard Making Organizations. Concepts and Terminology, Asynchronous and Synchronous Data Communications, Multiplexing Techniques. Communication Networking Techniques, Circuit Switching, Packet Switching, Local Area Networks. Protocols, Layered Approach, TCP / IP Protocol Suite, System Network Architecture. The Bridge and Routing, Connectionless internetworking, Connection oriented internetworking. Transport and Network Services TCP / UDP.Session Characteristics, OSI Session and Service Protocol. Presentation Concepts, Encryption and Authentication Codes, Virtual Terminal Protocols. Network Management, File Transfer and Electronic Mail. Communication Switching Techniques,Frame-mode Bearer Service, Frame Relay Congestion Control, Synchronous Transfer Mode.

Essential Reading:

1. W.Stallings,*Data and Computer Communications*, PHI, New Delhi, 2006.

Supplementary Reading:

1. A.S.Tanenbaum,*Computer Networks*, 2nd Ed.; PHI, New Delhi, 2002.
2. F. Halsall*, Data Communications, Computer Networks and Open Systems*, Pearson Education, 2003.

EC 620	MODELING AND CIRCUIT SIMULATORS FOR VLSI SYSTEMS	4 credits [3-1-0]

Introduction to VLSI modeling and simulation, Semiconductor Fundamentals, Metal Semiconductor Contacts. Schottky barriers, rectifying and ohmic contacts, I-V characteristics. PN junctions; MOS Structure, MOS capacitors and MOSFETs: MOS capacitor – fabrication, surface charge – accumulation, depletion, inversion, threshold voltage, C-V characteristics – low and high frequency, MOSFET – fabrication, operation, gradual channel approximation, simple charge control model (SCCM), Pao-Sah and Shichmann-Hodges models, I-V characteristics, high-frequency model, second-order effects – velocity saturation, short-channel effects, charge sharing model, hot cattier effects, gate tunneling, sub-threshold operation – drain induced barrier lowering (DIBL) effect, unified charge control model (UCCM), SPICE level 1, 2 and 3, and Berkeley short-channel IGFET model (BSIM); D.C. Analysis (Linear and Non-linear), Transient Analysis (Linear and Non-linear), Small Signal – (Freq – Domain) Analysis, Sensitivity, Noise, Logic Simulation; Nano-CMOS Circuit Modeling; Introduction to VLSI Design and Simulation CAD Tools

Essential Reading:

1. R.S.Muller and T.I.Kamins, *Device Electronics for Integrated Circuits* by John Wiely & Sons.

2. D.Foty, *MOSFET Modeling with SPICE* by PH.

Supplementary Reading:
1. Y.Tsividis, *Operation and Modeling of The MOS Transistor* by McGraw Hill, 1999
2. B.G.Streetman, “*Solid State Electronics Devices*”, PHI.
3. B.P.Wong, A.Mittal, Yu Gao and G.Starr, *Nano-CMOS Circuit and Physical Design* by Wiley Interscience, 2005
4. Reference Manuals of different CAD Tools

EC 621 ANALOG AND DIGITAL VLSI DESIGN 4 credits [3-1-0]

Introduction to VLSI Design, Levels of abstraction and the complexity of design, Challenges of VLSI design: power, timing, area, noise, testability, reliability and yield ; CAD tools: simulation, layout, synthesis, test; MOS modeling, MOS device models, Short-channel effects and velocity saturation, Scaling of MOS circuits; VLSI fabrication technology, Layout design, Design rules, Stick diagrams; The CMOS inverter, VTC, Switching behavior, Noise margins and power dissipation; Static and dynamic CMOS combinational logic gate, Transistor sizing in static CMOS, logical effort , Pass-transistor logic, sizing issues , Domino logic gates , estimating load capacitance , Simple delay models (RC) for CMOS gates , Power consumption; Latches and clocking, Flip-flops, Set-up and hold tests, Static and dynamic latch and flip-flop, Clock design; Datapath units, Adders, Shifters, Multipliers; Control logic strategies, PLAs , Multi-level logic, Synthesis and place-and-route CAD; MOS memories , Register, SRAM , DRAM; Global interconnect modeling, Capacitance, resistance and inductance of interconnect; Signal and power-supply integrity issues, Electromigration, RC interconnect modeling Driving large capacitive load, reducing RC delays; Layout design, Standard-cell layout, Chip layout and floor planning, Array layout; Implementation issues, Design for testability, Packaging technology,I/O issues: ESD protection, boundary scan, inductance, synchronization

Essential Reading:
1. J. M. Rabaey, A. Chandrakasan and B. Nikolic, *Digital Integrated Circuits: A Design Perspective*, Second Edition, Pearson/PH, 2003. (Cheap Edition)

Supplementary Reading:
1. J. P. Uyemura, *Introduction to VLSI Circuits and Systems*, Wiley, 2001.
2. W.Wolf, *Modern VLSI Design: Systems-on-Chip Design*, Third Edition, Pearson/PH, 2002. (Cheap Edition).
3. R. L. Geiger, P. E. Allen and N. R. Strader, *VLSI Design Techniques for Analog and Digital Circuits*, McGraw-Hill, 1990.

EC 622 DESIGN OF ANALOG AND MIXED MODE VLSI CIRCUITS 4credits [3-1-0]

Introduction to Analog IC Design, The Design Flow of Analog ICs, MOSFET Parameters, MOSFET models, MOS Diode, MOS Capacitors, MOS Switch, Noise in MOSFETs, MOS Current sources and current sink circuits, Voltage and Current reference circuits, MOS Gain stages, Source Followers, Amplifiers, Differential Amplifiers, Operation Amplifiers, Stability Theory and Compensation in CMOS Operational Amplifiers, Opamp Design Techniques and practical consideration in design of opamp, High Performance CMOS Opamp Design, Design of MOS Comparators, Data Converter Fundamentals, Digital-to-analog Converters, Analog-to-Digital Converters, Switch Capacitor Filters, Mismatch Issues in Analog Layouts, Phase locked loops, Introduction to RF IC Design

Essential Reading:
1. P.E. Allen and D.R.Holberg; *CMOS Analog Circuit Design*; Oxford University Press, 2004
2. R.Gregorian and G.C.Temes, *Analog MOS Integrated Circuits for Signal Processing*; John Wiley and Sons, 2004.

Supplementary Reading:
1. R.J.Baker, H. W. Li, D. E. Boyce; *CMOS Circuit Design, Layout, and Simulation*; PHI, 2002

2. P.R.Gray, P.J.Hurst, S.H.Lewis and R.G.Meye; *Analysis and Design of Analog Integrated Circuits*, John Wiley & Sons, Fourth Edition, 2003
3. D.A. Johns and K. Martin; *Analog Integrated Circuit Design*; John Wiley and Sons, 2004
4. B. Raza; *Design of Analog CMOS Integrated Circuits*; Tata McGraw-Hill, 2002
5. M. Ismail and Terri Fiez; *Analog VLSI;* McGraw Hill, 1994

EC 623 HDL AND HIGH LEVEL VLSI DESIGN 4 credits [3-1-0]

Basic concepts of hardware description languages., Hierarchy, Concurrency, logic and delay modeling, Structural, Data-flow and Behavioral styles of hardware description, Architecture of event driven simulators, Syntax and Semantics of VHDL, Variable and signal types, arrays and attributes, Operators, expressions and signal assignments, Entities, architecture specification and configurations, Component instantiation, Concurrent and sequential constructs, Use of Procedures and functions, Examples of design using VHDL., Synthesis of logic from hardware description. ; CMOS Process and Masking Steps: Concept of Lambda, Design Rules, Layer Properties and Parasitic Estimation, Sheet Resistance, U Cg, Capacitance Ratio for Layers, Concept of tau, Quick estimation of delays. Design of Buffers and I/O Pads, CMOS Logic Design Styles and their Comparison, CMOS Logic Design Styles and their Comparison (Continued), From Specifications to Silicon, Abstraction Levels in VLSI Design. ; Adder Architectures, Multiplier Architectures, Counter Architectures, ALU Architectures. Latches, Flip-flops, Registers and Register Files. PLA Design, Gate Array Approach, Standard Cell Approach. Moore and Mealy Machines, PLA-based Implementation, Random Logic Implementation, Micro-programmed Implementation (ROM-based Implementation) SRAM Cell, Different DRAM Cells, Arraying of Cells, Address Decoding, Read / Write Circuitry, Sense Amplifier Design, ROM Design.Clock Skew, Clock, Distribution and Routing, Clock Buffering, Clock Domains, Gated Clock, Clock Tree.

Essential Reading:

1. C. H. Roth,*Digital Systems Design Using VHDL* , Thomson Publications, Fourth Edition, 2002
2. V. A. Pedroni, *Circuit Design with VHDL*, MIT Press/PHI, 2004. (Cheap Edition)

Supplementary Reading:

1. Z. Navabi, *Verilog Digital System Design*, Second Edition, Tata McGraw-Hill, 2008.
2. R. C. Cofer and B. F. Harding, *Rapid System Prototyping with FPGAs: Accelerating the Design Process*, Elsevier/Newnes, 2005.

EC 624 EMBEDDED COMPUTING SYSTEMS 4 credits [3-1-0]

Introduction to software design: Requirements, specifications, structural and behavioral descriptions, UML ; **Embedded Processors**: Risc, super scalar, and VLIW architectures, ARM andSHARC, Processor and memory organization and Instruction level parallelism; **CPU architectures**: Input/Output, interrupts, modes, cache memories **Embedded bus architectures**: Bus architectures and transactions, Serial interconnects, Networked embedded systems: Bus protocols, I^2C bus and CAN bus; Internet-Enabled Systems, Design Example-Elevator Controller. **Program design and analysis:** Compilers and optimization. Testing. Performance Analysis. ; **Operating Systems**; Tasks, context switches, Operating system support (inter-process communication, networking), Scheduling, Development environment.; **Hardware Accelerators** : FPGA architectures , RISC IP Cores , Verilog HDL ; **Embedded System Application**, design challenge – optimizing design metrics, processor technology, design technology; real time-operating system : system modeling, static scheduling, Priority drive scheduling, Synchronization & mutual exclusion (real-time and non-real-time); H/W and S/W co-design; embedded multiprocessor ; **DSP Algorithm Design:** A/D conversion and finite precision analysis, Algorithms for embedded systems: source and channel processing, Portable embedded code. Low Power architectures for embedded systems

Essential Reading:

1. W. Wolf, *Computers as Components : Principles of Embedded Computer System Design*, Second Edition, Elsevier/MK, 2005

2. F. Vahid and T. Givargis, *Embedded System Design: A Unified Hardware/SoftwareIntroduction*, Wiley, 2002.

Supplementary Reading:
1. P. Marwedel, *Embedded System Design*, Springer, 2006.
2. Proceedings of the IEEE (Special Issue on HW/SW Codesign), March, 1997.

EC 626	**LOW POWER VLSI DESIGN**	**4 credits [3-1-0]**

Analysis of components of power dissipation in digital circuit techniques for low power at technology level, Techniques for low power design at logic design level (analysis of various logic design styles for their power consumption), Low power design techniques at architecture and system levels, Power consumption of dedicated hardware vs. software implementations of systems.

Essential Reading:
1. A.P.Chandrakasan and R.W.Broderson, "*Low Power CMOS Design*", IEEE Press, 1998.

Supplementary Reading:
1. J.B.Kuo and J.H.Lou, "*Low Voltage CMOS VLSI Circuits*", 1998, John Wiley

EC 627	**VLSI TECHNOLOGY**	**4 credits [3-1-0]**

Crystal structure, crystal growth and vapour phase epitaxy. Unit processes for VLSI-Oxidation, Photolithography, diffusion ion implantation. Deposition of metal and dielectric films by vacuum evaporation, sputtering and CVD techniques, Wet chemical and Dry etching techniques. Device and Circuit fabrication-Isolation, Self alignment and local oxidation techniques. OS based silicon ICs-NMOS and CMOS ICs, Memory Devices, SOI Devices, BJT based ICs – choice of transistor types, pmp transistors, advanced structures Bipolar-CMOS (BICMOS) ICs, Resisters, Capacitors.

Essential Reading:
1. S.K.Gandhi, "*VLSI Fabrication Principles*", John Wiley and Sons, NY, 1994

Supplementary Reading:
1. S.M.Sze, "*VLSI Technology*", McGraw Hill Book Company, NY, 1988.
2. D.Nagchoudhari, "*Principles of Microelectronics Technology*", Wheeler (India), 1998.

EC 628	**VLSI SIGNAL PROCESSING**	**4 credits [3-1-0]**

Typical Signal Processing Algorithms, Overview of VLSI Architectures, Representations of DSP Algorithms. Iteration Bound, Pipelining, Parallel Processing, Definitions and Properties, General Methodology, Unfolding Algorithm, Critical Path, Unfolding, and Retiming, Folding Transformation, Register Minimization. Overview, Design Methodology, Matrix Operations and 2D Systolic Array Design, Parallel Algorithm Expressions, Canonical Mapping Methodology, Generalized Mapping. Carry-Look ahead Addition, Prefix Computations, Carry-Save Addition, Multiplication and Convolution. Important Features, DSP Processors for Mobile and Wireless Communications, Processors for Multidimensional Signal Processing

Essential Reading:
1. K. K. Parhi, "*VLSI Digital Signal Processing Systems, Design and Implementation*", John Wiley, 1999.

Supplementary Reading:
1. S.Y.Kung, "*VLSI Array Processors*", Prentice-Hall, 1988

EC 629	**VLSI TESTING AND TESTABILITY**	**4 credits [3-1-0]**

Defects and their modeling as faults at gate level and transistor level. Various types of faults. Functional vs. Structural approach to testing, Complexity of the testing problem, Controllability and Observability, Generating test for a single stuck at fault in combinational logic, D-algorithm, FAN and PODEM algorithms, Test optimization and fault converage. The problem of testing of sequential of DFT hardware, Adhoc and structured approaches to DFT – Various kinds of scan design, Fault models for PLAs, Bridging and delay faults and their tests, Memory testing, Testing with random patters. The LFSRs and their use in random test generation and response compression (including MISRs) Built – in self-test.

Essential Reading

1. M.Abramoviei, M.A.Breuer and A.D.Friedman, "*Digital Systems Testing and Testable Design*", IEEE Press, 1995 (Revised).

Supplementary Reading:

1. V.Agrawal and S.C.Seth, "*Test Generation for VLSI Chips*", IEEE CS Press, 1989.

EC 640	PATTERN RECOGNITION ENGINEERING	4 credits [3-1-0]

Pattern Recognition, Classification, and Description, Pattern and Feature Extraction with Examples, Training and Learning in PR Systems, Pattern Recognition Approaches; The Gaussian Case and Class Dependence, Discriminant Functions, Classifier Performance, Risk, Errors., Parametric Estimation and Supervised Learning, Maximum Likelihood (ML) Estimation, The Bayesian Parameter Estimation Approach, Supervised Learning Using Non-parametric Approaches, Parzen Windows, k-nn Non-parametric Estimation, Direct Classification Using the Training Set [The Nearest Neighbor Role (NNR)]; Linear Discriminant Functions, Fisher's Linear Discriminant, Discrete and Binary Classification Problems, Techniques to Directly Obtain Linear Classifiers., Formulation of Unsupervised Learning Problems, A Modified Training Set, Unsupervised Learning Approaches, Clustering for Unsupervised Learning and Classification; Syntatic Pattern Recognition (SyntPR) Overview, Quantifying Structure in Pattern Description and Recognition, Grammar-Based Approach and Applications, Elements of Format Grammars, Recognition of Syntactic Descriptions, Parsing, The Cocke-Younger-Kasami (CYK) Parsing Algorithm, (Augmented) Transition Networks (ATNs) in Parsing, Higher Dimensional Grammars, Stochastic Grammars and Applications.

Essential Reading:

1. R.O. Doda, P E Hart, D G Stork; *Pattern Classification*; John Wiley and Sons (Student Edition); 2003
2. R. Singhal;*Pattern Recognition: Techniques and Applications*; Oxford University Press, 2006

Supplementary Reading:

1. C M Bishop; *Neural Network and Pattern Recognition; Oxford University Press, 2005.*

EC 641	DIGITAL SIGNAL PROCESSING	4 credits [3-1-0]

Introduction: Signals, systems and signal processing, concept of frequency in continuous and discrete time signal; **Discrete-time Signals and Systems:** Discrete time signals and systems, analysis of LTI system and implementation, correlation; **Z-transform:** Review, Analysis of LTI system in z-domain. ; **Frequency Domain Analysis:** Frequency analysis of continuous-time and discrete-time signals and LTI systems, LTI system as frequency selective filter, inverse system and de-convolution. ; **Discrete Fourier Transform:** Properties and Applications, Analysis using DFT; **Fast Fourier Transform Algorithms:** FFT algorithms and Applications, linear filtering approach to computation of DFT; **Implementation of Discrete-Time System:** FIR system, IIR system, representation of numbers, quantization of filter coefficients, round-off effects; **Design of Digital Filters:** Design of FIR and IIR filters, **Recent Developments.**

Essential Reading:

1. J.G. Proakis and D.G. Manolakis - *Digital Signal Processing: Principles Algorithms and Applications*, Pearson Education, 2005

Supplementary Readings:

1. A.V. Oppenheim, R.W. Schafer - *Digital Signal Processing*, Pearson Education, 2004
2. S.K. Mitra - *Digital Signal Processing: A computer based approach*, TMH, 2001
3. L. R. Rabiner and B. Gold – *Theory and Application of Digital Signal Processing,* Pearson Education, 2004

EC 642	ADVANCED TECHNIQUES IN DSP	4 credits [3-1-0]

Multi-rate Digital Signal Processing: Decimation by a factor D, interpolation by a factor 1, sampling rate conversion by a national factor I/D. ; Sampling rate conversion of band pass signals. ; Implementation of low pass filter and digital filter banks. ; lattice filters, Linear prediction, forward and backward linear prediction, FIR wiener filter. ; Power spectrum estimation, non-parametric method Barlett, Parametric method. ; Yule-Walker MA and ARMA models. Higher order statistics and its applications. ; DSP transforms: Discrete Hartely transform, Discrete consine transform, Discrete Wavelet transform, S-transform. DSP techniques for bioinformatics., recent topics

Essential Reading

1. J.G. Proakis, D.G. Manolakis, *Digital Signal Processing,* PHI, New Delhi, 1995.
2. S.J. Orfanidis, *Optimum Signal Processing,* Mac Millan Publishing Co., USA, 1985.

Suggested reading

1. C.K. Chui, *An Introduction to Wavelets,*Academic Press, USA, 1992.
2. Guoan Bi and Y. Zeng, *Transforms and Fast Algorithms for signal analysis and representations*, Springer, NY, USA, 2003.
3. Lecturer notes.

EC 643	DIGITAL IMAGE PROCESSING	4 credits [3-1-0]

INTRODUCTION: Fundamental steps in digital image processing, Components of an image processing system, DIGITAL IMAGE FUNDAMENTALS: Image sampling and quantization, Some basic relationships between pixels, Linear and nonlinear operations, IMAGE ENHANCEMENT IN SPATIAL DOMAIN: Some basic gray level transformations, Histogram processing, Smoothing and Sharpening spatial filters, IMAGE ENHANCEMENT IN FREQUENCY DOMAIN: Smoothing and Sharpening frequency domain filters, Homomorphic filtering, IMAGE RESTORATION: Noise models, Restoration in the presence of noise only-spatial filtering, Estimating the degradation functions, Inverse filtering, COLOR IMAGE PROCESSING: Color models, Pseudo-color processing, IMAGE COMPRESSION: Image compression models, Loss-less and Lossy compression, MORPHOLOGICAL IMAGE PROCESSING: Dilation and erosion, Opening and closing, Some basic morphological algorithms, IMAGE SEGMENTATION: Detection of discontinuities, Edge linking and boundary detection, Thresholding, Region based segmentation, RECENT DEVELOPMENTS**.**

Essential Readings:

1. R. C. Gonzalez and R.E. Woods - *Digital Image Processing*, Pearson Education, 2006
2. L. R. Rabiner and R.W. Schafer - *Digital Processing of Speech Signals*, Pearson Education, 2005

Supplementary Readings:

1. K. Jain - *Fundamentals of Digital Image Processing*, Pearson Education, 2007
2. L. R. Rabiner and B. Gold – *Theory and Application of Digital Signal Processing,* Pearson Education, 2004

EC 644	SOFT COMPUTING	4 credits [3-1-0]

Fundamental Concepts:- Introduction to Artificial Neural Networks (ANN). Learning Process:- error–correction learning, Hebbian learning, competitive learning, Boltzmann learning, the credit-assignment problem, supervised learning, and other learning techniques. Single neuron/ Perceptron networks:- training methodology, typical application to linearly separable problems. Multilayer Perceptron:- Back propagation algorithm, virtues and limitation of BP algorithm, modifications to back-propagation. Radial-basis function Networks – interpolation problem, Covers theorem, regularization networks, applications. Recurrent Networks, ; Introduction to Fuzzysystems, Membership function, Fuzzy relational operation, fuzzy IF THEN rules, Sugeno and Mamdani type systems, Adaptive Neuro-Fuzzy sytems, training methods ; Application of ANN and Fuzzy systems to non-stationary time series prediction; pattern classification; control; communication engineering;system identification and pattern classification.

Essential Reading:

1. S. Haykin, *Neural Networks - A Comprehensive Foundation;*Pearson Education, India (The book is also published by Prentice Hall of India), 200.
2. Martin T. Hagan, Howard B. Demuth, Mark H. Beale; *Neural Network Design*; (ISBN: 0-9717321-0-8); Thomson 2002
3. Jang, Sun and Mizutani; *Neuro-Fuzzy and Soft-Computing* – A computational approach to learning and machine intelligence; Prentice Hall of India

Supplementary Reading:

1. S. Kumar; *Neural Networks: A Classroom approach*, Tata McGraw Hill, 2004, ISBN:9780070482920

EC 646	**ADAPTIVE SIGNAL PROCESSING**	**4 credits [3-1-0]**

Adaptive systems : Examples and applications. Adaptive linear combiner : the performance function, gradient and minimum mean square error, alternative expression of gradient, LMS, NLMS, sign-error, sign-data and FXLMS algorithms, transform domain LMS, Recursive least square algorithm, windowed RLS, computational complexity, Block adaptive filter(time and DFT domains), adaptive lattice filters, IIR adaptive filter : equation error form. Adaptive filtering, adaptive channel equalization, Adaptive line enhancement and adaptive system identification. Hardware implementation of digital adaptive filter. Applications of adaptive filter : 50Hz interference in electrocardiography, cancellation of donor-heart interference, cancellation of maternal ECG in electrocardiography, cancellation noise in speech signals, adaptive echo cancellation in long distance telephone line, self tunning filter. Adaptive control systems : model inverse and model reference controls. Introduction of adaptive array and adaptive beam forming. Recent advances in adaptive filtering.

Essential readings

1. S.Haykin and T. Kailath, *Adaptive Filter Theory*, Pearson Education, 4th Edition, 2005.
2. B. Widrow and S. D. Sterns, *Adaptive Signal Processing*, Pearson Education, 2nd Indian reprint, 2002.

Suggested reading

1. Lecturer notes

EC 648	**EVOLUTIONARY COMPUTING TECHNIQUES**	**4 credits [3-1-0]**

Genetic Algorithm : Basic concepts, Search space, working principle. Encoding : binary, Octal, Hexadecimal, permutation, Value and Tree. Decoding, fitness function, Selection : Roulette-wheel, Boltzmann, Tournament, Rank and Steady-state. Elitism, Crossover : single-pint, two-point, multi-point, uniform, matrix and cross over rate, Mutation : mutation, mutation rate. Variations of GA: Adaptive GA and Real coded GA.; Ant colony optimization: Ant foraging behaviour, combinatorial optimization, Routing in communication network, traveling sales man problem, graph portioning, nest building. ; Particle swarm Optimization : basic principle, algorithm, flowchart. Variations of PSO: weighted, repulsive, stretched, comprehensive learning, combined effect PSO and clonal PSO. ; Bacterial Foraging Optimization: Forging theory, social foraging, foraging behaviour of E. coli bacteria, BFO algorithm, chemotatic, swarming, reproduction and elimination and dispersal.

Variations of BFO: fuzzy BFO and Adaptive BFO. ; Artificial Immune System: overview, central and peripheral immune systems, immune network: clonal selection and its mathematical modeling, beyond clonal selection, danger theory, negative selection. ; Applications: function optimization, adaptive system identification, channel equalization and financial forecasting.

Essential Reading:

1. D. E. Goldberg, *Genetic Algorithms in search, Optimization and machine learning*, 1989.
2. E. Bonabeau, M. Dorigo and G. Theraulaz, *Swarm Intelligence : From natural to Artificial Systems,* ***(Santa Fe Institute Studies in the Sciences of Complexity Proceedings)***, 1999.

Suggested Reading:

1. R. C. Eberhart, Y. Sai and J. Kennedy, *Swarm Intelligence*, The Morgan Kaufmann Series in artificial Intelligence, 2001.
2. K. M. Passino, *Biomimicry for optimization, control and automation*, 2004.
3. D. Dasgupta, *Artificial Immune Systems and their applications*, 1998.
4. Lecturer Notes

EC 670	**MOBILE COMMUNICATION LAB**	**2 credits [0-0-3]**

The laboratory course in Mobile Communication Lab consists of 2 parts. Part-I consists of experiments to be conducted using hardware and equipment. Part-II consist of simulation experiments ; Part-I: Generation different modulation signals using arbitrary function generator - BPSK, QPSK, GMSK, GSM at 900MHz, WLAN signal, Bluetooth signal, CDMA95 signal and CDMA2000 signal. ; Measurement of spectrum of different forms modulation at baseband, IF and RF using signal analyzer - BPSK, QPSK, GMSK, GSM at 900MHz, WLAN signal, Bluetooth signal, CDMA95 signal and CDMA2000 signal ; Analysis of signal through a communication link and measurement of frequency spectrum at different points of transmitter and receiver ; Part-II: All simulation exercised to be done using MATLAB/ Scilab if not specified ; Plotting BER characteristic using Monte Carlo simulation for different modulation schemes for signal propagation through AWGN channel, FIR channel and Rayleigh fading channel ; Generation of spreading codes of different types. Using the spreading codes for DSCDMA signal generation and detection. Plotting the BER curve for different SNR conditions and different numbers of users ; Simulation of a MH-SS system.

EC 671	**DSP LABORATORY**	**2 credits [0-0-3]**

Write a program for linear convolution of two sequences ; Write a program for circular convolution ; Write a program to perform linear convolution using circular convolution ; Write a program to perform N-point DFT. Also perform the IDFT on the result obtained to verify the result ; Write a program to perform circular correlation using ; Direct method b) circular convolution using rotation method ; Write a program to perform circular convolution and correlation using DFT ; Write a program to perform linear convolution using (a)overlap save method (b) overlap add method ; Write a program to perform FFT on a sequence using the following methods. (a) Decimation in time (b) Decimation in frequency ; Write a program to perform IDFT on a transformed sequence using DFT ; Write a program to design an FIR filter using windowing technique ; Write a program to design an IIR filter using (a) impulse invariant method (b) bilinear transformation method.

EC 672	**ADVANCED TECHNIQUES IN DSP LABORATORY**	**2 credits [0-0-3]**

To Compute and Plot the error performance surface ; Adaptive filtering using LMS algorithm ; System identification using different LMS algorithm and compare the performance ; System identification using block LMS algorithm ; System identification using RLS algorithm ; Channel equalization using different LMS algorithm and compare the BER performance ; Channel equalization using RLS algorithm ; IIR filter design using LMS and RLS algorithm.

EC 673	**ADVANCED COMMUNICATION LABORATORY**	**2 credits [0-0-3]**

To study Time division multiplexing ; To study PCM ; To study the different channel coding and decoding technique ; Generation and reception of different types of signals like ASK, PSK, FSK ; To transmit and receive three separate signal audio, video, tone simultaneously through satellite link ; To transmit PC data through satellite link using a satellite communication demonstration unit ; Experimentally compare different forms of BPSK, QPSK, OQPSK and analyze their spectrum with spectrum analyzer ; Spreading and dispreading using additive white Gaussian noise generation/ Gold code and other forms of spreading techniques ; Transmit different types of signals suing a ISDN system ; Analyze the process of data communication in LAN using LAN trainer and compare the performance different media access techniques.

EC 674	SOFT COMPUTING LABORATORY	2 credits [0-0-3]

All experiments in the Laboratory are based on simulation exercise. MATLAB/ Scilab should be used for programming/ simulations: Implementation of a 2input AND and OR logic using perceptron. Start with different set of initial weights and show that there are more than one solution to the problem ; Demonstrate that EX-OR gate is a non-linearly separable problem. Design a MLP for the purpose and train it using BP algorithm ; Using a MPS with BP algorithm approximate the function $y = 1 + Sin(2\pi x)$ for $-1 \leq x \leq 1$. Draw the actual output and simulated output. Show the signal matching after 100/ 500/ 1000 iterations ; Implement a 2input EX-OR gate using regularized RBF (Use 4centres). Plot the output surface for different input variable. Extend this for a 3input RBF using 8 centers. Tabulate the input output pattern mapping for each case ; Using MLP/ RBF design a non-stationary time series prediction network to predict the output against time sample. design a channel equalizer using MLP, RBF for BPSK signal.

EC 675	HIGH LEVEL VLSI DESIGN LAB	2 credits [0-0-3]

Design a full adder using Dataflow modeling ; Design a full adder using half-adder ; Design a half adder ; Design a 4-bit adder cum sub tractor using: (a) 4:1 MUX using the following: (a)dataflow (b)using when else (c) structural modeling using 2:1 MUX (d) behavioral modeling using (i)case statement (ii) if else statement (e)mixed style of modeling(use structural, behavioral, dataflow) ; Design a Decoder(3 : 8) and Encoder (Gray to Binary) ; Design a BCD to 7-Segment Decoder ; Interface the 2-bit adder with 7-segment display ; Design 4-bit Even/Odd parity checker & generator ; Design of Flip-Flops: (a)S-R Flip Flop (b)J-K Flip Flop (c) D Flip Flop (d)T Flip Flop ; Design of counters:bit up counter(use asynchronous reset) (b)4 bit down counter(use synchronous reset) (c) 4-bit up/down counter (d)Decade counter ; Design of Shift-Register: (a)Serial-in serial-out (b)Serial-in parallel-out ; Design the following using Generic (a)Generic Decoder (b)Generic parity (c) detector ; Generic parity generator ; Microcomputer programming. design programs for microcontrollers in assembly language, with the use of different addressing modes, subroutines and stack operations, and interrupts:Examples: Hexadecimal addition of two numbers; Splitting a byte into nibbles; Hexadecimal multiplication of two numbers ;Display letter 'A' on dot matrix display; Check the number for being odd or even.

EC 676	ANALOG AND MIXED SIGNAL IC LAB	2 credits [0-0-3]

The following experiments need to be carried out using Mentor Graphics and Cadence Digital and Analog Design environments: Design of different Current Mirror circuits ; Design of Reference Circuits ; Design of Amplifiers ; Design of Differential Amplifiers ; Design of CMOS OPAMP ; Design of Comparators ; Design of Flash ADC ; Design of SAR DAC ; Design of Switch Capacitor Filters ; Implementation of VCO by Ring Oscillator design ; Design of DPLL ; Design of ADPLL

EC 677	VLSI-LAB	2 credits [0-0-3]

Study of PMOS & NMOS Characteristics using SPICE ; Layout of Basic circuit elements NMOS, PMOS using L-Edit ; Layout & Circuit Simulation of CMOS Inverter ; Study the static behavior of CMOS inverter w.r.t. V_{DD} and Temperature ; Study the Dynamic behavior of CMOS inverter w.r.t. $V_{DD,}$;

Simulation of basic gates ; Simulation of Combinational and Sequential circuits ; Layout experiments of devices and inverter ; Layout of Combinational Circuits ; Layout of Sequential Circuits

EC 678	EMBEDDED SYSTEM LAB	2 credits [0-0-3]

Microcontroller architecture. Overall hardware architecture ofmicrocontrollers, including busses, memories, and input/output subsystems. Application of timer and A/D subsystems to solve measurement and control tasks.; Microcontroller interfacing. Derive waveforms for serial communications interfaces. Apply microcontrollers and external circuitry to interface to a variety of sensors and actuators ; Applications: Traffic light control using micro controller ; Stepper motor control using micro controller; Downloading and uploading from /on PC memory ; Structured approach and developing an embedded system (Mini Project): Initial Planning ; Detailed hardware planning ; Software Development ; Instruction details ; Future Improvements

EC 701	OPTICAL ENGINEERING AND LASER INSTRUMENTATION	4 credits [3-1-0]

Optical fields and waves – their interaction with bulk and structured matter; engineering principles for optical materials, components and systems; lasers and their related technologies; principles and devices based on electro-optics, acousto-optics, magneto –optics, guided wave-optics and harmonic generation; methods of Q-switching, mode-locking and ultra-short pulse generation; laser based methods and systems for measurement and sensing, interferometry, holography, speckle, fiber and Fourier optics.

Essential Reading:

1. Silfvast W.T, *Laser Fundamentals*, Cambridge University press, 2003.

Supplementary Reading:

1. Verdeyen J.T, *Laser Electronics*, Prentice Hall,2002.
2. Siegman A.E., Lasers, *University Science Books*, Mill Valley, CA, 2001.

EC 702	INSTRUMENTATION FOR ENERGY CONSERVATION AND MANAGEMENT	4 credits [3-1-0]

Principles and techniques of energy audit and management; energy conservation methods; evaluation and measurement techniques; heat flux meters; BTU meters suitable for heat exchangers and gaseous fuels calorimeters; instrumentation for renewable energy systems (solar thermal, photovoltaic and wind energy); energy management devices; electromechanical devices; micro controller based systems.

Essential Reading:

1. Liptak B.G., (Ed) Instrument Engineers Handbook, Chinton Book Company, 2004.

Supplementary Reading:

1. Reay. D.A, *Industrial Energy Conservation*, Pergamon Press, 2000.
2. Hodge B.K, *Analysis and Design of Energy Systems*, Prentice Hall, 2002.

EC 704	DIGITAL DESIGN FOR INSTRUMENTATION	4 credits [3-1-0]

Issues and challenges in digital design for instrumentation, combinational and sequential logic design principles and practices, design using programmable logic, CPLDs and FPGAs, CAE Tools, VHDL, testability, RISC processor and peripherals implementations, role of digital signal processors in instrumentation, implementations of DSP building blocks, case studies such as uCOS II based RT system implementation and applications to FTNMR spectrometer.

Essential Reading:

1. J.F. Wakerly,*Digital Design Principles and Practices*, Third Edition, Prentice-Hall (2000)

EC 705 SAFETY & RELIABILITY 4 credits [3-1-0]

Reliability and safety definitions, Risk factor, classification of failures and protective measures, Safety measurement, Preliminary hazard analysis, Subsystem fault hazard analysis, Common mode failures, Codes and standards for safety. Distributions, Markov Modeling, Stress-strength approach to reliability design. Relationship between MTBF, hazard rate, failure rate, reliability. Redundancy techniques. Examples from Electrical, Nuclear, Chemical and Process Engineering. Elementary Analysis and Estimation techniques.

Essential Readings:

1. E. Green, *Safety Systems Reliability*, John Wiley, 1993.
2. K. Daniels, Ed., *'Safety and Reliability of Programmable Electronic Systems'*, Elsevier, 1996.

EC 707 MICROCONTROLLERS AND APPLICATIONS 4 credits [3-1-0]

Architecture of 8/16 bit micro-controllers, assembly language programming and hardware interfacing techniques. Introduction to development tools like cross assembler, simulator, HLL cross compilers and in circuit emulators for system development. Introduction to advanced embedded controllers with built in multi channel ADC, PW M, watchdog timers and applications. Design considerations for single chip solutions and handheld instruments, case studies.

Essential Reading

1. J.B Peatman, Design with Microcontrollers, McGraw Hill (1988)
2. K.J.Ayala, 8051 Microcontroller architecture, programming and applications, Penram International Publications (1999)

EC 708 MICROSYSTEMS-MATERIALS, PROCESSES AND DEVICES 4 credits [3-1-0]

MEMS; introduction and applications, substrates; silicon, GaAs quartz, ceramics and polymers, materials: smart materials and their mechanical ,electrical properties, thin films for micro and nano technologies; thin film processing; physical and chemical methods; thin film characterization structure, microstructure, composition and other properties, Process parameter dependent on thin film properties and structure, lithography: fundamentals, photoresists, lithography processes, optical, electronbeam, focused ion beam, Xray liga and micro steriolithography, etching: bulk and surface micromaching; wet and dry etching, deep reactive ion etching, packaging - bonding, microassembly, packaging and reliability studies, Micro Sensors: Thermal sensors, Radiation sensors, Mechanical sensors, Magnetic sensors and bio sensors forautomotive, aerospace, biomedical and processing technologies.

Essential Readings:

1. J.W Gardner, *Micro sensors, MEMS and Smart devices*, John Wiley & sons (2001).
2. N. Maluf, *An Introduction to Microelectromechanical systems Engineering*.
3. M. Madou, *Fundamentals of Microfabrication*, CRC Press (1997)
4. Ristic L (Editor), *Sensor Technology and Devices*, Artech House Publications (1994)
5. Wise K.D (Guest Editor), *Integrated Sensors, Microactuators and Microsystems (MEMS)*.
6. *Special issue of Proceedings of IEEE*. Vol. 86, No.8, August 1998.

EC 709 MICROELECTRONIC DEVICES AND APPLICATIONS 4 credits [3-1-0]

Semiconductors, growth techniques and properties, thin film phenomena, PVD and CVD techniques, ion implantation and rapid thermal annealing, lithography and ion beam etching, ceramics, glasses and plastics in microelectronics, packaging techniques, microelectronic memory devices.

Essential Readings:

1. S.M.Sze,*Physics of Semiconductor Devices*, Wiley Eastern, (1993)
2. S.A.Campbell, *The Science and Engineering of Microelectronic Fabrication*, Oxford University Press, (1996)

EC 710 DIGITAL CONTROL SYSTEM 4 credits [3-1-0]

Introduction to Digital Control Systems: Continuous-time Vs Discrete-time Systems, Digital Control Vs Digital Signal Processing (DSP),Signal Discretization in time and in amplitude,Continuous-time System Analysis, Discrete-time System Analysis, Continuous-time Controller Design, Controller Design for Discrete-time Systems,Controller Implementation, Case Study and Practical Projects ; **State Variables Approach to Discrete-time Systems:** Definition of the State Vector, The MIMO Transfer Function Matrix G(z), State Transformations, Observability and Controllability, Solution of the State Equations ; **Direct Design of Digital Control Systems Using Transform Techniques:** Z-plane Specification of Control System Design Specifications, Design by Discrete Equivalent, Root Locus Design in the z-plane, Frequency Domain Design Methods ; Design of Digital Control Systems – A State Space Approach; Control Law Design, State Feedback, Estimator Design, Regulator Design; The Effect of Quantization; Analysis of Finite Precision Errors, Limit Cycles and Dither; Optimal control, Model reference control , Parameter estimation , Discrete-time adaptive control.

Essential Reading:

1. C.L. Phillips and H. Troy Nagle,*Digital Control System Analysis and Design*, 3rd. Edition, Prentice Hall,1995.

Supplementary Reading:

1. B.C. Kuo, *Digital Control Systems*, Oxford University Press, 2nd Ed., 1992.
2. A.K.J, Wittenmark B 1997, *Computer Control Systems,* 3rd Ed, Prentice-Hall.
3. Lu Y Z 1996, *Industrial Intelligent Control: Fundamentals and Applications*, Wiley.
4. M.Gopal,*Digital control and State Variable methods*, Tata McGraw –Hill , 1997
5. G.F.Franklin, J.D. Powell and M.Workman,*Digital Control of Dynamic Systems*, 3rd Ed.Addison Wesley, 2000.

EC 772 DSP HARDWARE LAB 2 credits [0-0-3]

Study of the specification of TI DSP kits ; Implement a FIR filter and analyze performance on a fixed point TI DSP processor; Implement a FIR filter and analyze performance on a Floating point TI DSP processor ; Calculation of FFT of a signal using a Floating point TI DSP processor ; Estimate the spectrum of a audio signal using a Floating point TI DSP processor ; Analysis of modulation schemes using software defined radio.

EC 774 IMAGE PROCESSING LAB 2 credits [0-0-3]

To get familiarized with basic functions available in Image Processing Toolbox of MATLAB ; To perform pixel-wise transforms on images (e.g. negative, logarithmic and power- low) ; To enhance the contrast level of an image by histogram equalization ; To design image denoising filters in spatial domain for suppressing additive, multiplicative and impulsive noise ; To study the performance of Ideal, Butterworth and Gaussian low pass filter ; To study the performance of Ideal, Butterworth and Gaussian high pass filter ; To design a homomorphic filter for obtaining an illumination invariant image ; To compress an image data using run-length coding ; To compress an image data using Hoffman coding ; To segment an image with histogram based technique ; To segment an image using region growing/region merging and/region splitting technique ; To perform geometric transformations on different images (scaling, translation and shearing) ; To perform basic morphological operations on an image (dilation, erosion, opening and closing) ; Mini Project.

EC 785 Transform Domain Signal Processing Lab 2 credits [0-0-3]

1. Study and development of DFT and IDFT algorithm.
2. To study LPF & HPF, band pass & reject filters using digital filters.
3. Implementation of a Discrete Walsh Hadamard Transform.

4. To study Z- transform of Sinusoidal signals and Step functions.
5. To represent a signal in Time frequency domain using STFT.
6. Study and design of analysis and synthesis filters using wavelets.
7. Development of an algorithm for compression an audio file and decompression using DCT and IDCT.
8. Decompose the signal using a 4-level filter bank.
9. Study and development of Hilbert Transform to obtain the phase information.
10. Study and development of Hilbert-Huang Transform to display the spectrum of the signal.

EC 786	Biomedical Signal Processing Lab	2 credits [0-0-3]

1. Study and visualize Electrocardiogram (ECG) signal. Determine the P,Q,R,S,T peaks from this signal
2. Develop a compression and decompression algorithm of ECG signal using Huffman coding, DCT and DST.
3. Design a 10^{th} order Butterworth low pass filter with 100Hz cut-off frequency for denoising the 5dB noisy ECG signal.
4. Visualize the frequency spectrum of original ECG signal, 10dB noisy ECG signal and de-noised ECG signal using FFT algorithm.
5. Design of Notch filter for elimination of 50Hz from ECG signal.
6. Study and visualize Phonocardiogram (PCG) signal. Determine S1, S2, diastole and systole periods.
7. Develop an algorithm to determine S1, S2, diastole and systole period from a PCG signal and also determine the duration of the cardiac cycle.
8. Study and display the Electroencephalography (EEG) signal and visualize the frequency spectrum of it.
9. Develop a compression and decompression algorithm of EEG signal using Huffman coding and

EC 787	Speech Processing Lab	2 credits [0-0-3]

1. Study and visualize speech signal for different speakers.
2. Development of an algorithm for FFT, STFT and spectrogram of Speech signal.
3. Develop the algorithms for cepstrum analysis (MFCC, LFCC) of speech signal.
4. Development of an algorithm for distortion measure of speech signal.
5. Development of an algorithm linear predictive coding of speech signal.
6. Development of an algorithm for compression of speech signals using wavelet-based coding and find the compression ratio.
7. Development of an algorithm for compression of speech signals using MPEG coding and find the compression ratio.
8. Develop the vector quantization algorithm automatic recognition of speech signal using cepstral features.

EC 788	Multimedia Signal Processing Lab	2 credits [0-0-3]

1. Development of an algorithm for multimedia data compression using waveform coders and vocoders.
2. Development of an algorithm for image compression using Huffman coding.
3. Development of an algorithm for image compression using run-length coding.
4. Study and analysis Discrete Cosine Transforms (DCT) based image Compression technique.

5. Study and development of an algorithm for image compression using wavelet based coding.
6. Development for algorithm of audio compression using MPEG coding.
7. Study and development of algorithms for video compression using MPEG-1 and MPEG-2.

DEPARTMENT OF ELECTRICAL ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
EE 604	Flexible AC Transmission Systems	3-1-0	4
EE 605	Power Plant Control and Instrumentation	3-1-0	4
EE 606	Transient in Power Systems	3-1-0	4
EE 607	Extra High Voltage Transmission	3-1-0	4
EE 608	Fault Detection and Diagnosis	3-1-0	4
EE 611	Machine Analysis	3-1-0	4
EE 612	Advanced Machine Drives	3-1-0	4
EE 615	Power System Dynamics	3-1-0	4
EE 616	Electrical Energy Systems	3-1-0	4
EE 621	Power Electronics Converters and Machine Drives	3-1-0	4
EE 622	Advanced Power Electronic Converters	3-1-0	4
EE 623	Control of Electric Drives	3-1-0	4
EE 624	Distributed Control & Communication Networks	3-1-0	4
EE 625	Systems and Control Theory	3-1-0	4
EE 626	Nonlinear Control Systems	3-1-0	4
EE 627	Optimal Control	3-1-0	4
EE 628	Industrial Process Automation	3-1-0	4
EE 629	Digital Control	3-1-0	4
EE 630	Robust Control	3-1-0	4
EE 631	Industrial Electronics	3-1-0	4
EE 632	Control and Guidance	3-1-0	4
EE 633	Power Plant Control and Instrumentation	3-1-0	4
EE 634	Robotics and Automation	3-1-0	4
EE 636	System Identification and Adaptive Control	3-1-0	4
EE 637	Soft Computing Techniques	3-1-0	4
EE 638	Intelligent Control	3-1-0	4
EE 639	Industrial Applications of Power Electronics	3-1-0	4
EE 640	Pattern Recognition & Applications	3-1-0	4
EE 641	Digital Communication	3-1-0	4
EE 642	Wireless Communication	3-1-0	4
EE 643	Microwave & Antenna Systems	3-1-0	4
EE 644	Antenna Synthesis & Analysis	3-1-0	4
EE 645	Adaptive Signal Processing	3-1-0	4
EE 646	Estimation of Signal and Systems	3-1-0	4
EE 647	Wireless Networks & Protocols	3-1-0	4
EE 648	Computer Vision	3-1-0	4
EE 649	Wireless Sensor Networks	3-1-0	4
EE 650	Nanoelectronic Devices Modeling & Simulation	3-1-0	4
EE 651	Digital Speech Processing	3-1-0	4
EE 652	Ad-Hoc Networks	3-1-0	4
EE 653	Digital Image Processing	3-1-0	4
EE 654	Satellite Communication	3-1-0	4
EE 655	VLSI Signal Processing	3-1-0	4
EE 656	Computer Communication Networks	3-1-0	4
EE 657	Optical communication	3-1-0	4
EE 658	Evolutionary Computing Techniques	3-1-0	4

EE 659	Digital VLSI Design	3-1-0	4
EE 661	Advanced Signal Processing	3-1-0	4
EE 663	Microprocessor and Microcontroller Systems	3-1-0	4
EE 664	Embedded Computing Systems	3-1-0	4
EE 666	Evolutionary Computing Techniques	3-1-0	4
EE 667	Microelectronic Devices and Circuits	3-1-0	4
EE 668	Instrumentation and Sensors	3-1-0	4
EE 670	Instrumentation Laboratory	0-0-3	2
EE 671	Microwave & Antenna Laboratory	0-0-3	2
EE 672	Advanced Communication Laboratory	0-0-3	2
EE 673	Modeling and Simulation Laboratory	0-0-3	2
EE 674	Embedded Systems Laboratory	0-0-3	2
EE 675	Power Electronics and Drives Laboratory – I	0-0-3	2
EE 676	Power Electronics and Drives Laboratory – II	0-0-3	4
EE 677	Machines and Control Laboratory	0-0-3	2
EE 678	Power Electronics and Drives Simulation Laboratory	0-0-3	4
EE 679	Control Systems Laboratory	0-0-3	2
EE 681	Special Topics in Signal Processing/ Special Topics in Electrical Engineering – I/ Special Topic in Industrial Electronics – I		3/4
EE 682	Special Topics in Communication/ Special Topics in Electrical Engineering – II/ Special Topic in Industrial Electronics – II		3/4
EE 683	Special Laboratory in Electronics Systems Design/ Special Laboratory in Electrical Engineering – I/ Special Laboratory in Industrial Electronics – I	0-0-3	2
EE 684	Special Laboratory in Communication & Signal Processing/ Special Laboratory in Electrical Engineering –II/ Special Laboratory in Industrial Electronics – II	0-0-3	2
EE 685	Seminar Technical Writing – I	0-0-3	2
EE 686	Seminar Technical Writing – II	0-0-3	2
EE 687	Seminar Technical Writing – III	0-0-3	2
EE 688	Seminar Technical Writing – III	0-0-3	2
EE 691	Summer Research / Industrial Project	0-0-0	4
EE 692	Comprehensive Viva Voce	0-0-0	4
EE 693	Research Project – I	0-0-0	20
EE 694	Research Project – II	0-0-0	20
EE 732	System Design using HDL	3-1-0	4
EE 734	Super Conducting Magnets and Devices	3-1-0	4
EE 735	Automotive Electronics	3-1-0	4
EE 773	Industrial Electronics Laboratory	0-0-3	2

EE 604 FLEXIBLE AC TRANSMISSION SYSTEMS 4 Credits [3-1-0]

FACTS Concept and general system consideration: Transmission Interconnections, Flow of Power in AC Systems, Loading capability, Power flow and Dynamic Stability Considerations of a transmission interconnection, Relative Importance of Controllable Parameters, Basic types of FACTS Controller. ; Static Shunt Compensators: Objectives of Shunt Compensation, Methods of Controllable Var Generation, Static Var Compensators: SVC and STATCOM, Comparison between STATCOM and SVC, Static Var Systems. ; Static Series Compensators: Objectives of Series Compensation, Variable Impedance type Series Compensators, Switching Converter type Series Compensators, External Control for Series Reactive Compensators. ; Static Voltage and Phase angle Regulators: Objective of

Voltage and phase angle regulators, Approaches to Thyristor-controlled voltage and phase angle regulators, switching converter-based voltage and phase angle regulators, Hybrid phase angle regulators. ; Combined Compensators: Unified power flow controller (UPFC) and Interline power flow controller (IPFC).

Essential Reading:

1. N.G.Hingorani & L.Gyugyi, *Understanding FACTS*: *Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press, 1999.

Supplementary Reading:

1. X.P. Zang, C. Rehtanz and B. Pal, *Flexible AC Transmission Systems: Modeling and Control*, Birkhauser, 2006.
2. Y. H. Song and A. T. Johns, *Flexible AC Transmission Systems*, IET, 1999.

EE 605	**POWER PLANT CONTROL AND INSTRUMENTATION**	**4 Credits [3-1-0]**

Control of voltage, frequency and tie-line power flows, Q-V and P-F control loops. Mechanism of real and reactive power control. Net interchange tie-line biascontrol. Optimal, sub-optimal and decentralized controllers. Discretemode AGC. Time-error and inadvertent interchange correction techniques. Online computer control. Distributed digital control. Data acquisition systems. Emergency control, preventive control, system wide optimization, SCADA.

Essential Reading:

1. P. Kundur, *Power System Stability and Control*, Tata McGraw Hill, 2006.

Supplementary Reading:

1. M. Shahidehpourand Y. Wang, *Communication and Control in Electric Power Systems: Applications of Parallel and Distributed Processing*, Willey, 2003.

EE 606	**TRANSIENTS IN POWER SYSTEMS**	**4 Credits [3-1-0]**

Transients in lumped parameter circuits; transients in distributed parameter circuits, wave equations; switching surge studies in large systems-Dommel’s method. Multiconductor systems. Frequency domain approach. Surge response of transformers. Overvoltage protection. Insulation co-ordination. Lightning arresters. Generation and measurement of impulse voltages and currents. Impulse testing of equipments.

Essential Reading:

1. L. V. D. Sluis, *Transients in Power Systems*, John Wiley, 2001.

Supplementary Reading:

1. C. S. Indulkar and D. P. Kothari, *Power System Transients – A Statistical Approach*, PHI, 2003.
2. P. Chowdhuri, *Electromagnetic Transients in Power Systems*, Research Studies Press, 2004.

EE 607	**EXTRA HIGH VOLTAGE TRANSMISSION**	**4 Credits [3-1-0]**

Transmission line Trends and preliminaries, Corona effects-Power loss and audible noise, Radio Interface. Electrostatic field of EHV lines. General comparison of A.C and D.C. transmission, AC\DC converters and components, control and protection for HVDC systems. Reactive power management. Integrated AC-DC systems. Multi-terminal D.C. transmission.

Essential Reading:

1. K. R. Padiyar, *HVDC Power Transmission Systems*, New Age, 1990.

Supplementary Reading:

1. M. G. Dwek, *EHV Transmission*, Elsevier Sc., 1991.

EE 608	FAULT DETECTION AND DIAGNOSIS	4 Credits [3-1-0]

Introduction to Fault Detection and Diagnosis: Scope of FDD:- Types of faults and different tasks of Fault Diagnosis and Implementation - Different approaches to FDD: Model free and Model based approaches. Classification of Fault and Disturbances- Different issues involved in FDD- Typical applications. Analytical Redundancy Concepts: Introduction- Mathematical representation of Fault and Disturbances: Additive and Multiplicative types – Residual Generation: Detection, Isolation, Computational and stability properties – Design of Residual generator – Residual specification and Implementation. Design of Structured Residuals: Introduction- Residual structure of single fault Isolation: Structural and Canonical structures- Residual structure of Multiple fault Isolation: Diagonal and Full Row canonical concepts – Introduction to parity equation implementation and alternative representation. Design of Directional structured Residuals: Introduction – Directional Specifications: Directional specification with and without disturbances – Parity Equation Implementation – Linearly dependent column. Advanced level issues and design involved in FDD: Introduction of Residual generation of parametric fault – Robustness Issues –Statistical Testing of Residual generators – Application of Neural and Fuzzy logic schemes in FDD – Case study.

Essential Reading:

1. R.Isermann, *Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance*, Springer, 2005

EE 611	MACHINE ANALYSIS	4 Credits [3-1-0]

Kron's Primitive Machine: Basic equations, impedance and connection matrix. Example with DC, Induction and Synchronous machine. Transformation of machine equations (a-b-c to D-Q-O to P-N-O), Operation of Induction machine under unbalanced conditions (stator voltage and impedance unbalance, Single phasing, Broken rotor bars). ; Analysis of Synchronous machine using D-Q reference frame attached to rotor, Concept of sub transients and transient armature inductances and field time constant, Operation of synchronous machine under asynchronous running, Hunting and small oscillations, Synchronizing and damping torques. ; Principles of electromagnetic energy conversion, Single and double excited systems. Production of electromagnetic torque. ; Field aspects of electrical machines: Vector potential; Classical two-dimensional analysis of air gap field in some simple cases. Field analysis and performance calculation in linear induction motor and linear synchronous motor. ; Finite element method of calculation vector potentials in machines and actual boundaries, magnetic saturation etc. Introduction to some FEM software packages.

Essential Reading:

1. K. Mukhopadhyay, *Matrix analysis of Electric Machines*, New Age International, 2003.
2. N. Biranchi, *Electrical Machines Analysis using Finite Elements*, CRC Press, 2005.

Supplementary Reading:

1. P.S. Bhimbra, *Generalized Theory of Electrical Machines*, Khanna Publishers, 2006.

EE 612	ADVANCED MACHINE DRIVES	4 Credits [3-1-0]

Drive Concept: different machine and load characteristics, equilibrium and steady state stability, four quadrant operation, referred inertia and load torque for different coupling mechanism, thermal selection of machines; Separately excited dc motor drive: operating limits using armature voltage control and field control techniques, dynamic model(armature voltage control only) of machine and converters (continuous conduction only), open-loop dynamic performance, starting and reversal time, energy consumption, closed loop control using single (speed) and two loops (speed, current), implementation using circulating current type three phase dual converter and four quadrant transistorized chopper. State feedback control and sliding mode control of separately excited dc machine, modeling and control of separately excited dc machine in field weakening region and discontinuous converter conduction mode, control of dc series machine; Review of variable frequency operation of three phase symmetrical induction machine: scalar control methods (constant volts/Hz and airgapflux control), vector control of induction machine, methods of flux sensing/estimation, implementation of IRFO scheme using current controlled PWM VSI, implementation of DSFO scheme using GTO CSI, effect of machine parameter variation on the performance of vector controlled permanent magnet machine control; Introduction to speed control of Switched Reluctance machine. Induction motor drive, speed sensorless control, flux observation, Direct Torque Control; Speed control of wound rotor induction motors: static rotor resistance control, static scherbius drive using line commutated converter cascade, harmonics and power factor, vector control of wound rotor induction machine using self commutated converter cascade and improvement in power factor, introduction to variable speed constant frequency (VSCF) generation; Control of wound field synchronous machine: constant volts/Hz control, scalar self control (commutator less motor), vector control; Control of permanent magnet synchronous machine: Brushless dc machine, surface permanent magnet machine and interior.

Essential Reading:

1. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI, 2002.
2. G. K. Dubey, *Power Semiconductor Controlled Drives*, Prentice-Hall International, 1989.

Supplementary Reading:

1. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa Publishing House, 2002.
2. W. Leonhard, *Control of Electrical drives*, Springer-Verlag, 1985.
3. P.C. Sen, *Thyristor DC Drives*, Wiley-Interscience Publication, Digitized on Dec, 2006.

EE 615	POWER SYSTEM DYNAMICS	4 Credits [3-1-0]

Basic ideas about Steady-state, Dynamic and Transient stability, Modelling of synchronous machines, excitation systems and Governors. State-space formulation of single and multi-machine models with control equipments. Application of numerical techniques to multi-machine dynamic and transient stability studies. State-space formulation of single and multi-area models for L.F control. ; Application of modern optimization methods to power system control problems. Application of Lyapunov function to transient stability problems.

Essential Reading:

1. P.Kundur, N. J. Balu and M.G. Lauby, *Power System Stability and Control*, McGraw Hill Inc., New York, 1994.
2. P.Sauer&M.A.Pai, *Power System Dynamics and Stability*, Prentice Hall, 1999.

Supplementary Reading:

1. K. R. Padiyar, *Power System Dynamics, Stability and Control*, John Wiley, 1999.

EE 616	ELECTRICAL ENERGY SYSTEMS	4 Credits [3-1-0]

Non-renewable reserves and resources; renewable resources, Transformation of Energy. Solar Power: Solar processes and spectral composition of solar radiation; Radiation flux at the Earth’s surface. Solar collectors. Types and performance characteristics. Applications. Wind Energy: Wind energy conversion; efficiency limit for wind energy conversion, types of converters, aerodynamics of wind rotors, power ~ speed and torque ~ speed characteristics of wind turbines, wind turbine control systems; conversion to electrical power: induction and synchronous generators, grid connected and self excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation; Characteristics of wind power plant. Applications. ; Tidal Energy: Wave characteristics. Conversion systems and their performance features. Application, Geothermal energy: Biological conversion of Energy.

Essential Reading:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.

Supplementary Reading:

1. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.

EE 621	POWER ELECTRONIC CONVERTERS & MACHINE DRIVES	4 Credits [3-1-0]

Power Electronic Devices: Diodes, Transistors, Thyristors, MOSFET and IGBT - operating principle, Static, dynamic and thermal characteristics, Data sheet ratings, gate drive circuits; Single phase half controlled and fully controlled AC/DC bridge converter with R, R-L, R-L-E (motor) loads: operation (both rectifier and inverter modes) , waveforms ,harmonics (output voltage/current and input current) assuming continuous conduction, input current (ac) displacement, distortion and power factor, effect of input line inductance assuming constant current dc load, closed form expression of output dc current with general R-L-E load, discontinuous conduction mode of operation, Torque-speed characteristics of converter controlled separately excited dc motor in continuous and discontinuous mode of conduction; Three phase half controlled and fully controlled AC/DC bridge converter assuming constant dc current load : operation in rectifier and inverter modes, waveforms, output voltage and input current harmonics, input power factor and effect of input line inductance, series and parallel operation of converters, power factor improvement, 12 pulse/18 pulse operation, transformer connection, dual converters; DC-DC choppers: basic voltage commutated thyristor chopper analysis , Separately excited DC motor drive using DC-DC choppers made of gate controlled devices, four quadrant operation, dynamic and regenerative braking of series DC motor using choppers; Basic DC-DC converters: buck, boost buck-boost and Cuk converter, operation, waveforms and design; DC-AC inverters using gate controlled devices: single phase and three phase square wave inverters, operation waveforms and harmonics in pole voltage, load phase voltage and line voltage, output voltage control in single phase square wave inverter using chopper control and phase shift, harmonic analysis, operating principles of single phase and three phase PWM inverters, modulation techniques, SPWM, Selective Harmonic Elimination PWM and delta modulation, harmonic spectrum and comparison among different PWM techniques; Variable frequency operation of three phase induction motors: Steady state analysis, Torque-speed , current-speed and slip frequency -speed characteristics and operating limits with constant volts/Hz and constant air gap flux operation, implementation using PWM VSI.

Essential Reading:

1. N. Mohan, T.M. Undeland& W.P. Robbins, *Power Electronics: Converter, Applications & Design,* John Wiley & Sons, New York, 2003.
2. G. K. Dubey, Fundamentals *of Electrical Drives*, Narosa Publishing House, 2002.

Supplementary Reading:

1. M.H. Rashid, *Power Electronics, Circuits, Devices, and Applications,* Pearson, 2003.
2. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI, 2002.

EE 622	ADVANCED POWER ELECTRONIC CONVERTERS	4 Credits [3-1-0]

Switched Mode Power Supply: Forward and flyback converter circuit, operation, waveforms and design, transformer design for power supplies, small signal analysis of DC-DC converters and closed loop control; Resonant DC-DC converters: operating principle, waveforms, switching trajectory and losses and control; PWM inverter modulation strategies: sine wave with third harmonic, space vector modulation and predictive current control techniques, Dynamic braking circuit, input side bidirectional power flow requirement for regeneration, Dual thyristor bridge and PWM rectifier; Three level inverter: basic topology and waveform, improvement in harmonics and high voltage application; Resonant ac link/dc link inverters; Cycloconverters: Circuit, operating principle, control, harmonics , power factor and applications; Non-drive application of power electronic converters: back to back HVDC transmission, induction heating, electronic ballast, UPS, static var compensators and active filters. Industrial PWM driver chips for power supplies such as UC 3843, 3825 or equivalent; Industrial gate driver chips for PWM voltage source inverters with isolation and protection circuits. Intelligent power modules

Essential Reading:

1. N. Mohan, T. M. Underland& W.P. Robbing, *Power Electronics: Converter, Applications & Design,* John Wiley & Sons, New York, 2003.

Supplementary Reading:

1. M. H. Rashid, *Power Electronics Circuits, Devices, and Applications*, Pearson, 2003.

EE 623	CONTROL OF ELECTRIC DRIVES	4 Credits [3-1-0]

Basic Concepts Characteristics and operating modes of drive motors. Starting, braking and speed control of motors. 4 quadrant drives. Types of loads. Torque and associated controls used in process industries. Applications of solid-state controllers such as choppers, rectifiers, inverters and cycloconverters in drive systems, and their performance characteristics. Modern trends in industrial drives and control. Case studies relating to steel mills, paper mills, textile mills, machine tools etc. A.C. motor drives in transportation system and traction. Duty cycle. Heating/cooling and insulation in motors. Choice of motors and rating. Electromagnetic Control of Motors. ; DSP control of drives.

Essential Reading:

1. N. Mohan, T.M. Undeland& W.P. Robbins, *Power Electronics: Converter, Applications & Design,* John Wiley & Sons, New York, 2003.
2. G. K. Dubey, Fundamentals *of Electrical Drives*, Narosa Publishing House, 2002.

Supplementary Reading:

1. M.H. Rashid, *Power Electronics, Circuits, Devices, and Applications,* Pearson, 2003.
2. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI, 2002.
3. W. Shephard, L. N. Hulley and D. T. W. Liang, *Power Electronics and Motor Control*, 2nd ed., 2000.

EE 624	DISTRIBUTED CONTROL AND COMMUNICATION NETWORKS	4 Credits [3-1-0]

Evolution-Functional requirements-Architecture-Operations work stations-Controller Sub systems-Data collection Sub systems- Process computing Sub systems. ; Communication networks in DCS-Operator interface-Displays-System issues-Architecture of the future-Popular DCSs available in market-Case studies in DCS. ; HART: Introduction- Evolution of signal standards-HART communication protocol-Communication modes-HART networks-Control system interface-HART commands-HART field controller implementation-HART and OSI model. ; FIELD BUS : Introduction-general field bus architecture-basic requirements of field bus standard-field bus topology-interoperability-interchangeability. ; Communication networks :Introduction-Data transmission-data encoding and modulation-data link control-network architecture-Open system inter connection of ISO-wide area networks-circuit and packet witching, ATM, Congestion control-ISDN. ; Local area networks – LAN technologies-LAN systems-Communication architecture and protocols-Internet.

Essential Reading:

1. Forouzan, *Data Communications and Networking,* Tata McGraw Hill, 4th Ed, 2007.
2. A.S.Tanenbaum, *Computer Networks,* Prentice Hall of India, 4th Ed, 2006.

Supplementary Reading:

1. W.Stallings, *Data and Computer Communications*, Prentice Hall of India, 7th Ed, 2006.
2. A.Leon-Garcia & I.Widjaja, *Communication Networks*, Fundamental Concepts & key Architecture, Tata McGraw Hill, 2nd Ed, 2003.

EE 625	SYSTEMS AND CONTROL THEORY	4 Credits [3-1-0]

Review of matrices, linear vector space including semi group, group, rings, and fields ; State Space Description: State space representations of systems, state variable modeling of dynamical systems in continuous and discrete-time systems, transfer functions, solution of state equation, transient response, stability of linear systems, Lyapunov methods. ; System Analysis: controllability, observability, duality, equivalent systems, system decomposition, diagonal form, controllable and observable canonical forms, state space realizations and minimal realizations. ; State Feedback Design: State variable feedback, pole placement for single and multivariable systems, optimal control concept, solution of linear quadratic regulator, system decoupling, direct transfer function design procedures. ; State Estimation and Servo Control: State observer, reduced order observers, combined observer-controller system, integral control, asymptotic tracking and regulation, robust servo control design. ; Nonlinear system Dynamics & Control: Analysis of Modelling equations: state-plane Analysis, Numerical Techniques, Principles of linearization, Describing function methods ; Introduction to Nonlinear Control Techniques: sliding mode control, feedback linearization methods

Essential Reading:

1. S.H. Zak, *Systems and Control*, Oxford Univ. Press, 2003.
2. H.K. Khalil, *Nonlinear Systems*, Prentice Hall, N.J., 2002.

Supplementary Reading:

1. R. C. Dorf and R. H. Bishop, *Modern Control Systems,* Prentice Hall, 2001
2. K. Ogata, *Modern Control Engineering*, Pearson, 2006

EE 626	**NON LINEAR CONTROL SYSTEMS**	**4 Credits [3-1-0]**

Classification of non-linear phenomena. Linear and piecewise linear approximations. Phase plane, describing function and quasi linearization techniques. ; Various notions of stability. Stability techniques of Lyapunov and Popov. Nonlinear controller design using feedback linearization and back stepping method. ; Introduction to variable structure control systems.

Essential Reading:

1. H. K. Khalil, *Nonlinear Systems*, Prentice Hall, 3rd ed., 2002.

Supplementary Reading:

1. J. J. E. Slotine and W. Li, *Applied Nonlinear Control*, Prentice Hall, 1991.

EE 627	**OPTIMAL CONTROL**	**4 Credits [3-1-0]**

Calculus of variation based techniques. Pontryagin's principle and control problems with constraints on control function. Dynamic programming. Numerical techniques. Optimal control of distributed parameter systems. ; Introduction. static and dynamic optimization. Parameter optimization.Caculus of Variations : problems of Lagrange,. Mayer and Bolza. Euler-Language equation and transversality conditions, Lagrange multipiliers. ; Pontryagin's maximum principle; theory; application to minimum time, energy and control effort problems, and terminal control problem. ; Dynamic programming : Belaman's principle of optimality, multistage decision processes. application to optimal control. Linear regulator problem : matrix Riccati equation and its solution, tracking problem. ; Computational methods in optimal control. application of mathematical programming. singular perturbations, practical examples.

Essential Reading:

1. M. Athans and P.L. Falb, *Optimal Control*, McGraw Hill, 2007.
2. S.P. Sethi and G.L. Thompson, *Optimal Control Theory*, 2nd edition, Kluwer Academic Publishers, 2000.

Supplementary Reading:

1. D.P. Bertsekas, *Dynamic Programming and Optimal Control*, Volume I, 3rd edition, Athena Scientific, 2005.

2. M. Green, D.E. Johnson and D.J. N. Limebeer, *Linear Robust Control*, Prentice Hall, Digitized Dec 2007

EE 628 INDUSTRIAL PROCESS AUTOMATION 4 Credits [3-1-0]

Introduction: Classification of process automation techniques, Basic definitions: System modelling and general problem solving Application analysis: Flow and batch production in electronics industries Organization theory: Matrix organizations as distributed problem solvers Decision theory: Complexity and uncertainty Hard- and software for automation projects: Process controllers, real-time computers, process automation systems- Development techniques for software projects: CASE-System modelling: Functional and software design of production systems- Factory implementations of real automation systems: Process diagnosis, cell optimization, throughput time minimization, dynamic order scheduling, factory coordination. Industrial Communication Network, influence of topology on network properties, Synchronization at different hierarchical levels, Error handling (detection, correction, repeat request), Flow control (window technique, channel utilization), Routing (shortest path routing, bifurcated routing, broadcast routing), Multiple access protocols (TDMA, reservation, token, ALOHA, CSMA, CSMA/CD),OSI reference model ,Interworking (bridges, routers) ,TCP/IP

Essential Reading:

1. K.Krishnaswamy, Industrial Instrumentation, New Age Publishers, 2003

Supplementary Readings:

1. J. Curtis, *Process Control Instrumentation Technology*, Prentice-Hall of India, 2005.
2. N. A. Anderson, *Instrumentation for Process Measurement and Control*, CRC Press, 1997.
3. W. Dunn, *Fundamentals of Industrial instrumentation and control system*, McGraw-Hill Professional, 2005.

EE 629 DIGITAL CONTROL 4 Credits [3-1-0]

Signal Processing in Digital Control, Models of Digital Control Devices and Systems, Stability of discrete systems: location of poles, Jury's stability criterion, stability analysis through bilinear transforms. ; Design of Digital Control Algorithms, control system analysis using state variable methods, state variable analysis of digital control systems, Lyapunov stability analysis, Linear Quadratic Optimal Control, Nonlinear Control systems, neural networks and fuzzy logic for control. ; Digital Control Implementations in Microcontrollers.

Essential Reading:

1. M. Gopal, *Digital Control and State Variable Methods*, TMH, 2003
2. D. Ibrahim, *Micro-controller based Applied Digital Control*, John Wiley & Sons Ltd., 2006

Supplementary Reading:

1. R.C. Dorf, R H Bishop; *Modern Control Systems,* 9th edition, Prentice Hall 2001.
2. G.F. Franklin, J. D. Powell, M.L. Workman, *Digital Control of Dynamic Systems Pearson*, 2008

EE 630 ROBUST CONTROL 4 Credits [3-1-0]

Introduction to modern H2 and H∞ optimal controller design and to LMI-based synthesis techniques for such controllers and for multi-objective design. Optimal regulator problem with finite time horizon, Riccati differential equation ; Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system ;Kalman’s identity, phase margin of LQR controllers, spectral factorization ; Optimal state estimation, Kalman filter, LQG control, Generalized plant, review of LQG control ; Signal and system norms, computing H2 and H∞ norms ; Singular value plots, input and output directions ; Mixed sensitivity design, H∞ loop shaping, choice of weighting filters ; Case study: design example flight control ; Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region) ; Controller synthesis by solving LMI problems, multi-objective design ; Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty ; Balanced realization and model order reduction.

Essential Reading:

1. K. Zhou, J. Doyle, and K. Glover, *Robust and Optimal Control*, Prentice-Hall, 1996.

Supplementary Reading:

2. K. Zhou and*J. C. Doyle*,*Essentials of Robust Control*, Prentice Hall, 1996

EE 631	INDUSTRIAL ELECTRONICS	4 Credits [3-1-0]

Power semiconductor devices: BJT, MOSFET, IGBT, GTO, and MCT- operating characteristics and gate drive requirement, Switched-mode rectifier: Various power circuit configurations and wave shaping techniques, AC Voltage Controller: Single phase bidirectional controllers, three phase full wave controller, three phase bidirectional Delta-connected controllers Inverters: Voltage source inverters:- single phase and six step inverters, voltage control and PWM strategies, and implementation aspects, Modification of Power circuit for four quadrant operation, Current source inverters: single phase and power circuit configuration and analysis, Load commutated inverters. DC-DC Converters- principle of operation of buck, boost, buck-boost, Input and output filter design, MMF equations.Resonant Inverters: DC link inverters, modified circuit topologies for DC link voltage clamping, quasi resonant inverters, DC-DC converters- series resonant and parallel resonant, application of zero voltage and zero current switching for DC-DC converters (Buck & Boost). ; Induction to machine control: constant volts/Hz and airgap flux control; vector control of induction machine, methods of flux sensing/estimation, effect of machine parameter variation on the performance of vector controlled induction motor drive, speed sensor-less control, Direct Torque Control, harmonics and power factor.

Essential Reading:

1. W. Shephard, L. N. Hulley and D. T. W. Liang, *Power Electronics and Motor Control*, 2nd ed., 2000.
2. G. K. Dubey, Fundamentals *of Electrical Drives*, Narosa Publishing House, 2002.

Supplementary Reading:

1. M.H. Rashid, *Power Electronics, Circuits, Devices, and Applications,* Pearson, 2003.
2. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI, 2002.

EE 632	MODELING AND CONTROL OF POWER ELECTRONICS CONVERTER	4 Credits [3-1-0]

Modeling: steady state analysis of converters, dynamic analysis of converters, state space average modeling, PWM switch modeling and discrete time modeling, modeling of converters operating in discontinuous conduction mode, converter transfer functions.
Switching Regulator Control and Analysis: PWM control technique and analysis, compensation design for voltage mode converter, Multi-loop control system analysis and design, peak-current-mode and average-current mode control, state feedback/pole placement technique.
System Interaction Analysis: Input/output filter design and analysis and Input filter compensation and control.

Essential Reading:

Erickson and Maksimovic, *Fundamentals of Power Electronics*, 2nd edition, Springer

EE 633	POWER PLANT CONTROL AND INSTRUMENTATION	4 Credits [3-1-0]

Power plant: Unit, overview, Types of boiler, Exhaust Gas Boilers and Incinerators, turbine

generators, condensers, material handling systems. Comparison of thermal power plant, hydroelectric power plant, Nuclear power plant, solar power plant, Wind power plant.
The concepts of accuracy and precision, Log errors and sources of measurement errors.
Non idealities involved in Power instrumentation Instrument transformers, structures of PT's and CT's ratio and phase errors. Current probes and their efficiency. DC current measurements by Hall devices, saturable reactor set, UPS.
Digital instrumentation in power application, A/D and D/A circuits and their operation, errors Basic concepts of digital filtering storage and related circuit design. Microprocessors in power instrumentation, configuration and software flowcharts for basic power measurement involving filtering, arithmetic operations and storage.
Boiler Instrumentation: Control and optimization, Combustion control, air to fuel ratio control, 3-element drum level control, steam temperature and pressure control, oxygen/CO2 in flue gases, furnace draft, boiler interlocks, sequence event recorder, supervisor control, data acquisition controls, burner management systems and controllers. Start-up and shut-down procedures, Boiler safety standard, Boiler inspection procedures. Boiler load calculation, boiler efficiency calculation.
Instrumentation for Boiler ancillaries viz. water treatment, electro-static precipitator, soot blower, economizer, de aerator, super heater, chemical dosing systems, air pre-heater, coal and ash handling systems, fuel storage and distribution, Bag House Filters
Turbine instrumentation and control, start-up and shut-down , thermal stress control, condition monitoring & power distribution instrumentation. Synchronous, Induction generators
Hydroelectric power generation, regulation & monitoring of voltage & frequency of output power. Pollution & effluent monitoring & control. Energy Management, electrical sub-station controls.

Essential Reading:
1. Process Control, B.G. Liptak
2. Solar Energy Technology Vol. I & II by Dicknson & Chereminoff (Dekker)
3. Efficient Boiler Operation source book by Payane & Thompson
4. Energy management Handbook by W.C. turner.

Supplementary Reading:
1. Energy Technology Handbook, Considine D.M., MGH

EE 634	ROBOTICS AND AUTOMATION	4 Credits [3-1-0]

Transformations and Kinematics of Position: Homogeneous transformations; Rotation matrices; Three and four parameter representations for orientation; Mathematical Singularities; Robot kinematic modeling; Forward kinematics; Inverse kinematics problem: closed-form and numerical solutions; Concept of decoupling. ; Kinematics of Velocity and Robot Statics: Translational and rotational velocities; Velocity transformations; Jacobian transformations; Derivatives of homegeneous transformation matrices; Forward kinematics; Inverse kinematics of velocity; Static force/torque transformations; Recursive equations of motion and static force/torque relationships. ; Trajectory Planning and Kinematic Control: Point-to-point vs Continuous motion. Polynomials. Linear functions with parabolic blends. Via points. Cartesian paths. Kinematic control. ; Robot Dynamics: Euler-Lagrange equations; Lagrangian approach to robot dynamics; Actuator dynamics; Properties of the robot dynamic model: inertial coefficients, centrifugal and coriolis coefficients, and gravity terms. Newton-Euler formulation of robot dynamics; Computational considerations. ; Robot Positional Control: Independent joint control: based on PD and PID compensators, based on feed forward control; State-space modelling and analysis; Lyapunov stability analysis; Multivariable PD control; Computed-Torque control; Implementaion and robustness issues; Cartesian based control schemes; Robust control methods; Adaptive control methods. ; Robot Compliance and Force Control: Compliance and stiffness; Force control in a single DOF system; Impedance control; Hybrid force and position control; Stability issues and other problems; Simultaneous force / position; control of constrained robots. ; Discrete geometry and quantization, length estimation, automated visual inspection, object recognition and matching, depth perception problems, stereo geometry and correspondences, motion analysis, optical flow, multi-resolution processing of images, application of computer vision, remote sensing, target tracking.

Essential Reading:

1. L. Sciavicco and B. Siciliano, *Modeling and Control of Robot Manipulators*. Springer, 2007
2. F.L. Lewis, D.M. Dawson, and C.T. Abdallah, *Robot Manipulator Control: Theory and Practice,* Revised and Expanded, Marcel Dekker, New York, 2004.
3. K.S. Fu, R.C. Gonzalez and C.S.G. Lee, *Robotics: Control, Sensing, Vision, and Intelligence*, McGraw Hill, NY, 1987.

Supplementary Reading:

1. J.J.Craig, *Introduction to Robotics, Mechanics and Control*, 2nd edition, Addison Wesley, MA. Digitized, Dec 4, 2007.
2. R.J. Schilling, *Fundamentals of Robotics Analysis and Control*, Prentice Hall, NJ, Digitized Dec 5, 2007

EE 636 SYSTEM IDENTIFICATION & ADAPTIVE CONTROL 4 Credits [3-1-0]

Introduction and overview of Systems Identification, Adaptive Control and applications. Parameter Estimation: Least Square, Generalized and Recursive Least Square, Estimator properties including error bounds and convergence, MES, ML and MAP estimators, Nonlinear Least Squares. Model Structures and Predictors. Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. ; Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient. ; Robust control. ; The adaptive control problem. ; The model following problem. MRAS based on stability theory. Model following when the full state is measurable. Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. ; The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators. Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR.; Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection).Implementation issues. ; Nonlinear System Identification Techniques

Essential Readings:

1. K.J. Astrom and B. Wittenmark, *Adaptive Control*, Addison, Pearson 2006.
2. L. Ljung, *System Identification Theory for the user*, Prentice-Hall, 2007.

Supplementary Reading:

1. K.S. Narendra and A.M. Annaswamy, *Stable Adaptive Systems*, Prentice-Hall, 1989.
2. Landau and Zito, *Digital Control Systems: Design, Identification and Implementation*, Springer, 2006

EE 637 SOFT COMPUTING TECHNIQUES 4 Credits [3-1-0]

Introduction: What is SC? Why is it useful? Fuzzy Set Theory: Fuzzy Sets, Fuzzy Set operations, Fuzzy Rules and Fuzzy Reasoning, Extension Principle and fuzzy relations, fuzzy compositions, Fuzzy Reasoning, Fuzzy Inference Systems Extension principle, Fuzzy Inference Systems (Mamdani Fuzzy Models, defuzzification methods, Sugeno Fuzzy Models), Fuzzy Modelling and identification. ; Neural Networks: Biological neurons and memory: Structure and function of a single neuron; Artificial Neural Networks (ANN); Typical applications of ANNs : Classification, Clustering, Vector Quantization, Pattern Recognition, Function Approximation, Forecasting, Control, Optimization; Basic Approach of the working of ANN - Training, Learning and Generalization. ; Supervised Learning: Single-layer networks; Perceptron-Linear separability, Training algorithm, Limitations; Multi-layer networks-Architecture, Back Propagation Algorithm (BTA) and other training algorithms, Applications. Adaptive Multi-layer networks-Architecture, training algorithms; Recurrent Networks; Feed-forward networks; Radial-Basis-Function (RBF) networks. ; Unsupervised Learning: Winner-takes-all networks; Hamming networks; Maxnet; Simple competitive learning; Vector-Quantization; Counter propagation networks; Adaptive Resonance Theory; Kohonen's Self-organizing Maps; Principal Component Analysis. Associated Models: Hopfield Networks, Brain-in-a-Box network; Boltzmann machine. ; Evolutionary Computation: Different variants, Genetic Algorithm. ; Hybrid Systems: ANFIS, Fuzzy Filtered NN & Neural Fuzzy Systems, GA tuned Fuzzy System

Essential Reading:

1. S. Haykin, *Neural Networks: A Comprehensive Foundation*, Pearson, 2006
2. T. J. Ross, *Fuzzy Logic with Engineering Application*, John Wiley and Sons, 2004.
3. D.B. Fogel, *Evolutionary Computation*, IEEE Press, 2003.

Supplementary Reading:

1. Konar, *Computational Intelligence: Principles, Techniques and Applications*, Spinger -Verlag, 2005
2. V. Kecman, *Learning & Soft Computing*, Pearson, 2006

EE 638	INTELLIGENT CONTROL	4 Credits [3-1-0]

MATLAB and SIMULINK: Introduction, Control Toolbox, System Identification Toolbox, Fuzzy Logic Toolbox, Neural Network Toolbox, Genetic Algorithm Toolbox. ; System Identification and Adaptive Control: Discrete-time models, least squares estimation, recursive least squares estimation, self-tuning regulator. ; Artificial Neural Networks Applications to System Identification & Control: Introduction, learning with ANNs, single-layer networks, multi-layer perceptrons, ANNs for identification, ANNs for control. ; Fuzzy Logic Control: Introduction, fuzzy sets, fuzzy logic, fuzzy logic controller design, Fuzzy Modelling& identification, Adaptive Fuzzy Control Design. ; Evolutionary Computation for Control & identification: Applications of EC methods to system identification and control. ; Combination of Soft Computation Approaches Control & Identification: Neuro-fuzzy, evolutionary neuro and evolutionary fuzzy systems

Essential Reading:

1. D Driankov, H Hellendoorn, M Reinfrank, *An Introduction to Fuzzy Control*, Springer-Verlag, 2001.
2. Li-Xin Wang*, A Course in Fuzzy Systems and Control*, Prentice Hall, Digitized 2007
3. K.F. Man, K.S.Tang, S. Kwong and W.A. Halang, *Genetic Algorithms for Control*, Springer, Digitized in 2007.

Supplementary Reading:

1. Li-Xin Wang, *Adaptive Fuzzy Systems and Control: Design and Stability Analysis*, 2007
2. S.H. Zak, *Systems and Control*, Oxford Univ. Press, 2003.

EE 640	PATTERN RECOGNITION AND APPLICATIONS	4 credits [3-1-0]

Pattern Recognition: Feature Extraction and classification stages, Different approaches to pattern recognition. Statistical Pattern Recognition : Hypothesis testing, Linear classifiers, Parametric and nonparametric classification techniques, Unsupervised learning and clustering, Syntactic pattern recognition, Fuzzy set Theoretic approach to PR, Applications of PR : Speech and speaker recognition, Character recognition, Scene analysis.

Essential Reading:

1. Peyton Z. Peebles, JR., *Probability, Random Variables, & Random Signal Principles*, McGraw-Hill, 3rd edition, 1993
2. A.Papoulis, *Probability, Random Variables, & Stochastic Processes*, McGraw-Hill, 1991

Supplementary Reading:

1. T.Y. Young & King-Sun Fu,*Handbook of Pattern Recognition & Image Processing*, Academic Press, 1986.

EE 641	**DIGITAL COMMUNICATION**	**4 credits [3-1-0]**

Baseband, narrowband and wideband signals and noise representation and characteristics of communication channels, Linear and optimal filtering. Baseband binary signal transmission intersymbol interference bit time recovery and errors, partial response signaling,linecodes,M-ary signals orthogonal representation,Gram-schmidt procedure, signal space concepts, bandwidth efficient digital modulation techniques, CARRIER AND SYMBOL SYNCHRONIZATION: Signal Parameter estimation, carrier phase estimation, symbol timing estimation, Joint estimation. Channel capacity and coding: Spread spectrum techniques and codes, transmitters, receivers.

Essential Reading:

1. H. Taub, D.L. Schilling and G. Sinha, *Principle of Communication Systems*, 3rd Ed., Tata McGraw Hill, 2008.
2. J.G. Proakis, *Digital Communication,* McGraw-Hill, 2000.
3. R. Bose, *Information Theory Coding and Cryptography*, 2nd Edition, Tata Mc-Graw Hill, 2008.

Supplementary Reading:

1. B. Sklar, *Digital Communications*, Pearson Education, India, 2001
2. J.G. Proakis and M. Salehi, *Communication Systems Engineering*, Pearson Education International, 2002
3. J.R. Barry, E.A. Lee and D.G. Messerschmitt, *Digital Communication,* Springer, 2004.

EE 642	**WIRELESS COMMUNICATION**	**4 credits [3-1-0]**

Evolution and example of mobile radio systems, recent trends, Frequency reuse, Channel assignment, hand off process, Interference. Path less:– Radio wave propagation, diffraction, Scattering, link budget; Outdoor and indoor propagation models; Principle of multi path propagation, Impulse response model of channels, parameters for mobile multi path channels, concept of fading, Rayleigh and Ricean fading; simulation of fading channels. Modulations techniques for mobile communication:- Linear Modulation techniques, constant envelop modulation, QPSK, MSK, GMSK, spread spectrum modulation techniques. Equalization:- Fundamentals, General adaptive equalizer, Linear and non-linear equalizers, diversity techniques, RAKE receivers. Basic concept of coding. Multiple access techniques: - Introduction, FDMA, TDMA, CDMA, Space division multiple access, capacity of cellular systems. Introduction to OFDM and Wireless LAN.

Essential Reading:

1. T.S. Rappaport, *Wireless Communications – Principles and Practice*, Prentice Hall of India, 2002.
2. W C Y Lee; Mobile Communication Engineering, Tata McGraw Hill, India, 2008

Supplementary Reading:

1. W.C.Y. Lee, *Digital Cellular Systems*, McGraw Hill, 2000.
2. G. Stuber; *Principles of Mobile Communication*, 2001, Springer

EE 643	**MICROWAVE & ANTENNA SYSTEMS**	**4 credits [3-1-0]**

Circuit Concepts, Transmission lines, Micro-strip lines, Wave guides, Microwave networks, Microwave resonator, Electromagnetic wave Generation Process, Microwave Amplifiers and oscillators, Scattering of electromagnetic waves; Antenna fundamentals and definitions, dipole and loop antennas, arrays. Method of Moments and its application to wire antenna or scatterer, Fourier transforms and its application to antenna theory. Aperture antennas, active antennas. GTD/UTD techniques and its applications to horn and reflector antennas. Broadband antennas. Antenna measurements: Test ranges, near field and far field techniques.

Essential Reading:
1. D.M. Pozar,*Microwave Engineering*, John-Wiley, 2004.
2. R. Chatterjee, *Antenna Theory and Practice*, New Age Publishers, 2nd Edition, 2008.

Supplementary Reading:
1. G.P. Srivastava, V.L. Gupta, *Microwave Devices and Circuit Design,*Prentice Hall of India, 2006.
2. R.S. Elliott,*Antenna Theory & Design*, Wiley-IEEE Press, 2003.
3. V. Fusco**,** *Foundations of Antenna Theory and Techniques*, Prentice Hall, 2005.

EE 644	**ANTENNA ANALYSIS & SYNTHESIS**	**4 credits [3-1-0]**

Design of Arrays: Array factor for linear arrays, uniformly excited, equally spaced Linear arrays, pattern multiplication, directivity of linear arrays, non- uniformly excited -equally spaced linear arrays, Mutual coupling, multidimensional arrays, phased arrays, feeding techniques, perspective on arrays.Antenna Synthesis: Formulation of the synthesis problem, synthesis principles, line sources shaped beam synthesis, linear array shaped beam synthesis — Fourier Series, Woodward — Lawson sampling method, comparison of shaped beam synthesis methods, low side lobe narrow main beam synthesis methods Dolph Chebyshev linear array, Taylor line source method.

Essential Reading:
1. C. A. Balanis: "*Antenna Theory Analysis and Design*", John Wiley, 2nd Edition, 1997

Supplementary Reading:
1. Stutzman and Thiele, "*Antenna Theory and Design*", 2ndEd, John Wiley and Sons
2. Kraus, "*Antennas*", McGraw Hill, TMH, 3" Edition, 2003
3. Kraus and R.J. Marhefka:, "*Antennas*", McGraw Hil1, 2nd Edition

EE 645	**ADAPTIVE SIGNAL PROCESSING**	**4 credits [3-1-0]**

Adaptive systems: Examples and applications. Adaptive linear combiner : the performance function, gradient and minimum mean square error, alternative expression of gradient, LMS, NLMS, sign-error, sign-data and FXLMS algorithms, transform domain LMS, Recursive least square algorithm, windowed RLS, computational complexity, Block adaptive filter(time and DFT domains), adaptive lattice filters, IIR adaptive filter : equation error form. Adaptive filtering, Adaptive channel equalization, Adaptive line enhancement and adaptive system identification. Hardware implementation of digital adaptive filter. Applications of adaptive filter : 50Hz interference in electrocardiography, cancellation of donor-heart interference, cancellation of maternal ECG in electrocardiography, cancellation noise in speech signals, adaptive echo cancellation in long distance telephone line, self tunning filter. Adaptive control systems: model inverse and model reference controls. Introduction of adaptive array and adaptive beam forming. Recent advances in adaptive filtering.

Essential readings:
1. B. Widrow and S. D. Sterns, *Adaptive Signal Processing*, Pearson Education, 2nd Indian reprint, 2002.
2. D. G. Manolakis, V.K. Ingle, S.M. Kogon, *Adaptive Signal Processing*, McGraw-Hill, 2000.

Supplementary Reading:
1. J. Benesty, Y. Huang, *Adaptive Signal processing: Applications to Real World Problems*, Springer, 2003.
2. S. Haykin and T. Kailath, *Adaptive Filter Theory*, Pearson Education, 2005.

EE 646	**ESTIMATION OF SIGNALS AND SYSTEMS**	**4 Credits [3-1-0]**

Introduction to probability theory and statistics. Static state estimation, recursive least squares (RLS). Statistically consistent estimation. Weighted L.S. Dynamic state estimation, Kalman filter and square root Kalman filter. System Identification, parametric models. L.S estimation, bais. Generalized least square (GLS) and instrumental variable (IV). Persistently exciting input signals. Likely functions and maximum likelihood estimation (MLE). ; Cramer Rao lower bound, Singular value decomposition (SVD).Stochastic approximation algorithm (STA) and convergence. Non-parametric estimation. Order and structure determination. PMM and PMM; rank collapse condition, Yule-Walker equation. Multivariable system representation. Controllability and observability indices, Guidorzi's formulation. Volterra series representation of non-linear systems. Introduction to time-series analysis, Auto-correlation function (ACF) and partial ACF, their use. Non-stationary time series model, ARIMA and SARIMA. ; Introduction to linear least square estimation: a geometric approach. Wiener filter, Levinson filter, updating QR filter and the Kalman filter. Filter implementation structures : lattice, ladder and the systolic QR. Stochastic realization theory (modelling given the covariance). Modelling given the raw data. Spectral estimation. ; Recursive least squares identification algorithms: Levinson-type, Kalman-type and the QR-type. ; Nonlinear System Identification Techniques.

Essential Reading:

1. M. S. Grewal and A. P. Andrews, *Kalman Filtering: Theory and Practice using MATLAB*, Wiley, 2001
2. F.L. Lewis, L. Xie, and D. Popa, *Optimal & Robust Estimation: With an Introduction to Stochastic Control Theory*, John Wiley and Sons, New York, 2007.

Supplementary Reading:

1. O. Nells, *Nonlinear System Identification*, Springer, 2007

EE 647	**WIRELESS NETWORKS & PROTOCOLS**	**4 Credits [3-1-0]**

Evolution of Wireless Networks, Challenges, Overview of various Wireless Networks. Fixed Wireless Access Systems: Wireless Local Loop versus Wired Access, Wireless Local Loop, Wireless Local Loop Subscriber Terminals (WLL), Wireless Local Loop Interfaces to the PSTN, IEEE 802.16 Standards. Wireless Local Area Networks: Wireless LAN Topologies, Wireless LAN Requirements, The Physical Layer, The Medium Access Control (MAC) Layer. Wireless ATM and Ad Hoc Routing: Introduction, Wireless ATM Architecture, HIPERLAN 2: An ATM Compatible WLAN, Personal Area Networks (PANs): Introduction to PAN Technology and Applications, Commercial Alternatives: Bluetooth Case Studies on Simulation of Wireless Network Systems: Performance Evaluation of IEEE 802.11 WLAN Configurations Using Simulation, Simulation Analysis of the QoS in IEEE 802.11 WLAN System, Simulation Comparison of the TRAP and RAP Wireless LANs Protocols, Simulation Modeling of Topology Broadcast Based on Reverse-Path Forwarding (TBRPF) Protocol Using an 802.11 WLAN-based MONET Model. Wired Equivalent Privacy (WEP) Protocol, Mobile IP, Weaknesses in the WEP Scheme, Virtual Private Network (VPN).

Essential Reading:

1. P.Nicopolitidis, M.S. Obaidat, G. I. Papadimitriou, A. S. Pomportsis ,*Wireless Networks* , John Wiley & Sons, 2003
2. W.Stallings, *Wireless Communications and Networks*, , Pearson Education,2009

Supplementary Reading:

1. T. S. Rappaport , Wireless *Communications Principles and Practices* , Pearson Education., 2002
2. S.Mann, S. Sbihli, *Wireless Application Protocol*, Wiley, 2002
3. J.Schiller, *Mobile Communications*, Pearson, Second Edition., 2004

EE 648	**COMPUTER VISION**	**4 credits [3-1-0]**

Discrete Geometry and Quantization, Length Estimations, Automated Visual Inspection, Object reorganization and matching, Depth perception problems, Stereo Geometry and correspondence, Motion analysis, Optical flow, Multiresolution Processing of Images, Applications of Computer Vision, Remote Sensing, Biomedical Imaging, Document Processing, Target tracking.

Essential Reading:

1. D.A. Forsyth, J. Ponce, *Computer Vision: A Modern Approach*, Prentice Hall, 2003.
2. L.G. Shapiro, G. C. Stockman, *Computer Vision*, Prentice Hall, 2001.

Supplementary Reading:

1. M. Sonka, V. Hlavac, R. Boyle, *Image Processing, Analysis, and Machine Vision*, Cengage Learning, 2008.
2. T. Morris, *Computer Vision and Image Processing*, Palgrave McMillan, 2003.

EE 649	WIRELESS SENSOR NETWORKS	4 Credits [3-1-0]

Network Topology: OSI layers architecture ; Communication connectivity & reliability, Capacity.Naming and addressing, Hierarchical topologies, Clusters & gateway nodes, Complexity & scalability, Communication Protocols, MAC protocols.TDMA, FDMA, CDMA, TCP internet protocols,Communication error tolerance & coding, Sources and sinks, Routing, Single-hop, multi-hop, Bottlenecks & queues, Flooding, directed diffusion, Event-based, attribute-based, content-based, data centric routing, Geographic routing, Deadlock, livelock. ; Deployment of WSN: Sensor coverage & communications connectivity, Capacity, Self organization & network calibration,Wakeup & Time synchronization, Communications configuration, Localization – relative & absolute positioning, Dynamic clustering and topology generation. ; Mobility in the WSN, Mobile ad hoc wireless networks, Mobility- due to source, user/sink, events, Preserve sensor coverage and communications connectivity, Localization,Adaptive sampling, Quality of Service QoS, For Communications for Sensing, WSN digital signal processing: Distributed digital signal processing & filtering, Collaborative DSP, Data dissemination & distributed data storage, EDI- Event detection, isolation, classification, Data aggregation/fusion, Beam forming, Decision & information fusion, Case study- tracking & pursuit, Responsive action & alarm functions, WSN as a decision aid for the user, Query response and data interpretation, Fault Tolerance & Failure Recovery, Communication connectivity & sensor coverage ; Node & link failure, WSN reconfiguration- node failure & addition, FDI- Fault detection, isolation, classification, Energy conservation,Network lifetime, Energy-aware routing, Energy-aware sensing, Network security & privacy, Attacks and node compromise, Collaborative security, Planning, Management, Monitoring, Supervisory Control, Net tasking and discrete event control, Missions & programming the WSN,Task scheduling & dynamic resource assignment ; Real-time sensor selection, Fault recovery, Node architecture and hardware,IEEE 1451 Smart sensor, COTS sensors, COTS nodes, Operating systems,WSN standards, Networked Feedback Control Systems.

Essential Reading:

1. C. S. Ram Murthy, B. S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*, Prentice Hall of India, 2nd Ed. 2005.

Supplementary Reading:

1. B. Tavli and W. Heinzelman, *Mobile Ad Hoc Networks: Energy-Efficient Real-Time Data Communications,* Springer, 1st Ed. 2006.

EE 650	NANOELECTRONIC DEVICES MODELING & SIMULATION	4 credits [3-1-0]

Band theory of solids, carrier transport mechanism, superconductor, Dielectrics, semiconductor diode, MOS capacitor, MOSFET device physics, EKV Model, circuit simulation techniques, SPICE, CMOS Scaling, Moore's Law, Advance CMOS (NanoCMOS) and beyond, ITRS, Problems with short channel devices, CMOS Scaling limit, Emerging Nanotechnologies, SET,QCA, RSQF, RTD. Device Fabrication and Characterization: Material requirement, MOS capacitor as a building block of FET, Physical Vapour Deposition(PVD), Metal Organic Chemical Vapor Deposition(MOCVD), Nanopatterening (OPLG,MBE,ALD)

Essential Reading:

1. W. Ranier, *Nanoelectronics and Information Technology*, Wiley-VCH, 2003.
2. J.H. Davis, *The Physics of Low Dimensional Structure*, Cambridge University Press, 1998.
3. A.M. Lonescu and S. Mahapatra, *Hybrid CMOS Single Electron Transistor Device and Circuit Design*, Artech House Publication, ISBN 1-59693-069-1, 2006

Suggested Reading:

1. *International Technology Roadmap* for Semiconductor (ITRS), Wikipedia

EE 651	**DIGITAL SPEECH PROCESSING**	**4 credits [3-1-0]**

Signal processing tools, digital filters, Fourier series and transforms, DFT, FFT ,Short-Term Fourier Transform (STFT), Filter banks, Speech acquisition and digitization, Speech analysis and parameter extraction, Short-term analysis, frames and windows, Time-domain analysis: energy, zero-crossings, statistic parameters, autocorrelation, Frequency-domain analysis: spectra and spectrograms, Cepstral analysis, Linear prediction analysis, Pitch and formant estimation Static and dynamic features, Speech signal synthesis, Speech coding, Speech enhancement.

Essential Reading:

1. T.F. Quatieri, *Discrete-Time Speech Signal Processing: Principles and Practice*, Prentice-Hall, 2001.
2. L.R. Rabiner, and R.W. Schafer, *Digital Processing of Speech Signals,* Prentice-hall, 2007.

Supplementary Reading:

1. S. Furui, *Digital speech processing, synthesis, and recognition*, CRC Press, 2001
2. R. Deller, J. H. L. Hansen, and J. G. Proakis, *Discrete-Time Processing of Speech Signals,* 2nd edition, IEEE Press, 2000.

EE 652	**AD HOC NETWORKS**	**4 credits [3-1-0]**

Mobile ad hoc networking; imperatives, challenges and characteristics. Bluetooth networks; Routing approaches. Proactive and reactive protocols. Clustering and hierarchical routing. Multipath routing. Security aware routing; Energy efficient communication in ad hoc networks. Measuring energy consumption. Power save protocols. Maximum life time routing; Secure routing protocols. Intrusion detection. Security considerations in ad hoc sensor networks. Key management; Characterization of IP traffic. QOS classification. Self similar processes. Statistical analysis of non – real time traffic and real – time services.

Essential Reading:

1. C.S. Murthy & B.S. Manoj, *AdHoc Wireless Networks*, Pearson, 2004.
2. T.Janevski, *Traffic Analysis and Design of Wireless IP Networks,* Artech House, 2003

Supplementary Reading:

1. S.Basagni & M.Conti, *Mobile Ad Hoc Networking*, Wiley, 2004
2. C.Perkins, *Ad Hoc Networking*, Addison Wesley, 2000.

EE 653	**DIGITAL IMAGE PROCESSING**	**4 credits [3-1-0]**

Sensor and Imaging: Imaging Optics, Radiometry of Imaging, Illumination sources and techniques, Camera Principles, Color Imaging, Single Sensor Color Imaging and Color Demosaicing, Range Images, 3D Imaging. Signal Representation: Vector Space and Unitary Trasnsforms, Multi-Resolutional Signal Representation, Wavelet Decomposition, Scale space and diffusion, Representation of color, Retinex Processing, Markov Random Field Modellings of Images. Non-linear Image Processing: Median and

Order Statistics Filters, Rank-Ordered-Mean Filters and Signal Dependent Rank-Ordered-Mean Filters, Two Dimensional Teager Filters, Applications of non-linear filters in image enhancement, edge detections, noise removal etc. Feature Estimation: Morphological Operations, Edge Detection, Edges in multichannel images, Texture Analysis, Optical flow based motion estimation, Reflectance based shape recovery, Depth from focus, Stereo matching and depth estimation. Image and Video Compression Standards: Lossy and lossless compression schemes: Transform Based, Sub-band Decomposition, Entropy Encoding, JPEG, JPEG2000, MPEG-1, MPEG-4, and MPEG-7. Object Analysis, Classification: Bayesian Classification, Fuzzy Classification, Neural Network Classifiers, Shape Reconstruction from volumetric data, Knowledge-based interpretation of images.

Essential Reading:

1. K. R. Castelman, *Digital Image Processing*, by Prentice-Hall, 1996.
2. J.R. Parker, *Algorithms for Image Processing and Computer Vision*, by John Wiley & Sons, 1996,ISBN: 0471140562.

Supplementary Reading:

1. Y.Q. Shi & Huifang Sun, *Image and Video Compression for Multimedia Engineering: Fundamentals, Algorithms, and Standards*, by CRC Press, 2000, ISBN: 0-8493-3491-8.
2. D.E. Dudgeon & R.M. Mersereau, *Multidimensional Digital Signal Processing*, by Prentice-Hall, 1984.
3. M.Vetterli & J. Kovacevic*, Wavelets and Subband Coding*, by Prentice Hall, 1995, ISBN: 0-13-097080-8.

EE 654	**SATELLITE COMMUNICATION**	**3 credits [3-0-0]**

Original Satellite Communications, History, Current State, Overview of Satellite System Engineering; Orbital Aspects of Satellite Communication**:** Orbital mechanism, look angle determination, orbit determination, orbit effects on Communication, System performance; Satellite Link Budget**:** Basic transmission theory, system noise and G/T ratio, down link design, satellite system using small earth station, up-link design; Modulation Multiplexing Techniques**:** Analog telephone transmission, Television transmission, Digital transmission, Digital TV and bandwidth Compression, time division multiplexing; Multiple Access Techniques**:** Frequency division multiple access, time division multiple access, code division multiple access, practical demand access systems, random access, multiple access with on-board processing; Satellite Earth Solution Techniques: Earth solution design, tracking, small earth station antennas, Equipment for the Earth station.

Essential Reading:

1. T.Pratt and W.Boston, *Satellite Communications,* John Wiley & Sons, 2004
2. W.W. Wu, *Elements of Digital Satellite Communication*, Vol. 1, Computer Science Press 2006.

Supplementary Reading:

1. T.T. Ha, *Digital Satellite Communications,* McGraw Hill, U.S.A., 2004
2. G.D.Gordon, W.L.Morgan, *Principles of Communication Satellite,* John Wiley & Sons, U.S.A., 2005.

EE 655	**VLSI SIGNAL PROCESSING**	**4 credits [3-1-0]**

Overview of VLSI Architectures, Typical Signal Processing Algorithms, representation of DSP algorithms; Iterative bound: data-flow graph representation, loop bound and iterative bound; Pipelining and parallel processing: pipelining of FIR filters, pipelining and parallel processing for low-power; Retiming: definition and properties, retiming techniques; Unfolding: properties of unfolding, critical path, unfolding and retiming; Folding: folding transformations, register minimization techniques; Systolic architecture design methodology, FIR systolic arrays; Fast convolution: Cook-Toom algorithm, Winograd algorithm, cyclic convolution; Algorithm strength reduction in filters and transforms: parallel FIR filters, DCT and IDCT, rank-order filters; Pipelined and parallel recursive and adaptive filters: pipeline inverting in digital filters, pipelining in first-order IIR filter, parallel processing for IIR filter; DSP Processors for Mobile and Wireless Communications, Processors for Multidimensional Signal Processing;

Essential Reading:

1. K. K. Parhi, *"VLSI Digital Signal Processing Systems, Design and Implementation"*, John Wiley, 2003

Supplementary Reading:

1. S.Y.Kung, "*VLSI Array Processors*", Prentice-Hall, 1988

EE 656	**COMPUTER COMMUNICATION NETWORKS**	**4 credits [3-1-0]**

Communication Model, Data Communications, Computer Communication Architecture, Standard Making Organisations. Concepts and Terminology, Asynchronous and Synchronous Data Communications, Multiplexing Techniques. Communication Networking Techniques, Circuit Switching, Packet Switching, Local Area Networks. Protocols, Layered Approach, TCP / IP Protocol Suite, System Network Architecture. The Bridge and Routing, Connectionless internetworking, Connection oriented internetworking. Transport and Network Services TCP / UDP. Session Characteristics, OSI Session and Service Protocol. Presentation Concepts, Encryption and Authentication Codes, Virtual Terminal Protocols. Network Management, File Transfer and Electronic Mail. Communication Switching Techniques, Frame-mode Bearer Service, Frame Relay Congestion Control, Synchronous Transfer Mode.

Essential Reading:

1. W.Stallings, *Data and Computer Communications*, Prentice Hall of India, 2006
2. A.Godbole, *Data Communications and Networks,* 1st Edition, Tata Mc-Graw Hill, 2002.

Supplementary Reading:

1. A.S.Tanenbaum, *Computer Networks*, 2nd Ed.; PHI, New Delhi, 2002.
2. F.Halsall, *Data Communications, Computer Networks and Open Systems*, Pearson Education, 2003
3. U.D. Black, *Computer Networks: Protocols, Standards, and Interfaces,* Prentice Hall, 2007

EE 657	**OPTICAL COMMUNICATION**	**4 credits [3-1-0]**

Introduction to optical communication: Characteristics of optical transmission media, optical fibres-preparation and transmission characteristics, loss and dispersion mechanisms; Optical sources**:** principles of operation, modulation characteristics and driver circuits,LED, laser diodes, light source linearity, modal, and partition and reflection noise**;** Power Launching and Coupling**:**Source to fibre power launching, lensing schemes for coupling improvement, fibre to fibre joints, couplers, multiplexers and splices;Photo detectors: principles of operation, circuits and performance,preamplifiers and post-detection amplifiers; Optical Fiber systems: intensity modulation/direct detection system, link budget using direct detection, coherent system,wavelength converters, coherent and WDM systems,Photonic switching.

Essential Reading:

1. G.Keiser, *Optical Fibre Communications*, McGraw Hill, 2008.
2. J.M. Senior, *Optical Fiber Communications: Principles and Practice*, PHI, 2008.

Supplementary Reading:

1. Jones, W.B. Jones, *Introduction to Optical Fiber Communications Systems*, Oxford University Press, 1995.
2. A.J. Rogers, *Understanding Optical Fiber Communications*,Artech House, 2001.
3. J.C. Palais, *Fiber optic communication*, 5th edition, Prentice Hall, 2004.

EE 658	**EVOLUTIONARY COMPUTING TECHNIQUES**	**4 credits [3-1-0]**

Genetic Algorithm: Basic concepts, Search space, working principle. Encoding: binary, Octal, Hexadecimal, permutation, Value and Tree. Decoding, fitness function, Selection: Roulette-wheel, Boltzmann, Tournament, Rank and Steady-state. Elitism, Crossover: single-pint, two-point, multi-point, uniform, matrix and cross over rate, Mutation: mutation, mutation rate. Variations of GA: Adaptive GA and Real coded GA (SR.; Ant colony optimization: Ant foraging behaviour, combinatorial optimization, Routing in communication network, traveling sales man problem, graph portioning, nest building. ; Particle swarm Optimization: basic principle, algorithm, flowchart. Variations of PSO: weighted, repulsive, stretched, comprehensive learning, combined effect PSO and clonal PSO. ; Bacterial Foraging Optimization: Forging theory, social foraging, foraging behaviour of E. coli bacteria, BFO algorithm, chemotatic, swarming, reproduction and elimination and dispersal. Variations of BFO: fuzzy BFO and Adaptive BFO. Artificial Immune System: overview, central and peripheral immune systems, immune network : clonal selection and its mathematical modeling, beyond clonal selection, danger theory, negative selection. Applications: function optimization, adaptive system identification, channel equalization and financial forecasting.

Essential readings:

1. D.E. Goldberg, *Genetic Algorithms in search, Optimization and machine learning*, 1989.
2. R.C. Eberhart, Y.Sai and J. Kennedy, *Swarm Intelligence* , The Morgan Kaufmann Series in artificial Intelligence, 2001.
3. D. Dasgupta, *Artificial Immune Systems and their applications*, 1998.

Supplementary Reading:

1. K.M. Passino, *Biomimicry for optimization, control and automation*, Springer-Verlag, London, UK, 2005.

EE 659	DIGITAL VLSI DESIGN	4 credits [3-1-0]

Introduction to VLSI Design, Levels of abstraction and the complexity of design, Challenges of VLSI design: power, timing, area, noise, testability, reliability and yield ; CAD tools: simulation, layout, synthesis, test; MOS modeling, MOS device models, Short-channel effects and velocity saturation, Scaling of MOS circuits; VLSI fabrication technology, Layout design, Design rules, Stick diagrams; The CMOS inverter, VTC, Switching behavior, Noise margins and power dissipation; Static and dynamic CMOS combinational logic gate, Transistor sizing in static CMOS, logical effort , Pass-transistor logic, sizing issues , Domino logic gates , estimating load capacitance , Simple delay models (RC) for CMOS gates , Power consumption; Latches and clocking, Flip-flops, Set-up and hold tests, Static and dynamic latch and flip-flop, Clock design; Datapath units, Adders, Shifters, Multipliers; Control logic strategies, PLAs , Multi-level logic, Synthesis and place-and-route CAD; MOS memories , Register, SRAM , DRAM; Global interconnect modeling, Capacitance, resistance and inductance of interconnect; Signal and power-supply integrity issues, Electromigration, RC interconnect modeling Driving large capacitive load, reducing RC delays; Layout design, Standard-cell layout, Chip layout and floor planning, Array layout; Implementation issues, Design for testability, Packaging technology, I/O issues: ESD protection, boundary scan, inductance, synchronization

Essential Reading:

1. J.M. Rabaey, A. Chandrakasan and B. Nikolic, *Digital Integrated Circuits: A DesignPerspective*, Second Edition, Pearson/PH, 2003. (Cheap Edition)

Supplementary Reading:

1. J.P. Uyemura, *Introduction to VLSI Circuits and Systems*, Wiley, 2001.
2. W.Wolf, *Modern VLSI Design: Systems-on-Chip Design*, Third Edition, Pearson/PH, 2002. (Cheap Edition)
3. R. L. Geiger, P. E. Allen and N. R. Strader, *VLSI Design Techniques for Analog and Digital Circuits*, McGraw-Hill, 1990.

EE 661	ADVANCED SIGNAL PROCESSING	4 Credits [3-1-0]

Signal representation using unitary transform, DFT, DCT, Haar and Walsh Hadmard transform.properties of DFT,Circular convolution, linear convolution using DFT,overlap add and save methods,FFT,Filter structures for IIR and FIR filters, direct form I and II ,parallel and cascade forms, frequency sampling structure for FIR filters, linear phase FIR filters, digital filter design trechniques,IIR filter design by impulse invariance and bilinear transformation. Transformation of digital filter, FIR filters design using windows. Introduction to multirate DSP,decimation and interpolation,polyphase decomposition, uniform DFT filter banks, quadrature mirror filters and perfect reconstruction, introduction to finite register length effects on digital filter performance, spectral estimation,Adaptive filter theory-MMSE criteria, Widrow LMS Algorithm, NLMS, RLS Algorithm

Essential Reading:

1. J.G. Proakis, D.G. Manolakis, *Digital Signal Processing,* PHI, New Delhi, 1995.

Supplementary Reading:

1. S.J. Orfandis, *Optimum Signal Processing,* Mac Millan Publishing Co., USA, 1985.
2. Haykin and T. Kailath, *Adaptive Filter Theory*, Pearson Education, 2005.

EE 663	**MICROPROCESSOR AND MICROCONTROLLER SYSTEMS**	**3 credits [3-0-0]**

Architecture of 8086 CPU architecture, Internal operations, Machine Language instructions, Addressing mode, Instruction Format, Instruction executions, Instruction execution timing, Assembly language programming and Instructions: Assembler instruction format, Data Transfer, Arithmetic, Branch, Flag manipulation, Logical, Shift and Rotate. String Manipulation Stack Manipulation, all and return instructions, REP Prefix, segment override prefix, and simple assembler directives such as real, variable, DB, DW, DD, EQU, END, Assume, pointer (byte, word, double word, Near, Short, and Far). Interfacing of peripherals to 8086. ; Hardware: 8051 Microcontroller Architecture: Function and basic description of 8051components to include Special Function Registers (SFRs). Interfacing and address decoding techniques. Essential hardware for computer control, Interfacing, address decoding, analogue and digital input/output. Input/output control A/D and D/A conversion, Interrupts, bus timing, serial and parallel communications. Bus timing, Interrupts Real-time systems. *Software:* Program creation, flow charting. Algorithms for embedded control. Structured programming, Data structures and types, Program classification. Computer control: Components of embedded control systems to include terminology and components. Discrete modelling for computer control. PID control in discrete form. Classification of programs, programs for sequential tasks, multitasking systems, real-time systems. Real World Interfacing – LCD, ADC, Sensors, Stepper motor, keyboard and DAC ; Real Time Operating System, System Architecture, selection of platform, booting linux, debugging. Interfacing- Asynchronous serial communication interfacing, parallel port interfacing, USB interfacing, Memory interfacing, Synchronous serial communication interfacing, System Integration.

Essential Reading:

1. B. B. Bray, *The Intel Microprocessors- 8086/8088, 80186, 80286, 80386, and 80486- Architecture, Programming and Interfacing*, Prentice Hall, 2000.
2. J.W. Valvano, *Embedded Microcomputer System: Real Time Interfacing*, Brooks/Cole, 2000.
3. D. Simon, *An Embedded Software Primer*, Addison Wesley, 2000.

Supplementary Reading:

1. W.A.Triebel and Singh, The 8088 and 8086 Microprocessors, Pearson, 2003
2. M. Mazid, J. G. Mazidi, and R. D. McKinlay, *The 8051 Microcontroller and Embedded System*, Pearson, 2007
3. Ledin, *Embedded Control Systems in C/C++: An Introduction for Software Developers Using MATLAB*, Elsevier, 2004.
4. R. Kamal, *Embedded System*, TMH, 2002

EE 664 EMBEDDED CONTROL SYSTEM 4 Credits [3-1-0]

Introduction to embedded system: Single purpose hardware and software. Architectural Issues: CISC, RISC, DSP Architectures. Component Interfacing: Interrupt, DMA, I/O Bus Structure, I/O devices. Software for Embedded Systems : Program Design and Optimisation techniques, O.S for Embedded Systems, Real-time Issues. Designing Embedded Systems: Design Issues, Hardware-Software Co-design, Use of UML. Embedded Control Applications: Open Loop and Closed Loop Control, Software Coding of PID Controller, applications – washing machine, automobiles. Networked Embedded Systems: Distributed Embedded Architectures, Protocol Design issues, wireless network. Embedded Multimedia and Telecommunication Applications: Digital Camera, Digital TV, Set-top Box, Voice and Video telephony. ; The concept of embedded systems design. Embedded microcontroller cores, embedded memories. Examples of embedded systems. ; Technological aspects of embedded systems: interfacing between analog and digital blocks, signal conditioning, digital signal processing. Sub-system interfacing, interfacing with external systems, user interfacing. Design trade offs due to process compatibility, thermal considerations, etc.; Software aspects of embedded systems: real time programming languages and operating systems for embedded systems.

Essential Reading:

1. J.W. Valvano, *Embedded Microcomputer System: Real Time Interfacing*, Brooks/Cole, 2000.
2. D. Simon, *An Embedded Software Primer*, Addison Wesley, 2000.

Supplementary Reading:

1. M.Mazid, J.G.Mazidi, and R.D.McKinlay, *The 8051 Microcontroller and Embedded System*, Pearson, 2007.
2. Ledin, *Embedded Control Systems in C/C++: An Introduction for Software Developers Using MATLAB*, Elsevier, 2004
3. R. Kamal, *Embedded System*, TMH, 2002

EE 667 MICROELECTRONIC DEVICES AND CIRCUITS 4 credits [3-1-0]

Physical Description and theory of MOSFET.MOS structure,MOS capacitance, Short channel effect's, hot carrier effects, Scaling laws of MOS transistors, LDD MOSFET, Non-classical MOSFET structures. Bipolar and CMOS IC technology, hertrojunctions, device Modelling.Introduction to mixed signal ICs, basic design methodologies: full custom and semi-custom design.

Essential Reading:

1. D. Neamen ,*Microelectronics Circuit Analysis and Design*, Mc GrawHill,2010
2. Sedra and Smith, *Microelectronics*, Oxford Press, 2009.

Supplementary Reading:

1. G. Harmen ,*Wire Bonding in Microelectronics*, Mc Graw Hill, 3rd Edition, 2010,

EE 668 INSTRUMENTATION AND SENSORS 4 Credits [3-1-0]

Measurement error and uncertainty. Accuracy, confidence limits, confidence level. Measuring methods. Characteristics of measuring instruments. Voltage and current measurement. Frequency measurement. Signals and noise. Signal conditioning: instrumentation amplifiers, sample and hold circuits, filters, current to voltage conversion analog multiplexers, isolation amplifiers. A/D and/a conversion: parallel, successive approximation and dual slope A/D converters. Data acquisition systems. Virtual instrumentation. Sensors and transducers: temperature, geometric displacement, force, torque, vibration. Microprocessor and PC based Instrumentation system Design. Introduction to computer control of processes.

Essential Reading:

1. D.V. Murty, *Transducers and Instrumentation*, PHI, 2008.
2. C. S. Rangan, G. R. Sarma, V. S. V. Mani, *Instrumentation: Devices and Systems*, TMH, 2008.

Supplementary Reading:

1. A.S. Morris, *Principles of Measurement and Instrumentation*, Prentice Hall, 2007.
2. J. Bouwens, *Digital Instrumentation*, TMH, 2002.

EE 732 SYSTEM DESIGN USING HDL 4 Credits [3-1-0]

INTRODUCTION: A little bit about microelectronics history. State-of-the-Art and the near future; IC TECHNOLOGIES AND TOOLS: IC technologies and design methodologies. VHDL sentences and structures: basic descriptions; DIGITAL IC DESIGN: Advanced VHDL descriptions: sequential, parallel and pipeline architectures. Arithmetic High-performance architectures; IC TEST: Design-for-testability, structures and techniques; FOUNDRY TECHNOLOGIES: Basic gates. Transistor-based design. Design rules and fabrication; LAYOUT; Microelectrónica: Circuitos y Sistemas. Una perspectiva práctica. Félix Moreno y Teresa Riesgo. Ed. Lulu, 2006. (www.lulu.com). ISBN 8-4690-2886-3. (Only Spanish) ; Circuitos Integrados Digitales. Jan M. Rabaey, Anantha Chandrakasan y Borivoje Nicolic, 2ª Edición. Ed. Pearson 2004. (Also in English)

Essential Readings:

1. Theodore Bogart, *Introduction to Digital Circuits*, Editorial McGraw-Hill.
2. Peter M. Kogge, *The Architecture of Pipelined Computers*. Hemisphere Publishing Corporation, McGraw-Hill Book Co., 1981, ISBN: 0-07-035237-2.
3. S.M. Sze, *VLSI Technology,* McGraw-Hill, 1985.
4. S.M. Sze, *ULSI Technology*. C.Y. Chang y McGraw Hill, 1997.
5. N. Weste, K. Eshraghian, *Principles of CMOS VLSI Design: A Systems Perspective*, Addison Wesley, 1993.
6. David A. Patterson y John L. Hennessy. *Computer Organization and Design*. 3ª Edición. Ed. Morgan Kaufmann, 2004. ISBN-1-55860-604-1

EE 734 SUPER CONDUCTING MAGNETS AND DEVICES 4 Credits [3-1-0]

Introduction of superconductivity, super conducting magnet winding configuration; magnetic forces, time varying field and AC losses; power supply, super conducting materials and their manufacture, applications; cryogenic application, super conducting magnetic energy storage, superconducting motors, infrared detectors.

Essential Readings:

1. Superconducting magnets by Martin N, Wilson, Oxford University press, USA, 1987.
2. Highfield super conducting magnets, Oxford University press, Asner. M. Fred, USA, 2005.

EE 735 AUTOMOTIVE ELECTRONICS 4 Credits [3-1-0]

Current trends in automotive electronic engine management system, electromagnetic interference suppression, electromagnetic compatibility, electronic dashboard instruments, onboard diagnostic system, security and warning system.

BATTERIES AND ACCESSORIES 9

Principle and construction of lead acid battery, characteristics of battery, rating capacity and efficiency of batteries, various tests on batteries, maintenance and charging. Lighting system: insulated and earth return system, details of head light and side light, LED lighting system, head light dazzling and preventive methods – Horn, wiper system and trafficator.

STARTING SYSTEM

Condition at starting, behavior of starter during starting, series motor and its characteristics, principle and construction of starter motor, working of different starter drive units, care and maintenances of starter motor, starter switches.

CHARGING SYSTEM
Generation of direct current, shunt generator characteristics, armature reaction, third brush regulation, cutout. Voltage and current regulators, compensated voltage regulator, alternators principle and constructional aspects and bridge rectifiers, new developments.

SENSORS AND ACTIVATORS
Types of sensors: sensor for speed, throttle position, exhaust oxygen level, manifold pressure, crankshaft position, coolant temperature, exhaust temperature, air mass flow for engine application. Solenoids, stepper motors, relay.

Essential Readings:

1. Young A.P. & Griffiths. L. “Automotive Electrical Equipment”, ELBS & New Press- 1999.
2. William B.Riddens “Understanding Automotive Electronics”, 5th edition - Butter worth Heinemann Woburn, 1998.

Supplementary Reading:

1. Bechhold “Understanding Automotive Electronics”, SAE, 1998.
2. Crouse, W.H “Automobile Electrical Equipment”, McGraw-Hill Book Co., Inc., New York, 3rd edition, 1986.
3. Judge A.W “Modern Electrical Equipment of Automobiles”, Chapman & Hall, London, 1992.
4. Kholi.P.L “Automotive Electrical Equipment”, Tata McGraw-Hill Co., Ltd., New Delhi, 1975
5. Robert Bosch “Automotive Hand Book”, SAE (5th Edition), 2000.
6. Ganesan.V. “Internal Combustion Engines”, Tata McGraw-Hill Publishing Co., New Delhi, 2003.

DEPARTMENT OF MECHANICAL ENGINEERING

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
ME 600	Applied Finite Element Analysis	3-1-0	4
ME 601	Optimization Methods in Engg. Design	3-1-0	4
ME 602	Robotics	3-1-0	4
ME 603	Applied Elasticity & Plasticity	3-1-0	4
ME 604	Advanced Mechatronics	3-1-0	4
ME 605	Advanced Decision Modeling Technique	3-1-0	4
ME 606	Neural Network & Artificial Intelligence	3-1-0	4
ME 607	Concurrent Engineering	3-1-0	4
ME 608	Control system Engineering	3-1-0	4
ME 610	Analysis and Synthesis of Mechanisms	3-1-0	4
ME 611	Vibration Analysis & Diagnostics	3-1-0	4
ME 612	Non-Traditional Parameter in Design	3-1-0	4
ME 613	Design of Material Handling Equipment	3-1-0	4
ME 614	Experimental Stress Analysis	3-1-0	4
ME 615	Computer Aided Design of Machines	3-1-0	4
ME 616	Fatigue and Fracture of Engineering Components	3-1-0	4
ME 617	Intelligent System Control	3-1-0	4
ME 618	Rotor Dynamics	3-1-0	4
ME 619	Human Response to Vibration	3-1-0	4
ME 620	Nonlinear Oscillation	3-1-0	4
ME 621	Analytical Methods in Rotor Dynamics	3-1-0	4
ME 622	Bearing and Lubrication	3-1-0	4
ME 623	Design of Tribological Elements	3-1-0	4
ME 624	Materials for Tribological Applications	3-1-0	4
ME 625	Intelligent Industrial Automation and its Application	3-1-0	4
ME 631	Production Technology	3-1-0	4
ME 632	Machine Tool Technology	3-1-0	4
ME 633	Modern Manufacturing Processes	3-1-0	4
ME 634	Metal Cutting & Tool Design	3-1-0	4
ME 635	Product Design for Manufacturing	3-1-0	4
ME 636	Theory of Plastic Deformation	3-1-0	4
ME 637	Production System & Computer Integrated Manufacturing	3-1-0	4
ME 638	Advanced Analysis in Metal Deformation Processes	3-1-0	4
ME 639	Modeling of Welding Phenomena	3-1-0	4
ME 640	Laser Application in Manufacturing	3-1-0	4
ME 641	Knowledge Based Systems in Manufacturing	3-1-0	4
ME 642	CNC Machine Tools and Automated Manufacturing	3-1-0	4
ME 643	Advanced Topics in Non-Traditional Manufacturing Processes	3-1-0	4
ME 644	Micro-Machining and Precision Engineering	3-1-0	4
ME 645	Soft Computing for Intelligent Manufacturing	3-1-0	4
ME 646	Reliability analysis & Maintenance Management	3-1-0	4
ME 647	Production Management	3-1-0	4
ME 648	Quality Engineering and Reliability	3-1-0	4
ME 650	Heat Transfer – I: Conduction and Radiation Heat Transfer	3-1-0	4
ME 651	Advanced Fluid Mechanics	3-1-0	4
ME 652	Heat Transfer – II: Convection Heat Transfer	3-1-0	4
ME 653	Computational Fluid Dynamics	3-1-0	4

ME 654	Advanced Thermodynamics	3-1-0	4
ME 655	Refrigeration and Cryogenic Systems	3-1-0	4
ME 656	Gas Turbines and Jet Propulsion	3-1-0	4
ME 657	Computational Methods in Thermal Engg.	3-1-0	4
ME 658	Air-Conditioning and Ventilating System	3-1-0	4
ME 659	Cryogenic Process Engineering	3-1-0	4
ME 660	Heat Transfer Equipments	3-1-0	4
ME 661	Design of Thermal Systems	3-1-0	4
ME 662	Thermal Processes in Surface Engineering	3-1-0	4
ME 663	Radiation Heat Transfer	3-1-0	4
ME 664	Thermal Measurements	3-1-0	4
ME 665	Furnace Design	3-1-0	4
ME 666	Alternative Fuels for IC Engines	3-1-0	4
ME 667	Aircraft and Rocket Propulsion	3-1-0	4
ME 668	Energy Conservation and Management	3-1-0	4
ME 670	Advanced Manufacturing Laboratory	3-1-0	4
ME 671	Non-Conventional Machining Laboratory	3-1-0	4
ME 672	Industrial Engineering Laboratory	3-1-0	4
ME 673	Stress Analysis Laboratory	0-0-3	2
ME 674	Tribology Laboratory	0-0-3	2
ME 675	Vibration and Machine Dynamics Laboratory	0-0-3	2
ME 676	Computational Heat Transfer Laboratory	0-0-3	2
ME 677	Computational Fluid Flow Laboratory	0-0-3	2
ME 678	Process Simulation Laboratory	0-0-3	2
ME 681	Special Topics in Mechanical Engineering – I	3-1-0	4
ME 682	Special Topics in Mechanical Engineering – II	3-1-0	4
ME 683	Special Laboratory in Mechanical Engineering - I	0-0-3	2
ME 684	Special Laboratory in Mechanical Engineering – II	0-0-3	2
ME 685	Seminar & Technical Writing – I	0-0-3	2
ME 686	Seminar & Technical Writing – II	0-0-3	2
ME 687	Seminar & Technical Writing – III	0-0-0	2
ME 688	Seminar & Technical Writing – IV	0-0-0	2
ME 691	Summer Research / Industrial Project	0-0-0	4
ME 692	Comprehensive Viva Voce	0-0-0	4
ME 693	Research Project Work – I	0-0-0	20
ME 694	Research Project Work – II	0-0-0	20
ME 701	Composite Materials	3-1-0	4
ME 710	Advanced Composites	3-1-0	4
ME 711	Fundamentals of Tribology	3-1-0	4
ME 712	Fundamentals of Ergonomics	3-1-0	4
ME 750	Gas Dynamics and Free Molecular Flow	3-1-0	4
ME 751	Heat Exchanger Analysis and Design	3-1-0	4
ME 752	Advanced Turbo-Machinery	3-1-0	4
ME 753	Cryogenic Heat Transfer & Superfluids	3-1-0	4
ME 754	Theory of Combustion and Emission	3-1-0	4
ME 755	Cryogenic Heat Transfer	3-1-0	4
ME 756	Nuclear Power Generation and Safety	3-1-0	4
ME 757	Two-Phase Flow and Heat Transfer	3-1-0	4
ME 758	Superconducting Materials Magnets and Devices	3-1-0	4
ME 759	Air Separation and Industrial Gases	3-1-0	4
ME 760	Vacuum Technology	3-1-0	4

ME 761	Bio-fluid Mechanics	3-1-0	4
ME 762	Transport Phenomena in Material Processing	3-1-0	4
ME 763	Microfluidics and Heat Transfer	3-1-0	4
ME 764	Space Propulsion	3-1-0	4
ME 765	Advanced IC Engine Technology	3-1-0	4
ME 766	Micro-scale Heat Transfer	3-1-0	4
ME 767	Fuel Cell Technology	3-1-0	4
ME 768	Turbulence	3-1-0	4
ME 770	Precession Engineering Laboratory	0-0-3	2
ME 771	Modeling & Simulation Laboratory	0-0-3	2
ME 772	Robotics and Mechatronics Laboratory	0-0-3	2
ME 773	CAD Laboratory	0-0-3	2
ME 774	Heat Transfer and Fluid Flow Laboratory	0-0-3	2
ME 775	Thermal System Design Laboratory	0-0-3	2
WS 671	Advanced Manufacturing Practice	0-0-3	2

ME 600 APPLIED FINITE ELEMENT ANALYSIS 4 credits [3-1-0]

Introduction, Basic concept of FEM, Methods of weighted residual techniques, Weak formulation, Analysis of one dimensional problems, Second order boundary value problems, Application in solid mechanics, fluid mechanics and heat transfer, Bending of beams, truss and frame analysis, Vibration of beams, bars and shafts. Natural coordinates, interpolation function, isoparametric formulation, Application in two dimensional problem, Plane stress and plane strain, Three dimensional solid, axisymmetric solid, Plate and shell structures, Flow of viscous fluid. Buckling of columns, Non linear analysis, Modern trends in applied finite element analysis.

Essential Reading:

1. P. Sheshu, *Text book of finite element analysis*, PHI, 2005.
2. *Schaum's outline of finite element analysis*, MGH, 2007.

Supplementary Reading:

1. O. C. Zienkiewicz, *The Finite Element Method in Engg Science*, 6th Ed, Wiley & Sons.
2. S. Lary, *Applied Finite Element Analysis*, John Wiley, 2008.

ME 601 OPTIMIZATION METHOD IN ENGINEERING DESIGN 4 credits [3-1-0]

Optimization problem formulation - Design variables, constraints, objective function and variable ; bounds Single-Variable. ; Single Variable Optimization Algorithm: Bracketing Melliotls Exhaustive Search Method and bounding; Phase Method. ; Region Elimination Methods: Fibonacci Search method and Golden section search method. Gradient based ; methods, Newton - Raphson method, Bisection Method, Secant Method, and Cubic Search Method. Computer programs for bounding phase method and golden section search method. ; Multivariable Optimization Algorithms: Direct search methods. Simplex search method and Hooke- Jeeves pattern search method. Gradient based methods- Cauchy's (steepest descent) method and Newton's method. Constrained Optimization Algorithms- Kuhn- Tucker conditions, penalty function. Method, method of multipliers, cutting plane method, Generalized Reduced Gradient method, computer program for penalty function method. Integer programming - penalty function method. Global optimization using the steepest descent method, genetic algorithms and simulated annealing.

Essential Reading:

1. K.Deb, *Optimization in Engineering Design* -, PHI.

Supplementary Reading:

1. S. S. Rao, *Optimization methods* - PHI.

ME 602 ROBOTICS 4 credits [3-1-0]

Robotics: Historical back ground, Definitions. Laws of Robotics, Robotics systematic robot anatomy; Common Robot configurations, coordinate system, work envelop. Elements of robotic system and effector, actuators, controller, teach pendant, sensors Specification of robots. Applications, Safety measures. ; Robot Kinematics: Forward and reverse Kinematics of 3 DOF Robot arms. Homogeneous transformations. Kinematics equation using homogeneous transformations. ; Actuators: Hydraulic actuators. Pneumatic actuator, Electrical actuators, Directional control, Servo; Control Flow control valves. ; End effectors: Classification, Drive systems. Magnetic, Mechanical, Vacuum and Adhesive Grippers, force analysis in Grippers. ; Sensors: Need for sensing systems, Sensory devices, Types of sensors, Robot vision system Robot Languages and Programming: Types of Programming, Motions Programming, Robot Languages - VAL systems. ; Flexible automation: Technology, FMS, Function of Robot in FMS flexible manufacturing cell.

Essential Reading:

1. S.R Deb, *Robotic technology and flexible automation* - TMH.

Supplementary Reading:

1. Lee, Fu, Gonzalez, *Robotics* - Mc Graw Hill.
2. Groover, *Industrial Robot* - Mc Graw Hill.
3. Paul Afonh, *Robots manufacturing and application* - John Wiley.

ME 603 APPLIED ELASTICITY & PLASTICITY 4 credits [3-1-0]

Analysis of stress and strain; Equilibrium, Compatibility and constitutive equations; Plane problems; Stress functions; Applications; Complex potentials in two dimensional and axisymmetric problems; Variational methods; Anisotropic elasticity; Finite deformation elasticity ; Yield surfaces. Deformation and flow theories; Theory of plastic constitutive equations; Axisymmetric and spherically symmetric problems; Slab, Slipline and upper bound theory and application to simple problems of forging extrusion, drawing and indentation; Wave propagation in plastic materials.

Essential Readings:

1. Timeshenko & Goodier, *Theory of Elasticity* - McGraw Hill, 3th ed. 1982
2. J. Chakrabarty, *Applied Plasticity*- Springer, New York, 1st ed., 2000

Supplementary Reading:

1. Hoffman and Sachs, *Theory of Plasticity* - McGraw Hill., 2nd ed. 1985
2. Johnson and Mellor, *Engineering Plasticity*- Van-Nostrand., 1st edition, 1983

ME 604 ADVANCED MECHATRONICS 4 credits [3-1-0]

Fundamental of Mechantronics: Definition and concepts of Mechatronics, Conventional system vs. mechatronic system, Need and Role of Mechantronics in Design, Manufacturing and Factory Automation. Hardware components for Mechatronics Number system in Mechatronics, Binary Logic, Karnaugh Map Minimization, Transducer signal conditioning and Devices for Data conversion programmable controllers. ; Sensors and Transducers: An introduction to sensors and Transducers, use of sensor and transducer for specific purpose in mechatronic. ; Signals, systems and Actuating Devices: Introduction to signals, systems and control system, representation, linearization of nonlinear systems, time Delays, measures of system performance, types of actuating devices selection. ; Real time interfacing: Introduction, Element of a Data Acquisition and control system, overview of the I/O process. Installation of the I/O card and software. ; Application of software in Mechatronics: Advance application in Mechantronics. Sensors for conditioning Monitoring, Mechatronic Control in Automated Manufacturing, Micro sensors in Mechatronics. Case studies and examples in Data Acquisition and control. Automated manufacturing etc.

Essential Reading:

1. C.W.De Silva, *Mechatronics: An Integrated Approach,* Publisher: CRC; 1 edition (July 15, 2004)

ME 605 ADVANCED DECISION MODELING TECHNIQUE 4 credits [3-1-0]

Network analysis: The shortest route problem, the minimal spanning tree problem, the maximal flow problem. ; Dynamic Programming: Deterministic and probabilistic dynamic programming. ; Game Theory: Simple games, Games with mixed strategies, graphical solution, solving by linear programming. ; Decision Analysis: Decision making with and without Experimentation, Decision Trees, Utility function. ; Simulation: formulation implementing a simulation model, Experimental design for simulation. ; Algorithms for linear programming: The dual simplex method, parametric linear programming. ; Integer Programming: The branch and bound technique, a branch and bound algorithms for binary linear programming a bound and scan algorithm for mixed integer linear programming, formulation possibilities through mixed integer programming. ; Nonlinear programming: The Kuhn-Tucher conditions, Quadratic programming, convex programming.

Essential Reading:

1. F.S. Hillter and G.J. Liebumana, *Operations Research* - 2nd Ed.

ME 606 NEURAL NETWORK & ARTIFICIAL INTELLIGENCE 4 credits [3-1-0]

Fundamental concepts and models of Artificial Neural Systems - Biological Neurons and their artificial models, single - layer perception classifiers, multilayer feed forward networks, Hopfield Networks, Associative memories, Matching and self-organizing networks, character Reorganization Networks, Neural Networks Control Applications, Networks for Robot Kinematics. Knowledge Representation using predicate logic, Structured Representation of knowledge, Natural Language understanding. Languages and Machines ; A.I Languages: The important characteristics, LJSP, PRQLQG, Computer Architecture for A.I A.N.

Essential Reading:

1. E. Rich, *Artificial Intelligence* - Mc Graw Hill.

Supplementary Reading:

1. J.M. Zurada, *Introduction to Artificial Neural Networks*, Jaico Pub. House.
2. S. Haykins, *Neural Networks* - Addison- Wesley.

ME 607 CONCURRENT ENGINEERING 4 credits [3-1-0]

Product life cycle, quality products, evaporative markets, globalization and Concurrent engineering. Review of concurrent engineering techniques like DFM (design for manufacture). DFA (design for assembly), QFD (quality function deployment), RP (rapid prototyping), TD (total design) for integrating these technologies. Product information systems and their architecture. Information environment for suppliers, management, testing & inspection design engineering, purchasing, process control, manufacturing, support plans, operators, quality control, servicing and maintenance. Product information modeling. Integration of information models and end users applications. Computer aided simultaneous engineering systems. Integrated concurrent design and product development. Constraint networks. ; created by capacity expansion and professional resource expansion. Case studies, DYNAMO, STELLA and SD based management games.

Essential Reading:

1. L. Miller, *Concurrent Engineering Design*, 1995, the CASA/SME Technical Council.

Supplementary Reading:

1. Landon C.G. Miller. *Concurrent Engineering Design: Integrating the Best Practices for Process Improvement.*

2. D.D. Bedworth, M.R. Henderson and P.M. Wolfe, *Computer Integrated Design and Manufacturing 1991.* McGraw Hill Series in Industrial Engineering and Management Science.
3. Carter D and Baker S, *Concurrent Engineering: The Product Development Environment for the 1990s.1992.* Addison-Wesley Publishing Company,Inc.

ME 608 CONTROL SYSTEM ENGINEERING 4 credits [3-1-0]

Closed loop and open loop system, design principles of control systems, Laplace transforms method ; transfer functions, block diagrams, deriving transfer functions of physical systems, signal flow graphs ; proportional, derivation and integral controllers, impulse response functions. ; First order systems, second order systems, higher order systems, Routh's stability criterion, static and dynamic error coefficients, introduction to system optimization. ; Root locus plots, root locus analysis of control systems. ; Logarithmic, polar and log magnitude versus phase plots, Nyquist stability criterion, stability analysis, closed loop frequency response lag, lead compensations. ; Nonlinear control systems, describing function analysis of nonlinear control systems. ; Introduction to discrete time systems, state space representation of systems, Liapunov stability analysis, optional control systems based on quadratic performance indexes, adaptive control systems.

Essential Reading:

1. Katsuhiko Ogata, *Modern Control Engineering* - PHI.

Supplementary Reading:

1. B. Kuo, *Control System Engineering*- PHI

ME 610 ANALYSIS AND SYNTHESIS OF MECHANISMS 4 credits [3-1-0]

Basic concepts of kinematics and mechanisms-type, number and dimensions, kinematic pairs, chains and inversions, accuracy point and error analysis, velocity and acceleration analysis of different complex mechanism (I, II & III), gross motion in the 4-bar mechanisms, static and dynamic force analysis of mechanisms. ; Synthesis of coordinated positions, synthesis of mechanism to trace a curve or path generation, synthesis for function generation. ; Dimensional synthesis, method of approach and optimization of a solution. ; Equivalent and conjugate linkages, four bar chains, copular curves, Robert's Law chebycheve's polynomials, path curvature Euler -Savary equation, Polode curvature. ; Planer and spatial problems, graphical and analytical methods, finite displacements, analytical design of 4-bar mechanisms for coordinated motion. ; Cams: synthesis of cam profiles, advanced cam curves, dynamic analysis, accuracy analysis and design of cams. ; Gears and gyroscopes: Elements of different secondary space curves, conjugate action, general mechanism, noncircular sensors, dynamics of gears, Gyrodynamics, gyroscopic actions in machines.

Essential Reading:

1. A. Ghosh & A.K. Mallik, *Theory of Mechanism And Machines*, Affiliated East-West Press: 1998

ME 611 VIBRATION ANALYSIS & DIAGNOSTICS 4 credits [3-1-0]

Forced Vibration with non harmonic and transient excitation of single degree freedom systems: Fourier analysis, Response to arbitrary loading (Duhamel’s Integral), Impulse response, Mechanical shock, Parametric Excitation. Two degree Freedom System, Multi-degree Freedom systems, modal analysis, Matrix iteration Method, Transfer matrix Method, Myklestadt-Prohl Method, Rayleigh’s minimum principle, Stodola’s Method, Hoizer’s Method. Vibrations of Continuous systems governed by wave equation and Euler Bernoulli equation, strings, membranes, rods, beams. Experimental Methods in Vibration Analysis, industrial applications - rotors and other systems, vibration standards, vibration monitoring.

Essential Reading:

1. P. Srinivasan, *Mechanical Vibration analysis* – 2nd Ed., TMH.1995

2. J.G. Rao & K.Gupta, *Introductory course onTheory and Practice of Mechanical Vibrations*,– New Age Publication, 1995.

Supplementary Reading:

1. L. Meirovitch, *Elements of Vibration Analysis,* Tata McGraw Hill, Second edition, 2007.
2. W. T. Thomson, *Theory of Vibration with Applications*, CBS Publ., 1990.

ME 612 NON-TRADITIONAL PARAMETER IN DESIGN 4 credits [3-1-0]

Design for Fatigue: Fatigue under normal conditions, controlling factors in fatigue, Design for fatigue, Fracture Theories of strength and working stress. ; Temperature and creep stress strain properties, creep in tensor, creep in bending, members, subjected to creep and combined stresses, Basic modes fracture. ; Formulation and solution of two dimensional thermo elastic problems, basic problems in Thermoelasicity, circular disc and cylinder with radial temperature distribution, thermal stress and deflection in beams, introductory problems.

Essential Reading:

1. J.M. Lessels. *Resistance of Materials* - (Ch.6, 7, 8 and 11).
2. J.Marie, *Mechanical Behavior of Engineering Materials* - (Chap.7 and 8).
3. Boley and Weiner, *Theory of thermal stresses* - John Wiley. (Chap. 4, 8, 9 and 10).

ME 613 DESIGN OF MATERIAL HANDLING EQUIPMENT 4 credits [3-1-0]

Introduction, development of material handling technology, design objectives, salient features of design, classification and characteristics of materials, types of industrial transport, classification and working principles of materials handling devices, cranes, design of structural components, i.e. trolley, main girder, auxiliary truss, platform truss, end carriage and mechanical components i.e. wire rope, drum, pulley system, crane hook, brakes and drives of electric overhead traveling crane, stability and luffing motion of jib crane, conveyors, layout and design of components of belt conveyors, capacity and power requirement of screw conveyors, design of apron, gravity, roller and vibratory conveyors, hydraulic conveyors, layout, industrial installation, elevators, design of bucket and swing tray elevators, steel mill cranes, working principles and operations of various types of stripper, charger, ladle and soaking pit cranes, modern trends in the design of material handling devices.

Essential Reading:

1. N.Rudenko, *Material handling equipments*, MIR publishers, 2nd Ed.
2. T. K. Roy, *Mechanical handling of materials*, Asian Books, 2004.

Supplementary Reading:

1. A. Spivakovsky, *Conveyors and related equipments* –MIR Publishers.
2. M.P. Alexandrov, *Materials handling equipment* –MIR Publishers.

ME 614 EXPERIMENTAL STRESS ANALYSIS 4 credits [3-1-0]

Photoelasticity: Light and Optics as Related to Photoelasticity Behavior of Light, Polarized Light, Plane Polarizers,, Wave Plates, Arrangement of Optical Elements in a Polariscopic, Constructional Details of Diffused Light and Lens - Type.Theory of Photoelasticity: The Stress Optic Law in Two Dimensions at Normal Incidence, Effects of a Stressed Model in a Plane Polariscope, Effects of a Plane Model in a Circular Polariscope with Dark and Light Field Arrangements.Analysis Techniques: Isochromatic Fringe Patterns, Isoclinic Fringe Patterns, Compensation Techniques, separation Techniques, Sealing Model to Prototype Stresses.Three Dimensional Photoelasticity: Locking in Model Deformation Slicing the Model and Interpretation of the Resulting Fringe Pattern, Effective Stresses. the Shear Difference Method in Three Dimensions. ; Strain Measurement Methods: Basic Characteristics of a Strain Gauge, Types of Strain Gauge, Moire Method of Strain Analysis, Grid Method of Strain Analysis.Electrical Resistance Strain Gauge: Factors Influencing Strain sensitivity in Metallic Alloys, Gauge Construction Temperature Compensation, Factors-Influencing Gauge Section

Gauge Sensitivity and Gauge Factor, Correction for transverse Strain Effects, Semiconductor Strain Gauges.Rosette Analysis - three element rectangular Rosette. the Delta Rosettee, the Four Element. The Delta Rosette, The Strain Gauge, Strain Circuits, Potensiometer Circuits, The Wheatstone Bridge.Brittle Coating Method: Coating Stresses, Failure Theories Brittle Coating Crack Patterns Produced by Direct Loading Brittle-Coating Crack Patterns Produced by refrigeration Techniques, Brittle Coating Crack, Pattern Produced by Releasing the Load, Double Crack Pattern, Crack Detection, Load-Time Relation and Its influence on the threshold Strain Effects of a Biaxial stress Field.

Essential Reading:

1. J.W. Dally and W.F. Riley, *Experimental Stress Analysis*, 2nd Ed. MGH.
2. Mubin Khanna, *Experimental Stress Analysis*, 2003.

Supplementary Reading:

1. Dureli, *An Introduction to Experimental Stress and Strain Analysis*.
2. Srinath et.al. *An Introduction to Experimental Stress Analysis* - MGH.

ME 615	COMPUTER AIDED DESIGN OF MACHINES	4 credits [3-1-0]

Purpose and application of optimum design, effects of manufacturing errors, factor of safety, characteristics of mechanical system, selection of optimum configuration, critical regions, materials and dimension, primary and subsidiary design equation, limit equations, normal, redundant and incompatible specifications, General techniques, digital in optimum design, exact and iterative techniques. Optimal design of elements and system: Shafts beams, gears, bearings, springs, high speed machinery, came, intermittent motion devices, case studies.

Essential Readings:

1. R. C. Johnson, *Optimum Design of Mechanical elements* - John Wiley, 1981.
2. R.L. Fox, *Optimization Methods for Engineering Design,* Addison Wesley, 1971.
3. R. Matonsek, D.C. Johnson, *Engineering Design* - Edited by Blackie and Sons Ltd., 1963.

ME 616	FATIGUE AND FRACTURE OF ENGINEERING COMPONENTS	4 credits [3-1-0]

Mechanisms of crack growth and fracture; Basic modes of fracture; Stress Concentration factor; Griffith's theory of brittle fracture; Irwin's theory of fracture in elastic-plastic materials; Theories of linear elastic plastic fracture mechanics (LEFM); Stress intensity factor, SIF and Energy release rate; Fracture toughness, stress distribution at crack tip: plane stress, plane strain cases; Crack tip plasticity. ; Types of fatigue loading, Fatigue test methods; Endurance limit and S-N diagram; Various failure relations; Factors influencing fatigue strength; Influence of stress concentration; Fatigue crack growth initiation and propagation;Empirical relations describing crack growth; Crack closure; Fatigue Life calculations; methods of increasing fatigue life; Retardation models; Fatigue at low temperature.

Essential Reading:

1. S Suresh, *Fatigue of Materials,* Cambridge University Press.
2. D. Broek, *Elementary Engineering Fracture Mechanics,* Kluwer Academic Publishers.
3. K. Hellan, *Introduction to Fracture Mechanics*, McGraw-Hill.

Supplementary Reading:

1. T L Anderson, *Fracture Mechanics: Fundamentals and Applications*, CRC Press.
2. P. Kumar, *Elements of Fracture Mechanics*, Wheeler Publishing.

ME 617	INTELLIGENT SYSTEM CONTROL	4 credits [3-1-0]

Intelligent control, Hierarchical control architectures, Review of classical and modern control, Digital control systems, Rule based systems, Fuzzy logic control system, Neural networks control system, Hybrid Techniques, Mobile Robot Control.

Supplementary Reading:

1. R.R. Murphy, *An Introduction to AI Robotics*, The MIT Press; 1 edition (Nov 13 2000)

ME 618	**ROTOR DYNAMICS**	**4 credits [3-1-0]**

Rotor-bearing interaction. Flexural vibration, critical speeds of shafts, Effects of anisotropic bearings, unbalanced response of an asymmetric shaft. Gyroscopic effects. Aerodynamic effects. Equivalent discrete system. Geared and branched systems. Fluid film bearings: Steady state characteristics of bearings. Rigid and flexible rotor balancing. Condition monitoring of rotating machinery. Measurement techniques.

Essential Reading:

1. J. S. Rao, *Rotor Dynamics*, Third ed., New Age, New Delhi, 1996.
2. Childs, Dara, *Turbomachinery Rotor Dynamics: Phenomena, Modeling and Analysis*, John Wiley and sons, 1993

Supplementary Reading:

1. M. J. Goodwin, *Dynamics of Rotor-Bearing Systems*, Unwin Hyman, Sydney, 1989.
2. C.W. Lee, *Vibration Analysis of Rotors*, Kluwer Academic Publishers, London, 1993.

ME 619	**HUMAN RESPONSE TO VIBRATION**	**4 credits [3-1-0]**

Introduction to Vibration: Human response to vibration in context, Wave theory, Classification of vibration. Whole body vibration: Whole body vibration perception, Whole body vibration comfort & discomfort, Health effects of Whole Body Vibration, Biomechanical response to Whole body vibration, Motion Sickness: Signs and symptoms of motion sickness Travel sickness, Habituation of motion sickness, Prevention of motion sickness, Hand transmitted vibration: Hand transmitted vibration perception, Health effects of Hand Transmitted Vibration, Classification and diagnosis of Hand Arm Vibration Syndrome, Reducing Risks from Hand Transmitted Vibration, Vibration Measurement: Equipments, Measurement techniques, Assessment.

Essential Reading:

1. N.J.Mansfield, *Human response to vibration*, CRC press, 2005.

ME 620	**NONLINEAR OSCILLATION**	**4 credits [3-1-0]**

Introduction, Linear vibration, Free vibrations of undamped systems with nonlinear restoring forces, Free oscillations with damping and the geometry of integral curves – a) study of singular points, b) applications using the notion of singularities, Forced oscillations of systems with nonlinear restoring force, self sustained oscillations – a) free oscillations, b) forced oscillations in self-sustained systems, Hill's equation and its application to the study of the stability of nonlinear oscillations.

Essential Reading:

1. A.H. Nayfeh, *Applied nonlinear dynamics: analytical, computational, and experimental methods*, Wiley-Interscience, Jan. 1995.
2. Ali H. Nayfeh, *Nonlinear interactions: analytical, computational, and experimental methods*, Wiley-Interscience, June 2000.

Supplementary Reading:

1. A.H. Nayfeh and P.F. Pai, *Linear and nonlinear structural mechanics*, Wiley-Interscience, May 2004.
2. A.H. Nayfeh and D. T. Mook. *Nonlinear oscillations.*
3. A.H. Nayfeh. *Perturbation technique.*

ME 621 ANALYTICAL METHODS IN ROTOR DYNAMICS 4 credits [3-1-0]

A brief review of non-traditional machining processes, Analysis of mechanical, thermal and Electrochemical Approximate evaluation of eigen frequencies, Variable elasticity effects in rotating machinery, Mathematical models for rotor dynamic analysis, Flow-induced vibration of rotating shafts – the New Kirk effect, Dynamics of cracked shafts, Identification of cracks in rotors and other structures by vibration analysis, Thermal effects due to vibration of shafts.

Essential Reading:

1. A.D. Dimarogonas and S.A. Paipetis, *Analytical methods in rotor dynamics*, Applied Science Publishers.

ME 622 BEARING AND LUBRICATION 4 credits [3-1-0]

Introduction-Historical background, Bearing concepts and typical applications. Viscous flow concepts-Conservation of laws and its derivations: continuity, momentum (N-S equations) and energy, Solutions of Navier-Strokes equations. Order of magnitude analysis, General Reynolds equation-2D and 3D (Cartesian and Cylindrical), Various mechanisms of pressure development in an oil film, Performance parameters. ; Boundary Layer Concepts-Laminar and turbulent flow in bearings, mathematical modeling of flow in high-speed bearings. Elastic Deformation of bearing surfaces-Contact of smooth and rough solid surfaces, elasticity equation, Stress distribution and local deformation in mating surfaces due to loadings, methods to avoid singularity effects, Estimation of elastic deformation by numerical methods-Finite Difference ; Method (FDM), Governing equation for evaluation of film thickness in Elasto Hydrodynamic Lubrication (EHL) and its solution, Boundary conditions. Development of computer. ; Programs for mathematical modeling of flow in bearings, Numerical simulation of elastic deformation in bearing surfaces by FDM.

Supplementary Reading:

1. B.C.Majumdar, *Introduction to Tribology of Bearings.*
2. Dr S.P.Srivastava, *Lubricants Additives and Tribology*, 2008, Tech book international, New Delhi

ME 623 DESIGN OF TRIBOLOGICAL ELEMENTS 4 credits [3-1-0]

Introduction-Tribological consideration in design, Conceptual design, Classification of tribological components, Mechanisms of tribological failures in machines, Zero wear concept, Computational techniques in design. Design of Dry Frictional Elements-Dry friction concepts, Brakes and Clutches, Friction belts and Dry rubbing bearing. Design of Fluid Frictional Elements- Fluid friction concepts, Design of hydrodynamically loaded journal bearings, externally pressurized bearings, Oscillating journal bearings, Externally pressurized bearings, Design of oil groove, Design of elliptical, multilobe and titled pad bearings, Rolling elements bearings, Performance analysis of bearings, gears, seals, piston rings, machine tool slide ways, cams and follower and wire rope. Design exercises using TK-Solver, Finite Elements analysis.

Supplementary Reading:

1. P.Sahoo, *Industrial Tribology*, Tata Mc Graw Hill
2. B.C.Majumdar, *Introduction to Tribology of Bearings*

ME 624 MATERIALS FOR TRIBOLOGICAL APPLICATIONS 4 credits [3-1-0]

Introduction to tribological processes and tribological relevant properties of materials. An overview of engineering materials having potential for tribological application. Characterization and evaluation of Ferrous materials for tribological requirements/applications, Selection of ferrous materials for rolling element bearings, gears, crank shafts, piston rings, cylinder liners, etc. Non-ferrous materials and their applications such as sliding bearings, piston rings, cylinder liners, etc., materials for dry friction materials. Composite materials (PM, CMC and MMC) for tribological applications. Surface treatment techniques with applications such as carburising, nitriding, induction

hardening, hard facing, laser surface treatments, etc. Surface coating techniques such as electrochemical depositions, anodizing, thermal spraying, Chemical Vapour
Deposition (CVD), Physical Vapour Deposition (PVD), etc. and their applications. Lubricants-Introduction, requirements, types, Evaluation and Testing of lubricants

Supplementary Reading:

1. Dr S.P.Srivastava, *Lubricants, Additives and Tribology*, 2008,Tech book International,NewDelhi.
2. Dr N.Chand, *Tribology of FRP materials*, Allied publishers.
3. Lech Pawlowski, *The Science and Engineering of Thermal spray Coatings*, John Wiley and Sons, New York.

ME 625	INTELLIGENT INDUSTRIAL AUTOMATION AND ITS APPLICATION	4 credits [3-1-0]

Introduction to Industrial Automation, Intelligent Systems, Hydraulic Actuators for Industrial Automation, Pneumatic Actuators for Industrial Automation, Electric Drives, Sensors and Vision used for automation, Trajectory planning, Automation Algorithm, Programming and flow control for automation.

Supplementary Reading:

1. G.S. Hegde, *A Textbook on Industrial Robotics*, University Science Press, Second Edition 2008, ISBN 978-81-318-051803

ME 631	PRODUCTION TECHNOLOGY	4 credits [3-1-0]

Foundry: Fluidity and factors effecting fluidity, Design of gating system, gases in metals and alloys, gas porosity and shrinkage phenomena in casting, direction solidification, risering of casting, riser design, mechanism of feeding, method of risering, feeding distance and feeder heads, use of padding, chills and fine inoculation of C.I., grain refinement principle, casting defects and their elimination. ; Welding: Heat flow of metals, isothermal contours, cooling rate of welds, heat effects in base metal, residual stress and weld ability test, TIG, MIG, ultrasonic and laser welding, plasma area welding, underwater welding, friction welding, electron beam welding, electros lag and electro gas welding, Explosive welding. ; Forging: classification, equipments, forging defects, forgability of steels. ; Rolling: Classification, rolling equipments, hot and cold rolling, rolling of bars and shapes, camber in rolling defects, variables in rolling. ; Extrusion: Classification, extrusion equipment, load displacement, characteristics, process variables and their optimization, different extrusion dies, extrusion defects, tube extrusion Hydrostatic extension, formality limit diagram. ; Sheet metal forming: Formability of sheets, forming tests, principles of deep drawing, redrawing ironing and sinking, stretch forming, hydro-forming, spinning, bending, forming defects. ; MEMS: Introduction, history, development, and need of micro-electro-mechanical systems, IC fabrication processes used for MEMS; Mechanical process techniques and process models for micromachining, Introduction to nano-technology processes.

Essential Reading:

1. P.C. Mukherjee, *Fundamentals of metal casting technology* - Oxford and IBH. (Ch. 9,10,11,12)
2. R. Little, *Welding technology*, TMH. (Chap. 3 and 4)
3. W.H.Bruckner, *Metallurgy of welding* - Pitam. (Chap 1, 2, 10 and12)
4. Dieter, *Mechanical Metallurgy,* Mc Graw Hill, Kogakusha. (Chap. 18, 19, 20 and 22)

Supplementary Reading:

1. V. Korolkove. *Casting properties of metals and alloys.*
2. Alexander and Brewar, V. Nostrand. *Manufacturing properties of metals and Alloys.*
3. Campbell, *Manufacturing properties of materials* - TMH.

ME 632 MACHINE TOOL TECHNOLOGY 4 credits [3-1-0]

General classification of machine tools: Making and Auxiliary motions, Hydraulic transmission and the elements, Mechanical Transmission and the elements. General requirements of machine tools, Copy Turing, Transfer machines. ; Kinematics of machine tools: Drives in Machine tools, Mechanical drives for providing rotational motions, Requirements for layout of stepped drive, Designing the layout of mechanical drive, Mechanical drive for reciprocation, Gear drive for feed motions, steeples drive. ; Strength and rigidity analysis of machine tool structures: Basic Principles of design for strength and rigidity, Optimum design criteria, state compliance of M/C tool, Design of lathe beds, Design of columns for pillar drill, Radial drill milling machine, Analysis and design of tailstock assembly. ; Guide ways and power screws: Classification of guide ways, Material and Lubrication, Design criteria and calculation for slide ways, Design of guides under hydrostatic lubrication, Aerostatic slide ways, Antifriction slide ways, Combination guide ways, Classifications of Power Jarms, Design Principles of power screw, Repower screw analysis. ; Machine tool spindles and the Bearings: Materials of spindles, Effect of machine tool compliance or machining accuracy, Design principles of spindles, Antifriction and sliding bearing. ; Cold rolling system in machine tools: Classification, control system for charging speeds and feeds, Ergonomic considerations applied for design of control members, Principles of automatic and adaptive control. ; Vibration in Machine Tools: Sources and effects of vibration theory of chapter, Chapter in drilling, Milling and grinding, Elimination vibration, Stick-ship vibration and, Vibration.

Essential Readings:

1. G.C. Sen and A. Bhattacharya, *Principles of machine Tools* - New Central Book Agency.
2. N.K. Meheta, *Machine Tool Design*, TMH.

Supplementary Reading:

1. G.E. Dieter, *Engineering Design:A Materials and processing approach*, McGraw Hill, 1991

ME 633 MODERN MANUFACTURING PROCESSES 4 credits [3-1-0]

Modern Machining Processes: Electro Discharge Machining (EDM), Processes mechanism of material removal, parameters effects EDM & application, Electrical Discharge Grinding(EDG), Traveling Wire EDM, Electro-chemical Machining (ECM), Processes, Mechanism of material removal, Tool design, Parameters affecting ECM , Applications, Electro-chemical Honing(ECH), Electrochemical Debarring (ECD), Electrochemical Grinding(ECG), Electrochemical Discharge Grinding, Chemical Machining, Ultrasonic Machining, Cutting Tool System Design, Mechanism of cutting, Parameters affects USM applications, Abrasive Jet Machining, Variables of AJM, Nozzle Design, Laser Beam Machining, Thermal and Non-thermal analysis, and applications, Electron – Beam Machining and its mechanism, Applications, Plasma arc machining, Equipments, Arc transfer mechanism, Metallurgical efforts, Safety precautions and applications, Plasma are surfacing and plasma Arc Springing, Iron Beam machining and water Jet Machining. ; Modern forming processes: Measurement of stress and strain under high strain rate, principles of drop forging operation cam plastometer and mushrooming of billets, formability criteria, explosive forming, electro hydraulic forming, magnetic pulse forming, pneumatic mechanical high velocity forming, comparison with conventional process, introduction to kinetic forming, explosive welding.

Essential Readings:

1. *HMT - Production Technology* - TMH, 1980. (Chapter 14)
2. *ASME -High velocity forming of metals*, PHI. (Chapters 2, 4, 5, 6, 7 and 8)

Supplementary Reading:

1. Bhattacharya, *New Technology* I.E. (India), 1973.
2. Fishlock and Hards, *New ways of working with metals* - Geroge Newnes.
3. Pandey, *Modern machining process* - TMH, 1980.

ME 634 METAL CUTTING AND TOOL DESIGN 4 credits [3-1-0]

Theory of metal cutting: System of tool nomenclature, machine reference system and tool reference system and its conversion, effect of geometrical parameters on tool force, power consumption and surface finish, mechanics of chip formation, types of chip orthogonal and oblique cutting , angle relationships, chip formation in milling and drilling, the force system in turning for orthogonal and oblique cutting, force and velocity relationships, frictional force and energy in cutting, cutting force in drilling and milling, fundamental of friction processes in metal cutting, theory and application of cutting fluid, methods of tool failure, tool wear, Taylor's tool life equation, Tool life test, effect of variables on tool life, machinability criteria, stess-distribution at the chip-tool interface chatter and its effect. Methods of tool grinding. Controlled contact cutting, Effect of Chip-Breaker ; Cutting tool design: Design of single point turning, parting and boring tools, design of form tools, broach design, milling cutter, Design of twist drills. ; Economics of Machining, Gilbert's model: Minimum cost, Maximum production and maximum profit rate. ; Introduction to advanced machining methods: Hot machining, Cryomachining, Explosive machining, Ultra-sonic Machining ; Introduction to micro-machining method, micro-turning, micro-milling, micro-drilling, hybrid-micro-machining, micro-edm, micro-wedm, micro-wedg.

Essential Reading:

1. Bhattacharyya, *Metal Cutting, Theory and Practice*, New Central Book Agency (P) Ltd
2. Arshinov, *Metal Cutting Theory and Design*- MIR publishers.

Supplementary Reading:

1. Boothroyd, *Fundamentals of metal machining and machine tools*, McGraw Kogakusha.
2. T. H. C. Childs, K. Maekawa, T. Obikawa and Y. Yamane, *Metal Machining, Theory and applications*, Butter worth Heinemann

ME 635 PRODUCT DESIGN FOR MANUFACTURING 4 credits [3-1-0]

Engineering Materials, metals and their Properties, uses, processing methods, design data and applications, selection criteria, manufacturing and processing limitations, comparative studies; plastics and composites, types, classification, properties, processing techniques and limitation, selection of plastics for specific applications, finishing and surface coating for different materials. Bio-compatibility, Ergonomics, Recycling, etc. ; An overview of three stages of product design, generating and evaluating conceptual alternatives from manufacturability point of view, selection of materials and processes, Evaluating part configurations for manufacturability, Evaluating parametric designs for manufacturability. ; Design for manufacture, influence of materials, process and tooling on the design of components manufactured by metal casting, forming and joining, form design of components, recent developments in casting, machining, forming and finishing, processing of polymers and ceramics, surface modification of materials. Product design for manual assembly, product design for high-speed automatic assembly and product design for robot assembly. Case studies on product design for manufacturing and assembly.

Essential Readings:

1. G.E. Dieter, *Engineering Design; A Materials and processing approach*, McGraw Hill, 1991
2. M.F. Ashby, *Materials selection in Mechanical Design*; Pergamon press, 1992

Supplementary Reading:

1. W.J. Patton, *Plastics Technology, Theory*, *Design and Manufacture*; Lenton Publishing Co.
2. B.H. Amstead, P.F. Oswald and M. Begeman, *Manufacturing Processes*; John Wiley 1987
3. J.C. Bralla, *Handbook of Product Design for Manufacturing*; McGraw Hill 1988
4. S Levy and L.H. Dubois, *Plastics Production Design Engineering Handbook*; Methuen Inc, 1985

ME 636	THEORY OF PLASTIC DEFORMATION	4 credits [3-1-0]

True stress-strain curve, Bauschinger effect, theory of plasticity, empirical equations to strain, strain Curves, three dimensional stress and strain, invariants of stress and strain. ; Yield criteria of metals, Tresca and Von Misces theory, Prandtl Reuss and Levy-Mises stress-strain Relations work handling. ; Plastic instability application to rods in tension, thin walled pipes spherical shells subjected to internal Pressure circular natural diaphragm. ; Equilibrium approach, concepts of friction in metal forming column friction and constants shear friction Factor. Application of stress equilibrium approach to extrusion, drawing, rolling and forging. Slipline field theory, application to frictionless flat punch and wedge indentation, simple solution for Frictionless extrusion and drawing. ; Upper and lower bound theorems, application plane-strain problems, simple indentation and extrusion using hodographs.

Essential Reading:

1. Johnson, V. Nostrand, *Plasticity*, 2000 (Indian Edition)

Supplementary Reading:

1. Rowe, E. Arnold, *An introduction to the principles of Metal working* - 2000 (Indian Edition).
2. Avitzur, *Metal forming processes and analysis* - TMH, 2000(Indian Edition)

ME 637	PRODUCTION SYSTEM & COMPUTER INTEGRATED MANUFACTURING	4 credits [3-1-0]

Fundamental of Manufacturing and Automation: Production operation and automation strategies, Manufacturing industries, Types of production function in manufacturing, Production concept and mathematical models, Automation strategies. Cost-benefit analysis. ; Group Technology: Part families, Part classification and coding, Production flow analysis, Machine cell design, Benefits of Group Technology. ; Industrial Robotics: Robotic programming, Robotic languages, work cell control Robot cleft design, types of robot application, Processing operations. ; Flexible Manufacturing system : What is FMS ?, FMS work station, Material Handling and storage systems, Computer control system, Analysis methods for flexible manufacturing systems, application & benefits. ; Computer Integrated Manufacturing: What is CAD, CAM & CIMS? CIM Data base Model and Manufacturing data base. Computer aided process planning, Computer integrated Production Planning system. ; Brief introduction to concurrent Engineering, Rapid Prototypes and Reverse Engineering. ; Programmable Logic controllers: Parts of PLC, Operation and application of PLC, Fundamentals of Net workings. ; Computer Aided Quality Control: QC and CIM, objectives of CAQC, CMM, Flexible Inspection systems.

Essential Readings:

1. M.P Groover, *Automation, Production systems & Computer Integrated Manufacturing* - PHI.
2. P.Radhakrishnan, S.Subramanyam and V.Raju, *CAD/CAM/CIM*, New Age International, 3rded. 2008

Supplementary Reading:

1. Ray, *Robots and Manufacturing Automation*, John Wiley, New York, 1985.
2. G. Boothroyd and C. Poli, *Automation Assembly*, Marcel Dekkar, New York, 1982.

ME 638	ADVANCED ANALYSIS IN METAL DEFORMATION PROCESSES	4 credits [3-1-0]

Upper Bound technique for three dimensional metal deformation problems: Basic principle, Dual steam function method, conformal transformation method, SERR Technique. A case study of a three dimensional extrusion using the above technique. ; Introduction to matrix operator methods, series representation of slip line curvature, matrix ; representation of slip line fields. Lee and Shaffer's slip line field solution to metal machining with sticking friction, slip line field solution for carled chip and with restricted contact. ; Finite-element analysis for elastic-plastic deformation, Fundamentals of finite-element elastic analysis, expressions for the displacements of the modes of one triangular element, evaluation of the local strain from the displacement, evaluation of the local stress from the strain, the stiffness matrix for the whole system, method of solution of an elastic problem, finite element analysis in plastic deformation, weighted residual methods in plasticity, Application of weighted residuals to axisymmetric extrusion.

Essential Reading:

1. J. Chakrabarty, *Applied Plasticity*- Springer, New York, 1st ed., 2000.

Supplementary Reading:

1. G.W. Rove, *Principles of Industrial metal working Processes* - Edward Arnold.

ME 639	MODELING OF WELDING PHENOMENA	4 credits [3-1-0]

Introduction, computer simulation of welding processes, models for welding heat sources, Gaussian surface flux distribution, hemi-spherical power density distribution, ellipsoidal power density distribution, double ellipsoidal power density distribution, , kinematic models for welding heat transfer, evaluation of double ellipsoidal model, modeling thermal stresses and distortions in welds, thermal analysis of welds, heat transfer theory, weld heat source, data to characterize a weld heat source, power input, prescribed temperature model, starting transient, boundary conditions, FEM solutions with prescribed temperature, evolution of microstructure depending on temperature, evolution of microstructure depending on deformations, carburized and hydrogen diffusion analysis, welded structures and applications of welding in industrial fields, analysis of welded structure, real time for CWM, current performance for CWM, implications of real time CWM, fracture mechanics, input data for computational welding mechanics, computer simulation of welding technique, process modeling, simulation and optimization.

Essential Reading:

1. S. V. Nadkarni, *Text Book: Analysis of welded structure*, 1988, Oxford & IBH Publishing company Pvt. Ltd.

Supplementary Reading:

1. K.Masubhchi, *Reference: Analysis of welded structure*, 1980, Pergamon Press Oxford.

ME 640	LASER APPLICATIONS IN MANUFACTURING	4 credits [3-1-0]

Laser Fundamentals: spontaneous & stimulated emission/absorbtion, population inversion & pumping, cavity design, coherence and interference. Common industrial lasers and their output characteristics: CO2, Ruby, Nd-YAG, Nd-glass, excimer & He-Ne. Overview of laser Applications: Laser application in various fields, advantages & disadvantages, economics. Laser processing fundamentals: beam characteristics, optical components and design of beam delivery systems, absorption characteristics of materials, heat flow theory and metallurgical considerations. Cutting and drilling: Process characteristics, material removal modes, development of theoretical models and practical performance. Welding: Process mechanisms like keyhole & plasma, development of theoretical models, operating characteristics and process variation. Surface modification: heat treatment, rapid solidification, alloying and cladding, surface texturing, development of theoretical models, LCVD, LPVD. Introduction to interferometry: working principles of Michelson interferometer and Fabry-Perot interferometer and elementary holography. Special topics: detection and measurement of radiation, laser safety

Supplementary Reading:

1. W. M. Steen, K. Watkins, *Laser Material Processing*, 3rd edition, Springer, London, 2003.
2. C. L. Caristan, *Laser Cutting Guide for Manufacturing society of Manufacturing Engineers*, USA, 1st Ed. 2004
3. John Ion, *Laser Processing of Engineering Materials: Principles, Procedure and Industrial Application*, Elsevier, Butterworth- Heinemann, 1st ed, 2005

4. W. W. Duley, *Laser Welding,* Wiley-Interscience; 1 edition 1999

ME 641	KNOWLEDGE BASED SYSTEMS IN MANUFACTURING	4 credits [3-1-0]

Intelligent Manufacturing Systems – Architecture, Basic building blocks, Techniques for Knowledge modeling and representation, rule based and fuzzy systems Artificial Neural Networks – The Perceptron model, network architectures, Pattern recognition and classification, Learning methodologies, Back propagation algorithm, Design of neural networks Genetic Algorithms – Basics, Encoding, crossover and mutation strategies, case studies Product–Process Design – Network modeling techniques, Analysis and decomposition of Process / System models, Assembly planning, Tolerance synthesis and optimization, Intelligent Manufacturing Planning – Process Planning, Operation Sequence and Path planning with constraints, Case studies in CAPP, Robot navigation, routing, configuration design etc. Intelligent online Process monitoring and control.

Essential Readings:

1. K Mehrotra, C. K.Mohan, and S Ranka, *Elements of Artificial Neural Networks*, The MIT Press, 2000.
2. P. Gu and D. H. Norrie - *Intelligent Manufacturing Planning*, Chapman and Hall, London, 1995.

Supplementary Reading:

1. A. Kusiak - *Engineering Design – Products, Processes and Systems*, Academic Press, 1999.
2. T. C., Chang, R. A. Wysk, and H. P. Wang– *Computer Aided Manufacturing*, Prentice Hall International, 1998.
3. J Shah and M Mantyala– *Parametric and Feature based CAD/CAM*, John Wiley and Sons, 1995.
4. D Goldberg– *Genetic Algorithms in Search, Optimization and Machine learning*, Pearson Education, 1989.

ME 642	CNC MACHINE TOOLS AND AUTOMATED MANUFACTURING	4 credits [3-1-0]

Introduction: Current/future trends in CNC machine tool technology. Classification of CNC machine tools. Accuracy, precision, and resolution CNC Machine Tool Architecture ; Feed drive systems. Spindle drive systems. Auxiliary systems. Automatic tool changers. Overall CNC System NC Programming ; Coordinate system and axis nomenclature. Types of numerical control Elements of NC programs. Examples for manual NC programming Computer Aided NC programmingGeneral-purpose NC programming languages. Elements of the APT language Definition of geometric entities. : Definition of cutter motion path.Programming examples with APT CNC Structure for Machine Tools Control computer architecture. Sensors in CNC technology. Overall control system. Interpolators. CNC Software Organization Electrical Drives for CNC Machine Tools DC Motor Drives. Brushless DC Motor (AC Servo-motor) Drives. Induction Motor Drives. Step Motor Drives

Essential Readings:

1. T. K. Kundra, P.N. Rao and N. K. Tewari, *Numerical Control and Computer Aided Manufacturing*, , Tata McGraw-Hill Publishing Co., New Delhi, , 2001
2. P.Radhakrishnan, S.Subramanyam and V.Raju, *CAD/CAM/CIM*, Publication Year: Oct, 2007, Edition: 3rd, Reprint: 2008.

Supplementary Reading:

1. M. P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Prentice Hall, Publication, July 2007
2. M. Lynch, *Computer Numerical Control for Machining*, McGraw Hill Book Publishing Company,1992.
3. J.S. Stenerson, *Computer Numerical Control: Operation and Programming*, Kelly Curran, Publisher: Prentice Hall, 2007.

ME 643 ADVANCED TOPICS IN NON-TRADITIONAL MACHINING PROCESSES 4 credits [3-1-0]

A brief review of non-traditional machining processes, Analysis of mechanical, thermal and Electrochemical type non-traditional machining processes. Analysis of micro-machining processes. Tool design for selected non-traditional machining processes. Modeling and simulation of selected processes. A comparative study of various processes. Application of CNC concepts to non-traditional machining processes machines. Computer aided process planning of non-traditional processes.

Essential Readings:

1. HMT - *Production Technology* - TMH, 1980.
2. Gary F. Benedict, *Non Traditional Manufacturing Processes*, Marcel Dekker, Inc, 1st Ed. 1987

Supplementary Reading:

1. W. Grzesik, *Advanced Machining Processes of Metallic Materials: Theory, Modelling and Applications*, Elsevier Science, 1st ed. 2008
2. Pandey, *Modern machining process* - TMH, 1980.
3. C. Sommer, *Non-Traditional Machining Handbook*, Advance Publishing (TX), 1st ed., 1999
4. P.M. Dixit, U.S. Dixit, *Modeling of Metal Forming and Machining Processes: by Finite Element and Soft Computing Methods (Engineering Materials and Processes)*, Springer; 1 edition, 2008.

ME 644 MICRO-MACHINING AND PRECISION ENGINEERING 4 credits [3-1-0]

Introduction to micromachining technologies, bulk micromachining, LIGA, Surface Micromachining, Characterization of micro-machining, Tool making, Micromachinability of materials, Diamond micro-machining: machining principles, diamond turning, diamond grinding, accuracy and dimensional control, molecular dynamics simulation of the atomic processes in micro-machining, principles of molecular dynamics, atomistic forces of chip formation and surface generation, future trends in ultrahigh speed machining. ; Microelectro discharge Machining: Principles of micro-EDM, micro-EDM by Die-sinking and WEDG, micro-WEDM, micro-WEDG, micro-ECM, Principles of micro-turning, micro-drilling and micro-milling, hybrid micro-machining method, on-line measurement by machine vision and integrated probe. ; Abrasive micromachining and micro grinding: Abrasive micromachining mechanisms, micro-grinding mechanism, micro-machining rate, micro-machining cooling media. ; Laser micromachining: Principles of laser material removal, laser micro-drilling, laser micro-adjustment, laser surface structuring, laser micro-cutting. ; Micro-machining by finishing techniques: micro-lapping, micro-honing, magneto-abrasive micromachining and finishing (MAF), ELID Grinding. ; Measuring Techniques in micro-machining: stylus instruments, scanning tunneling microscopes, atomic force microscope, measurement of micromoles and slots using optical method, vibro-scanning method, elastic transmission method, computer-aided measurement testing and diagnostics, surface integrity and other related measurements.

Essential Reading:

1. J. M. Geough, *Micro-machining of Engineering Materials*, Edited by Marcel Dekker, 2002
2. R.W. Johnstone, M. Parameswaran, *An introduction to surface-micromachining*, Kluwer Academic Publishers, 2004

Supplementary Reading:

1. N. P Mahalik. *Micro-manufacturing and nano-technology*, edited by, Springer Publication, 2006
2. M. P. Groover, *Automation, Production Systems and Computer-Integrated Manufacturing*, 2003

ME 645 SOFT COMPUTING FOR INTELLIGENT MANUFACTURING 4 credits [3-1-0]

Introduction, Foundations: Stochastic processes; Principal component analysis; Learning theory; Generalization and regularization; Fuzzy Logic: fuzzy set theory, fuzzy rule and fuzzy reasoning, fuzzy relation, fuzzy inference system, fuzzy modeling, Sugneo type fuzzy system ; Supervised learning network: Back propagation learning algorithm, Back propagation multi layered perceptron, method for speeding of back propagation, Radial basis function network, Summary ; Unsupervised learning: Competititve learning network, Kohenberg self organisng network, LVQ, Hebbian learning, Hopefield network, ART Network ; Role of sensors in manufacturing automation: operation principles of different sensors - electrical, optical, acoustic, pneumatic, magnetic, electro-optical and vision sensors Condition monitoring of manufacturing systems - principles - sensors for monitoring force, vision, vibration, acoustic, temperature, current and noise, selection of sensors and monitoring techniques ; Application of soft computing to Fault diagnosis and Failure Analysis: Online Tool wear monitoring in turning, drilling, milling operation, Online Dimensional deviation detection in turning, Online roughness evaluation of EDM, ECM process, online measurement of hole straightness in a LBM.

Essential Readings:
A. Kaufmann and M. M. Gupta, *Introduction to fuzzy arithmetic theory and application*, International Thomson computer press, 1st edition (1991)

Supplementary Reading:
1. S Haykin, *Neural Network*, PHI, 2004
2. G. Onwubolu, E. Butterworth, *Mechatronics Principle and Application,* Heinnmen Pub.

ME 646 RELIABILITY ANALYSIS & MAINTENANCE MANAGEMENT 4 credits [3-1-0]

Concept of Reliability, Reliability data and analysis, Reliability & quality. Life testing, Accurate life testing. ; Maintainability and availability cost analysis, Replacement policies, types of maintenance, objective and function of maintenance organization. ; Simulation and reliability predication, Sylicon reliability modeling modules. ; Reliability management, Integrated logistic support life cycle cost.

Essential Reading:
1. P.Gopalakrishnan & A. K. Banerjee, *Maintenance and spares parts management* - PHI, 1991.
2. A.K. Govil, *Reliability Engineering* - TMH.

Supplementary Reading:
1. Kelly, *Maintenance planning and control* - EWP.
2. A.K. Gupta, *Reliability Engineering and Technology* - McMillan India, 1996.
3. S. Halperu, *The Assurance Science* - PHI.

ME 647 PRODUCTION MANAGEMENT 4 credits [3-1-0]

Introduction to Production Management: Role of production/operation management, Decision making in production/operation management cost models. ; Analytical methods: System concepts-analytical methods in production/ operation. ; Design of Production System: Design of production and services distribution and facility location processes and job design layout of physical facilities line. ; Production planning and control: Demand for casting and operation-aggregate planning.

Essential Reading:
1. Buffa, *Modern Production Management* - 5th Ed, John Wiley.

Supplementary Reading:
1. D.J. Sumanth, *Productivity Engineering and Management* - TMH, 1990.

ME 648 QUALITY ENGINEERING AND RELIABILITY 4 credits [3-1-0]

Statistics: Statistical Methods: Important statistical distribution and their properties, correlation and regression, multiple regression analysis. Statistical Inference: t-tests, F-tests, Chi-square tests, ANOVA, DOE and RSM, time series analysis. ; Quality Engineering: Taguchi's quadratic loss function, off line and on-line quality control, importance of parameter design. Experimental design principles for product and process design, two-level experimental for full factorial and fractional factorial design. S/N ratio, inner and outer arrays, experimental design for control and noise factors ANOVA in Engg. design, computer software's in experimental design. Components of TQM, PDCA cycle, TQM implementation. Quality costs, Ishikawa diagram, brain storming QCS, QFD, JIT philosophy and techniques. Characteristics features and clauses of ISO 9000 standards, certification procedures, quality audit procedure, Implementation procedures. ; Reliability: System effectiveness mission reliability design adequacy, operational readiness serviceability performance indices, their evaluation, uses and limitations. ; Reliability models of maintained systems, fundamental definitions, relationship between reliability and maintainability single equipment systems parallel stand by K-out-of n-configuration steady state availability. Maintainability predication. ; Inspection policies bases on profits, downtime and performance degradation, inspection under emergency condition.

Essential Reading:

1. Freund and Miller, *Statistics for engineering and scientists* by PHI
2. *Quality Engineering using Robust design* by M/s phadke, Prentice Hall.

Supplementary Reading:

1. S S. Singh, *Total quality control essentials* by McGraw Hill Inc.93 Singapore.
2. P. Gopalkrishnan, A.K.Banerjee, *Maintenance and spare parts management* by PHI, 1991.
3. L.S. Srinath, *Reliability Engineering* by EWP.

ME 650 HEAT TRANSFER – I: CONDUCTION AND RADIATION HEAT TRANSFER 4 credits [3-1-0]

Unit I: Conduction; Derivation of generalized conduction equation for anisotropic inhomogeneous solids, conductive tensor, concepts of isotropic and homogeneous conductivity. ; Steady state conduction: Recapitulation of fundamentals analysis and design variable and cross section and circumferential fins. Analysis of heat conduction in 2-D fans, 2-D and 3-D conduction in solids with complex boundary conditions and heat generation. ; Transient conduction: Recapitulation of transient conduction in simple systems. Analysis of transient heat conduction with complex boundary. ; Application of Duhamel's theorem and Special topics: Use of lap lace transformation in linear conduction problems. The use of green function in the solution of the equations of conduction. ; Numerical methods: Fundamentals of discrimination treatment of boundary conditions, on linearity of properties, anisotropy and complex boundaries. Unit II : Radiation ; Recapitulation of fundamentals of radioactive heat transfer, radiative properties of surfaces, methods of estimating configuration factors, heat exchange between diffusively emitting and diffusively reflecting surfaces. Radiant energy transfer through absorbing, emitting and scattering media. Combined conduction and radiation systems: fins, Introduction to solar radiation in earth's atmosphere.

Essential Reading:

1. V.S Arpaci – *Conduction Heat Transfer*
2. E.M Sparrow, R.D Cess – *Radiation Heat Transfer*

Supplementary Reading:

1. R.Siegal and J.R Howell-*Thermal radiation heat transfer*.

ME 651 ADVANCED FLUID MECHANICS 4 credits [3-1-0]

Standard pattern of flow: velocity potential and stream, uniform flow source, sink, doublet and combinations. Flow past cylinder with and without circulation, flow past Rankine body. ; Conformal Transformation: Analytic functions, Simple transformation, flow at a wall angle, flow past a cylinder, flow parallel and normal to a flat plate, flow past a streamlined structure Schwartz Christroffel Theorem simple applications. ; Flow of Real Fluid: Laminar and turbulent flows, Navier-Stokes equations exact solutions for simple cases, boundary layer principles, flat plate, conducts, curved solid bodies, Prandtl mixing length turbulent theory, universal velocity profile, momentum eddy concept – simple applications. ; Compressible Fluid Flow Basics: One dimensional compressible flow through ducts and nozzles, isentropic flow with friction, heat transfer, plane shock. Use of stagnation properties from gas table in application.

Essential Reading:
1. V.L. Streeter, *'Fluid Dynamics'*, Mc Graw-Hill 1971.
2. A.H. Shapin, *'The dynamics and thermodynamics of compressible fluid flow'*, Vol. I and II, The Ronald Press Co., 1955.

Supplementary Reading(s):
1. S.W. Yuan, *'Foundations of Fluid Mechanics'*, Prentice Hall of India, 1976.
2. Robertson. *'Hydrodynamics Theory and Application'*, Prentice Hall of India, 1965.
3. M.J Zucrwo and J.D. Hoffman*, 'Gas dynamics'*, Vol. I and II, John Wiley and Sons Inc., 1977.
4. R.N. Fox and A.T McDonald., *'Fluid Mechanics',* John Wiley & Sons, 1994.
5. Dr. J.K Goyal I K.P. Gupta., *'Fluid Dynamics',* 3rd revised Ed., Pragathi Prakasan, Meerut, 1989.
6. N.Pillai and C.R.Ramakrishnan, *Principles of Fluid Mechanics and Fluid Machines*, University Press, Hyderabad.

ME 652 HEAT TRANSFER – II: CONVECTION HEAT TRANSFER 4 credits [3-1-0]

Convection: Energy equation – thermal boundary layer. Forced convection – Practical correlations – flow over surfaces – internal flow. Natural convection, combined forced and free convection combined convection and radiation in flows. ; Boiling and Condensation: Boiling – Pool and flow boiling, correlations. Condensation – modes and mechanisms – correlations and problems. Heat Exchangers: Heat Exchanger and Mass Transfer -Heat exchanger: types – LMTD method and the effectiveness – NTU method. Mass Transfer: types – Fick's law of diffusion – mass diffusion equation, Equimolar counter diffusion – convective mass transfer. Evaporation of water into air.

Essential Readings:
1. J.P. Holman., *'Heat and Mass Transfer'*, Tata McGraw Hill, 8th Ed., 1989.
2. D.D. Kern, *'Extended Surface Heat Transfer'*, New Age International Ltd., 1985.

Supplementary Reading:
1. F.P. Incropera and D. P. Dewit, '*Fundamentals of Heat and Mass Transfer'*, 4th Ed., John
2. Wiley & Sons, 1998.
3. C.P. Kothandaraman., '*Fundamentals of Heat and Mass Transfer'*, 2nd Ed., New Age International, 1997.
4. E.R.D Eckert and R.M. Drake, '*Analysis of Heat and Mass Transfer'*, McGraw Hill, 1980.
5. Kays, W.M. and Crawford W., '*Convective Heat and Mass Transfer'*, McGraw Hill Inc., 1993.
6. Burmister L.C., *'Convective Heat Transfer'*, John Willey and Sons, 1983.

ME 653 COMPUTATIONAL FLUID DYNAMICS 4 credits [3-1-0]

Introduction: Basic tools of CFD, Numerical Vs experimental tools. ; Mathematical Behavior of PDEs: Parabolic, Hyperbolic and Elliptic PDEs. ; Methodology of CFDHT:Discrete representation of flow and heat transfer domain: Grid generation, Governing equations and boundary conditions based on

FVM/FDM, Solution of resulting set of linear algebraic equations, Graphical representation and analysis of qualitative results, Error analysis in discretization using FVM/FDM. ; Solution of 1-D/2-D steady/unsteady: Diffusion problems, Convectionproblems, Convection-diffusion problems, source term linearization. ; Explicit and Implicit Approach: Explicit and implicit formulation of unsteady problems, Stability analysis. ; Solution of Navier-Stokes Equations for Incompressible Flows: Staggered and collocated grid system, SIMPLE and SIMPLER algorithms. ; Special Topics in CFDHT: Numerical Methodology for Complex Geometry, Multi-block structured grid system, Solution of phase change Problems.

Essential Reading:

1. S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Taylor and Francis, ISBN-10: 0891165223.

Supplementary Reading:

1. H. K. Versteeg and W. Malalasekra, *Introduction to Computational Fluid Dynamics: The Finite Volume Method,* Prentice Hall (2nd Edition), ISBN-10: 0131274988.
2. Jr. D. A. Anderson, *Computational Fluid Mechanics and Heat Transfer* by McGraw-Hill Education
3. M. N. Ozisik, *Finite Difference Method,* CRC (1st Edition).

ME 654	**ADVANCED THERMODYNAMICS**	**4 credits [3-1-0]**

Review of Basics: First law and Second law analysis – concept of entropy – principle of increase of entropy – entropy generation – Availability – concept of exergy – exergy analysis of combustion processes. Helm Holtz function – Gibb's function – OnSagar reciprocity relation. Thermodynamic relations, Maxwell's relations, T-ds equations – specific heat relations – energy equation – Joule Thomson effect – Clausius Claperyon Equation. Criteria for Equilibrium – Gibb's phase rule – Conditions for stability. Compressibility factor, fugacity and activity, computation from the generalized charts, dependence of fugacity and activity on pressure and temperature, chemical – equilibrium. Phase rule – ideal and real solution of gases, liquids, equilibrium system. Statistical Thermodynamics: Thermodynamics probability, Maxwell statistics, Fermi Dirac and Bose – Einstein statistics, Entropy and probability, Degeneracy of energy levels, Partition functions. Kinetic Theory of Gases: Perfect gas model, Distribution of translational velocities distribution function, molecular collisions and mean free path, equipartition of energy.

Essential Readings:

1. A.S. Michael, *'Thermodynamic for Engineers'*, Prentice Hall, 1972.
2. P.K. Nag., *'Engineering Thermodynamics'*, II Ed., McGraw Hill, 1995.

Supplementary Reading:

1. G.J. Van Wylen & R.E. Sonntag., *'Fundamentals of Classical Thermodynamics'*, Willy Eastern Ltd. 1989 (Unit I, II & III)
2. J.P. Holman., *'Thermodynamics'*, 4th Ed., McGraw Hill, 1988.
3. J. Hsieg, *'Principles of Thermodynamics'*, McGraw Hill, 1978.
4. Lee and Sears, *'Statistical Thermodynamics'*, Addition Wesley, 1976.
5. V. Nastrand, S. Glasstne., '*Thermodynamics for Chemists'*, 1974.
6. M.D. Burghardt, *'Engineering Thermodynamics for Engineers'*, Harper and Row, NY, 1987.
7. K. Wark*, 'Advanced Thermodynamics for Engineers'*, McGraw Hill, NY, 1987.
8. K. Smith, H.C. Van Ness, *Introduction to Chemical Engineering Thermodynamics*. McGraw Hill, 1987.

ME 655	**REFRIGERATION AND CRYOGENIC SYSTEMS**	**4 credits [3-1-0]**

Review of Thermodynamic Principles of Refrigeration: Vapour compression cycle, actual vapour compression cycle, multistage, multi evaporator system, cascade system, gas cycle refrigeration, aircraft refrigeration. ; Refrigeration Systems: Estimation of thermal load, selection and matching of components compressors, evaporators, condensers, expansion devices, cyclic controls requirements of refrigerants, lubricants in refrigeration, Secondary refrigerants, mixed refrigerants. Theory of mixtures ; enthalpy composition diagrams, absorption system calculation, aqua ammonia systems, LiBr water system, Three fluid absorption systems, solar refrigeration system. ; Cryogenic Systems: Introduction: Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction ; Cycles. Inversion Curve - Joule Thomson Effect. ; Liquefaction Cycles: Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle, Dual Cycle, Helium Regrigerated Hydrogen Liquefaction Systems. Crtical components in Liquefaction Systems ; Cryogenic Refrigerators: J.T.Cryocoolers, Stirling Cycle Refrigerators, G.M.Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators Applications: Applications of Cryogenics in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications.

Essential Reading:

1. W.F Stocker. and J.W. Jones, *'Refrigeration and Air-conditioning Data'*, McGraw Hill, 1985.
2. M. Prasad., *'Refrigeration and Air Conditioning'*, Willey Eastern Ltd., 1990.

Supplementary Reading:

1. Jordan and Priester, *'Refrigeration and Air conditioning'*, Prentice Hall of India, 1974.
2. '*Ashrae Hand Book'*, 4 Vol., Current Ed.,
3. K. D. Timmerhaus and T.M. Flynn, *Cryogenic Process Engineering*, Plenum Press, 1989.
4. R. F. Barron, *Cryogenic Systems*, McGraw Hill, 1985.
5. R.B.Scott, *Cryogenic Engineering*, Van Nostrand and Co., 1962.
6. H. Weinstock, *Cryogenic Technology*, 1969.
7. R. W. Vance, *Cryogenic Technology*, John Wiley & Sons, Inc., New York, London.

ME 656	**GAS TURBINES AND JET PROPULSION**	**4 credits [3-1-0]**

Introduction, application, shaft power gas dynamics – Compressibility effect, steady one dimensional compressible flow of a perfect gas in a duct, isentropic flow in a constant area duct with friction, normal shock waves, oblique shock wave, isentropic two dimensional, supersonic expansion and compression. ; Centrifugal fans Blowers and Compressors: Principle of operations, work done and pressure rise, slip factor, diffusers, compressibility effects, non dimensional qualities for plotting compressor characteristics. Bray ton cycle, regeneration and reheating cycle analysis ; Axial flow fans and compressors: Elementary theory, degree of reaction, three dimensional flow, simple design methods, blade design, calculation of stage performance, overall performance, and compressibility effects. Performance characteristics. ; Combustion system: Form of combustion, important factors affecting combustion chamber design, combustion processes, combustion chamber performance, practical problem. ; Axial flow turbines: elementary theory, vortex theory, choice of blade profile, pitch and chord ; estimation of stage performance, he cooled turbine. ; Prediction of performance of simple gas turbines: component characteristic, off design shaft gas turbine, equilibrium running gas generators, off design o free turbine and jet engine, methods of displacing the equilibrium, running line, incorporation of variable pressure losses, methods of improving part load performance, matching procedure for twin spool engines, behavior of gas turbine .Gas turbine rotors and stresses.

Supplementary Reading:

1. J.E Lee, *Theory and design of stream and gas turbine*.
2. Cohen & Rogers, *Gas Turbines*

ME 657	**COMPUTATIONAL METHODS IN THERMAL ENGG.**	**4 credits [3-1-0]**

Introduction: Concepts of consistency, stability, and convergence of numerical schemes. Various finite difference and finite element methods and their applications to fundamental partial differential equations in engineering and applied sciences. Case studies selected from fluid mechanics and heat transfer. ; Finite Difference Method: Classification, Initial and Boundary conditions, Forward, Backward difference, Uniform and non-uniform Grids, Grid Independence Test.

Basic finite difference schemes. Boundary treatments. Fourth order RK methods and Predictor-corrector methods and Nachsheim-Swigert iteration with applications to flow and heat transfer. ; Parabolic and hyperbolic problems: Model problems and stability estimates. Examples of the methods of lines. The Lax-Richtmyer equivalence theorem. Stability analysis. Discrete Fourier series. Von- Neumann stability analysis. Consistency, convergence and error estimates. Keller Box and Smith's method with applications to thermal boundary layers. ; Convection dominated problems: The failure of standard discretization, Upwinding and Higher order methods.

Supplementary Reading(s):

1. K.Muralidhar and T.Sundararajan, "*Computational Fluid Flow and Heat Transfer*", Narosa Publishing House ,New Delhi1995.
2. P.S., Ghoshdasdidar, *"Computer Simulation of flow and heat transfer"* Tata McGraw-Hill Publishing Company Ltd., 1998.
3. S.V. Patankar, "*Numerical heat transfer fluid flow*", Hemisphere Publishing Corporation, 1980.
4. D.A. Anderson, I.I. Tannehill, and R.H. Pletcher, *Computational Fluid Mechanics and Heat Transfer*, Hemishphere Publishing Corporation, New York, USA, 1984.
5. C.A.J. Fletcher, ,"*Computational Techniques for Fluid Dynamics*
6. *Fundamental and General Techniques*, Springer-Verlag,1987.
7. T.K. Bose, "*Numerical Fluid Dynamics*" Narosa Publishing House, 1997.
8. T.K. Sengupta, *Fundamentals of Fluid Dynamics*, University Press, Hyderabad.

ME 658 AIR-CONDITIONING AND VENTILATING SYSTEM 4 credits [3-1-0]

Psychrometry: simple psychometrics processes, use of psychometrics chart. ; Summer Air – conditioning, Winter Air-Conditioning, Comfort and industrial air conditioning ; Design Conditions, ventilation loads, Comfort air-Conditioning, Physiological factors. Comfort index. Load Estimation, Applied Psychrometrics Air conditioning systems: Spray systems, chilled water and DE Coils, absorption and adsorption systems. Humidifiers. ; Principles of ventilation. Air filtration, Air conveying Fans, ducts and air diffusion equipment. Estimation of air conditioning load, determination of supply state. Design and constructional details of Unitary air conditioning equipment. ; Noise level and acoustic control. Automatic controls in air conditioning.

Supplementary Reading(s):

1. W.F. Stoecker, and J.W. Jones, *Refrigeration and Air Conditioning*, 2nd Edition, Tata McGraw Hill, New Delhi 1982.
2. *ASHRAE Handbook- Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc*., Atlanta, USA, 1997.
3. W.R Haines and C.L Wilson, *HVAC Systems Design Handbook*, McGraw Hill, 2nd Ed., New Delhi, 1994.
4. R.C Legg, *Air Conditioning Systems - Design, Commissioning and maintenance*, Batsford Ltd, London 1991.

ME 659 CRYOGENIC PROCESS ENGINEERING 4 credits [3-1-0]

Cryogenic Systems: Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve - Joule Thomson Effect. ; Liquefaction Cycles: Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle, Collins Cycle, Dual Pressure Cycle, Helium Regrigerated Hydrogen Liquefaction Systems. Critical components in Liquefaction Systems, Introduction to air separation. ; Cryogenic Refrigerators: J.T. Cryocoolers, Stirling Cycle Refrigerators, G.M. Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators ; Storage and transfer of Cryogenic liquids, Design of storage vessels. ; Cryogenic Insulation, Multi layer insulation, Vacuum insulation etc. ; Applications: Applications of Cryogenics in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications.

Essential Reading:

1. K. D.Timmerhaus and T.M. Flynn, *Cryogenic Process Engineering*, Plenum Press, 1989.
2. R. F. Barron, *Cryogenic Systems*, McGraw Hill, 1985.
3. R.B.Scott, *Cryogenic Engineering*, Van Nostrand and Co., 1962.

Supplementary Reading(s):

1. H. Weinstock, Cryogenic Technology, 1969.
2. R.W. Vance, Cryogenic Technology, John Wiley & Sons, Inc., New York, London.

ME 660	HEAT TRANSFER EQUIPMENTS	4 credits [3-1-0]

Laws of conduction, convection and radiation; solution for some ideal geometries, Heat flow paths in series and parallel. ; Insilation systems – solid, foam, fiber, powder, vacuum and multilayer insulation. Design of insulation systems. ; Conductive heat flow devices – fins, heat sinks etc. ; Convective heat transfer and flow friction phenomena co-relations. Heat exchangers –their classification based on flow direction and construction geometry. Design of Shell & Tube, Plate fin, Matrix and other types of heat exchangers; use of TEMA codes. Design of heat exchangers for automotive, refrigeration, cryogenic and chemical process plants. Heat exchangers with phase change. ; Regenerative heat exchangers – dual regenerators as continuous heat exchangers, single regenerators in cryogenic devices. ; Radiation coolers, heat transfer in vacuum; cryopumps – their structure and design; cryogenic storage vessels – their structure and insulation system design.

Essential Reading(s):

1. R. K. Shah & D. P. Sekulic, *Fundamentals of Heat Exchanger Design*, John Wiley, 2003.
2. E. M. Smith, *Advances in Thermal Design of Heat Exchangers*, John Wiley, 2005.

Supplementary Reading:

1. E. Hesselgreaves, *Compact Heat Exchangers*, Elsevier, 2001.
2. R.F. Barron, *Cryogenic Systems*, McGraw Hill, 1985.

ME 661	DESIGN OF THERMAL SYSTEMS	4 credits [3-1-0]

Modeling of Thermal Systems: types of models, mathematical modeling, curve fitting, linear algebraic systems, numerical model for a system, system simulation, methods for numerical simulation; Acceptable Design of a Thermal System: initial design, design strategies, design of systems from different application areas, additional considerations for large practical systems; Economic Considerations: calculation of interest, worth of money as a function of time, series of payments, raising capital, taxes, economic factor in design, application to thermal systems; Problem Formulation for Optimization: optimization methods, optimization of thermal systems, practical aspects in optimal design, Lagrange multipliers, optimization of constrained and unconstrained problems, applicability to thermal systems; search methods: single-variable problem, multivariable constrained optimization, examples of thermal systems; geometric, linear, and dynamic programming and other methods for optimization, knowledge-based design and additional considerations, professional ethics.

Essential Reading:

1. W.F. Stoecker, *Design of Thermal Systems* - McGraw-Hill, 1971.

Supplementary Reading:

1. Y. Jaluria, *Design and Optimization of Thermal Systems* –CRC Press, 2007.
2. Bejan, G. Tsatsaronis, M.J. Moran, *Thermal Design and Optimization* - Wiley, 1996.
3. R. F. Boehm, *Developments in the Design of Thermal Systems* - Cambridge University Press, 1997.
4. N.V. Suryanarayana, *Design & Simulation of Thermal Systems* - MGH, 2002.

ME 662 THERMAL PROCESSES IN SURFACE ENGINEERING 4 credits [3-1-0]

Surface dependent engineering properties, viz., wear friction, corrosion, fatigue, reflectivity, emissivity, etc.; common surface initiated engineering failures; mechanism of surface degradation; importance and necessity of surface engineering; classification and scope of surface engineering in metals, ceramics, polymers and composites, tailoring of surfaces of advanced materials. Wear, wear related industrial problems, different wear modes, temperature effects on surface damage due to wear, wear at elevated temperature, wear modeling and surface damage prediction. ; Thermal Processes in surface engineering: physical/chemical vapor deposition; plasma spray coating; plasma assisted ion implantation; surface modification by directed energy beams like ion, electron and laser beams; energy transfer, beam configuration and modes, surface integration, heat and mass transfer (composition and temperature profile) during directed energy beam irradiation; novelty of composition and microstructure;

Essential Reading:

1. R. Chattopadhyay, *Advanced Thermally Assisted Surface Engineering Processes*, Kluwer Academic Publishers, MA, USA (now Springer, NY), 2004

Supplementary Reading:

1. J.S. Burnell-Gray, P.K. Datta, *Surface Engineering Casebook*, Published 1996, Woodhead Publishing

ME 663 RADIATION HEAT TRANSFER 4 credits [3-1-0]

Fundamentals of Thermal Radiation: Introduction, Basic Laws of Thermal Radiation, Emissive Power, Solid Angles, Radiative Intensity, Radiative Heat Flux. ; View Factors: Introduction, Definition of View Factors, Methods for the Evaluation of View Factors, Area Integration, Contour Integration, View Factor Algebra, The Crossed-Strings Method, The Inside-Sphere Method, The Unit Sphere Method. ; Radiative Exchange Between Gray, Diffuse Surfaces: Introduction, Radiative Exchange Between Black Surfaces, Radiative Exchange Between Gray, Diffuse Surfaces, Electrical Network Analogy. ; The Equation of Radiative Transfer in Participating Media: Introduction, Radiative Intensity in Vacuum, Attenuation by Absorption and Scattering, Augmentation by Emission and Scattering, The Equation of Transfer, Formal Solution to the Equation of Transfer, Boundary Conditions for the Equation of Transfer, Radiative Energy Density, Radiative Heat Flux, Divergence of the Radiative Heat Flux, Overall Energy Conservation, Solution Methods for the Equation of Transfer. ; The Treatment of Collimated Irradiation: Introduction, Reduction to the Problem, The P1- Approximation with Collimated Irradiation, FVM Solution Methodology for Collimated Irradiation Problem, Short pulse collimated irradiation and its biomedical applications.

Essential Reading:

1. M. F. Modest, *Radiative Heat Transfer,* Academic Press (2003), ISBN-10: 0125031637.

Supplementary Reading:

1. R. Siegel and J. Howell, *Thermal Radiation Heat Transfer* by Taylor and Francis Inc.
2. E. M. Sparrow and R. D. Cess, *Radiation Heat Transfer,* CRC.

ME 664 THERMAL MEASUREMENTS 4 credits [3-1-0]

Advanced Principles of Measurement: Static characteristics and accuracy in the steady state – Generalized model, Statistical characteristics, Measurement errors, Probability function and error reduction techniques. ; Dynamic characteristics, Loading effects and noise, Transfer function, Time and frequency responses, dynamic errors and compensation, generalized loading. ; Economics of measurement systems, Reliability, Selection of measurement systems, Operating cost. ; Measurement System Design: Sensing elements – Resistive, Capacitive, Inductive, Electromagnetic, and other sensing elements; Signal conditioning and processing elements – Deflection bridges, amplifiers, AC carrier systems, Current transmitters, Oscillators and Resonators, A/D conversion, Sampling, Quantization, Encoding. ; Data Acquisition, Multiplexing, Data acquisition system, Digital signal analysis. ; Specialized Measurement Systems: Flow, optical and ultrasonic measurement systems, Heat transfer effects and particle size analysis.

Essential Reading:

1. J. P. Bentley, *Principles of Measurement Systems* by Pearson Prentice Hall (4th Ed., 2005), ISBN-10: 0130430285.

Supplementary Reading:

1. R. S. Figliola, *Theory and Design of Mechanical Measurements*, John Wiley and Sons Inc (1992), ISBN-10: 0471535141.
2. J. W. Dally, W. F. Riley and K. G. McConnell, *Instrumentation for Engineering Measurements,* John Wiley and Sons Inc.
3. E. Doebelin, *Measurement Systems: Application and Design*, McGraw-Hill.

ME 665	FURNACE DESIGN	4 credits [3-1-0]

Introduction-Types of industrial furnaces. Components of a total furnace systems. Furnaces/kiln construction materials. ; Heat/fuel economy-Energy audit and its necessities. Sources of heat loss in furnace. Thermal efficiency in operation of furnace. ; Dynamics of gas in a furnace Definition of Draught, its necessities, classification of draughts. ; Deduction of the equations for natural draught & chimney height. ; Design of Burners & Fire boxes, Grate firing systems, mechanical stokers, selection of burners, burner components, classification of burners. ; Design parameters applicable to different Furnaces/Kilns, Down Draft Kiln, Tunnel Kiln, Shuttle kiln, Bell type kiln, Glass Tank Furnace, Blast Furnace, LD Converters, Roller Hearth Kiln, etc.).

Supplementary Reading:

1. O.P. Gupta. *Elements of Fuels, Furnaces & Refractories.*
2. W Trincs, *Industrial Furnaces* Vol. I & II.
3. M.W. Thring. *The science of Flames and Furnaces.*
4. A.K. Biwas. *Principles of Blast Furnaces for iron making*
5. CT-404: *Process Calculations*: Credits: 3

ME 666	ALTERNATIVE FUELS FOR IC ENGINES	4 credits [3-1-0]

Estimation of petroleum reserve - Need for alternate fuel - Availability and properties of alternate fuels – general use of alcohols - LPG - Hydrogen - Ammonia, CNG and LNG - Vegetable oils and Biogas – Solar - Merits and demerits of various alternate fuels ; Properties, alcohols and gasoline blends, performance in SI engine. Methanol and gasoline blends - Combustion characteristics in engines - emission characteristics - Engine modifications ; Availability of CNG, properties, modification required to use in engines - performance and emission characteristics of CNG using LPG in SI & CI engines. Performance and emission for LPG - Hydrogen – Storage and handling, performance and safety aspects ; Various vegetable oils for engines – Single and dual fuel use – Engine modifications - SVO - Esterification - Performance in engines - Performance and emission characteristics ; Layout of an electric vehicle - Advantage and limitations - Specifications - System component. Electronic control system - High energy and power density batteries - Hybrid vehicle - Solar powered vehicles.

Supplementary Reading(s):

1. M. Dayal, "*Energy today & tomorrow* ", I & B Horishr India, 1982.
2. Nagpal, "*Power Plant Engineering* ", Khanna Publishers, 1991.
3. “*Alcohols and motor fuels progess in technology* ", Series No.19, SAE Publication USA 1980 SAE Paper Nos. 840367, 841156, 841333, 841334
4. “*The properties and performance of modern alternate fuels*" - SAE Paper No.841210. SAE Handbook

ME 667 AIRCRAFT AND ROCKET PROPULSION 4 credits [3-1-0]

Introduction, Rocket system and aerodynamics of rockets, Fundamentals of gas turbine engines, Illustration of working principles of gas turbine engine, Propulsion system and operating principle, Thermodynamics of propulsion system, Engine performance parameters, The ramjet cycle, Working principles of ideal ramjet cycle, The turbojet cycle, Working principles of turbojet cycle, Non-ideal turbojet cycle, Axial flow fans and compressors, Polytrophic efficiency of compression, Calculation of stage performance and overall performance, Working principles of turbofan cycle, Rocket performance, Introduction and working principles of multistage rocket, Solid propellant rockets, Liquid propellant rockets ,Thrust control in liquid rockets Cooling in liquid rockets, Hybrid rockets, Limitations of hybrid rockets, Relative advantages of liquid rockets over solid rockets

Supplementary Reading:

1. G.C. Oates, *Aerothermodynamics of Aircraft Engine Components*, AIAA Education Series, New York, 1985.
2. W.W. Bathie*, Fundamentals of Gas Turbines*- John Wiley & Sons, 1984.
3. M.L. Mathur, and R.P. Sharma, *Gas Turbine Jet and Rocket Propulsion*, Standard Publishers and Distributors, Delhi, 1988.
4. P.G. Hill, *Mechanics and Thermodynamics of Propulsion*- Addison Wesley, 1970.
5. S.M. Yahya, *Fundamentals of Compressible Flow* - John Wiley, New York, 1982.
6. A.K. Mohanty, *Fluid Mechanics* - Prentice Hall, New Delhi, 2003.

ME 668 ENERGY CONSERVATION AND MANAGEMENT 4 credits [3-1-0]

Energy sources, Classification and characterization of fuels (fossil and bio-fuel), conversion and utilization, environmental and economic issues, optimum use of energy resources, Thermodynamic cycles, Principles of thermal energy conversion in boilers, internal combustion engines and gas turbines, cogeneration and combined cycle power generation, fuel cells and MHD technology, solar, wind and nuclear power, utilization of industrial heat, Energy management in industry, Environmental and economic evaluation advanced pollution control technology.

Supplementary Reading:

1. R. Gold Stick and A. Thumann, *Principles of Waste Heat Recovery*, PHI, 1986.
2. D. Y. Goswami, F. Kreith, *Energy Conversion*- CRC Press, 2007
3. V. Kadambi, and M. Prasad, *Introduction to energy conversion turbo machinery*: *Energy conversion cycle*- Wiley Eastern, New Delhi, 1974,

ELECTIVE LABORATORIES 2 credits [0-0-3]

ME 670
ME 671
ME 672
ME 673
ME 675
ME 772
ME 773 &
WS 671

These Laboratory classes aims at:

1. Understanding the phenomena involved
2. Study of influencing parameters
3. Develop setup, instrumentation, equation, product, etc
4. Modeling & Simulation of the process
5. Simple project
6. Creation of concept
7. Application to real problem

8. Assignments suggested by the instructor

ME 701 COMPOSITE MATERIALS 4 credits [3-1-0]

Definition and Classification of Composites, MMC, PMC, CMC. Reinforcing fibres- Natural fibres (cellulose, jute, coir etc), boron, carbon, ceramic glass, aramids, polyethylene (UHMWPE), polybenz-thiazoles etc. Particulate fillers-importance of particle shape an size. Matrix resins-thermoplastics and thermosetting matrix resins. Coupling agents-surface treatment of fillers and fibres, significance of interface in composites. Nanocomposites, short and continuous fibre reinforced composites, critical fibre length, anisotropic behaviour, SMC, BMC, DMC etc. Fabrication techniques pultrusion, filament winding, prepreg technology, injection and compression moulding, bag moulding, resin transfer moulding, reaction injection moulding. Properties and perfor mance of composites. Applications.

Essential Reading:

1. K.K. Chawla, *Composite Materials – Science & Engineering*, Springer-Verlag, New York, 1987.
2. F.L. Matthews and R.D. Rawlings, *Composite Materials: Engineering and Science*, Chapman & Hall, London, 1994.
3. Dr Navin Chand, *Tribology of Natural fiber Composites*, Wood Head Publishing Limited, England.

ME 710 ADVANCED COMPOSITES 4 credits [3-1-0]

Principles of composites, micromechanics of composites. Various types of reinforcements and their properties. Role of interfaces. Fabrication of metal matrix composites: insitu, dispersion hardened, particle, whisker and fibre reinforced; composite coatings by electrodeposition and spray forming. ; Fabrication of polymeric and ceramic matrix composites. Mechanical physical properties of omposites. Mechanisms of fracture in composites. Property evaluation and NDT of composites. Wear and environmental effects in composites.

Supplementary Reading:

1. *Composites, Engineered Materials Handbook*, Vol.1, ASM International, Ohio, 1988.
2. F.L. Matthews and R.D. Rawlings, *Composite Materials: Engineering and Science*, Chapman & Hall, London, 1994.
3. Weinheim, *Structure and Properties of Composites, Materials Science and Technology,* Vol. 13, VCH, Germany, 1993.
4. J.Prasad /CGK Nair, *NDT and Evaluation of Materials*, Mc Graw Hill

ME 711 FUNDAMENTALS OF TRIBOLOGY 4 credits [3-1-0]

Introduction to tribology and its historical background. Factors influencing Tribological phenomena. Engineering surfaces - Surface characterization, Computation of surface parameters. Surface measurement techniques. Apparent and real area of contact. Contact of engineering surfaces- Hertzian and non-hertzian contact. Contact pressure and deformation in non-conformal contacts. Genesis of friction, friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction. Stick-slip friction behavior, frictional heating and temperature rise. Friction measurement techniques. Wear and wear types. ; Mechanisms of wear - Adhesive, abrasive, corrosive, erosion, fatigue, fretting, etc., Wear of metals and non-metals. Wear models - asperity contact, constant and variable wear rate, geometrical influence in wear models, wear damage. Wear in various mechanical components, wear controlling techniques. Introduction to lubrication. Lubrication regimes.Introduction to micro and nano tribology.

Supplementary Reading:

1. G Bayer, *Mechanical wear prediction and prevention*,-Marcel Dekkar. Inc. New York
2. P.Sahoo, *Industrial Tribology* Tata Mc Graw Hill

ME 712 FUNDAMENTALS OF ERGONOMICS 4 credits [3-1-0]

To develop awareness, acquire information, and experience human factors in design. Datalogging, data collection, data reduction and data analysis techniques. Gross human anatomy, anthropometry, biomechanics, muscle strength and exertion potential of different limbs, work capacity, environmental effects. Exercises for evaluation of postural forms and work spaces. Environmental conditions including temperature, illumination, noise and vibration. Perception and information processing, design of displays, hand controls, typography and readability, layout and composition. Exercises in evaluation of human response to product interface. Product safety and products liability.

Supplementary Reading:

1. D C Alexgander, *Applied Ergonomics*, Taylor and Francis.

ME 750 GAS DYNAMICS AND FREE MOLECULAR FLOW 4 credits [3-1-0]

Fundamental Aspects of Gas Dynamics: Introduction, Isentropic flow in a stream tube, speed of sound, Mach waves; One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations ; Normal Shock Waves: Shock waves, stationary normal shock waves, normal shock wave relations in terms of Mach number; Oblique Shock Waves: Oblique shock wave relations, reflection of oblique shock waves, interaction of oblique shock waves, conical shock waves; Expansion Waves: Prandtl-Meyer flow, reflection and interaction of expansion waves, flow over bodies involving shock and expansion waves ; Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers ; Adaiabatic Flow in a Duct with Friction: Flow in a constant area duct, friction factor variations, the Fanno line ; Flow with Heat addition or removal: One-dimensional flow in a constant area duct neglecting viscosity, variable area flow with heat addition, one-dimensional constant area flow with both heat exchanger and friction ; Generalized Quasi-One-Dimensional Flow: Governing equations and influence coefficients, solution procedure for generalized flow with and without sonic point ; Two-Dimensional Compressible Flow: Governing equations, vorticity considerations, the velocity potential, linearized solutions, linearized subsonic flow, linearized supersonic flow, method of characteristics.

Essential Reading:

1. L. D. Landau and E. M. Lifshitz, *Fluid Mechanics*. 2nd ed., Butterworth-Heinemann, 1995.
2. H. W. Liepmann, and A. Roshko, *Elements of Gas Dynamics*, Dover Pub, 2001.

Supplementary Reading:

1. P. H. Oosthuizen and W. E. Carscallen. *Compressible Fluid Flow*. NY, McGraw-Hill, 1997.
2. M. A. Saad, *Compressible Fluid Flow*. 2nd ed. Upper Saddle River, NJ: Prentice-Hall, 1993.
3. F. M. White, *Viscous Fluid Flow*. 2nd ed. New York: McGraw-Hill, 1991.
4. A. H. Shapiro, *Compressible Fluid Flow 1 and 2*. Hoboken NJ: John Wiley.

ME 751 HEAT EXCHANGER ANALYSIS AND DESIGN 4 credits [3-1-0]

Constructional Details: Types, Fluid flow arrangements, parallel, counter and cross flow, shell and tube heat exchanger, Regenerators and recuperator. Condensers – Industrial applications. ; Heat Transfer: Modes of Heat Transfer, Overall heat transfer coefficient, Thermal resistance, Efficiency. Temperature Distribution and its implications, LMTD, effectiveness ; Flow Distribution: Effect of Turbulence, Friction Factor, Pressure Loss, Orifice, Flow nozzle, Diffusers, Bends, Baffles, Effect of Channei Divergence, Manifolds. ; Stress in tubes, Headers sets and Pressure vessels: Differential Thermal Expansion, Thermal stresses, Shear stresses, Thermal sleeves, Vibration, Noise, types of failures. ; Design Aspects: Heat transfer and pressure loss flow configuration effect of baffles. Effect of deviations from ideality. Design of typical liquid-liquid, gas-gas-liquid heat exchangers. Design of cooling towers.

Essential Reading:

1. W.M. Kays and A.L. London., '*Compact Heat Exchangers*', 3rd Ed., McGraw Hill, 1984.
2. A.P. Frass and M.N.Ozisik, '*Heat Exchanger Design*', John Wiley and Sons Inc., 1965.
3. G.Wlker, '*Industrial Heat Exchangers*', A basic guide, McGraw Hill V Book Co., 1980.

Supplementary Reading:

1. '*Standards of the Turbular Exchanger Manufacturer Association*', 6th Ed., Tubular Exchanger Manufacturers Association, New York, 1978.
2. D. Q Kern, '*Process Heat Transfer*', McGraw Hill Book Co., 1984.
3. E.A.D. Saunders., '*Heat Exchangers*', Longman Scientific and Technical, New York, 1988.

ME 752 ADVANCED TURBO-MACHINERY 4 credits [3-1-0]

Introduction, Classification of turbo machinery. Application of TT – theorem in turbo machinery. Incompressible fluid in turbomachines – Effects of Reynolds Number and Mach number. Energy transfer between a fluid and a rotor - Euler turbine equation – components of energy transfer impulse and Reaction – Efficiencies. ; Radial flow pumps and compressors – head capacity relationship – Axial flow pumps and compressors – Degree of reaction dimensionless parameters – Efficiency and utilization factor in Turbo Machinery. ; Thermodynamics of Turbo machine processes – Compression and expansion efficiencies – Stage efficiency – Infinitesimal stage and finite stage efficiencies. ; Flow of fluids in Turbo machines – flow and pressure distribution over an airfoil section – Effect of compressibility cavitations – Blade terminology- Cascades of blades – fluid deviation – Energy transfer of blades – Degree of reaction and blade spacing – Radial pressure gradient – Free vortex flow – losses in turbo machines. ; Centrifugal pumps and compressors – Inlet section – Cavitation – flow in the impller channel – flow in the discharge casing pump and compressor characteristic. ; Radial flow turbines – inward flow turbines for compressible fluids – inward flow hydraulic – velocity and flow coefficients – gas turbine blading – Kaplan turbine – pelton wheels.

Essential Reading:

1. Lee, '*Theory and Design of Steam and Gas Turbine*', McGraw Hill, 1954.
2. Yahya, '*Turbines, Compressions & Fans*', Tata McGraw Hill, 1983.

Supplementary Reading(s):

1. D.G. Stephard, '*Principles of Turbo machines*', Macmillan Co., 1984.
2. W.J Kerten, '*Steam Turbine Theory and Practice*', CBS Publisher & Distributors, 1988.
3. C. Rogers, S Muttoo, '*Gas Turbine Theory*', Long man, 1988.
4. W N.Bathe, '*Fundamentals of Gas Turbines*', Willey & Sons, 1994.

ME 753 NON-CONVENTIONAL ENERGY SYSTEMS 4 credits [3-1-0]

Solar Radiation: Solar thermal process, heat transfer devices, solar radiation measurement, estimation of average solar radiation. Solar energy storage: stratified storage, well mixed storage, comparison, Hot water system, practical consideration, solar ponds, Non-convective solar pond, extraction of thermal energy and application of solar ponds. Wind energy: The nature of wind. Wind energy resources and modeling. Geothermal energy: Origin and types of geothermal energy and utilisation. OTEC: Ocean temperature differences. OTEC systems. Recent OTEC developments. Wave energy: Fundamentals. Availability Wave-energy conversion systems. Tidal energy: Fundamentals. Availability Tidal-energy conversion systems. ; Energy from biomass: Photosynthesis; Biomass resource; Utilisation of biomass.

Essential Reading:

1. S.P.Sukhatme, '*Solar Energy Principle of Thermal Collection and Storage*', Tata McGraw Hill, 1990.
2. G.L. Johnson, *Wind energy systems*, Prentice Hall Inc. New Jersey.
3. J.M.Kriender, '*Principles of Solar Engineering*', McGraw Hill, 1987.

Supplementary Reading:

1. V.S. Mangal, '*Solar Engineering*', Tata McGraw Hill, 1992.
2. N.K.Bansal, '*Renewable Energy Source and Conversion Technology*', Tata McGraw Hill, 1989.
3. P.J. Lunde., '*Solar Thermal Engineering*', John Willey & Sons, New York, 1988.
4. J.A. Duffie, and W.A. Beckman, '*Solar Engineering of Thermal Processes*', Wiley & Sons, 1990.

ME 754	**THEORY OF COMBUSTION AND EMISSION**	**4 credits [3-1-0]**

UNIT 1.CYCLE ANALYSIS ; Gas, steam and combined power cycles, refrigeration and air conditioning cycles, second law analysis.
UNIT 2.COMBUSTION THEORY ; Fuels and types, combustion process, combustion mechanism, adiabatic flame temperature, flame propagation, stability, kinetics, combustion aerodynamics, gaseous detonations, flame ignition and extinction and condensed phase combustion, combustion in SI and CI engines, ignition and burning rate analysis.
UNIT 3.COMBUSTION SYSTEMS ; Solid burning equipments, stokers, pulverized coal burning systems, cyclone combustors, emissions, types of fluidized beds, fluidized bed combustion, fundamentals bubbling bed, gas and liquid burners types, gas turbine combustion systems, combustion modeling
UNIT 4.DESIGN OF COMBUSTION SYSTEMS ; Design of combustion systems for boilers, furnaces, gas turbines and internal combustion engines, combustion chamber performance.
UNIT 5.PROPELLANT SYSTEMS; Types, theory of combustion, energy balance calculations

Supplementary Reading(s):

1. C.R. Ferguson and A.T. Kirk Patrick, *"Internal Combustion Engines*", John Wiley & Sons. Inc. 2001.
2. Stephen R Turns, "*Introduction to Combustion: Concepts and Applications*", McGraw Hill, 2000
3. G.L. Borman and K.N. Ragland, "*Combustion Engineering*", McGraw Hill, 1998.
4. D.Winterbone, "Advanced Thermodynamics for Engineers", Elsevier, 1996

ME 755	**CRYOGENIC HEAT TRANSFER**	**4 credits [3-1-0]**

Introduction: Cryogenic heat transfer applications, Material Properties at cryogenic temperatures, specific heats and thermal conductivity of solid, liquid and gases, Cryogenic insulations, gas-filled and evacuated powders and fibrous materials, microsphere and multi-layer insulations. ; Conduction: One-dimensional steady-state and transient conduction, conduction in composite materials, thermal contact resistance, cool-down in coated surfaces and fluid-storage vessels. ; Convection: Free and forced convection over external surfaces and tubes, Heat transfer in nearcritical region and its correlations, Kapitza conductance. ; Two-Phase Heat Transfer: Flow regimes, pressure drop, Lockhart-Martinelli correlation, pool boiling, forced convection boiling. ; Radiation: Radiation from LNG fires, free-molecular flow and heat transfer, free-molecular heat transfer in enclosures. ; Heat Exchanger: Cryogenic heat exchanger types, NTU-effectiveness design method, Giauque- Hampson design, Plate-fin and perforated-plate heat exchanger design, effect of variable specific heat, effect of longitudinal heat conduction, effect of heat transfer from ambient, Regenerators, Regenerator design.

Essential Reading:

1. R.F. Barron, '*Cryogenic Systems*', McGraw Hill, 1985.
2. R.B. Scott, '*Cryogenics Engineering*', Van Nostrand & Co., 1962.

Supplementary Reading:

1. H. Weinstock, '*Cryogenic Technology*', 1969.
2. K. D. Timmerhaus and T. M. Flynn., '*Cryogenic Process Engineering*', Plenum Press, New York, 1989.
3. R. W. Vance., '*Cryogenic Technology*', John Wiley & Sons Inc., New York, London, 1971.
4. Sengapatha, A. Bose, '*Cryogenics – Progress and Applications*', Tata McGraw Hill, 1987.

ME 756	NUCLEAR POWER GENERATION AND SAFETY	4 credits [3-1-0]

Descriptions of nuclear power plants and operations, Thermodynamics of nuclear power, Nuclear power cycles, Fluid systems analysis and introduction to two-phase flow, Heat generation in nuclear reactors, heat conduction in fuel matrixes, Heat transfer and fluid flow phenomena in rod bundles, Heat transfer with phase change, Quenching and rewetting phenomena in rod bundles, Hydrodynamics of countercurrent two-phase flow, Nuclear reactor accidents, Loss of coolant accident and emergency core cooling system, Principles and methods used in safety evaluation of complex engineered systems, Safety characteristics of LWR and BWR, Safety culture,Safety improvements in nuclear reactors, Waste management, Indian nuclear power programme.

Essential Reading:
1. M.M.El. Wakil., '*Nuclear Power Engineering'*, McGraw Hill Book Company, New York, 1987.
2. S. Glasstone and A. Setonske., '*Nuclear Reactors, Engineering*', 3rd Ed., CBS Publishers and Distributors, 1992.

Supplementary Reading:
1. Loftness, '*Nuclear Power Plants'*, D. Van Nostrand Company Inc, Princeton, 1964.
2. S. Sarg et al., '*Physics of Nuclear Reactors'*, Tata McGraw Hill Publishing Company Ltd., 1985.
3. T. J. Connoly., '*Fundamentals of Nuclear Energy'*, John Wiley, 1978.

ME 757	TWO-PHASE FLOW AND HEAT TRANSFER	4 credits [3-1-0]

Two phase flow: Simultaneous flow of liquids and gases, horizontal two phase flow lock chart and Martenelli procedure flow factor method – vertical two phase flow – Two phase flow through inclined pipes. Gas – Liquid flow in pipes. Flow regimes in vertical horizontal and inclined pipes. Pressure drop and void fraction Modeling for specific flow regimes. Pneumotransport and Hydrotransport of solids in pipes. Modelling of interaction forces. Gas – Liquid – Solid three-phase flow. Air-Lift Pump modeling. Two-phase flow boundary layer analysis. Circulation in boiler – natural and forced – effective pressure head in boiler tubes variation of major parameters of drum during transient conditions - The hydrodynamics stability of vapour – liquid system – simultaneous flow of fluids and solids, dynamics of particles submerged in fluids – flow through packed bed. ; Fluidization, calculation of pressure drop in fixed bed-determination of minimum fluidization velocity, Expanded bed, dilute phase, moving solids fluidization - Elutriation in fluidized bed – Semi fluidization – applications. Pulsating column – oscillating fluidized beds. ; Heat Transfer with Change of Phase: Film wise condensation of pure vapours – Drop wise condensation in plated surfaces – condensation in presence of non condensable gas – pool boiling – Boiling in forced flow inside tubing. ; Gas – Liquid Fluidization: Gas liquid particle process, Gas liquid particle operation – Gas liquid fluidization. Flow of Gas – Bubble formation, bubble growth gas hold up – Gas mixing liquid hold up – liquid mixing – flow of liquid mixing – Gas liquid mass transfer.

Essential Reading:
1. J.N. Ginou, '*Two Phase Flow & Heat Transfer'*, McGraw Hill, New York, 1978.
2. Mc Adams., '*Heat Transmission'*, McGraw Hill, 1963.

Supplementary Reading:
1. Daugherty and Franzini, '*Fluid Mechanics with Engineering Applications'*, McGraw Hill, 1985.
2. S.C. Kutateladeze, '*Problems of Heat Transfer and Hydraulics of Two Phase Media'*, Pergamon Press, 1982.
3. J.F Davidson and D.Harrison, '*Fluidization*', Prentice Hall, 1976.
4. L.S. Tong., '*Boiling Heat Transfer and Two Phase Flow'*, Wiley, New York, 1965.

ME 758	SUPERCONDUCTING MATERIALS, MAGNETSAND DEVICES	4 credits [3-1-0]

Thermal, electrical and magnetic properties of materials at low temperature, Basic properties of superconductors; Type I and Type II superconductors; Tunneling phenomena. Critical current densities and critical magnetic fields of type II superconductors; Magneto-thermal instabilities in type II superconductors; Concept of flux pinning mechanisms. Techniques of preparation of superconducting materials of type NbTi, Nb_3Sn, V_3Ga and ceramic superconductors in the form of wires and tapes; Stabilization criteria. Superconducting coil devices: Superconducting magnets, persistent current switches; Basic concepts of superconducting bearings, motors and energy storage devices. Superconducting thin film devices: negative resistance devices. Weak link devices including SQUIDS and their applications; infrared detectors.

Essential Reading:

1. THK Frederking, SWK Yuan, *Cryogenics-Low Temperature Engineering & Applied Sciences*, Yutopian Enterprises (December 15, 2005).

Supplementary Reading:

1. C. David, SG David, *Handbook of Superconducting Materials Volume 2*, Taylor & Francis Group 2005.
2. Asner, M. Fred, *High Field Superconducting Magnets*, Oxford University Press, USA.

ME 759	AIR SEPARATION AND INDUSTRIAL GASES	4 credits [3-1-0]

Principles of Diffusion and Mass Transfer, Fick's Law of Diffusion, Molecular diffusion in fluids, mass transfer coefficients in laminar and turbulent flow; mass, heat and momentum transfer analogies. Introduction to cryogenic gas separation and purification systems; principles of absorption, adsorption, condensation and rectification. Adsorption equilibria; types of adsorbant; adsorption/desorption cycles; PSA, TSA; steady state and dynamic adsorption; concept of break point and mass transfer zone; design of fixed bed adsorption system for gas separation and purification. Phase equilibria and phase rule; equilibrium stage operation; X-Y, T-X,Y and H-X,Y diagrams and their use; design of rectification columns; different tray assemblies; types of column assemblies for cryogenic rectification; Gas separation using membranes. Linde single column and double column for air separation. Production of argon and rare gases; Air separation processes for different product mixtures. Processes for production of CO_2 , N_2O and C_2H_2, Helium and Hydrogen.

Essential Reading:

1. R. E. Treybal, *Mass Transfer Operations*, Mc Graw-hill Education(Asia), 2003.
2. K.D.Timmerhaus and T.M.Flynn, *Cryogenic Process Engineering*, Plenum Press, 1989.

Supplementary Reading(s):

1. R.F. Barron, *Cryogenic Systems*, McGraw Hill, 1985.

ME 760	VACUUM TECHNOLOGY	4 credits [3-1-0]

Basic Theory: Gas kinetic theory, pressure, conductance, gas flow regimes, vapour pressure, pumping speed, throughput. Gas surface interactions: physisorption, chemi-sorption, condensation. ; Vacuum Pumps: Mechanical, diffusion, molecular drag, turbo molecular, cryopumps, ion pumps - general working principles, operating regimes. ; Vacuum Instrumentation: Vacuum gauges, gas regulators, flow meters, residual gas analyzers, interpretation of data. ; Design Concepts: Materials, chambers, components, joins, seals, valves. Overall system design and integration. ; Problem Solving: Leak detection and detectors, gas signatures. ; Vacuum Applications: Freeze drying, packaging, vacuum coating, microelectronics, particle accelerators, distillation, metallurgical processes, television and X-ray tubes, cryogenic insulation, space simulation.

Essential Reading:

1. V.V. Rao, T.B. Ghosh, K.L. Chopra, *Vacuum Science and Technology*, Allied Publishers Ltd., New Delhi (1998).
2. A. Roth, *Vacuum Technology*, North Holland Publishing Company, Amsterdam (1976).

Essential Reading:

1. M. H. Hablanian, M. H. Hablanian, H. H. Hablanian, *High-vacuum Technology: A Practical Guide*, Second Edition, Crc Press, 1997.
2. A.D. Tripathi A. Gupta Ac, *Ultra High Vacuum Techniques*, Allied Publishers Private Limited, 2002.

ME 761 BIO-FLUID MECHANICS 4 credits [3-1-0]

Review of Basic Fluid Mechanics Concepts: Fluid Characteristics and Viscosity, Introduction to Pipe Flow, Bernoulli Equation, Navier-Stokes Equation. ; Cardiovascular Function: The Heart as a Pump, Cardiac Muscle, Electrocardiograms, Heart Valves, Cardiac Cycle, Heart Sounds, Coronary Circulation, Microcirculation, Lymphatic Circulation, Pulmonary Anatomy, Pulmonary Physiology and Respiration: Work of Breathing, Airway Resistance, Gas Exchange and Transport, Pulmonary Pathophysiology, Respiration in Extreme Environments ; Hematology and Blood Rheology: Anatomy and Physiology of Blood Vessels, General Structure of Arteries, Types of Arteries, Mechanics of Arterial Walls, Pulse Wave Velocity and the Moens–Korteweg Equation, Vascular Pathologies, Stents, Coronary Artery Bypass Grafting ; Mechanics of Heart Valves: Aortic and Pulmonic Valves, Mitral and Tricuspid Valves, Pressure Gradients across a Stenotic Heart Valve, Prosthetic Mechanical Valves, Prosthetic Tissue Valves ; Pulsatile Flow in Large Arteries: Pulsatile Flow in Rigid Tubes—Womersley Solution, Pulsatile Flow in Rigid Tubes—Fry Solution, Instability in Pulsatile Flow.

Essential Reading:

1. L. Waite, J. Fine, *Applied Biofluid Mechanics*.

ME 762 TRANSPORT PHENOMENA IN MATERIAL PROCESSING 4 credits [3-1-0]

Transport Phenomena Fundamentals: Definitions and Concepts, Field Theory and Field Operations, Transport Processes and Transport Laws. ; Physical Laws and Governing Equations: Frame of Reference and Coordinate System, Kinematics of fluids and model philosophy, Differential and Integral Formulation and Procedures, Property Balance and Equation of Change, Equation of Continuity, Momentum Equations, Initial/Boundary Conditions, Application Examples, Convection-Diffusion Equation and Examples, Energy Equation and Examples. ; Transient Heat Transfer: Lumped Capacitance Method, Semi-infinite System, Example. ; Solidification of Metal Castings: Introduction, Analysis and Modeling of Metal Castings, Solidification in Sand Mold, Analysis and Modeling of Metal Melting, Melt Efficiency, Stefan-Neumann Problem, Drag Induced Melt Removal. ; Fluid Flow and Heat Transfer in a Porous Medium: Introduction, Macroscopic Model for a Porous Medium, Darcy's Equation and Permeability, Fluid Flow and Heat Transport Governing Equations in a Porous Medium.
Rheology of Non-Newtonian Fluids: Material Functions, Constitutive Equations, Linear Viscoelastic Fluids.

Essential Reading:

1. R. B. Bird, W. E. Stewart and E. N. Lightfoot, *Transport Phenomena,* Wiley (2nd Edition).

Supplementary Reading:

1. W. J. Beek, K. M. K. Muttzall and J. W. Van Heuven, *Transport Phenomena*, Wiley (2nd Edition).
2. B.R. Munson, D. F. Young and H. Theodore, *Fundamentals of Fluid Mechanics* by Okiishi, Wiley (5th Edition).
3. M. N. Ozisik, *Heat Conduction,* Academic Press.

ME 763 MICROFLUIDICS AND HEAT TRANSFER 4 credits [3-1-0]

Introduction: An overview of Microfluidics, Fundamentals of Fluid Mechanics. ; Surface tension-driven capillary flow In Microfluidics. Electrokinetic transport phenomena, Heat and Mass Transfer in Microfluidics, Numerical methods and simulation Experimental techniques and measurement in Microfluidics, Fabrication techniques for Microfluidics. Prototype applications of Microfluidics.

Essential Reading:

1. N.T. Nguyen and S.T. Wereley, *Fundamentals and Applications of Microfluidics,* Second Edition (2006), Artech House Inc.

Supplementary Reading:

1. S. Chakraborty, *Encyclopedia of Microfluidics and Nanofluidics* (Donquing Li Edition) by Springer.
2. P. Tabeling and S. Chen, *Introduction to Microfluidics*, Oxford University Press.
3. K. Chakrabarty and Fei Su, *Digital Microfluidic Biochips: Synthesis, Techniques and Reconfiguration Techniques,* CRC Press.

ME 764	**SPACE PROPULSION**	**4 credits [3-1-0]**

UNIT 1 :THERMODYNAMICS OF AIRCRAFT JET ENGINES ; Theory of Jet Propulsion – Thrust and efficiency – Ram Jet – Turbojet and Turbofan engines – Turboprop and Turbo shaft Engines – Thrust augmentations – Typical engine performance – Engine – Aircraft matching, Fuels.
UNIT 2 :AERO-THERMODYNAMICS OF JET PROPULSION SUBSTEMS ; Subsonic inlets - Supersonic inlets - Gas turbine combustors -After burners and Ramjet Combustors - Supersonic Combustion - Exhaust Nozzles, Cryogenic Engines.
UNIT 3 :PERFORMANCE OP ROCKET VEHICLES ; Static performance - Vehicle acceleration - Chemical rockets - Electrical rocket ; vehicles - Space missions.
UNIT 4:CHEMICAL ROCKET THRUST CHAMBERS ; Performance Characteristics – Nozzles – Rocket Heat Transfer – Liquid Propellant-Rocket Performance.
UNIT 5:CHEMICAL ROCKET PROPELLANT COMBUSTION & EXPANSION ; Liquid propellants – Equilibrium composition – Non equilibrium expansion – Solid and Liquid Propellant Combustion Chambers – Combustion Instabilities.

Supplementary Reading:

1. P.G. Hill and C.R. Peterson, *Mechanics and Thermodynamics of Propulsion*, Second Edition, Addition – Wesley Publishing Company, New York, 1992.
2. N.J. Zucrow, *Principles of Jet Propulsion and and Gas Turbines*, John Wiley and Sons Inc, New York, 1970.
3. N.J. Zucrow, *Aircraft and Missile Propulsion,* Vol. I and Vol. II, John Wiley and Sons Inc, New York, 1975.
4. E.A. Bonney, N.J. Zucrow, *Principles of Guided Missile Design*, Van Nostranc Co., 1985.
5. S.M. Yahya, *Gas Dynamics and Jet Propulsion*, McGraw-Hill Co.,
6. Barnes. W. Mc Cormick, "*Aerodynamics Aeronautics & Flight Mechanics*", John Wiley & Sons, 1995.

ME 765	**ADVANCED IC ENGINE TECHNOLOGY**	**4 credits [3-1-0]**

SI Engine-introduction-carburetion- mixture requirements-Fuel supply - Ignition - Stages of combustion-Normal and abnormal combustion-factors affecting knock -Combustion chambers. ; CI engine- Injection systems-Mechanical and electronic-Combustion in CI engines-stages of combustion-Factors affecting combustion-Direct and indirect injection systems –Combustion chambers – Fuel spray behaviour – spray structure, spray penetration-and evaporation – air motion – Introduction to Turbo charging and supercharging. ; Basic concepts of engine simulation, governing equations, simulation of various engine processes for SI and CI Engines. Thermodynamic and fluid mechanic based models. Different types of combustion chamber ; Engine instrumentation-Types of pollutants-Euro and Bharat norms-Emission control methods in SI and CI engines-catalytic converters-EGR-Modern evaporative emission control system ; Lean Burn Engines – Stratified charge Engines – homogeneous charge compression ignition engines – Plasma Ignition – Zero Emission Vehicles, Engines for special applications – Mining, Defence, Off-highway -Tractor, Bulldozer etc. Submarines, Race car Engine systems, Flexible fuel systems. Surface ignition,

Essential Reading:

1. J.B Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill
2. V. Ganesan, *Int. Combustion Engines*, II Edition, TMH, 2002.

Supplementary Reading:

1. M.L. Mathur and R.P.Sharma, *A course in internal Combustion Engines*, Dhanapat Rai Publications, New Delhi.
2. R.B.Mathur and R.P. Sharma, *Internal combustion Engines*.
3. K.K. Ramalingam, *Internal Combustion Engine Fundamentals*, Scitech Publications,
4. D. Smith, *Auto fuel Systems*, The Good Heart Willox Company, Inc.
5. V. Ganesan, *Computer simulation of spark ignition process: University process*, Hyderabad 1993.
6. V. Ganesan, *Computer simulation of compression ignition engine*. Orient Long man

ME 766	**MICRO-SCALE HEAT TRANSFER**	**4 credits [3-1-0]**

Microscale heat transfer regimes, Review of thermodynamics and heat transfer, Crystal structure, Reciprocal lattice / crystal bonding, Lattice vibration,Kinetic description of dilute gases, Elementary kinetic theory, Boltzmann transport equation, Microscale heat conduction equations, Thermal lagging behavior, conservation laws, H-Theorem (2nd law), BGK models, continuum limit; the laws of Navier-Stokes and Fourier (NSF), temperature jump and velocity slip, beyond NSF; higher order methods and moment equations, Knudsen layers.

Essential Reading:

1. S. Kandlikar, S. Garimella, D. Li, S. Colin, M. King (2005), *Heat Transfer and Fluid Flow in Minichannels and Microchannels*, Elsevier Publications, ISBN: 0-08-044527-6, 450 pages.
2. C.-L. Tien, A. Majumdar and F.M. Gerner, 1998, *Microscale Energy Transport*, Taylor & Francis, Washington.

Supplementary Reading:

1. S. Kakac, L.L. Vasiliev, Y. Bayazitoglu and Y. Yener, *Microscale Heat Transfer: Fundamentals and Applications*, Springer, 2005, ISBN 1-4020-33591, 509 pages.

ME 767	**FUEL CELL TECHNOLOGY**	**4 credits [3-1-0]**

Overview of current fuel cell technology. Operating principles, fundamental thermodynamics and electrochemistry. Types of fuel cells and applications. Proton exchange membrane fuel cells; components; performance; testing. Micro fuel cells. High temperature fuel cells. Modelling of transport phenomena in fuel cells. Hydrogen production and storage. Fuel cell systems and ancillaries. ; Overview and status of various fuel cell technologies. Fundamentals: fuel cell thermodynamics; electrode kinetics; performance and efficiency; transport processes. Proton Exchange Membrane Fuel Cells (PEMFCs). Solid Oxide Fuel Cells (SOFCs). Fuelling issues. Fuel cell systems and applications.

Essential Reading:

1. A.V. Da Rosa, 2005, *Fundamentals of Renewable Energy Processes*, Elsevier academic press.

Supplementary Reading:

1. W. Vielstich, A. Lamm and H.A. Gastieger, 2003, *Handbook of Fuel Cells*, vol. 1-4, John Wiley
2. G. Hogen ed. 2003, *Fuel Cell Technology* Handbook, crc press

ME 768	**TURBULENCE**	**4 credits [3-1-0]**

Introduction, statistical description and scales, Importance of fluid flow, prevalence of turbulence, description of turbulence, history of turbulence, definitions, mathematical tools, derivation of Reynolds-averaged Navier-stokes (RANS)equations Vortex stretching and Reynolds stresses, description and comparison of RANS models, Direct numerical simulation (DNS), Large-eddy simulation (LES)

Supplementary Reading:

1. H. Tennekes and J. L. Lumley, *A first course in Turbulence*, MIT press, Cambridge, MA 1972.
2. U. Frisch, *Turbulence*, *The legacy of A. N. Kolmogorov*, Cambridge University Press, 1995.
3. G. T. Chapman and M. Tobak. *Observations, Theoretical Ideas, and Modeling of Turbulent Flows — Past, Present and Future, in Theoretical Approaches to Turbulence*, Dwoyer et al. (eds), Springer-Verlag, New York, pp. 19–49, 1985.
4. P. Constantin and C. F. Navier–*Stokes Equations,* University of Chicago Press, Chicago, 1988.
5. Tsinober. *An Informal Introduction to Turbulence*, Kluwer Academic Publishers, Dordrecht, 2001.
6. J. O. Hinze. *Turbulence*, McGraw-Hill, New York, 1959.

DEPARTMENT OF METALLURGICAL AND MATERIAL ENGINEERING

DETAILED SYLLABI OF COURSES

MM 601	Metallurgical Thermodynamics & Kinetics	3-1-0	4
MM 606	X – Ray & Electron Microscopy	3-1-0	4
MM 611	Phase Transformation of Materials	3-1-0	4
MM 615	Structure & Properties of Materials	3-1-0	4
MM 616	Alloy Steel Technology	3-1-0	4
MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4
MM 618	Joining of Materials	3-0-0	3
MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4
MM 623	Iron & Steel Making	3-1-0	4
MM 624	Advanced Foundry Technology	3-0-0	3
MM 625	Ferro – Alloy Technology	3-0-0	3
MM 628	Advances in Steel Making	3-1-0	4
MM 634	Metallugical Failures: Detection and Analysis	3-1-0	4
MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4
MM 636	Advanced Processing of Materials	3-0-0	3
MM 637	Mechanical Behaviour of Materials	3-1-0	4
MM 638	Mechanical Working of Materials	3-1-0	4
MM 642	Advances in Materials Science and Engineering	3-1-0	4
MM 646	Composite Materials	3-1-0	4
MM 652	Experimental Techniques in Materials Engineering	3-1-0	6
MM 655	Transport Phenomena	3-0-0	3
MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3
MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3
MM 665	Powder Technology	3-1-0	4
MM 666	Computational Modeling of Materials	3-1-0	4
MM 667	Computational Metallurgy Laboratory	0-0-3	2
MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
MM 673	Phase Transformation Laboratory	0-0-3	2
MM 674	Materials Science Laboratory	0-0-3	2
MM 675	Process Metallurgy Laboratory	0-0-3	2
MM 681	Special Topics in Metallurgical and Material Engineering – I		3/4
MM 682	Special Topics in Metallurgical and Material Engineering – II		3/4
MM 683	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 684	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 685	Seminar & Technical Writing – I	0-0-3	2
MM 686	Thermal plasma applications in Metallurgy	3-0-0	3
MM 686	Seminar & Technical Writing – II	0-0-3	2
MM 687	Texture of Materials	3-0-0	3
MM 687	Seminar & Technical Writing – III		2
MM 688	Seminar & Technical Writing – IV		2
MM 688	Ultra-high strength materials: Processing, properties and applications	3-0-0	3
MM 690	Surface Engineering	3-0-0	3
MM 691	Summer Research/Industrial Project	0-0-0	4
MM 692	Comprehensive Viva	0-0-0	4

MM 693	Research Project – III	0-0-15	10
MM 694	Research Project – IV	0-0-30	20
MM 695	Advanced Extraction Processes	3-0-0	3
MM 695	Research Project Review – I		8
MM 696	Research Project Review – II		6

MM 601 METALLURGICAL THERMODYNAMICS & KINETICS 4 Credits [3-1-0]

Laws of thermodynamics and their applications; Enthalpy; Entropy associated with different processes; Gibbs and Helmholtz free energy; Criteria of equilibrium; Concepts of activity, fugacity and standard states; Ellingham diagram; Free energy – composition diagram; Solutions – Raoult's and Henry's Laws; Ideal, real and regular solutions; Gibbs – Duhem equation. ; Activation energy and its applications; Homogeneous and heterogeneous reactions; Factors affecting the heterogeneous reactions kinetics in solid – solid, solid – gas and solid – liquid systems; Rate controlling steps; Kinetic model equations, Fick's laws of diffusions and their applications in metallurgy; Slag – metal reaction kinetics ; Concept of boundary layer and its impact on reaction kinetics.

Caretaker: Prof.M.Kumar

Essential Readings:

1. D.R.Gaskell, *Introduction to Metallurgical Thermodynamics*, McGraw Hill, New York, 1973.
2. G.S.Upadhyay and R.K.Dubey, *Problems in Metallurgical Thermodynamics and Kinetics*, Pergamon, New York, 1977.
3. J.Szekely and N.J.Themelis, *Rate Phenomena in Process Metallurgy*, John Wiley, New York.

Supplementary Readings:

1. A.K.Mohanty, *Rate Processes in Extractive Metallurgy*, Prentice Hall of India.

MM 606 X-RAY & ELECTRON MICROSCOPY 4 credits [3-1-0]

X-ray and electron beam analysis techniques: Characterization of x-rays, absorption, x-ray diffraction techniques (viz. Laue, powder and rotating crystal methods), interpretation of diffraction datas, qualitative and quantitative phase composition analysis, analysis of particle size, residual stress/strain, phase diagram determination, order disorder transformation study. ; X-ray fluorescence: Origin, basic theory/concept, characterization of materials through x-ray fluorescence. ; Microscopy with light and electrons: Introduction, Methods of image formation, Pixels, the light-optical microscope, Magnification, Resolution, depth of field and depth of focus, Aberrations in optical system, electron versus light. ; Electrons and their interaction with specimen: Introduction, Electrons, generation of electrons-magnetic lenses, the scattering of electrons by atoms, Elastic scattering, Inelastic scattering, secondary effect, the family of electron microscopes. ; The transmission electron microscope: The instrument, Contrast mechanisms, Bright field & Dark field imaging, SAD technique. ; The scanning electron microscope: How it works, obtaining a signal in the SEM, the optics of the SEM, the performance of the SEM, the ultimate resolution of the SEM, Topographic images, compositional images, Crystallographic informations from the SEM, the use of generated signals in SEM study. ; Chemical analysis in the electron microscope: The generation of x-rays from/on the specimen, Quantitative analysis in an electron microscope, Electron energy loss spectroscopy (EELS).

Caretaker: Prof.S.C. Mishra

Essential Reading:

1. B.D.Cullity, *Element of X-ray Diffraction*, Addison Wesley.
2. C.S.Barret and T.B. Massalski, *Structure of Metals*, McGraw Hill.
3. V.A. Phillip, *Modern Metallographic Technique & their Application*, Wiley Interscience Publ., 1971.

Supplementary Reading:
1. S.K.Chaterjee, *X-ray Diffraction, its theory and applications*, PHI.
2. P.J. Goodhow, J.Humhreys, R.Beanland: *Electron microscopy & Analysis (III Edn.)*; Taylor & Francis (publ.) 2001.

MM 611	PHASE TRANSFORMATION OF MATERIALS	4 credits [3-1-0]

Thermodynamics and Kinetics of solid state Phase transformation, Atomic models of Diffusion, Functions of alloying elements, Allotropy of Iron and Fe – C Phase diagram, Importance of Austenite Grain size. ; Formation of Austenite, TTT and CCT Diagrams. ; Homogeneous and Heterogeneous nucleations, Strain energy effects. ; Pearlitic, Bainiatic and Martensitic Transformation (Mechanisms, Kinetics and Morphologies). ; Pearlitic transformation: Factors influencing pearlitic transformation, Mechanism of transformation, Nucleation of growth, Orientation relationship. ; Bainite transformation: Mechanism of transformation, Nucleation and growth, Orientation relationship, Surface relief, Classical and non-classical morphology, Effect of alloying elements. ; Martensitic Transformation: Characteristics of transformation, Thermodynamics and kinetics, Nucleation and growth, Morphology, Crystallography, Stabilization. ; Annealing (Full, Homogenising, Spherodization and Stress-relieving annealing), Normalising, Comparison of Annealing and Normalizing, Hardening and Tempering of steel, Aims and stages of tempering, Effect of Carbon and alloying elements, Tempering of alloy steels and Multiply tempering.

Caretaker: Prof. B.C.Ray

Essential Reading:
1. D.A.Porter & K E Easterling, *Phase Transformation in Metals and Alloys*, CRC Press.
2. V Raghvan, *Solid State Phase Transformation*, PHI.
3. V Sing, *Heat Treatment of Metals*, Standard Publishers.

Supplementary Reading:
1. J W Christian, *The Theory of Transformations in Metals and Alloys*, Pergamon Press.
2. J E Hilliard, *Phase Transformations*, ASM.
3. S.H. Avner, *Introduction to Physical Metallurgy*, Tata McGraw – Hill.
4. R.E. Reed Hill, *Physical Metallurgy Principles*, East – West Press.
5. A K Jena and M C Chaturvedi, *Phase Transformation in Materials*, Prentice Hall.

MM 615	STRUCTURE AND PROPERTIES OF MATERIALS	4 credits [3-1-0]

Crystal Structure: Space lattices, Bravais lattices and Reciprocal lattice concept. Miller Indices of planes and directions. ; Bonding in Solids: Ionic, Covalent, and Metallic bonding. Theory of alloy formation, Solid solution, Substitutional and interstitial solid solution, Hume Rothery Rules, Intermetallic compounds, Normal valency compounds, Electron compounds, Interstitial compounds. ; Imperfections: Point defects: vacancies, Interstitialcies, Dislocations: Edge & Screw dislocations, Burgers vector. ; Binary Phase Diagrams: Isomorphous, Eutectic, Peritectic, Eutectoid, Monotectic & Syntectic systems. Phase rule and Lever rule. ; Iron-Cementite Equilibrium diagrams and its applications. ; Diffusion: Fick’s First and Second law of diffusion. Atomic model of diffusion. Grain boundary, surface and thermal diffusion. Kirkendall Effect, Grube method, Matano method, Interstitial diffusion. ; Nucleation: Homogeneous and Heterogeneous nucleation, Kinetics of nucleation. Growth and overall transformation kinetics.

Caretaker: Prof. D. Chaira

Essential Reading:
1. V. Raghavan, *Materials Science and Engineering*, Prentice-Hall of India Private Limited (2003).
2. W.F. Smith, *Principles of Materials Science and Engineering*, McGraw Hill, New York (1994).

Supplementary Reading:

1. R.E. Reid Hill, *Physical Metallurgy Principles*- PWS-Kent Publishing (2004).
2. V. Singh, *Physical Metallurgy*, Standard Publisher (2008).
3. W.D.Callister, *An Introduction Materials Science & Engineering*, John Wiley & Sons (2007).
4. L.H. Van Vlack, *Elements of Materials Science and Engineering*, Addison Wisley, New York (1985).

MM 616	ALLOY STEEL TECHNOLOGY	4 credits [3-1-0]

Production Technology ; Electric arc furnace: Design, Construction and operation, Refractory lining, Electrode movement and slag control, Manufacture of alloy steels such as low alloy steels, stainless steels, Tool steels and silicon steels. ; Induction melting furnace: Classification, Construction and Refractory lining, Operation and manufacture of alloy steels. ; Processing, microstructure & mechanical properties of different alloy steels such as HSLA steels, Dual phase steels, IF steels, stainless steels, silicon steels, high speed steels, ball bearing steels, Had field steels etc.

Caretaker: Prof.S.Sarkar

Essential Reading:

1. F.P. Edneral: *Electrometallurgy of Steel and Ferro – Alloys*, Vol. I, Mir Publishers, 1979.
2. R.W.K.Honeycomb: *Steels, Microstructures and Properties*, Edward Arnold.

Supplementary Reading:

1. G.Karuss, *Steel Heat Treatments and Processing Principles,* ASM.
2. P.G.Shewmon, *Transformations in Metals*, McGraw Hill.
3. Dr. S. Smith, *Principles of Materials Science and Engineering*, McGraw Hill.
4. J.D. Verhoeven, *Fundamentals of Physical Metallurgy*, John Wiley.

MM 617	PHYSICAL METALLURGY OF ADVANCED METALLIC MATERIALS	4 credits [3-1-0]

Special steel: High strength low alloy (HSLA) steel, Dual phase steel, Duplex stainless steel, TRIP steel, Maraging steel, High speed steel, Stainless steel: ferritic, austenitic and martensitic. Precipitation & dispersion hardenable materials, Age hardenable alloys: Al-Cu alloys, Al-Fe-V-Si alloys. Super alloys: Ni, Fe and Co based super alloys, Ti based alloys & their thermomechanical treatment, Nanomaterials: Synthesis, properties and applications. ; Non-structural materials: Dielectric materials; dielectric constant and polarization, linear dielectric materials, capacitors and insulators, non-linear dielectrics, pyro, piezo and ferro-electrics properties; Semiconductor: direct and indirect band gap, band diagrams, applications of semiconductors, degenerate and non-degenerate semiconductors, extrinsic and intrinsic semiconductors. Superconducting materials, Optical & Photoionic materials, electron-hole-recombination. Biomaterials, property requirements for biomaterials, concept of biocompatibility, important biometallic alloys; Ti based, stainless steel. Intelligent materials.

Caretaker: Prof. D.Chaira.

Essential Reading:

1. W.F. Smith, *Principles of Materials Science and Engineering,* Mc Graw Hill, New York (1994).
2. W.D. Callister, *An Introduction Materials Science & Engineering*, John Wiley & Sons (2007).

Supplementary Reading:

1. ***V. Raghavan***, **Material Science and Engineering**, Prentice Hall of India, 2004.
2. R.Sharma, Sharma, *Heat Treatment: principles and techniques*, Prentice Hall of India, (2004).

MM 618 JOINING OF MATERIALS 3 credits [3-0-0]

Introduction: Principle, Theory and Classification of welding and other joining processes. ; Manual metal arc (MMA): Equipment requirement, electrodes for welding of structural steels, coating constituents and their functions, types of coatings, current and voltage selection for electrodes, Arc welding power sources; Conventional welding transformers, rectifiers and current and voltage. The influence of these power sources on welding. Metal transfer. ; Submerged arc welding (SAW): Process details, consumables such as fluxes and wires for welding mild steel, Variations in submerged arc welding process. ; Gas metal arc welding (GMAW) or MIG/ MAG welding: Process details, shielding gases, electrode wires, their sizes, and welding current ranges. TIG welding: Process details, power sources requirements, electrode sizes and materials, current carrying capacities of different electrodes, shielding gases, application of process. Resistance welding: General principle of heat generation in resistance welding, application of resistance welding processes. ; Process details and working principle of spot, seam, and. projection welding, electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages. ; Welding metallurgy of carbon and alloy steels, Cast irons, Stainless steels, Al- and Cu-based alloys. Weldability and Heat affected zones (HAZ). ; Welding defects and detection techniques. ; Soldering and brazing: Difference between both the processes, consumables used, methods of brazing, fluxes used, their purposes and flux residue treatment.

Caretaker: Prof. B C Ray

Essential Reading:
1. J F Lancaster, *Metallurgy of Welding*, Allen and Unwin.
2. R L Little, *Welding and Welding Technology*, TMH.

Supplementary Reading:
1. J. Norrish, *Advanced Welding Processes*, Woodhead.
2. K Weman, *Welding Processes Handbook*, Woodhead.

MM 619 PHYSICAL METALLURGY OF ALLOY STEELS 4 credits [3-1-0]

Effect of alloying elements on steels. Hot rolling of structural steels. High Strength Low Alloy (HSLA) steels; Controlled rolling of HSLA steels. Strengthening mechanisms in HSLA steels: Grain size control and precipitation strengthening Ausforming, Isoforming; Dual phase steels: Metallurgy and Thermo mechanical processing. ; Stainless steels: Austenitic, Ferritic, Martensitic Stainless Steels. Schaeffler diagram. Effect of martensitic and other phases in Austenitic Stainless Steels. Sensitization of Austenitic Stainless Steels. Intermetallic phases and 475^0C embrittlement in Ferritic Stainless Steels. Martensitic Stainless Steel, their heat treatment Precipitation Hardening Stainless Steels. ; Duplex stainless steels. ; High speed steels: Their composition and heat treatment. ; Hadfied steels: their composition, heat treatment. Ball bearing steels. ; Marging steels: Their composition, heat treatment.

Caretaker: Prof.A.K.Panda

Essential Reading:
1. R.W.K. Honeycombe and H K D H Bhadesia, *Steels Microstructure & Properties – (2nd Edition)* Edward Arnold, 1995, ISBN No. 0-340-58946-9.
2. I Tamura, H.Sekine, T Tanaka, and C.Ouchi, *Thermo Mechanical Processing of High Strength Low Alloy Steels*, Butterworths (1988), ISBN No. 0-408-11034-1.
3. G Kranss, *Steels Heat Treatment and Processing Principles,* ASM International, Materials Park, Ohio 44073, ISBN No. 0-87170-370-X.

Supplementary Reading:
1. *HSLA steels Metallurgy and Applications (Conference Proceedings),* ASM International (1986), ISBN No. 0-87170-299-0.

2. C.R. Brooks, *Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels,* ASM International, (1996), ISBN No. 0-87170-538-9.

MM 623 IRON AND STEEL MAKING 4 Credits [3-1-0]

Blast Furnace Route for Iron Making: The blast furnace and its accessories; The burden and its preparation; Physical and Chemical processes in a blast furnace, Blast furnace slag and its control; Control of hot metal composition; Blast furnace plant and accessories; Modern trends in blast furnace practice; Control of irregularities in the blast furnace. ; Alternative Methods: Need for alternative methods, Sponge iron production by using solid and gaseous reductants, Smelting reduction processes. ; Modern Steel Making: Different routes of steel making. Oxygen steel making; Top and bottom blown converter processes, Hybrid processes. Electric steel making; Electric arc furnaces, Induction furnaces, Secondary steel making. ; Casting of Liquid Steel: Ingot casting of steel, Continuous casting of steel, Iron and steel scenario in India in the last decade.

Caretaker: Prof. S.Sarkar

Essential Reading:

1. A.Ghosh and A.Chatterjee, *Iron Making & Steel Making Theory and Practice* –Prentice – Hall of India Pvt. Ltd., 2008.

Supplementary Reading:

1. A.K Biswas, *Principles of Blast Furnace Iron Making* –SBA Publication, 1999.
2. D.H Wakelin, *The Making, Shaping and Treating of Steel (Iron making volume)*, The AISE Steel Foundation, 2004.
3. R.J. Fruehan (Ed.), *The Making, Shaping and Treating of Steel (Steel making volume)* –, The AISE Steel Foundation, 2004.

MM 624 ADVANCED FOUNDRY TECHNOLOGY 3 credits [3-0-0]

Critical review of some foundry operations: Various casting processes, Mould reinforcements, Mould factors in Metal flow, Moulding factors in casting design, Limitations in controlling some moulding factors in casting design, Effect of process variables on property of core and Mould making sand. ; Properties of Liquid Metals: Thermal properties, Viscosity, Surface tension and Density of Liquid metals and their role in Foundry Technology. ; Gases in Liquid Metals: Simple gases in Metals, Complex gases in Metals, Gas-defects and their control. ; Solidification of Metals and Alloys: Plane front solidification, Interface stability, Dendritic growth, Cellular growth, Independent nucleation, Structure of casting as influenced by alloy constituents, Thermal conditions, Inherent nucleation and growth condition in the liquid like Temperature gradient, Liquidus temperature profile and G/R ratio. Brief discussion on control of cast structure. ; Principles of Gating and Risering, The concept of yield: Directionality in solidification, Freezing characteristics of different alloys, Measures for obtaining a solid-casting through directionality in solidification, Chworinov rule, Design of gating system, Wlodawer system of determining the feeder head requirements. Feeder head efficiency, concept of feeding range, Use of supplementary techniques and introduction of design modifications for increasing feeder-head efficiency. ; Special Casting Processes: Investment casting, Die casting, Centrifugal Casting, Full-mould casting, Vaccum-shield casting, etc. ; Industrial Melting Practices: Aim of Melting and post melting treatment. A brief idea about various melting units and their working. Industrial Melting practice as adopted in case of a few Metals and alloys like C.I. Steel, Cu, Al, etc. ; Casting Defects and their Remedies: Shaping faults arising in pouring, Inclusions and sand defects, Gas defects. Shrinkage defects during solidification in liquid phase. Contraction defects after solidification, Dimensional errors, Compositional errors and segregation.

Caretaker: Prof. U.K. Mohanty

Essential Reading:

1. P.R. Beeley, *Foundry Technology*, 2001 edition, Publisher – Butterworth & Co.

Supplementary Reading:

1. P.C. Mukherjee, *Fundamentals of Metal Castiang Technology.*

2. P.D. Webster, *Fundamentals of Foundry Technology.*

MM 625 FERRO-ALLOY TECHNOLOGY 3 credits [3-0-0]

General survey of ferroalloy industries in India and its future prospect, use of ferroalloys in Iron & Steel Industries. ; Ferro-alloy furnaces – principle of submerged electric arc furnace, design of submerged electric arc furnace, transformer capacity, electrode manufacture; thermodynamics and kinetics of ferro alloy production; production of ferro silicon, ferro chrome, ferro manganese, calcium silicon alloy, ferro titanium, ferro boron, ferro vanadium, ferro-niobium, ferro tungsten etc., raw materials; process conditions etc; safety aspects in the production and storage of ferroalloys, techno-economic indices; use of ferroalloys. Numeral problems based on the above.

Caretaker: Prof. S. Sarkar

Essential Reading:

1. F.B. Edneral, *Electrometallurgy of Steel and Ferro-Alloys* –Vol.2, Mir Publisher.

Supplementary Reading:

1. Riss & Khodorusky, *Production of Ferro-Alloys* –Mir Publisher

MM 628 ADVANCES IN STEEL MAKING 4 credits [3-1-0]

A critical appraisal of hybrid blowing process, Ultra high power electric arc furnace and induction furnace with respect to raw materials, energy consumption, productivity and product quality; special grade steels. ; Development of secondary steel making and their importance under Indian conditions, sources of inclusions, sulphur, phosphorus and gases in steel; secondary steel making technologies; inert gas purging, vacuum degassing – RH/DH, OD, VAD etc., ladle furnace; powder injection system – powder dispenser, lance etc.; physicochemical and fluid dynamic aspects of powder injection and stirring processes; role of slag and powders in inclusion control, desulphurization; cored wired feeding; production of ultra low Sulphur, ultra low phosphorus and inclusion free steels, ultra-low carbon steels; modification of inclusion morphologies. ; Production of stainless steel through VOD, AOD, CLU processes. Production of Ultraclean steel through post solidification treatments (VAR, ESR processes). ; Refractory for secondary steel technology-slide gate, porous plug, ladle lining etc., properties and selection of refractories.

Caretaker: Prof.S.Sarkar

Essential Reading:

1. A. Ghosh, *Secondary Steel Making – Principle & Applications*, CRC Press, 2001.
2. A. Ghosh & A. Chatterjee: *Iron Making & Steel Making Theory and Practice*, Prentice – Hall of India Pvt. Ltd., 2008

Supplementary Reading:

1. F.P. Edneral: *Electrometallurgy of Steel and Ferro – Alloys*, Vol. 1, Mir Publishers, 1979.
2. A. Ghosh, *Principles of Secondary Processing & Casting of Liquid Steel*, Oxford & IBH Publication.

MM 635 FRACTURE MECHANICS AND FAILURE ANALYSIS 4 credits [3-1-0]

Stress intensity factor, Stress analysis of cracks, Strain energy release rate, Derivation of relationship between strain energy release rate and stress intensity factor, Crack-tip plastic zone, Dugdale’s plastic strip model. ; Fracture mode transition: Plane stress versus plane strain, Crack opening displacement, Plane strain fracture toughness (K_{IC}) testing, Fracture toughness determination with elastic plastic analysis (J_{IC}), Concept of R-curve and fracture toughness measurement using it, Microstructural aspect of fracture toughness, Optimizing microstructure and alloy cleanliness to enhance fracture toughness. ; Fatigue stress life approach, Basquin’s equation, Fatigue strain life approach, Low cycle fatigue, Cofin-Manson's equation, Fatigue total strain life relation, Fatigue life calculation using this approach, Neuber's analysis for notched specimens. ; Fatigue crack growth rate, Paris law, Fatigue life calculation using this approach, Mechanism of fatigue crack nucleation and propagation, Factors affecting fatigue crack growth rate, Influence of load interaction, Short fatigue crack. ; Stress corrosion cracking and K_{ISCC} determination, Corrosion fatigue, Temper embrittlement, Hydrogen embrittlement, Liquid metal embrittlement, Neutron embrit-tlement. ; Fractographic analysis of ductile, brittle, fatigue and high temperature fractured surfaces. ; Failure Analysis: Steps involved in it. Case studies of some engineering failures.

Caretaker: Prof. A. K. Panda

Essential Reading:

1. R.W. Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials* - (John Wiley & Sons Pub.).
2. *Metal Hand Book, Failure Analysis & Prevention (Vol. - X)* - ASM Publication

Supplementary Reading:

1. G.E. Dieter, *Mechanical Metallurgy* by Mc-Graw Hill (1988).
2. D. Broek, *Elementary Fracture Mechanics* - Martinus Nijho Publisher.
3. N. Perez, *Fracture Mechanics,* Klwer Academic Publishers.

MM 636 ADVANCED PROCESSING OF MATERIALS 3 credits [3-0-0]

Rapid solidification, Powder processing, Preparation and consolidation of nanopowders, Sintering, Spark Plasma and Microwave sintering, Shock compaction, Severe plastic deformation, Mechanical Alloying, near-net-shape forming, self-sustaining high temperature synthesis, sol-gel processing, zone refining, molecular beam epitaxy, laser processing, EDM, etching, CMP (Chemical Mechanical Polishing)technologyFreeze casting, glass-ceramic seals, optical/photonic media, hybrid materials, solution-derived materials, solid oxide fuel cells, armor ceramics, Processing and manufacturing technologies for non-oxide and oxide based structural ceramics, composites, multifunctional materials. ; Stereolithography (SLA), selective laser sintering (SLS), direct metal laser sintering; (DMLS) and laser engineered net shaping (LENS), Spray formed tooling for rapid manufacture, Plasma spray coating. ;Preparation of single crystals, doping, sputter coating, CVD and EVD process, Inkjet printing as a manufacturing tool. ; Modelling, commercial softwares such as FLUENT and Comsol Multiphysics.

Caretaker: Mr. S.N. Alam

Essential Reading:

1. W.F. Smith, *Principles of Material Science and Engineering*, McGraw Hill, 1990.
2. O. Tatsuki, *Advanced processing & manufacturing technologies for structural & multifunctional materials*, Lavoisier, 2007.
3. O.Tatsuki, M.Singh, J.Salem, D. Zhu,*Advanced Processing and Manufacturing Technologies for Structural and Multifunctional Materials, (eds.)*, Ceramic Engineering and Science Proceedings. Vol. 28(7).1st Edition 2007. ISBN-10: 0-470-19638-6 - John Wiley & Sons.

Supplementary Reading:

1. R.Hugon, *Thin Film Technology*, Elsevier Pub., UK, 1978.
2. L.Pawlowski, *The Science and Engineering of Thermal Spray Coatings*, John Wiley Publications, New York, 1995.
3. F. Kongoli (Editor), R.G. Reddy (Editor) *Advanced Processing of Metals and Materials: New, Improved and Existing Technologies: Iron and Steel; Recycling and Waste Treatment* Vol.5,Publisher: The Minerals, Metals & Materials Society ISBN-10: 0873396383.
4. G.Goodman, M. Dekkar, *Ceramic Materials for Electronics*, New York, 1968.
5. S.Kalpakjian, S. Schmid, *Manufacturing Engineering and Technology*, Prentice Hall; 5th edition, ISBN-10: 0131489658, 2005.

MM 637 MECHANICAL BEHAVIOUR OF METALS 4 credits [3-1-0]

Dislocation Theory: Introduction, dislocation reaction, cross slip and climb of dislocations, Dislocation sources and dislocation multiplication, Dislocation pile ups. ; Tensile Behaviours of Metals: True stress-true strain curve, Strain hardening coefficient, Instability in tension, Effect of strain rate and temperature on flow properties. ; Fracture: Griffith's theory of brittle fracture, Mechanism of brittle and ductile fracture, Fractographic aspects of fracture, Notch effects. ; Impact Behaviour: Notch bar impact test, Transition temperature phenomenon, Instrumented Chapry test. ; Fracture Mechanics: Strain energy release rate, Stress intensity factor, Plan strain facture toughness, Crack-tip plastic zone, Dugdale's plastic strip model, Fracture toughness determination with elastic plastic analysis (J_{IC}), Design approach. ; Fatigue: Micromechanisms of crack initiation and growth, Stress and strain approaches of fatigue, Fracture mechanics approach, Fatigue crack growth, Life prediction. ; Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys. ; Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue.

Caretaker: Dr. B. B. Verma.

Essential Reading:

1. G E Dieter, *Mechanical Metallurgy* –McGraw – Hill Publication (1988).
2. R W Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials* – John Wiley & Sons Publication (1995).

Supplementary Reading:

1. R E Reed, *Physical Metallurgy Principals,* Hill Litton Education Publication (2004).
2. W.Soboyejo, *Mechanical Properties of Engineering Materials,* Marcel Dekker Publication (2003).

MM 638 MECHANICAL WORKING OF MATERIALS 4 credits [3-1-0]

Fundamentals of Metal working processes: Theory of plasticity and yield – criterion, Workability Tests, Hot working, Cold working and warm (semi-hot) working of metals, structure of cold worked and hot worked metals. ; Rolling of Metals: Various rolling Mills and rolling processes, Theories of Hot and Cold rolling Defects in rolling and their remedial measures. Rolling Mill Control, Concepts of roll-pass-design, Roll pass design of some simple shapes like Flat products, Blooms, rounds, etc. ; Forging of Metals: Type of forging processes, Die design, Various forging equipments, Forging defects and their remedies, Load and energy requirements in Forging, Forging of Rail wheels and tyres. ; Extrusion of Metals: Types of Extrusion processes, Metal flow in Extrusion process, Variables in extrusion, Extrusion defects and their remedies, Load and energy requirements, sheathing and cladding by Extrusion. ; Drawing of Metals: Type of operation, Dies, Load and Energy requirement, Drawing of seamless Tubes. ; Sheet Metal Forming: Operations, Equipment, Technology, Defects and their remedies. ; Non conventional Processes: High Energy rate forming processes Explosive forming of Metals, Electromagnetic forming.

Caretaker: Prof. U.K.Mohanty

Essential Reading:

1. G.E. Dieter, *Mechanical Metallurgy*.
2. A.Ghosh & A. Mallick. *Manufacturing Sciences*.

Supplementary Reading:

1. P.Polukhin, N.Fedosov, A.Korolyov & Y. Matveyer, *Rolling Mill Practice,* Making Shaping and Treating of Steel.

MM 642 ADVANCES IN MATERIALS SCIENCE AND ENGINEERING 4 credits [3-1-0]

Introduction: Various classes of advanced materials. ; Ultra light Materials and Metallic Foams: Material Definition and Processing, Characterization of cellular metals, Material properties and applications. ; Bio-Materials: Various types of biomaterials, Biopolymer, Bioceramics, Nanostructured bio-materials, Classes of materials used in medicine, Application of materials in medicine and dentistry, Various materials and coatings for implants. ; Composite Materials: Material definition and classifications, Advanced polymer composite, Ceramic composite, Metal matrix composite, Nanocomposite, Applications. ; Coatings, surface modification and high temperature materials. ; Semiconductors: Electronic structure, Macroscopic properties, Applications. ; Smart materials: Piezoelectric materials, Shape memory alloys, Magnetic shape memory, Thin film shape memory alloys for MEMS application; Super alloys: Types of super alloys, Properties and applications. ; Structural Ceramics: Crystalline and amorphous ceramics, Bonding in ceramics, Properties, Applications.

Caretaker: Mr. S. Mula

Essential Reading:

1. Jr. W. D. Callister, *Materials Science and Engineering*, An Introduction, 5th Edition, John Wiley & Sons, Inc., New York, 1999, with CD-ROM.
2. R E Smallman, A.H.W. Ngan, *Physical Metallurgy and Advanced Materials, Seventh Edition*, Butterworth-Heinemann, 2007, ISBN: 0750669063.
3. Edited by B.D. Ratner, A.S. Hoffman, F.J. Sckoen, and J.E.L Emons,*Biomaterials Science, An Introduction to Materials in Medicine*, Academic Press, Second edition, 2004.

Supplementary Reading:

1. Edited by H.P. Degischer & B. Kriszt, *Handbook of Cellular metals, Production, processing, Application,* Wiley - VCH, 2002.
2. Edited by J. R. Davis, *Handbook of Materials for Medical Devices,* ASM international, 2003.
3. L.J. Gibson, and M.F. Ashby, *Cellular Solids, Structure and Properties*, 2nd Edition, Cambridge University Press, 1999.
4. Ashby, M. F. Evans, A. Fleck, N. A. Gibson, L. J. Hutchinson, J. W. & Wadley, *H. N. G. Metal Foams: A Design Guide*, Butterworth-Heinmann, Massachusetts; 2000.
5. Disegi, Kennedy, and Pilliar, *Cobalt-Base Alloys for Biomedical Applications,*ASTM-STP1365.
6. J.F. Shackelford,*Advanced Ceramics, Vol.1- Bioceramics,* Gordon and Breach Science Publishers, 1999.
7. M. Ohring, *Materials Science of Thin Films*, 2nd Edition, Academic Press, 2002.
8. C.T. Herakovich, *Mechanics of Fibrous Composites*, John Wiley & Sons, Inc., New York, 1998.
9. M.P. Grover, *Fundamentals of Modern Manufacturing*, Materials, *Processing, and Systems*, 2nd edition, John Wiley & Sons, Inc.
10. S.Suresh, A. Mortensen and A. Needleman, *Fundamentals of metal matrix composites*, Butterworth Heinemann, 1993.
11. Henkel and Pense, *Structure and properties of engineering materials, fifth edition*, McGraw Hill, 2002.

MM 646 COMPOSITE MATERIALS 4 credits [3-1-0]

Introduction to Composites, Matrices, Reinforcements, Classifications, Applications, Advantages, Fundamental concept of reinforcement, review of current developments; design fabrication and economic considerations. ; Basic mechanics of reinforcement, Stiffness of parallel arrays of fibres in a matrix. Discontinuous and particulate reinforcement. Fibres and resin materials. Rule of Mixtures, Critical Fiber Length, Short and Continuous Fibers, Fiber Orientation. ; Matrix and Reinforcement Materials, Polymeric Matrices, Metallic Matrices, Ceramic Matrices, Particulates, Flakes, Whiskers, Fibers: C, B, Glass, Aramid, Al_2O_3, SiC, Nature and manufacture of glass, carbon and aramid fibres. Review of the principal thermosetting and thermoplastic polymer matrix systems for composites. ; Polymer Matrix Composites (PMCs), Metal Matrix Composites (MMCs), Ceramic Matrix Composites

(CMCs), CFRP & Carbon/Carbon Composites (CCCs) ; Types, Manufacturing, Processing methods, Interfaces, Properties, Applications, Toughening Mechanisms, Fiber Forms, Prepregs, Molding Compounds-Processes, Lay-Ups, Filament Winding, Pultrusion, Recycling. ; Matrix –Reinforcement Interface, Wettability, Interactions at Interface, Interfacial Bonding Types, Interfacial Strength Tests, The role of the interface. The nature of fiber surfaces, wetting and adhesion. ; Strength, Stiffness, Fracture, Toughness and toughening mechanisms of composites ; Strengths of unidirectional composites. Multiple fracture in Laminates. Macroscopic fracture and energy dissipating processes. Application of fracture mechanics to composite materials. Fracture Mechanics and Fracture Toughness in Composites, Linear Elastic fracture mechanics, Toughness, Fiber matrix debonding, Fiber Pullout Buckling and Post-Buckling ; Failure criteria, Fatigue and Creep in composites, Environmental effects in Composites, Green composites. ; Synthesis and Properties of Nanocomposites. ; Green Composites.

Caretaker: Prof. B.C. Ray

Essential Reading:

1. Chawla, *Composite Materials: Science and Engineering*, Springer, 2ndEd. 1998.

Supplementary Reading:

1. Matthews & Rawlings, *Composite Materials: Engineering and Science,* Chapman & Hall, 1994.
2. Hull, *An Introduction+ to Composite Materials,* Cambridge, 2nd Edt. 1997.

MM 652	EXPERIMENTAL TECHNIQUES IN MATERIALS ENGINEERING	4 credits [3-1-0]

X-ray and diffraction: Characterization of x-rays, absorption, x-ray diffraction techniques, interpretation of diffraction datas, qualitative and quantitative phase analysis, analysis of particle size, residual stress/strain, phase diagram determination, order disorder transformation study. ; X-ray fluorescence: Origin, basic theory/concept, characterization of materials through x-ray fluorescence. ; Electron microscopy: TEM & SEM, construction, different components & their functions, aberration of electron lenses, depth of field & depth of focus etc. Bright field & dark field image, SAD image etc., microprobe analysis. ; WDS & EDS: Principle, application for analytical studies. ; Spectroscopic analysis techniques: Fundamental principles of spectroscopy, origin of molecular & atomic spectra, atomic absorption & molecular absorption. ; Fundamentals of Flame emission & atomic absorption spectrometry: Flame emission spectroscopy & Flame spectra, chemical reaction in flames, effect of organic solvants on flame spectra, instrumentation, Photosensitive detectors, different methods of sample analysis, errors in flame photometry. ; Absorption spectroscopy: Infrared spectroscopy, FTIR (Fourier transform infrared spectroscopy) nuclear magnetic resonance (NMR) spectral analysis. ; Atomic emission spectroscopy: Emission sources, atomic emission spectrometers. ; Thermal analysis techniques: Thermo gravimetric analysis, differential thermal analysis and differential scanning calorimetry, the basis, instrumentation, data acquisition and interpretation of analytical results.

Caretaker: Prof.S.C.Mishra

Essential Reading:

1. B.D.Culity, *Elements of X – Ray Diffraction,* Addison-Wesley Publication.
2. P.J.Goodhow, J.Humbreys & R.Beanland, *Electron Microscopy & Analysis (III Edn.);* Taylor & Francis Publ., 2001.
3. D. Brandon & W.D. Kaplan, *Microstructural Characterization of Materials;* John Wiley & Sons Publ., 1999.

Supplementary Reading:

1. O.Kubashewski, E. Vans & C.B. Alcock: *Metallurgical Thermochemistry*, Pergamon Press, 1967.

2. G.Thomas: *Trasmission Electron Microscopy*.
3. A.Guthrie & R.K.Wakerling: *Vaccum Equipments and Techniques*; McGraw Hill, New York.
4. B.Chalmers & A.G.Quarell: *Physical Examinations of Metals*, Edward Arnold, 1960.
5. E.C. Subba Rao; *Metal Experiments in Material Science*, T.M.H. 1973.

MM 655	**TRANSPORT PHENOMENA**	**3 credits [3-0-0]**

Fluid flow: Review of basic principles, Continuity and Navier stokes equation, Some special solution of Navier stokes equation, Boundary layer equations and some solutions, Significance of stream functions, Stability of laminar flow and the causes of transition to turbulence, Bubble in liquids, Behaviour of droplets, Friction factor, Pressure drop in flow, Energy requirements for flow of fluids, Jets and jet behaviour, Compressible fluid flow, Fluid flow in packed and fluidized beds. ; Heat Transfer : Review of basic principles, Heat conduction equation and its solution for some simple boundary conditions, Heating and cooling of bodies , Heat transfer by convection, Energy equation, Correlation for heat transfer coefficient, Concept of thermal boundary layer in natural and forced connective Heat Transfer by radiation, Review of basic laws, View factor, Radiant heat exchange between surfaces, Radiation from gasses and flames, Heat transfer with change of phases, Combined effects of conduction, convection and radiation in Metallurgical systems, Heat transfer in packed beds and fluidized beds. ; Basic concepts of mass transfer: Diffusion and mechanism of diffusion in solids, Ficks Law, Diffusion in multi component system, Connective mass transfer, Mass transfer coefficient, Mass transfer in laminar and turbulent flow, Correlations for mass transfer coefficient combined effect to heat, Mass and momentum transfer, Application to metallurgical processes.

Caretaker: Mrs. A. Mallik

Essential Readings:

1. R.B. Bird, W.E. Stewart & E.N. Lightfoot: *Transport Phenomena*, John Wiley & Sons Inc., New York 1994.
2. G.H. Geoger & D.R. Poirer: *Transport Phenomena in Metallurgical*, Addison-Wesely Publishing Co., Reading, Mass, U.S.A. 1973.
3. A.K. Mohanty: *Rate Processes in Metallurgy,* Prentice – Hall, New Delhi, India-2000.

Supplementary Reading:

1. *Journal of Heat Transfer*, Trans, ASME.
2. C.V.Seshadri & S.V. Patankar; *Journal of Iron and Steel Institute*. Elements of Fluid Mechanics, Prentice – Hall (India) Ltd., New Delhi, 1971.

MM 656	**CORROSION AND DEGRADATION OF MATERIALS AND THEIR PREVENTION**	**3 credits [3-0-0]**

Degradation of materials: Oxidation, corrosion and wear. Basics of thermodynamics and kinetics of oxidation and corrosion. Pourbaix diagram, Polarization, Mixed potential theory. Passivity, Characteristics of passivation, Degredation of composites. ; Corrosion: Fundamentals of corrosion studies. Different types of corrosion. Atmospheric, galvanic, pitting, crevice corrosion, intergranular and de-alloying. Stress corrosion cracking, season cracking, Hydrogen damage and radiation damage. Hydrogen embrittlement. Corrosion rate measurement. Weld-decay and knife line attack. Taffel's extrapolation. Oxidation and hot corrosion of materials at high temperature. Kinetics of oxidation. Pilling-Bed worth ratio. ; Prevention of degradation: Alloying environment, environmental conditioning, design modification, cathodic and anodic protection, organic and inorganic coating, inhibitors and passivators. Wear resistant coating.

Caretaker: Mr. D.Chaira

Essential Reading:

1. M.G. Fontana& N.D Greens, *Corrosion Engineering*- Mc Graw Hill publishing company, (2006).
2. H.H. Uhlig, *Corrosion & Corrosion Control*, John Wiley & Sons, (2000).

Supplementary Reading:

1. S.N. Banerjee, *An introduction to science of corrosion & its inhibition*, Oxonian Press Pvt. Ltd., India, (1985).

MM 657	ENVIRONMENTAL POLLUTION IN METALLURGICAL INDUSTRIES	3 credits [3-0-0]

Various types of solid, liquid and gaseous pollutants and their harmful effects; Environmental impact assessment in metallurgical industries; Pollutant emissions from integrated iron and steel plants, sponge iron plants, etc.; Environmental aspects of coal and metal mines; Management of solid, liquid and gas wastes generated during iron and steel making operations; Pollutant emissions from Al, Zn and Pb industries; Preventive measures to reduce atmospheric pollution from these industries. ; Scope of alternative energy sources to combat pollution from metallurgical industries; Environmental legislation related to metallurgical industries.

Caretaker: Prof. M. Kumar

Essential Reading:

1. C.S.Rao, *Environmental pollution controls engineering*, Willey Eastern Ltd., 1991.
2. R.C. Gupta, *Proceedings of the International Conference on Environmental Management in Metallurgical Industries*, EMMI – 2000, 14 – 16th December, 2000, Editor – Allied Publisher Ltd., Kolkata.

Supplementary Readings:

1. G.N.Pandey and G.C.Carney, *Environmental Engineering,* Tata McGraw Hill Publishing Co., 1989.

MM 665	POWDER TECHNOLOGY	4 credit [3-1-0]

Care taker: Dr. D. Chaira and Dr. S. C. Mishra

Introduction: Development of powder metallurgy-scope of powder metallurgy, characterization of metal powders, physical properties-particle size and shape determination, technological properties-apparent density, flow rate etc. and chemical properties. Powder manufacture: Reduction, electrolysis, and atomization processes. Compaction and sintering: Die compaction and other consolidation techniques, sintering, sintering with liquid phase. Consolidation of Metal Powders I: Compaction: Theory of consolidation: Pressure transmission in powders; compressibility and compactibility of powders; Green strength; Hot isostatic pressing; Powder rolling. Consolidation of Metal Powders II: Sintering: Mechanisms of Sintering; Factors affecting sintering; activated sintering; Liquid phase sintering; Sintering atmospheres; Properties of sintered parts. Applications: Porous parts: Self-lubricating bearings, filters: Dispersion strengthened materials, bearing, filters, friction parts, hard metals, refractory metals, contact materials, magnetic materials, structural parts, automobile, aerospace and defence components manufactured by powder metallurgy route.

Essential Reading:

1. R.M.German, *Powder Metallurgy Science*, 2nd edition- Metal Powder Industries Federation, Princeton, New Jersey, 1994.
2. M.N. Rahaman, *Ceramic Processing and Sintering*, Marcel Dekker, New York, 1995.
3. G. Goetzel, *Treatise on Powder Metallurgy*, Interscience Publishers, New York, 1952.

Supplementary Reading:

1. A.K. Sinha, Powder Metallurgy, Dhanpat Rai Publication, 2006.

2. G.S. Upadhyaya, *Powder Metallurgy Technology*, Cambridge International Science Publishing, 1997.

MM 666	COMPUTATIONAL MODELLING OF MATERIALS	4 credit [3-1-0]

Basic C/C++ programming, Useful programs using C/C++, Numerical methods, Molecular dynamics simulation: introduction, potentials, super cells, relaxation and methodology classification, methods, steps of MD simulation, periodic boundary conditions; Lammps (Large scale atomic/molecular massively parallel simulator): introduction, general features, particle and model types, force fields, atoms creation, ensembles, constraints, boundary conditions, integrator, energy minimization, output, input script: initialization, atom definition, running a simulation, simulation studies: deformation-tensile, compression, shear, dislocation modeling; solidification; fracture mechanics.

Care-taker: Dr. S.N. Alam and Prof. Nataraj.

Essential Reading:

1. Kanetkar Y, *Basic Programming* in C++ By Publisher: BPB.
2. Balagurusamy E, *Programming In ANSI C*, 4th Edition (Paperback) by Publisher: Tata McGraw Hill.
3. Sidney Yip, *Handbook of Materials Modeling*, Set Of 2 Parts {Part A+B} by Kluwer Academic Publishers.

Reference Books:

1. Brian W. Kernighan, Dennis M. Ritchie, *The C Programming Language (Ansi C Version)* (Paperback) Publisher: Phi Learning.
2. Jean Lemaitre (Editor), *Handbook of Materials Behavior Models, Three-Volume Set: Nonlinear Models And Properties* (Hardcover) by Publisher: Academic Press.

MM 671	METTALURGICAL THERMODYNAMICS & KINETICS LABORATORY	2 Credits [0-0-3]

To determine the tumbler and abrasion indices of lump iron ore ; To determine the micuum indices of coke ; To study the decomposition of calcium carbonate and determination of equilibrium constant and free energy change ; To determine the partial molal volume of each component in a solution of water and methanol ; To determine the equilibrium constant and free energy change for the C+CO2 = 2CO reaction ; To study the effect of temperature on % reduction of iron ore pellet ; To study the effect of time on % reduction of iron ore pellet ; Pelletization of iron ore fines, firing of pellets and measurement of their crushing strength.

MM 672	EXPERIMENTAL TECHNIQUES IN MATERIALS ENGINEERING LABORATORY	2 Credits [0-0-3]

Study of diffract meter & Debye Scherrer camera & determination of lattice parameter from Debye Scherrer powder photograph ; Analysis of diffractogram of FCC and BCC metals & Study of diffractograms of mechanical mixture & alloys of same composition ; Determination of the residual stress and grain size, residual strain of deformed metal ; Thermal analysis by DTA, TGA, DSC on Alumina sample ; Study of Scanning Electron Microscope and EDS analysis of Zirconia powder ; Study of particle size analysis ; Elemental analysis by flame Atomic Absorption Spectroscopy

MM 673	PHASE TRANSFORAMTION LABORATORY	2 Credits [0-0-3]

Study of pearlitic transformation in mild, rail and file steels ; Study of Martensitic transformation in steel ; Study of Bainitic transformation in Austempered Ductile Iron ; Phase transformation in Brass ; Phase transformation in Aluminium Bronze ; X-ray analysis of phases ; Thermal analysis to study phase transformation ; Quantitative estimation of phases

MM 674 MATERIAL SCIENCE LABORATORY 2 Credits [0-0-3]

Heat Treatment of different metals/alloys and post heat treatment hardness and microstructure study ; Tensile Testing of Mild Steel and Al/Al alloy ; Fractography study ; Ball milling and particle size analysis ; FRP Composite fabrication and Bend test ; P/M pellet preparation and density estimation

MM 675 PROCESS METTALURGY LABORATORY 2 Credits [0-0-3]

Caretaker: Prof. M Kumar
Tumbling of Iron Ore Lumps ; Carbonization of coking coal and determination of % δ coke yield ; Determination of shatter index of iron ore lumps ; Reduction of iron ore pellet at 900° C by coal ; Reduction of iron ore pellet at 850° C by coal. Carbothermic reduction of iron ore pellet at 1000° C and termine of activation energy. Firing of pellet and determination of its crushing strength. Drop no. test of pellets.

DEPARTMENT OF MINING ENGINEERING

DETAILED SYLLABI OF COURSES

MN 601	Rock Excavation Engineering	3-1-0	4
MN 602	Mine Management	3-1-0	4
MN 603	Geo-aspects Management of low and high risk byproducts	3-0-0	3
MN 604	Advanced Mine Planning	3-1-0	4
MN 605	Rock Slope Technology	3-1-0	4
MN 606	Strata Control Technology	3-1-0	4
MN 607	Ground Control Instrumentation	3-1-0	4
MN 608	Tunneling	3-1-0	4
MN 609	Advanced Surface Mining	3-1-0	4
MN 610	Mining of Deep Seated Deposits	3-1-0	4
MN 611	Advanced Coal Mining	3-1-0	4
MN 612	Surface Mining Systems	3-0-0	3
MN 613	Underground Mining Systems	3-0-0	3
MN 614	Rock Mechanics Application to Environmental Problems	3-1-0	4
MN 616	Advanced Metaliferrous Mining	3-1-0	4
MN 620	Application of Artificial Intelligence in Mining	3-1-0	4
MN 623	Advance Environmental Engineering	3-1-0	4
MN 632	Environmental Management	3-1-0	4
MN 633	Mine Fires and spontaneous heating	3-1-0	4
MN 635	Advanced Mine Ventilation	3-1-0	4
MN 637	Noise Impact Assessment And Control	3-1-0	4
MN 638	Hazardous Waste Management	3-1-0	4
MN 639	Safety Risk Assessment & Management	3-1-0	4
MN 671	Rock Excavation Engineering Laboratory	0-0-3	2
MN 672	Advance Environmental Engg. Laboratory	0-0-3	2
MN 673	Mining Engineering Laboratory – I	0-0-3	2
MN 674	Mining Engineering Laboratory – II	0-0-3	2
MN 681	Special Topics in Mining Engineering – I		3/4
MN 682	Special Topics in Mining Engineering – II		3/4
MN 683	Special Laboratory in Mining Engineering – I	0-0-3	2
MN 684	Special Laboratory in Mining Engineering – II	0-0-3	2
MN 685	Seminar & Technical Writing – I	0-0-3	2
MN 686	Seminar & Technical Writing – II	0-0-3	2
MN 687	Seminar & Technical Writing – III	0-0-3	2
MN 688	Seminar & Technical Writing – IV	0-0-3	2
MN 691	Summer Research / Industrial Project		4
MN 692	Comprehensive Viva Voce		4
MN 693	Research Project Work - I		8
MN 694	Research Project Work – II		8
MN 695	Research Project Review - I		8
MN 696	Research Project Review – II		4

MN601 ROCK EXCAVATION ENGINEERING 4 credits [3-1-0]

Ground Characterization: Character of Rock Materials and Rock Mass, Stresses, Site Investigation; Measurement, prediction and monitoring of rock behavior, Fragmentation Blasting, Drilling, Breaking and Cutting, Rock Reinforcement.

Essential Reading:

1. R.E. Goodman, *Introduction to Rock Mechanics*, John Wiley and Sons, 1980
2. V.S. Vutukuri and K. Katsuyama, *Introduction to Rock Mechanics*, Industrial Publishing & Consulting Inc., Tokyo, 1994

Supplementary Reading:

1. B. H. G. Brady and E.T. Brown, *Rock Mechanics for Underground Mining*, George Allen and Unwin Ltd., 1992
2. J.A. Hudson, *Comprehensive Rock Engineering*, Pergamon Press, UK,2000
3. L. Hartman, *Mining Engineering Handbook*, Society for Mining, Metallurgy and Exploration Inc., USA, 1992
4. J.A. Hudson and J.P. Harrison, *Engineering Rock Mechanics*, Pergamon Press, UK,2000
5. J. A. Franklin and M.B. Dusseault, *Rock Engineering*, McGraw-Hill, Inc., 1991

MN602	**MINE MANAGEMENT**	**4 credits [3-1-0]**

Management and its functions, Evolution of scientific management and management sciences. The production systems, Elements of its design and operation, Design of physical facilities; Plant location and layout, production development and analysis, production system including sales. Technology Forecasting, Planning inventory models, Design of job and wage system , Methods study, work measurement, Job evaluation ; Wage and incentive plans, Budgetary Control, Cost analysis, Depreciation, Productivity: Concepts and measurements, Organizational structure for management functions, Project Planning, Evaluation and Management ; Operation Research Applications in Management, MIS, Environmental Management and Safety Management Systems, Principles of financial management, Statistical Quality Control, Simulation and Modeling Applications in Management.

Essential Reading:

1. C. R. Basu, *Organization & Management*, Oxford & IBH Pub.

Supplementary Reading:

1. O.P. Khanna, *Industrial Engineering and Management*, Dhanpat Rai Delhi,1993
2. S.G. Britton, *Practical Coal Mines Management*, Willy Eastern Ltd. 1981

MN603	**GEO-ASPECTS MANAGEMENT OF LOW AND HIGH RISK BYPRODUCTS**	**3 credits [3-0-0]**

Introduction to Industrialisation and Mineral Exploitation, Combustion Techniques, generation of solid wastes/byproducts, types of byproducts, classification, properties, collection and utilization mechanisms, alternatives, geo-techno-environmental and time influences, societal and technical challenges, regulatory framework, future need –national and global scenario.

Essential Reading:

1. L.K.A. Sear, *Coal Fly Ash: Properties and Use of Coal Fly Ash: a Valuable By-product*, Published by Thomas Telford Ltd. London, 2001

Suggested Reading:

1. U.Dayal and R.Sinha, *Geo Environmental Design Practice in Fly Ash Disposal & Utilization*, Allied Publishers Private Limited, New Delhi, 2005
2. *Comprehensive Rock Engineering*, Chief Editor: J.A. Hudson, Pergamon Press, 1992
3. A.Sridharan and K. Prakash,*Geotechnical Engineering Characterization of Coal Ashes*, C.B.S Publishers and Distributors, New Delhi, 2007
4. *Disposition of High-Level Waste and Spent Nuclear Fuel,*Report by Committee on National Research Council, National Academic Press, Washington D.C.,2001

MN604 ADVANCED MINE PLANNING 4 credits [3-1-0]

Principles of planning; Features of mine planning; Short range and long range planning; Determination of optimal output, life and size of a mine field; Optimal location of mine entries; Theoretical considerations in opening up and development of mine field; Preparation of feasibility report and detailed project report; Production planning and scheduling; Mine equipment planning and estimation of their numbers; Infrastructure planning, mine turn around and restructure planning; Rehabilitation, mine closure and post industrial land use planning.

Essential Reading:

1. S.P.Mathur, *Mine Planning for Coal*, M.G. Consultants, Bilaspur, 1993
2. J Bhattacharya, *Principles of Mine Planning*, Allied publishers Pvt Limited, Allied Publishers Pvt Limited, New Delhi, 2003

Supplementary Reading:

1. W.Hustrulid and M.Kuchta, *Open Pit Mine Planning and Design*, A.A.Balkema Rotterdam, 1995
2. B.M. Vorobjev and R.T. Desmukh,*Advanced Coal Mining Vol-II*,Asia Publishing house London, revised edition,1966
3. PWJ Van Rensbarg, *Planning Open-pit mines*, AA Balkema Cape Town, 1970
4. A.A. Myasnikov, *Principle of Coal Mine Ventilation Planning*,N.T.I.S.,1981.
5. R D Singh, , *Principles and Practices of Modern Coal Mining*, New age International Pvt limited Publishers, New Delhi, 1998

MN605 ROCK SLOPE TECHNOLOGY 4 credits [3-1-0]

Types and Mechanics of Slope Failure: Site investigation for slope assessment. Geological appraisal of slope behaviour, Types of slope failure, falls, slides and flows. Mechanics of slope failure ; **Factors Affecting Slope Stability:** Geological factors, slope geometry, ground water, equipment loading, dynamic loading and effect of time ; **Slope Stability Analysis:** Failure mechanisms, shear strength of soil and rock masses. Influence of groundwater. Evaluation of stability and risk. Earth dams, stability analysis, numerical models, empirical models ; slope Mass Rating System, Slope instrumentation. Remedial measures; **Design of Waste Dumps and Tailings Dams:** stability analysis of opencast high walls and benches, overburden dumps, case studies.

Essential Reading:

1. R N Chowdury, *Slope Analysis*, elseveir, 1978
2. E Hoek &J Bray, *Rock Slope Engineering,* The Inst. of Mining & Metallurgy, London, 1981

Supplementary Reading:

1. B F Walker and R Fell, *Soil slope instability and stabilisation*, A A Balkema, 1987
2. E N Bromhead, *Stability of slopes*, Wiley, London
3. M L Jeremic, *Strata mechanics in coal mining*, A A Balkema, Rotterdam, Taylor and Francis, 1985
4. J.A. Hudson, *Comprehensive Rock Engineering*, Pergamon Press, UK,2000
5. Z.T.Bieniawski, *Engineering Rock Mass Classifications,*Wiley, New York, 1989

MN606 STRATA CONTROL TECHNOLOGY 4 credits [3-1-0]

Geomining conditions: Geological factors contributing to strata control problems in mines, Geomechanics classification of rocks ; **Safety status:** Status of safety in coal mines vis-à-vis strata control problems, Assessing the risk from the hazards of roof & side falls ; **Design of support system**: Design of support system for development and depillaring workings, Design of support system for long wall workings, Application of modeling techniques to strata control problems ; **Strata behaviour studies**: Instrumentation for evaluation of strata condition in coal mines, Strata control techniques and its application to coal mining industry, Case studies on geotechnical instrumentation and strata control in coal mines, Demonstration of geotechnical instrumentation and computer software's ; **Organization of strata control cell**: strata control cell in mines, Training needs of the first line supervisors for effective implementation of the latest strata control technologies.

Essential Reading:

1. M. L. Jeremic, *Strata mechanics in coal mining*, A A Balkema, Rotterdam, Taylor and Francis, 1985
2. T. B. Ziti, *Strata Control in Mineral Engineering*, New York: John Wiley & Sons, 1987.

Supplementary Reading:

1. T. N. Singh, *Underground winning of Coal*, Oxford and IBH New Delhi,1992
2. B.H. G. Brady and E.T. Brown, *Rock Mechanics for Underground Mining*, George Allen and Unwin Ltd., 1992
3. J.A. Hudson, *Comprehensive Rock Engineering*, Pergamon Press, UK,2000
4. Z.T. Bieniawski,*Engineering Rock Mass Classifications,* Wiley, New York, 1989
5. S S Peng and H S Chiang,*Longwall mining* , Wiley; New York.

MN607 GROUND CONTROL INSTRUMENTATION 4 credits [3-1-0]

Deformation and Strain Measuring Instruments: Convergence meters, convergence recorders, tape extensometers, bore hole deformation, gauge, multipoint borehole extensometers and bore hole camera; **Load and Pressure Measuring Instruments:**Load cells, pressure measuring instruments – stress capsules, stress meters, borehole pressure,cells and flat jacks. Strain gauges and transducers, readout units, sensors, transmitters and data acquisition systems; **Testing Equipment:** UTM, MTS and acoustic emission equipment. Rock bolt pull tester, Monitoring and interpretation of the data; **Applications:** Mining Engineering applications: Instrumentation in underground mines and opencast mines; Civil Engineering applications; Instrumentation in Hydro electric projects and Tunnels, case studies.

Essential Reading:

1. J.A. Hudson, *Comprehensive Rock Engineering*, Pergamon Press, UK,2000
2. M L Jeremic, *Strata Mechanics in coal mining*, A A Balkema, Rotterdam, Taylor and Francis, 1985

Supplementary Reading:

1. Z. T. Bieniawski, *Strata Control in Mineral Engineering*, New York: John Wiley & Sons, 1987.
2. B.H. G. Brady and E.T. Brown, *Rock Mechanics for Underground Mining*, George Allen and Unwin Ltd, 1992
3. Z.T. Bieniawski 1989. *Engineering Rock Mass Classifications*. Wiley, New York

MN608 TUNNELING 4 credits [3-1-0]

Design of tunnels: Rock mass classification, stability analysis of tunnels, elastic and plastic deformation; **Ground control:** stress conditions, behavior of ground, Geomechanics instrumentation, design of supports; Equipments, Tunnel Boring Machines, ventilation, tunnel economics.

Essential Reading:

1. R. E. Bullock, *Tunneling and Underground Construction Techniques*, SME Publication, 2002
2. S. Barbara, *Hand book of Mining & Tunneling Machinery,* John Wiley and Sons. 1982

Supplementary Reading:

1. F. O. Franciss, *Weak rock tunneling*, Taylor and Francis, 1994
2. J. Johansen, *Modern trends in tunneling and blast design*, Taylor and Francis, 2000
3. F. D. Davidson, *Tunneling and Transport*, Elsevier APPLIED Science, 1987
4. Z.T. Bieniawski, *Rock Mechanics Design in Mining & Tunneling*, A A Balkema, 1984

5. D. Kolymbas, *Tunnelling and Tunnel Mechanics: A Rational Approach to Tunnelling*, Springer, 2008
6. B. Maidl, L. Schmid, W. Ritzand Martin Herrenknecht,*Hardrock Tunnel Boring Machines*, Ernst & Sohn, Wiley, 2008

MN609	**ADVANCED SURFACE MINING**	**4 credits [3-1-0]**

Introduction, Indian context of advance surface mines, Advancement in mine unit operation. ; Planning of surface mines viz, Procedural steps of planning, Ore body description, Mining Systems, Ultimate pit configuration. Design of surface mines, Feasibility Report & Detailed Project Report, Modern surface mining equipments. ; Legislations related to surface mining, Mine Closure Planning.

Essential Reading:
1. R. T. Desmukh, *Opencast Mining*, Lovely prakashan Dhanbad, 1st ed, 1990.
2. S. K.Das, *Surface Mining Technology*, Lovely prakashan Dhanbad, 1st ed, 1994.

Supplementary Reading:
1. G. B. Mishra, *Surface Mining,* Lovely Prakashan Dhanbad, 1st ed, 1971.
2. E. Hoek and J. Bray, *Rock Slope Engineering*, 3rd Ed., Inst. Of Mining and Metallurgy, London, 1980
3. W. Hustrulid and M. Kuchta, *Open pit mine planning and Design*, Vol - I, A. A. Balkema Rotterdam, 1st ed, 1995.
4. B. Cummins Arthur, *SME Mining Engineers Hand Book*, American Institute of Mining,Metallurgical and Petroleum Engineers New York,1973

MN610	**MINING OF DEEP SEATED DEPOSITS**	**4 credits [3-1-0]**

Exploration: Modern Exploration Techniques to Identify the Complex Coal Deposits ; **Classification:** Classification of Coal Deposits Lying under Typical Geo-mining Conditions ; **Challenges:** Challenges to improve Production and Productivity from Deep Seated Deposits, Challenges in Liquidation of Locked-up Pillars ; **Experimental trials:** Innovative Technologies for Stability Analysis, Design and Development of Deep Seated Deposits ; **Modern techniques:** Application of Numerical Modeling Techniques to Control Ground Problems of Complex Deposits, Use of Modern Instruments for Strata Control of deep seated deposits, In-situ Gasification and Mineral Biotechnology for Complex Coal Deposits.

Essential Reading:
1. R. D. Singh, *Principles & Practices of Modern Coal Mining*, New age international New Delhi,1997
2. T. N. Singh, *Underground winning of Coal*, Oxford and IBH New Delhi,1992

Supplementary Reading:
1. S. S. Peng and H S Chiang,*Longwall mining*, Wiley; New York, 708p.
2. S. K. Das, *Modern Coal Mining Technology,* Lovely prakashan Dhanbad,1992
3. D. Prasad and S Rakesh, *Legislation in Indian Mines-A critical Appraisal*, Niskam Press, New Delhi, 1883p.
4. S. P. Mathur, *Coal Mining in India*, M.S. Enterprises Bilaspur,1999

MN611	**ADVANCED COAL MINING**	**4 credits [3-1-0]**

Extraction of thick seams:Problems and issues, recent experimental trials Chirimiri caving Method, Blasting Gallery Method, Integral Caving method, Sublevel caving method, Hydraulic Mining, Shield Mining ; **Extraction underneath surface features:** Non-Effective width (NEW) , Back filling methods, Wide stall mining. ; Extraction of multiple seams: Problems and issues, recent experimental trials, Parting failures and control, design of workings ; **Extraction of locked up pillars:** Status of Board and pillar mining in India, techniques of extraction and future requirements ; **Support systems:** Strata behavior at greater depths, problems of strata control in high horizontal stress fields, design of support system.

Essential Reading:

1. R. D. Singh, *Principles & Practices of Modern Coal Mining*, New age international New Delhi,1997
2. T. N. Singh, *Underground winning of Coal*, Oxford and IBH New Delhi,1992

Supplementary Reading:

1. D.J. Deshmukh, *Elements of Mining Technology*, Vol - I, EMDEE publishers Ranchi, Revised edition, 2000.
2. S. K. Das, *Modern Coal Mining Technology,* Lovely prakashan Dhanbad,1992
3. S. P. Mathur, Coal Mining in India, M.S. Enterprises Bilaspur,1999

MN 612	**SURFACE MINING SYSTEMS**	**3 credits [3-0-0]**

Introduction: Applicability and limitations, Stripping Ratio, Preliminary evaluation of surface mining projects. ; **Surface Mining Methods**: Development of Mineral deposits by opencast mining, design and layout of opencast mines. Methods of stripping, Bench geometry, Bench slope. Drilling, blasting, loading and transportation in opencast mines, Equipment used for different operations, Choice and their application. ; **Placer Mining and Sea bed Mining:** Ground sluicing, Hydraulicking and Dredging. Exploitation systems of ocean mineral resources. Relevant provisions of coal mines and metalliferous mines regulations. ; Environmental problems due to surface mining and their remedial measures, Recent developments in the deployment of heavy earth moving machineries in the surface mines.

Essential Reading:

1. G. B. Mishra, *Surface Mining*, Lovely prakashan Dhanbad, 2nd ed,2006.
2. K. R. Singhal, *Mine Planning and Equipment Selection*, A. A. Balkema Rotterdam,1st ed,1995.

Supplementary Reading:

1. S. K. Das, *Surface Mining Technology*, Lovely prakashan Dhanbad, 1st ed,1994.
2. V. V. Rzhevsky, *Opencast Mining Unit operations*, Mir Pub., Mascow, 1985.
3. W. Hustrulid and M. Kuchta, *Open pit mine planning and Design*, Vol-I, A.A. Balkema Rotterdam,1st ed,1995.
4. T. G. Rozgonyi,*Continuous surface Mining*, A.A. Balkema Rotterdam,1st ed,1988.
5. J. T. Crawford, *Open pit mine planning and Design*, American Institute of Mining, Metallurgical and Petroleum Engineers,1979.

MN 613	**UNDERGROUND MINING SYSTEMS**	**3 credits [3-0-0]**

Development of Stratified Deposits: Choice of mine size, methods of entry and primary development. ; **Underground Coal Mining Methods**: Classification and choice, Bord and Pillar mining, development and extraction, Long-wall mining, face mechanization, production equipment and face machinery used, viz. coal cutting machines, drills, mechanical loaders, LHDS, shuttle car etc. – their performance and choice. Special coal mining methods. ; **Underground Metal Mining Methods**: General Development of property level, crosscuts, raises and winzes, drifting and tunneling, U/g metalliferrous mining methods – their classification and choice. Stoping of ore bodies, supporting and development of stopes Special techniques of mining mechanization. Mining equipment and production machine used below ground. Provision of MMR 1961. ; **Supports:** Roadway and face supports, supports for junctions and special conditions, setting and withdrawal of supports, roof bolting, roof stitching, systematic supporting, protective of pillars. ; Stowing and Filling Methods, gathering and transportation arrangements, stowing plants and layout. Provision of CMR 1957.

Essential Reading:

1. T. N. Singh, *Underground winning of Coal*, Oxford and IBH New Delhi,1992
2. Y.P.Chacharkar, *A study of Metalliferous Mining Methods*, Lovely prakshan Dhanbad,1994

Supplementary Reading:

1. I.C.F. Statham, *Coal Mining Practice,* Caxton eastern agencies,Calcutta,Reprint,1964
2. D.J. Deshmukh, *Elements of Mining Technology*, Vol - I & II ,EMDEE publishers Ranchi, Revised edition,2000
3. S. K. Das, *Modern Coal Mining Technology*, Lovely prakshan Dhanbad,1992
4. R. D. Singh, *Principles & Practices of Modern Coal Mining*, New age international New Delhi,1997
5. B. C. Arthur, *SME Mining EngineersHand Book*, American Institute of Mining, Metallurgical and Petroleum Engineers New York,1973

MN614	ROCK MECHANICS APPLICATION TO ENVIRONMENTAL PROBLEMS	4 credits [3-1-0]

Classification of Rock for specific engineering purposes- Underground, Surface, etc. ; Mechanical properties of discontinues rocks – Planes of discontinuity in rocks, characteristics and orientation of Joints; Measurement of rock mass deformability- Insitu Testing; Applications - Opencast mining and slope stability, Underground mining and excavation, - massive rocks, layered rocks, weak rocks; Application to waste disposal and underground storage, application to earthquakes

Essential Reading:

1. J. A. Franklin and M.B. Dusseault, *Rock Engineering*, McGraw-Hill, Inc., 1991
2. R.E. Goodman, *Introduction to Rock Mechanics*, John Wiley and Sons, 1980

Supplementary Reading:

1. L. Hartman et al, *Mining Engineering Handbook*, Society for Mining, Metallurgy and Exploration Inc., USA, 1992
2. V.S. Vutukuri and K. Katsuyama, *Introduction to Rock Mechanics*, Industrial Publishing & Consulting Inc., Tokyo, 1994
3. B.H.G. Brady and E.T. Brown, *Rock Mechanics for Underground Mining*, George Allen and Unwin Ltd., 1992
4. J.C. Jeager and N.G.W. Cook, *Fundamentals of Rock Mechanics*, Chapman and Hall, 1979
5. E. Hoek and J. Bray, *Rock Slope Engineering*, 3rd Ed., Inst. of Mining and Metallurgy, London, 1980
6. J.A. Hudson, *Comprehensive Rock Engineering*, Pergamon Press, UK,2000
7. J. A. Franklin and M.B. Dusseault*, Rock Engineering Applications,* McGraw-Hill, Inc., 1991

MN616	ADVANCED METALIFERROUS MINING	4 credits [3-1-0]

Methods: Techno-economic analysis on choice of stoping methods, high productivity methods: blasthole stoping, vertical retreat method of mining, block caving, raise stoping, underground bench blasting, stope design and production planning in the various methods of stopping ; **Special underground excavations:** shaft pockets, ore bins, ore transfer, ramp, decline, step mining methods, stope fills: preparation, transportation and filling operation, stope design and production planning, methods of pillar extraction, solution mining: in situ leaching, underground retorting, under-sea mining, introduction to novel mining methods, Special underground excavation and system of supports ; **Pillar extraction:** methods of pillar extraction, salt, potash and sulphur mining- their special problems.

Essential Reading:

1. Y. P. Chacharkar, *A study of Metalliferous Mining Methods*,Lovely prakshan Dhanbad,1994
2. K. S. Stout, *Mining Methods and Equipment*, McGraw hill New York,1980

Supplementary Reading:

1. B. Cummins Arthur, *SME Mining Engineers Hand Book*, American Institute of Mining, Metallurgical and Petroleum Engineers New York, 1973.
2. D.J. Deshmukh, *Elements of Mining Technology*, Vol - II ,EMDEE publishers Ranchi, Revised edition,2000

MN 620 APPLICATION OF ARTIFICIAL INTELLIGENCE IN MINING 4 credits [3-1-0]

Introduction to Artificial Intelligence, Fundamental of classification, Linear and non-linear classifier, Bayesian Classifier, Solving two class problems with linear classifier, Fundamental of neural network, Introduction of different neural network learning rules, Supervised and unsupervised learning, Multi layered perceptron, Self organize Map, Learning vector quantization, Fundamental of Support Vector machine, Quadratics optimization problem, Fundamental of kernel function, Concept of genetic algorithm, Idea about genetic parameters like selection, cross over, mutation, Different selection rules, Technique of genetic optimization, Fusion of NN and genetic algorithm for mining application, Fundamental of Fuzzy logic, crisp and fuzzy sets, different Fuzzy rules, Fuzzification and defuzzification, Industrial application of fuzzy logic ; Examples and solution of mining problems with artificial intelligence, resource estimation of coal and metal using Neural network and Support vector machine, Application of fuzzy logic in quality control problems, Application of genetic algorithm in Mine planning, Blast parameter design using neural network and genetic algorithm.

Essential Reading:

1. S.Haykins, *Neural networks: A comprehensive foundation* (2nd Ed): Prentice Hall, New Jersey, 1999.
2. C.M.Bishop, *Neural Networks for Pattern Recognition* (Clarendon Press, Oxford), 1998.

Supplementary Reading:

1. V. Vapnik, *The Nature of Statistical Learning Theory*, Springer, N.Y., 1995.
2. H.J. Zimmermann, *Fuzzy Set Theory and its applications*, Kluwer Academic, Dordrecht, 1991.
3. D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley Professional; 1 edition,. 1989.
4. N. Russell, *AI: A Modern Approach* (2nd ed.), Prentice Hall Publisher, 2002.

MN 623 ADVANCED ENVIRONMENTAL ENGG 4 credits [3-1-0]

The theory and practice of creating safe, healthy and efficient working environment at an underground or surface mine. Surface mining vs. ecological balance ; Air pollution from surface mining and processing –monitoring, control and standards. Air pollution dispersion ;models. Water pollution – types, control and monitoring, ground water contamination. Noise and ground vibrations ; Tailings dams design, Reclamation, Revegetation, Environmental legislation, Environmental management plan and Economics of mining environment control ; Environment & development planning systems & methodologies based on the principle of sustainable development including: environmental impact assessment & project assessment; site assessment & site planning; local & regional planning systems for urban & regional environmental planning, conservation planning.

Essential Reading:

1. M. A.Ramlu, *Mine Disaster and Mine Rescue*, Oxford& IBH, 1991

Supplementary Reading:

1. A.T. Donald, *The lighting of Underground Mines*,Trans Tech Switzerland,1982
2. R. Mcadam and D. Davidson, *Mine Rescue Work* , Oliver and Boyd, London,2000

MN633 MINE FIRES AND SPONTANEOUS HEATING 4 credits [3-1-0]

Mine Fires: Survey of various causes of mine fires with statistical data of Indian mines. Physical and chemical factors governing proneness to fire in coal and metaliferrous mines.Various methods adopted to combat fires and their advantages and disadvantages.Advances in fire fighting techniques and equipments, rescue operations in fire-zones.; **Spontaneous Heating:** Literature survey of various causes of spontaneous heating and statistical data in Indian mines, Various theories about spontaneous heating of coal, Factors governing spontaneous heating. Properties of various substances e.g.-porosity, permeability, pore distribution Moisture etc. Sulphide determination and characteristics of relative proneness to spontaneous heating in India and abroad. ; Early detection of spontaneous heating in mines and stacks, recent trends to eliminate recurrence of spontaneous heating.

Essential Reading:

1. S.C. Banerjee, *Coal and Mine Fire*, Oxford and IBH,1985
2. M.A. Ramlu, *Mine Disasters and Mine Rescue*, Oxford and IBH, 1991

Supplementary Reading:

1. L.C. Kaku, *Fires in Coal Mines*, Oriental Publishers, 2nd Edition, 1985

MN635	**ADVANCED MINE VENTILATION**	**4 credits [3-1-0]**

Basics of mine thermodynamics and computation of psychrometric properties of mine air using accurate equations; Basic modes of heat transfer in mine airways; Heat and mass transfer in bord and pillar panels, development of equations and calculations for designing climatic conditions in panels; Sources of heat in longwall panels; Computation of volume flow using equivalent resistance method and using direct analysis. Application of Kirchoff's 2nd law to solve simple field problems; Derivation of Hardy Cross Iteractive method. Concept of application of Hardy Cross iterative method to solve complex mine ventilation network problems; Thermodynamic principles applied to mine ventilation network analysis ; Leakage, Recirculation and reversal of air flow; Air conditioning – refrigerants, heat exchangers etc; Environmental monitoring and automatic control; Computer application in network analysis; Health and safety aspects of the mine environment, application of ventilation survey instruments and computer simulations; Study of the design of coal dust control plan; methane and noise control.

Essential Reading:

1. M.J. McPherson,*Subsurface Ventilation and Environmental Engineering*, Chapman & Hall, 1993
2. G.B. Mishra, *Mine Environment and Ventilation*, OxfordUniversity Press, Fifth Impression, 1993

Supplementary Reading:

1. H.L.Hartman,*Mine Ventilation and Air Conditioning*, John Wiley, Paperback edition,1989
2. H. L. Hartman, J. M. Mutmansky, R. V. Ramani and Y. J. Wang, *Mine Ventilation And Air Conditioning*, Wiley-interscience, 3rd Edition, 1997
3. S.P.Banerjee, *Mine Ventilation*, Lovely Prakashan, 1st Edition, 2003

MN 637	**NOISE IMPACT ASSESSMENT AND CONTROL**	**4 credits [3-1-0]**

Fundamentals of Noise, Sources and Classification of Noise; Mechanism of Hearing : Types of Hearing Loss, AAOO Criteria; Noise Measuring Instruments and Survey: Sound level meter, audiometer, dose meter, octave band analyzer; Noise Indices : Leq, Ld_n , TNI, NII ; Noise Control Measures: noise control at source, path and receiver, acoustic barriers, enclosures, control of machinery noise, community and industrial noise control strategies; Noise Standards in India and Abroad; Noise Impact Assessment and Prediction Techniques ; Noise Modeling Software : ENM, CONCAWE, OCMA, VDI

Essential Reading:

1. D.P.Tripathy, *Noise Pollution*, 1st Edition, APH Pub., New Delhi, 1999.
2. M. Sengupta, *Environmental Engineering*, V.II, CRC Press, Boca Raton, Florida, 1990.

Supplementary Reading:

1. G.N. Pandey and G.C. Carney, *Environmental Engineering*, Tata McGrawHill, New Delhi, 1989.
2. L. Beranek, *Noise and Vibration Control*, McGrawHill Co, NY, 1971
3. P.R. Trivedy, *Int. Encyclopedia of Ecology & Environment, Noise Pollution* V.13, IIEE, New Delhi, 1995.

MN 638	HAZARDOUS WASTE MANAGEMENT	4 credits [3-1-0]

INTRODUCTION: Types and Sources of solid and hazardous wastes - Need for solid and hazardous waste management – Salient features of Indian legislations on management and handling of municipal solid wastes, hazardous wastes, biomedical wastes, lead acid batteries, plastics and fly ash; WASTE CHARACTERISATION AND SOURCE REDUCTION: Waste generation rates and variation - Composition, physical, chemical and biological properties of solid wastes – Hazardous Characteristics – TCLP tests – waste sampling and characterization plan - Source reduction of wastes – Recycling and reuse – Waste exchange; STORAGE, COLLECTION , DISPOSAL AND TRANSPORT OF WASTE: Handling and segregation of wastes at source – storage and collection of municipal solid wastes – Analysis of Collection system-Optimizing waste allocation– compatibility, storage, labeling and handling of hazardous wastes – hazardous waste manifests and transport.Waste disposal options – Disposal in landfills - Landfill Classification, types and methods – site selection - design and operation of sanitary landfills.

Essential Reading:

1. G.Tchobanoglous, H.Theisen and A Samuel and Vigil,*Integrated Solid Waste Management*, McGraw- Hill International edition, New York, 1993.
2. P.A.Vesilind, W Worrell and Reinhart, *Solid waste Engineering*, Thomson Learning Inc., Singapore, 2002.

Supplementary Reading:

1. CPHEEO, *Manual on Municipal Solid waste management*, Central Public Health and Environmental Engineering Organisation, Government of India, New Delhi, 2000.
2. M. D. LaGrega, P. L. Buckingham, C.Jeffrey, E vans,*Environmental Resources Management, Hazardous waste Management*, McGraw-Hill International edition, New York, 2001.

MN 639	SAFETY RISK ASSESSMENT & MANAGEMENT	4 credits [3-1-0]

Introduction to Accident Prevention and Health & Safety in Industry: Terminology, Reason for preventing accidents – moral, cost, legal. Accident statistics and trends in mining industry; Safety Risk in Opencast and Underground Mines; Risk Assessment: Concepts, Qualitative and Quantitative Approaches; Components of Risk Assessment : Risk Identification, Risk Estimation and Evaluation; Risk Analysis using FTA,HAZOP, ETA etc.; Risk Analysis Softwares; Heath Risk Assessment and Epidemiological Studies; Statistical and Economic Analysis of Accident Data; Risk Minimization Techniques in Mines; Generic approach to loss control within mining operations; Safety Policies, Safety Audit and Safety Management in Mines; Application of Virtual Reality for Safety, Training and Marketing; Case studies on Safety Risk Assessment in Mining and allied industries

Essential Reading:

1. S.K.Das, *Mine Safety and Legislation*, Lovely Prakashan, Dhanbad, 2002.
2. B.K.Kejriwal, *Safety in Mines*, Lovely Prakashan, Dhanbad, 2002.
3. N. J.Bahr, *System Safety Engineering And Risk Assessment: A Practical Approach*, Taylor and Francis, NY, 1997.

Supplementary Reading:

1. A.Bhattacharya, *Accident Prevention and Safety Management in Mines*, Short Term Course, Nov. 30-3rd Dec., 2004, IIT, Kharagpur, 2004.

2. A.Clifton, EricsonII, *Hazard Analysis Techniques for System Safety*, John Wiley & sons, New Jersey, Canada, 2005.

MN 671 ROCK EXCAVATION ENGINEERING LABORATORY 2 credits [0-0-3]

MN 672 ADVANCE ENVIRONMENTAL ENGINEERING LABORATORY 2 credits [0-0-3]

MN 673 MINING ENGINEERING LABORATORY- I 2 credits [0-0-3]

MN 674 MINING ENGINEERING LABORATORY- II 2 credits [0-0-3]

DETAILED SYLLABI OF M.Sc, INTIGRATED. MSc, MA, MBA PROGRAMMES

Sl. No	Branch.Code	Branch Name	Page No.
1	CH	Chemistry	
2	LS	Life Science	
3	MA	Mathematics	
4	PH	Physics	
5	HS	MA in Developmental Studies	
6	SM	School of Management	

DEPARTMENT OF CHEMISTRY

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
CY 101	Chemistry	3-1-0	4
CY 170	Chemistry Laboratory	0-0-3	2
CY 211	Name Reactions & Rearrangements	3-0-0	3
CY 232	Chemical Kinetics	3-0-0	3
CY 311	Concerted Reactions	3-0-0	3
CY 312	Basic Organic Chemistry- II	3-0-0	3
CY 322	Basic Inorganic Chemistry-I	3-1-0	4
CY 323	Basic Inorganic Chemistry-II	3-1-0	4
CY 413	Spectroscopic Methods of Analysis	3-0-0	3
CY 431	Chemistry of Nanomaterials	3-0-0	3
CY 432	Introduction to Nanobiotechnology	3-0-0	3
CY 511	Stereochemistry and Reaction Mechanism	3-1-0	4
CY 512	Structure and Functions of Biomolecules	3-1-0	4
CY 514	Environmental Chemistry	3-1-0	4
CY 515	Spectroscopic Methods of Analysis	3-0-0	3
CY 516	Industrial Organic Chemistry	3-0-0	3
CY 517	Chemistry of Natural Products	3-0-0	3
CY 518	Polymer Chemistry	3-0-0	3
CY 519	Pericyclic Reactions and Photochemistry	3-0-0	3
CY 521	Principles of Inorganic Chemistry	3-1-0	4
CY 522	Chemistry of Transition & Non-transition Elements.	3-1-0	4
CY 523	Industrial Inorganic Chemistry	3-0-0	3
CY 524	Group Theory and Molecular Orbitals	3-0-0	3
CY 525	Advanced Co-ordination Chemistry	3-0-0	3
CY 526	Bio-inorganic Chemistry	3-0-0	3
CY 527	Supramolecular Chemistry	3-0-0	3
CY 531	Thermodynamics & Chemical Equilibria	3-1-0	4
CY 532	Chemical Kinetics & Photochemistry	3-1-0	4
CY 533	Quantum Chemistry	3-1-0	4
CY 534	Principles of Heterogeneous Catalysis	3-0-0	3
CY 535	Electrochemistry	3-0-0	3
CY 536	Colloids and Surface Chemistry	3-0-0	3
CY 537	Advanced Solid State Chemistry	3-0-0	3
CY 538	Molecular Spectroscopy	3-0-0	3
CY 539	Biophysical Chemistry	3-0-0	3
CY 541	Chemistry of Heterocyclic Compounds	3-0-0	3
CY 542	Methods on Organic Synthesis	3-0-0	3
CY 543	Molecular Rearrangement	3-0-0	3
CY 544	Instrumental Methods of Analysis	3-0-0	3
CY 558	Organometallic Chemistry	3-0-0	3
CY 571	Organic Chemistry Laboratory	0-0-9	6
CY 572	Inorganic Chemistry Laboratory	0-0-9	6
CY 573	Physical Chemistry Laboratory	0-0-9	6
CY 574	Environmental Chemistry Laboratory	0-0-9	6
CY 581	Special Topics in Chemistry – I	3-1-0	4
CY 582	Special Topics in Chemistry – II	3-1-0	4
CY 583	Special Laboratory in Chemistry – I	0-0-3	2

CY 584	Special Laboratory in Chemistry – II	0-0-3	2
CY 591	Research Project-I	0-0-6	4
CY 592	Research Project – II	0-0-9	6
CY 593	Seminar & Technical Writing-I	0-0-3	2
CY 594	Seminar & Technical Writing-II	0-0-3	2
CY 595	Short term Industrial/ Research Experience	0-0-0	2
CY 596	Comprehensive Viva-voce	0-0-0	2
CY 597	Research Project-III	0-0-6	4
CY 598	Research Project – IV	0-0-9	6

CY 101 CHEMISTRY 4 Credits [3-1-0]

Electrochemistry : Electrochemical cells, galvanic cells, general equation for emf of cells, Electrode potentials and its relevance to oxidation and reduction, measurement of EMF, determination of pH, dry cells, fuel cells and storage battery ; Metallic Corrosion : Types of corrosion, mechanism of corrosion, Galvanic corrosion, principle of corrosion control; Introduction to Polymer Chemistry : Introductory concepts, definition, common system chemistry and classification of polymers, resins, rubber, plastics. Characterization: molecular weight studies and molecular weight distribution. Mechanistic aspects: addition, ionic, condensation polymerization, polymerization techniques; Atomic Structure - Wave-particle duality and principle of Indeterminacy, Schrodinger wave equation, atomic orbitals, degeneracy, radial and angular dependence of hydrogen orbitals and probability distribution,Spectroscopy and Instrumentation :Introduction, basic principles and instrumentations of rotational, vibrational, electronic spectroscopy. Chemical Kinetics- First and Second order reactions, Determination of rate-reaction. Consecutive, concurrent and chain reactions. Influence of rate constant. Theory of reaction rate. Principles of Organic chemistry: Inductive effects, resonance, homolytic and heterolytic fission of covalent bonds, reaction intermediates, addition, elimination and substitution reactions. Principles of catalysts and catalysis, industrial and biocatalysis.

Essential Reading:

1. P. W. Atkins, *Elements of Physical Chemistry*, 4th Ed., Oxford University Press, 2007.
2. J. Singh, L.D.S. Yadav, *Advanced Organic Chemistry*, Pragati Prakashan, 2009.
3. C. N. Banwell and E. M. McCash*, Molecular spectroscopy,* Tata McGraw-Hill, 7th reprint, 1999.

Supplementary Reading:

1. G. N. Mukherjee and A. Das*, Elements of Bioinorganic Chemistry,* U. N. Dhar and Sons Pvt. Ltd., Kolkata, Revised Second Edition, 2002.
2. J. E. Huheey, E. A. Keiter and R. L. Keiter, *Inorganic Chemistry, Principles of structure and reactivity,* Harper Collins, 1993.
3. Clayden, Greeves, Warren and Wothers*, Organic Chemistry,* Oxford, 2001.
4. B. R. Puri, L. R. Sharma, M. S. Pathania, *Principles of physical Chemistry,* Shoban Lal Nagin Chand & Co., 2001.

CY 170 CHEMISTRY LABORATORY 2 Credits [0-0-3]

LIST OF EXPERIMENTS

Determinations of hardness of water ; Determinations of percentage purity of lime stone sample ; Determinations of dissovled oxygen in water ; Determinations of sodium carbonate & sodium bicarbonate content in a mixture ; Determinations of sodium carbonate & sodium hydroxide content in a mixture ; Determinations of iron content in a sample ; Determinations of chloride content of water ; Determinations of proximate analysis of coal ; Determinations of carbon residue of an oil by conradson's apparatus ; Determinations of flash point of an oil by pensky-marteins closed cup flash point apparatus ; Determinations of viscosity of an oil by redwood viscometer ; Determination of Dissociation constant of weak acids by conductometric Titration ; Determination of pH of an electrolyte by potentiometric Titration.

Essential Reading:
Material supplied in the laboratory.

CY 211 NAME REACTIONS & REARRANGEMENTS 3 Credits [3-0-0]

Name reactions in organic synthesis : Demijanov, Pinacol-Pinacolone rearrangement, Favorski Rearrangement, Fries rearrangement,Wagner-Meerwein Rearrangement, Benzil-Benzilic Acid Rearrangement, Beckmann Reaction, Curtius, Schmidt, Lossen and Wolff Reaction, Cope Reaction, Chugev Reaction,Perkin, Stobb, Hofmann, Reimer-Tiemann, Reformatsky, Grignard reaction, Diels-alder reaction, Aldol Condensation, Claisen condensation, Dieckmann condensation,Claisen rearrangement, Friedel-craft reaction, Witting reaction, Meerwein-Pondroff-Verley and Birch reduction, Clemmenson reduction, Wolf-kishner reduction.

Essential Reading:
1. A. R. Parikh, H. Parikh and K. Parikh, *Name reactions in Organic Synthesis,* Foundation Books, 2006.
2. S. N. Sanyal, *Reactions*, *Rearrangements and Reagents,* Bharati Bhawan, 2000.

Supplementary Reading:
1. J. J, Li*, Name reactions in organic synthesis,* 3rd Edition, SPRINGER 2006.
2. G. Bramhachari, Organic Name Reactions, Narosa Publishers, 2009.

CY 214 BASIC ORGANIC CHEMISTRY - I 3 Credits [3-0-0]

Aliphatic Hydrocarbons: alkanes, alkenes addition reaction, Markownikov's rule, peroxide effect, hydroboration, allylic substitution by NBS, polymerization types, free radical, cationic and anionic including the mechanism; *Alkynes*: acidity of alkynes in comparison with alkanes and alkenes, formation of acetylides, oxidation, ozonolysis and hydroboration- polymerization; Dienes: types, synthesis of 1, 3-butadiene from 1, 4-Butanediol, 1,2- and 1, 4- diol, reaction of 1, 3-butadiene, Diels-Alder reaction, synthesis rubber-buna, neoprene and natural rubber; *Cycloalkanes*: reactions, hydrogenation and halogenations, comparison of the stabilities of cycloalkanes-Beaver's-strain theory-postulates and limitations, Sasche-Mohr's theory of strainless rings, chair and boat conformations of cyclohexane; *Aromatic hydrocarbons*: aromaticity, resonance energy, resonance structures of naphthalene, anthracene and phenanthracene, electrophyllic substitution reactions of benzene with mechanism, ortho-para orienting groups; *Alchohols*: synthesis and reactions, *phenols*: synthesis, reactions (Reimer-Tiemann's reaction. Kolbe's reaction and Frie's rearrangement), synthesis of resorcinol and napthols (α- and β-); Carbonyl compounds: nomenclature, addition reaction, Aadol condensation, Knoevenagel condensation, Perkin's reaction, Cannizzarro's reaction, Claisen condensation, Wolf- kishner, MPV, base catalyzed halogenations reaction of ketones (mechanism for all the reactions). Alpha, beta unsaturated carbonyl compounds- preparation and properties, mechanism of Michael addition; Carboxylic acids, Hydroxyl acids: classification, synthesis and synthetic applications; *Aromatic nitro compounds*: reduction in neutral, acidic and alkaline media, TNT, distinction between nitroalkanes; Amines: classification, separation of amines from mixture by Hinsberg's method using toluene sulphonyl chloride, basicity of amines. Reaction with nitrous acid, Hoffmann-Martius rearrangement; Diazonium Compounds: preparation and application in organic transformations.

Essential Reading:
1. P.Y. Bruice, Organic Chemistry, 3rd Edition, Pearson Education, 2009.
2. R.K. Bansal, Organic Chemistry, Norosa Publication, 2001.

Supplementary Reading:
1. S.K. Ghosh, Advanced general organic Chemistry, Part I & II, New Central Book Agency, Pvt. Ltd. 2009.

CY 221 CHEMISTRY OF INDUSTRIAL MATERIAL 4 Credits [3-1-0]

Fuel and combustion: Introduction, classification, calorific value, Petroleum and coal based chemicals: Composition of petroleum, cracking processes, knocking, diesel engine fuels, distillation of coal water gas, CNG, LPG, Biodiesels. *Polymers:* polymerization mechanisms, Addition, condensation, step growth, chain growth, method of polymerization. *Oils and fats:* Solvent extraction of oils, hydrogenation of oil, use of oil in the manufacturing of soap, Surface active agents: classification and manufacturing of detergents used for cleansing purpose. Dyes and pigments: Types of dyes, paints and varnishes. Chemistry of cement, metal extraction, Pesticides : DDT manufacture, BHC manufacture, parathion manufacture.

Essential readings:

1. Outlines of Chemical Technology. By M. Gopala Rao and Marshall Sittig, Affiliated East-West Press Pvt. Ltd.

Supplementary readings:

1. P. J. Chenier, *Survey of Industrial Chemistry*, 3rd Ed. Springer, 2002
2. C. A. Clausen and G. Mattson, *Principles of Industrial Chemistry*, Wiley-Interscience, 1978.

CY 231 BASIC PHYSICAL CHEMISTRY I 4 Credits [3-1-0]

Macroscopic properties of matter: The properties of gases, kinetic model of gases, Real Gases, Thermodynamics, 1st Law, conservation of energy, internal energy and enthalpy, Thermochemistry: Physical and chemical change, 2nd law; Entropy, Gibb,s energy, phase equilibrium, Pure substances: Thermodynamics of transitions, Phase diagrams, Properties of mixtures: Thermodynamic descriptions, Colligative properties, Phase diagram of mixtures, Principles of Chemical equilibrium: Thermodynamic background, Response of equillibria to the conditions, Consequence of equilibrium: Proton transfer reactions, salts in water, solubility equillibria, Electrochemistry: Ions in solutions, electrochemical cells, applications of standard potentials, Chemical Kinetics: Rates of reactions, Temp dependence of reaction rates, reaction mechanisms, reactions in solutions, catalysis and chain reactions

Essential readings:

1. P.W. Atkins and Julio de Paula, Elements of Physical Chemistry, Oxofrd University Press, 1992

Supplementary readings:

1. G N Barrow, *Physical Chemistry,* TATA MCGRAW-HILL, 2007.
2. K. L. Kapoor*, Text Book of Physical Chemistry,* MACMILLAN, 2006

CY 232 CHEMICAL KINETICS 3 Credits [3-0-0]

Chemical Kinetics : Methods of determining rate laws.Mechanisms of photochemical, chain and oscillatory reactions.Collision theory of reaction rates; steric factor, treatment of unimolecular reactions.Theory of absolute reaction rates, comparison of results with Eyring and Arrhenius equations, ionic reactions; salt effect.Homogeneous catalysis and Michaelis – Menten kinetics;

heterogeneous catalysis. **Kinetics in the excited electronic states** : Laws of light absorption, Photoelectric effect, photo chemical equivalence, fluorescence, Phosphorescence, Chemiluminiscence, Photosensitization, pre-dissociation and quantum efficiency of photochemical reaction, photodissociation. Isomerisation and cycloaddition, Flash phtolysis, Chemistry of vision.

Essential Reading:

1. M. R. Wright*, An Introduction to Chemical Kinetics,* John Wiley & Sons, 2005.
2. J. Raja Ram, and J. C. Kuriacose,*Kinetics and Mechanism of Chemical Transformations,* MacMillan Indian Ltd., New Delhi, 1993.

Supplementary Reading:

1. R. I. Masel, *Chemical Kinetics & Catalysis, Wiley-Interscience;* 1st Edition, 2001.
2. K. K. Rohatgi, S. Mukherjee, *Fundamentals of Photochemistry,* Wiley, New York, 3rd Edition, 1978.

CY 271	**UG ORGANIC CHEMISTRY LABORATORY**	**2 Credits [0-0-3]**

Detection of functional groups: Element detection, detection of amine, alcohol, nitro, acid, amide etc., Distilation, chromatography, Purification of organic solvents, drying of organic solvents. Preparation of picric acid, Benzoin. Extraction of caffine from tea leaf, cassine from milk, isolation of club oil.

Essential Reading

V K Ahluwalia and R Aggarwal, *Comprehensive practical organic chemistry*, University press. 2000

1. Brian S. Furniss, *Vogel's Text Book of Practical Organic Chemistry*, ELBS Longman, 5th edition, 1996.

Supplementary Reading

1. D S Gupta , *Experimental Organic Chemistry, Qualitative and Quantitative*, TATA MCGRAW HILL 2004 *,*
2. Addison Ault, *Techniques and Experiments for Organic Chemistry*, University Science Book.1998

CY 273	**PHYSICAL CHEMISTRY LABORATORY**	**2 Credits [0-0-3]**

1. Study of the distribution equilibrium of iodine in water/tolune
2. Determination of hydrolysis rate of ester
3. Determination of molecular mass by Victor Mayer apparatus
4. Estimation of Ca and Mg in mixture by EDTA
5. Determination of Eutectic point of a binary mixture
6. Estimation of Ni by DMG complex by spectrometry
7. Ionization constant of a week acid
8. Solubility of a sparingly soluble salt

Essential Reading

1. R.C. Das and B. Behera *, Experimental Physical Chemistry, ,* Tata McGraw Hill 2000

Supplementary Reading

1. D. Alart, *Practical Physical Chemistry*, Longman, 1993.

CY 311 CONCERTED REACTIONS 3 Credits [3-0-0]

Molecular orbitals and symmetry operations; Pericyclic reactions, Froniter orbital approach, Aromatic transition state approach (Huckel and Mobius systems) Woodward Hofmann rule for pericyclic reactions); Electrocyclic Reactions, correleation diagram; Cycloaddition reaction, [4+2]-cycloaddition reaction (Diels-Alder reaction), regioselectivity of Diels-Alder reaction, [2+2]-cycloaddition reaction; 1,3 dipolar cycloaddition reaction; Sigmatropic reactions :Orbital description, [1,5], [2,3], [3,3] sigmatropic rearrangement, Claisen rearrangement, Cope rearrangement.

Essential Reading:

1. J. Singh & J. Singh, Photochemistry & Pericyclic Reactions, New Age International (P) Ltd., 2007.
2. I. Fleming, *Frontier Orbitals and Organic Chemical Reactions,* Wiley, 1976.

Supplementary Reading:

1. B. B. Woodward and Hoffman*, Conservation of Orbital Symmetry,* Verlag Chemie Academic Press, 1971.
2. M. Smith, *Organic Synthesis,* Mc Graw Hill, 2nd Ed. 2004.

CY 312 BASIC ORGANIC CHEMISTRY-II 3 Credits [3-0-0]

Active methylene compounds: Preparation and synthetic applications of malonic ester and ethyl acetoacetate, Keto-enol tautomerism in ethyl aceto acetate.

Stereochemistry: Elements of symmetry, asymmetry and dissymmetry, Chiiral carbon atom, cause of optical activity, enantiomers, diastereomers, Optical isomerism in tartaric acid and biphenyls, Racemisation, resolution, methods of resolution Walden inversion, Asymmetric synthesis.

Geometrical isomerism: Designation of cis-trans and E-Z notations, Geometrical isomerism of oximes, Backmann rearrangement.

Organometallic compounds: Definition with examples, Preparation and synthetic applications Grignard reagent, organolithium compounds, Organozinc compounds, organo copper compounds, selected Name reactions and their application in organic synthesis.

Oils and fats: Analysis of oils and fats-determination of acid value saponification value, iodine value and their importance, merits and demerits of syndets in relation to soaps, Cleansing action of soaps.

Waxes: Animal and plant waxes (one example each)

Natural pigments: Structural formulae and their importance of anthocyanin, β-carotene, haemoglobin.

Dyes: Colour and constitution, chromophore-auxochrome theory, Classification of dyes based on applications with examples, Synthesis of malachite green and indigo, Structural elucidation of alizarin and its synthesis.

Heterocyclic compounds: Classification, synthesis of furan, thiophene, pyrrole, pyridine, indole, quinoline, isoquinoline, pyrimidine (one method each), Aromaticity and basicity of pyrrole and pyridine.

Uric acid: Elucidation of structure and synthesis by Fischer's by Fischer's method, conversion of uric acid to purine and caffeine, Synthesis of guanine and theobromine.

Essential readings:

1. P.Y. Bruice, Organic Chemistry, Pearson Education, 3rd Ed. 2009.
2. T. W. G. Solomons & C. B. Fryhle, Organic Chemistry, Wiley student Edition, 8th Ed. 2004.

Supplementary readings:

1. T. L. Gilchrist, *Heterocyclic Chemistry*, Pearson Education, 3rd Ed. 2007.
2. S. K. Ghosh, Advanced General organic Chemistry, Part I &II, New Central Book Agency, Pvt. Ltd. 2009.

CY 313	NATURAL PRODUCTS	4 Credits [3-1-0]

Alkaloids: Introduction, Occurrence, Functions of Alkaloids, Classification, Isolation, Properties, Determination of molecular structure, Detailed discussions on Coniine *(Hemlock alkaloid)*, Nicotine, piperine, Atropine.

Terpenoids: Introduction, Occurrence, Isolation, Classification, Structural features of Terpenoids, Determination of molecular structure, specific importance to reactions of double bonds with Chromic acid, Ozone, catalytic hydrogenation, Tilden reagent, Hydroxylating agents etc. Monoterpenoids, diterpenoids, Triterpenoids. Detailed discussions on Myrcene, Citral, Menthol, Bisabolone. Geometrical considerations of Neral & Geranial, Menthol.

Carbohydrates : Introduction, Nomenclature, Reactions of Monosaccharides, Interconversions, Ring structure of Aldoses and ketoses. Projection formula for Monosaccharides. Conformation of Monosaccharides.

Hormones: Definition, classification, synthesis of adrenaline, thyroxine, Structural formulae of estradiol, progesterone and testosterone and their importance. Peptide hormones-oxytocin and insulin – action, uses and side effects.

Insecticides: Fungicides and Herbicides: Classification, synthetic organic insecticides and fungicides and their importance; BHC, Lindane, Malathion, Herbicides: Diuren, 2, 4-D[2,4-dichlorophenoxy acetic acid] and their importance.
Wood protectants: Creosote oil, pental chloraphenols.

Essential readings:

1. S. V. Bhat, B.A. Nagaramgagi, M. Srikumar, *Chemistry of Natural Products*, Alpha Science International Ltd, 2005.
2. O. P. Agarwal, *Chemistry of Natural Products*, Vol- 1 &Vol-2, Goel publishing House, 1989.

Supplementary Reading

1. K. C. Nicolaou, T. Montagnon, *Molecules that changed world*, Wiley-VCH, 1st ed., 2008.
2. James R Hanson, *Natural Products: the secondary metabolites*, Royal society of Chemistry, 2003.

CY 322	BASIC INORGANIC CHEMISTRY-I	4 Credits [3-1-0]

Atomic structure: de-Broglie matter waves, Uncertainty principle, Schrodinger wave equation, hydrogen atom, quantum numbers and its significance, Radial and angular wave functions, spherical harmonics, Radial and angular distribution curves, shape of s, p, d orbitals, LS coupling.
Chemical bonding: Ionic bond: Born equation, polarizability, Fajan's rule, percentage ionic character and solvation energy, covalent bonds, VBT, Resonance, directional characteristics, hybridization and deduction of geometry, Qualitative treatment of MO theory.
p-Block elements: Boron, Carbon, Nitrogen, Oxygen and Halogen family
d-Block elements: electronic configuration and comparative study of ionic radii, ionization potential, redox potential, oxidation state, metallic nature.
Coordination chemistry: Ligands, coordination numbers, coordination sphere, Nomenclature, Werner's theory, EAN, Chelates, isomerism in coordination compounds, Valence Bond theory, octahedral, tetrahedral and square planner complexes

Essential readings:

1. J.D. Lee, Concise Inorganic Chemistry, 5th edition, Blackwell Publishing, 2008

Supplementary readings:

3. Huheey, Keiter and Keiter, Inorganic chemistry Principle, structure and reactivity. 4th edition.

CY 323	BASIC INORGANIC CHEMISTRY-II	4 Credits [3-1-0]

Crystal field Theory, qualitative idea about d-orbital splitting in octahedral and square planner complexes, Calculation of CFSE, explanation of magnetism, geometry and colour of coordination compounds, John-Teller distortion. Thermodynamic, kinetics and magnetic aspects of metal complexes. Chemistry of f-block elements, Lanthanides and actinides, Organometallic chemistry: definition, nomenclature and classification, preparation and properties, Bonding and application alkyl and aryl and carbonyl complexes, Inorganic polymers: Types of inorganic polymers, comparison with organic polymers, structure aspects and application of silicones, phosphonitrilic halides and condensed phosphates.

Essential readings:

1. J.D. Lee, Concise Inorganic Chemistry, 5th edition, Blackwell Publishing, 2008

Supplementary readings:

3. Huheey, Keiter and Keiter, Inorganic chemistry Principle, structure and reactivity. 4th edition.

CY 374	UG INORGANIC CHEMISTRY LABORATORY	2 Credits [0-0-3]

Quantative analysis of mixture of inorganic substances containing six radicals (interfering acid radicals like phosphate, fluoride and mixture of acid radicals like carbonate, sulfite, sulfide, nitrate, chloride, bromide, phosphate, arsenate, nitrate, iodate and sulfate)

Essential Reading

1. G. Svehla, *Vogel's qualitative inorganic analysis*, Harlow Longman, 2002.
2. A I Vogel, John Bassett, *Vogel's textbook of quantitative inorganic analysis: including elementary instrumental analysi*, Longman,2003

Supplementary Reading

1. A I Vogel , *Qualitative Inorganic Analysis*, Orient Longman – 1979.

CY 375	INSTRUMENTATION LABORATORY	2 Credits [0-0-3]

Simple experiments will be conducted to elucidate the working principles, instrumentation and handling of Gas Chromatograph, UV-Vis spectrometer, IR spectrometer, Polarimeter, conductivity meter, pH meter and Nephlometer

Essential Reading

1. R.C. Das and B. Behera *, Experimental Physical Chemistry, ,* Tata McGraw Hill 2000

Supplementary Reading

1. D. Alart, *Practical Physical Chemistry*, Longman, 1993.

CY 413	SPECTROSCOPIC METHODS OF ANALYSIS	3 Credits [3-0-0]

General introduction to electromagnetic spectrum and molecular spectrospocpy, spectroscopy, spectrometry, and spectrum, Nature of electromagnetic radiation and spectrum, Absorption of electromagnetic radiation by organic molecule. Types of molecular energy and molecular spectroscopy. Infrared Spectroscopy: Basic theory, instrumentation and application to functional group determination,;UV-Visible Spectroscopy :Basic concepts, instrumentation and applications;Mass Spectrometry, Principle, Instrumentation and applications; NMR Spectroscopy: Basic principles, Chemical shift, Spin-Spin Coupling, Coupling Constant, NOE, ^{13}C NMR, heteronuclear coupling, Elementary ideas on 2D NMR spectroscopy; Problem involving these techniques for structural determination and other applications.

Essential Reading :

1. D. C. Pavia, G. M. Lampman, G. S. Kriz *, Introduction to Spectroscopy, 3rd Edition,* THOMSON, 2007.
2. J. Mohan, *Organic Spectroscopy,* Narosa Publishing House, 2004

Supplementary Reading:

1. B. H. Williams, I. Flemming*, Spectroscopy Methods in Organic Chemistry,* McGraw Hill,2005.
2. Bessler and Silverstein*, Spectroscopy of Organic Compounds,*JOHN WILEY, 2001.

CY 431	**CHEMISTRY OF NANOMATERIALS**	**3 Credits [3-0-0]**

Introduction to Nanoparticles and Nanotechnology, Methods of Preparation, top down and bottom up approach, Characterization methods, Properties and size effect of nanomaterials, electrical, Mechanical, Magnetic, Optical and catalytic properties, Applications of nanotechnology in industry.

Essential Reading:

1. G. Ozoin*, Nanochemistry: A Chemical approach to nanomaterials,* Springer-Verlag, 2005.
2. C. N. R Rao, A. Muller, A. K Cheetham, *Nanomaterials Chemistry,* Wiley-VCH, 2007.

Supplementary Reading:

1. M. Hosokawa, K. Nogi, M. Naito, Y. Yokoyama, *Nanoparticles Technology Handbook,* Elsevier, 2007.

CY 432	**INTRODUCTION TO NANOBIOTECHNOLOGY**	**3 Credits [3-0-0]**

Introduction tonanomaterials, nanobiotechnology**,** nanoparticle production by microbes,DNA and Protein based nanostructures, Application of nanoparticles in Biological Detection**,** gold nanoparticle conjugates, Application of luminescent quantum dots in biological imaging**,** Emerging Nanotechnologies: nano labels, biosensors, medicines.

Essential Reading:

1. C. M. Niemeyer and C. A. Mirkin,*Nanobiotechnology: Concepts, Applications and Prospectives*, Wiley Interscience Publications, 2005.
2. M. A. Stroscio and M. Dutta, *Bioelectric Engineering Vol II, Biological nanostructures and Applications of Nanostructures in Biology: Electrical, Mechanical, and Optical Properties*, Kluwer academic publications, 2000.

Supplementary Reading:

1. C. A. Mirkin and C. M. Niemeyer *Nanobiotechnology II: More Concepts and Applications*,Wiley Intersciences Publications, 2008.

CY 511	**STEREOCHEMISTRY AND REACTION MECHANISM**	**4 Credits [3-1-0]**

Stereochemistry : Classification, recemic modification, molecules with one, two or more chiral centres; Configuration nomenclature, D L, R S and E Z nomenclature, conformations and stability of cyclohexanes (mono-, di-, and trisubstituted), cyclohexenes, cyclohexanones. Reaction intermediates, Carbocation, carbanion, Free radicals, carbene and nitrene (generation, structure, stability and reactions). Substitution Reaction: Classification, Aliphatic nucleophilic substitution reaction:S_N1, S_N2, S_Ni reactions, solvent effect, neighboring group participation reactions.Aromatic Nucleophilic substitution reactions, benzyne mechanism. Aliphatic Electrophilic substitution reactions, aromatic electrophilic substitution reaction, orientation and reactivity in substituted benzene ring ortho-para ratio. Addition to Carbon-Carbon Multiple Bonds, addition to carbon-hetero multiple bonds. Electrophilic, nucleophilic and free radical addition reactions. Elimination Reactions E1, E2 and E1 CB mechanisms. Stereospecificity, regioselectivity and stereoselectivity of elimination reactions. Relative reactivity of distereoisomers in ionic elimination, intermolecular rearrangements and neighboring group participation reactions.

Essential Reading:

1. J. March, *Advanced Organic Chemistry: Reactions Mechanism and Structure* , 4th Ed., John-Wiley and Sons,1999.
2. J. Singh & L. D. S. Yadav, Advanced Organic Chemistry, 4th Ed., Pragati Prakashan, 2009.

Supplementary Reading

1. Clayden, Greeves, Warren and Wothers*, Organic Chemistry;* Oxford, 2001.
2. J. M. Coxan*, Principles of Organic Synthesis,* 3rd Ed. Thomson Science, 1998.

CY 512	STRUCTURE AND FUNCTIONS OF BIOMOLECULES	4 Credits [3-1-0]

Carbohydrates: Ring and open chain structure of glucose and fructose. Reactions of glucose and fructose. mutarotation. Inter conversion reactions- aldose to ketose, ketose to aldose, chain elongation and chain degradation, epimerization. Disaccharides: sucrose, Lactose, cellobiose, Reducing and non-reducing sugars, Polysaccharide: Starch, glycogen, Cellulose and Chitin, analysis of carbohydrates. Aminoacids, Proteins and nucleic acid: Proteins *(structure and functions):* Amino acids, structural features, optical activity, essential and non-essential amino acids, iso-electric point, synthesis and chemical properties of α amino acids. Peptides and it's structure determination. Polypeptides or proteins: classifications, primary, secondary, tertiary and quaternary structure of proteins, glycoproteins, denaturation and folding, enzymes.Nucleic acids*:* Nitrogeneous base and pentose sugars, Nucleosides, nucleotides,Chemical and enzymatic hydrolysis, structure and functions of nucleic acids; DNA, RNA (m-RNA, t-RNA, r-RNA), an overview of gene expression (replication, transcription and translation), genetic code (origin, Wobble hypothesis and other important features), genetic errors, Central dogma, Protein synthesis.

Essential Reading:

1. D. L. Nelson and M. M. Cox*, Lehlinger Principles of Biochemistry,* W. H. Freemanpublisher,4th Ed, 2004.
2. T. K. Lindhorst, *Essentials of Carbohydrate Chemistry and Biochemistry* (Wiley-VCH), 2nd Revised Edition, 2003.

Supplementary Reading:

1. U. Satyanarayan , *Biochemistry,* New Central Book Agency, 3rd ed.,2006.
2. L.Stryer, J. Berg, J.L. Tymoczko , Biochemistry,W.H. Freeman Publisher, 6th Ed., 2006.

CY 514	ENVIRONMENTAL CHEMISTRY	4 Credits [3-1-0]

Chemistry of Environment : Environmental segments, atmospheric structure chemistry of lower and upper atmosphere, radiation balance of earth .Major air pollutant, sources and their effect. Green house effect, acid rain, depletion of ozone layer, global worming .Air pollution abatement technology. Chemistry of water environment: Classification of water pollutants, characteristics of waste water, water quality parameters and their measurements.Waste water treatment: preliminary, primary, secondary, tertiary treatment . Waste water from some typical industries ,sources, characteristics , effect and treatment option:textiles, refinery, leather, foods, sugar, fermentation, paper and pulp ,fertilizer ,soap and detergents ,electroplating and pharmaceuticals. Solid waste disposal and management: classification and origin, methods of solid waste disposal. Microbiology involved in solid waste disposal. Soil pollution :Chemical composition of the soil, the exploitation of the mineral resources and abuse of the earth, soil pollution due to natural and artificial agencies and its effects, remedial measures to check the pollution. Energy and Environment: Energy sources, renewable and non-renewable, primary and secondary fossil fuels, their occurrence and estimation of reserves.

Essential Reading:

1. Mani Vasakam, *Physico Chemical Examination of Water, Sewage and Industrial effluents*, Pragati Prakashan, 1991.
2. A. K. Dey, *Environmental Chemistry*, Wiley Eastern, 2002.

Supplementary Reading:

1. L.T. Pryde, *Environmental Chemistry – An Introduction*, Menlopark, 1973.
2. *Environmental Chemistry: A Global Prospective,* Oxford University, 2000.

CY 515	SPECTROSCOPIC METHODS OF ANALYSIS	3 Credits [3-0-0]

General introduction to electromagnetic spectrum and molecular spectroscopy, spectroscopy, spectrometry, and spectrum, Nature of electromagnetic radiation and spectrum, Absorption of electromagnetic radiation by organic molecule. Types of molecular energy and molecular spectroscopy; Infrared Spectroscopy: Theory and instrumentation, application of IR Spectroscopy for determination of functional groups;UV-Visible Spectroscopy, Basic concepts and instrumentation. Factors affecting the position of UV bands, Characteristic absorption of Organic compounds, Application of UV spectroscopy, NMR spectroscopy. Spin active nuclei, orientation of spinning nuclear magnets, chemical shift, factor affecting the chemical shift, Spin-spin splitting theory, NOE, de-coupling experiments, CNMR, hetronuclear coupling, 2D NMR, applications of NMR spectroscopyfor structure determination; Mass Spectrometry, Principle, Instrumentation, General methods of fragmentation, interpretation and application of mass spectra. Problem involving these techniques for structural determination, Recent development in the above fields.

Essential Reading:

1. Bessler and Silverstein, *Spectroscopy of Organic Compounds*, John Wiley, 2001.
2. D. C. Pavia, G. M. Lampman, G. S. Kriz, *Introduction to Spectroscopy*, 3rd Edition, THOMSON, 2007

Supplementary Reading:

1. J. Mohan, *Organic Spectroscopy*, Narosa Publishing House, 2004.
2. B. H. Williams, I. Flemming, *Spectroscopy Methods in Organic Chemistry* , McGraw Hill, 2005.

CY 516	INDUSTRIAL ORGANIC CHEMISTRY	3 Credits [3-0-0]

Basic products of industrial syntheses, chemicals from natural gases, petrochemicals and coal; chemicals of industrial importance: olefins, diolefines, acetylens, halocompounds, alcohols, aromatics, amides, polyamides, organic reactions in industrial synthesis (oxidation, hydration, hydrogenation, dehydrogentation, hydroformylation and polymerization) fermentation technology, polymers, thermoplastics, thermosetting resins, polymerization techniques, polymer characterization, polymer degradation, paints, pigments and coating.

Essential Reading:

1. K. Weissermal, H. I. Arpe, C. R. Lindley,*Industrial Organic Chemistry*, 4th Edition,Wiley-interscience 2003.
2. A. Wittcoff, B. G. Reuben, and J. S. Plotkin, *Industrial Organic Chemistry,* 2nd Edition,Wiley – interscience, 2004.
3. F. W Billmeyer, *Text book of Polymer Science*, Johns Wiley and sons Publication, 3rd Edition, 1984

Supplementary Reading:

1. K. Weissovmel, H. J. Prpe;*Industrial Organic Chemistry*;Wiley-VCH, 2002.
2. P. J. Chenier, *Survey of Industrial Chemistry*, 3rd Edition, Springer, 2002.

CY 517	**CHEMISTRY OF NATURAL PRODUCTS**	**3 Credits [3-0-0]**

Alkaloids: Introduction, Occurrence and isolation, function of alkaloids in plant, general properties, nomenclature, and classification of alkaloids. Isolation, properties and structural elucidation of Quinine, Morphine: (structure, synthesis, molecular re-arrangement, stereo chemistry and bio-genesis). Steroids: Introduction, nomenclature of steroids, absolute configuration of steroid. Occurrence, isolation, Structure elucidation, and chemical properties of Cholesterol. Terpenoids: Introduction, isolation, and classification of terpenoids. General properties, structure determination of Citral and Camphor. Vitamins: Introduction, chemical properties and structure elucidation of vitamin A, Vitamin B, Ascorbic Acid and Vitamin D.

Essential Reading:

1. S. V. Bhat, B. A. Nagaramgagi, M. Srikumar, *Chemistry of Natural Products*, Alpha Science International Ltd, 2005.
2. O. P. Agarwal, *Chemistry of Natural Products*, Vol- 1 &Vol-2, Goel publishing House, 1989.

Supplementary Reading:

1. K. C. Nicolaou, T. Montagnon, *Molecules that changed world*, Wiley-VCH, 1st Ed., 2008.
2. J. R. Hanson, *Natural Products: the secondary metabolites*, Royal society of Chemistry, 2003.

CY 518	**POLYMER CHEMISTRY**	**3 Credits [3-0-0]**

Introductory concepts, definition, common system chemistry and classification of polymers, synthetic and natural polymers, types of polymerization, addition, condensation, co-ordination and ring opening polymerization, Preparation, properties and uses of some important thermoplastic (i.e. PE, PVC, Teflon, PS, PMMA)and thermosetting resins (i.e. Phenolic resin, Amino resin and Epoxy resin), natural and synthetic rubbers, Fibers (i.e. Nylons, PAN, Polyurethanes). Polymer Characterization: molecular weight studies and molecular weight distribution, polydispersive index, determination of molecular weight of polymers. Polymer behavior, crystalline and thermal behavior, Glass transition temperature, factor influencing glass transition.Polymerization techniques: bulk, solution, emulsion, and suspension polymerization, polymer colloids and polymer solution. Thermodynamics aspect of Polymerization, Stereo Chemistry and mechanism of polymerization: free radical, cationic and anionic polymerization. Relevant aspects of physical properties of polymer systems, rheological properties, polymer processing, processing techniques i.e. molding, casting, extrusion and, calendaring techniques. Polymer degradation and stabilization, biological degradation of polymers.Polymers & environments, environmental pollution by polymers.

Essential Reading:

1. J. W. Nicolson, *The chemistry of polymers*, RSC publishing, 3rd Ed., 2006
2. P. Bahadur and N.V. Sastry, *Principles of Polymer Science*, Norosa Publication, 2nd Edition, 2005.

Supplementary Reading:

1. F. W Billmeyer, *Text book of Polymer Science*, Johns Wiley and sons Publication, 3rd Edition, 1984
2. I. M. Cambell, *Introduction to synthetic polymer*, Oxford university press, 2nd Ed., 2000.

CY 519	**PERICYCLIC REACTIONS AND PHOTOCHEMISTRY**	**3 Credits [3-0-0]**

Molecular orbitals and symmetry operations; Pericyclic reactions, Froniter orbital approach, Aromatic transition state approach (Huckel and Mobius systems) Woodward Hofmann rule for pericyclic reactions); Electrocyclic Reactions, correleation diagram; Cycloaddition reaction, [4+2]-

cycloaddition reaction (Diels-Alder reaction), regioselectivity of Diels-Alder reaction, retroDiels-Alder reactions, heteroatom Diels-Alder reactions, Intramolecular Diels-Alder reactions [2+2]-cycloaddition reactions, 1,3 dipolar cycloaddition reactions; Sigmatropic reactions : Orbital description, [1,5], [2,3], [3,3] sigmatropic rearrangement, Claisen rearrangement, Cope rearrangement. Photochemistry: Introduction, Jablonski diagram, photochemical reactions including photochemical elimination reactions, Norrish type I process, Norrish type II process, photochemical reductions, photochemical oxidations, photochemical cyclization and photochemical isomerization and rearrangement, photosubstitution, photoaddition, Barton reaction, Paterno Buchi reaction, Nazarov cyclization,.

Essential Reading:

1. J. Singh & J.Singh, Photochemistry and Pericyclic Reactions, New Age International (P) Ltd., 2007.
2. B. B. Woodward and Hoffman,*Conservation of Orbital Symmetry*, Verlag Chemie Academic Press, 1971.
3. M. Smith, *Organic Synthesis*, Mc Graw Hill, 2nd Ed. 2004.

Supplementary Reading:

1. W. Carruthers, *Some Modern Methods of Organic Synthesis*, Cambridge University, Press, 1993.
2. I. Ninomiya and T. Naito, *Photochemistry Synthesis*, Academic Press, 1989.

CY 521	**PRINCIPLES OF INORGANIC CHEMISTRY**	**4 Credits [3-1-0]**

Modern view of atomic structure, wave mechanical description of electron and orbital. Covalent Bond: The natures of covalent bond, resonance, formal charge, overlap of atomic orbital, partial ionic character of a covalent bond, electronegativity, electron affinity, polarization. VBT/VSEPR, inert pair effect, diagonal relationships. Molecular Orbital Treatment: Hydrogen molecule ion, molecular orbital of diatomic molecules like H_2, N_2, O_2, F_2, CO and NO. Hydrogen bond & Vander wall force bond. **Acid-base theories**: Bronsted, Lewis and Lux-Flood theories, HSAB model. Theories of Metal-Ligand bonding and stereochemistry: Valency bond theory, crystal field theory, tetrahedral, octahedral complexes; Chemistry of selected Inorganic Compounds: Acyclic & cyclic ring systems, boranes, carboranes, silicones, phosphazens (structure and reactivity); Inert gases, Structure and reactions of inert gas compounds.

Essential Reading:

1. J. E. Huheey, E. A. Keiter and R. L. Keiter, *Inorganic Chemistry, Principles of structure and reactivity,* Harper Collins 1993.
2. Cotton and Wilkinson*, Advanced Inorganic Chemistry,* Wiley Eastern, 1976.

Supplementary Reading:

1. M. Chanda*, Structure and Chemical bond,* Tata McGraw Hill Atomic Edition, 2000.
2. D. F. Shriver, P. W. Atkins and C. H. Langford*, Inorganic Chemistry,* Oxford University Press, 1990.
3. N. N. Greenwood and E. A. Earnshaw, *Chemistry of Elements*, Pergaman Press, 1984.

CY 522	**CHEMISTRY OF TRANSITION AND NON- TRANSITION ELEMENTS**	**4 Credits [3-1-0]**

S and P-block elements and their reactivity; d-block Elements : Introduction, chemistry of titanium group elements, technetium and Rhenium, Metal carbonyls : Preparation, properties and bonding of iron, cobalt and nickel carbonyls, general treatment of isopoly molybodates and vanadates. heteropoly acids. Cages & clusters of elements, structural variety, properties and implications of borides, carbides, silicides, nitrides, phosphides, oxides and sulphides of transition elements, multiple bonds and cluster variety of transition metals. Structure, synthesis and reactions of boranes, carboranes and metalloboranes. f-block Elements : Chemistry of lanthanides, position in the periodic table. Electronic configuration, oxidation states, color paramagnets, lanthanide contraction general methods of extraction. Actinides : Electronic structure, ionic radii, oxidation state, spectra and paramagnetic properties of actinides elements, Actinide hypothesis, chemistry of uranium and thorium, isolation of neptunium, plutonium and americium and their aqueous chemistry, introduction to transamoricium elements.

Essential Reading:

1. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann *,Advanced Inorganic Chemistry,* 6th Edition Wiley, Chichester, 1999.
2. D. F. Shriver, P. W. Atkins and C. H. Langford, *Inorganic Chemistry,* Oxford University press, 2002.
3. J. D. Lee, Advanced Inorganic Chemistry, Wiley Sons, 2009.

Supplementary Reading:

1. A. Kettle*, Physical Inorganic Chemistry,* Freeman, N.Y., 1996.
2. N. N. Greenwood and A. Earnshaw,*Chemistry of the Elements*, 2^{nd} ed Butterworth- Heinman, London, 1997.
3. Cotton*, Lanthanide and Actinide Chemistry,* John Wiley & Sons, 2006.

CY 523	INDUSTRIAL INORGANIC CHEMISTRY	3 Credits [3-0-0]

Introduction to chemical industry, Industrial Gases: carbon dioxide, carbon monoxide, sulphur dioxide, hydrogen, oxygen, nitrogen, rare gases of the atmosphere, coal gas, water gas, manufacture of producer gas. Manufacture of ammonia, urea, nitric acid, calcium ammonium nitrate, cement, glasses, carbon black, abrasives, fertilizers, pulp and paper. Zeolites, Surface active agents, High purity electronic materials, explosives and propellants, extraction of iron, aluminium, copper, tin, lead from ores. Application of catalysis in industry.

Essential Reading:

1. H. L. White, *Introduction to Industrial Chemistry*, Wiley-Interscience, 1986.
2. P. J. Chenier, *Survey of Industrial Chemistry*, 3^{rd} Ed. Springer, 2002.

Supplementary Reading:

1. A. Clausen and G. Mattson, *Principles of Industrial Chemistry*, Wiley-Interscience, 1978.

CY 524	GROUP THEORY AND MOLECULAR ORBITALS	3 Credits [3-0-0]

Groups, sub-groups, cossets, classes, symmetry elements and symmetry operations. Matrix formulation of group theory (Idea of matrix multiplication, inverse, trace, diagonalisation, eigen values and eigen vectors should be given). Classification of point groups (and octahedral group are to be discussed). Molecular orbitals : Hydrogen like orbitals, Molecular orbital calculation Electronic energy levels. The LCAO method, Overlap and Coulomb Integrals. Solution of problems dealing with bicylobutadiene, butadiene pentene and toluene. Bond order, free valance index, charge distribution, mobile bond order, self consistent field and length. Aromaticity rule, Application of group theory to simplification of M.O.determination.

Essential Reading:

1. F. A. Cotton, *Chemical Applications of Group Theory*, Wiley Eastern, 1991.
2. M. S. Gopinathan and V. Ramakrishnan, Group Theory in Chemistry, Vishal Publishers, 1988.

Supplementary Reading:

1. J. D. Roberts, *Notes on M.O.Calculation*, McGraw Hill, 1990.
2. A. Streitweiser, Jr *Molecular Orbital for Organic Chemistry*, John Wiley & Sons, 1991.
3. David M. Bishop, *Group theory and Chemistry*, Dover, 1989.

CY 525	ADVANCED CO-ORDINATION CHEMISTRY	3 Credits [3-0-0]

Theories of metal-ligand bonding, Crystal field theory with respect to octahedral, tetrahedral and square planner, regular symmetry, distortion from regular system, John Teller effect. Ligand field theory. Spectral Properties : Selection rule, mechanism for breakdown of selection rule, absorption band width & shape, energy level diagrams, derivation of term symbols, nephelauxetic effect, Orgel and Tanabe-Sugano diagrams. Charge transfer spectra, Magnetic properties of complexes, Isomerism and stability of metal complexes. Mechanism of Inorganic Substitution Reactions : The nature of substitution reactions, Kinetic application of crystal field theory, Acid hydrolysis of octahedral cobalt Complexes, Effect of charge, chelation, steric crowding in determining the mechanism. Base hydrolysis of octahedral cobalt complexes: Conjugate base and ion pair mechanisms, tests for conjugate base mechanisms. Mechanism of redox reactions. Mixed valence complexes. Modern aspects of crystal field theory, molecular orbital theory and valence bond methods applied to chemical, optical and magnetic properties of coordination compounds.

Essential Reading:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, *Inorganic Chemsitry: Principles of Structure and Reactivity,* Pearson, 2006.
2. J. D. Lee, *Concise Inorganic Chemistry,* Blackwell Science, 1996

Supplementary Reading:

1. D. J. Newman, Betty, *Crystal Field,* Science, 2000
2. Emeleous & Sharpe*, Inorganic Chemistry,* Longman,1981.

CY 526	BIO- INORGANIC CHEMISTRY	3 Credits [3-0-0]

Metal ions in biology,their vital role in the active-site structure and function of metallo-proteins and enzymes especially those containing Mg, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo and W ions. Both heme and non-heme systems with one-, two- or multi-metal centers (e.g., Fe: Hb, Mb, Hr, P-450, MMO, ferridoxins, Fe-S clusters: Cu: hemocyanin, SOD, Mn: vitamin B12; Zn: CPA, CA, Ni: urease will also be highlighted. Focus will be on the metal environment (ligand type, coordination, geometry), electronic, magnetic and redox properties; functions such as electron - transfer, O_2-binding, reduction to O_2^-, O_2^{2-}, and O_2^- species their utilization in hydroxylation and epoxidation; fixation of N2, water-oxidation (Oxygen Evolving Complex) reactions.

Essential Reading:

1. G. N. Mukherjee and A. Das, *Elements of Bioinorganic Chemistry*,U.N. Dhar and Sons Pvt. Ltd., Kolkata, Revised Second Edition, 2002.
2. S. J. Lippard, and J. M. Berg, *Principles of Bioinorganic Chemistry*, Univ. Science Books, 1994.

Supplementary Reading:

1. D. E. Fenton, *Bio coordination Chemistry* (Chemistry Primer 26), Oxford Univ. Press, 1996.
2. L. Bertini, H. B. Gray, S. J. Lippard, and J. S. Valentine, *Bioinorganic Chemistry*, Univ. Science Books, 1994.

CY 527	SUPRAMOLECULAR CHEMISTRY	3 Credits [3-0-0]

From molecular to supramolecular chemistry: factors leading to strong binding, hydrogen bonding and stacking interactions. Molecular models of biological receptors, biomimetic chemistry, design, synthesis and binding studies of synthetic receptors. Metal guided self assembly reactions, molecular knot with double helical complexes of Cu(I). Self assembly of polynuclear metal complexes. New molecular receptors: crown ethers, siderophores, cyclophanes, cyclodextrin and their application in specific recognition processes. Anion coordination chemistry and recognition. Supramolecular reactivity and catalysis, supramolecular devices.

Essential Reading:

1. J. W. Steed and J.L.Atwood , *Supramolecular Chemistry* , CRC Press, 2004.

2. H. W. Roesky ,Rings, *Clusters & Polymers of the main group & Transition Elements*, Elsevier, 1989.

Supplementary Reading:

1. P. Beer, P. Gale and D.Smith , *Supramolecular Chemistry* (Oxford Chemistry Primers), 1999.
2. J. M. Lehn, *Supramolecular Chemistry*, VCH, 1995.

CY 531	THERMODYNAMICS AND CHEMICAL EQUILIBRIUM	4 Credits [3-1-0]

Thermodynamics : Concept of system, exact differentials. First law of thermodynamics : energy and heat changes, Reversible processes, heat capacities, relation between Cp and Cv, Isothermal and adiabatic process, Joule-Thomson coefficient of ideal and real gases. Thermo Chemistry: Hess Laws, Heat changes of chemical reactions. Kirchoff's equation and its application, Calculation of heat of reaction from bond energy. Second Law of Thermodynamics. Elementary concept of entropy and free energy, Entropy and its variation with temperature, pressure and volume, entropy of mixing, Thermodynamic equation of state. Entropy and heat capacities relationship, Boltzmann-Plank equation for entropy. Work function, Gibb's Helmholtzs equation and its application, Carnot cycle, Heat engine. Third Law of Thermodynamics and its application to solid liquids and gases, Partial Molar Properties, Chemical potential and its variation with temperature and pressure, Fugacity. Chemical Equilibrium: Free energy and entropy, partial molar quantities, Equilibrium constant, Temperature – dependence of equilibrium constant, phase diagram of one – and two – component systems, phase rule.

Essential Reading:

1. G. N. Barrow, *Physical Chemistry,*TATA MCGRAW-HILL, 2007.
2. T. Engel, P.Reid, *Physical Chemistry,* Pearson, 2006.

Supplementary Reading:

1. K. L. Kapoor*, Text Book of Physical Chemistry,* MACMILLAN, 2006.
2. A. W. Atkins, *Physical Chemistry,* W. H. Freeman and Company, 1997.

CY 532	CHEMICAL KINETICS & PHOTOCHEMISTRY	4 Credits [3-1-0]

Chemical Kinetics : Methods of determining rate laws; Dependence of rate on concentration; Determination of order and rate constant from experimental data; Integrated rate expressions; Collision theory of reaction rates; steric factor, treatment of unimolecular reactions; Modified collision theory; Transition state theory; Chain reactions; Characteristic experimental features of chain reactions; Identification of a chain reaction; Normal and branched chain reactions; Theory of absolute reaction rates, comparison of results with Eyring and Arrhenius equations, ionic reactions; Salt effect; Mechanisms of photochemical, chain and oscillatory reactions; Homogeneous catalysis and Michaelis – Menten kinetics; - Lineweaver-Burk and Eadie plots, Effect of temperature and pH, inhibition effect, transient-phase kinetics, heterogeneous catalysis. **Kinetics in the excited electronic states** : Jablonskii diagram, Laws of light absorption, kinetics of unimolecular photophysical and photochemical processes, photostationary states, photoisomerisation, bimolecular photophysical and photochemical proceses: excimers, exciplexes and sensitisation. Mechanism of fluorescence quenching - Stern - Volmer equation, solar cells, photocatalysis, photosensitization, photo-initiated polymerization, epoxy polymers, photorefractive polymers supramolecules, dendrimers, photochromic compounds, Flash photolysis, Chemistry of vision.

Essential Reading:

1. M. R. Wright, *An Introduction to Chemical Kinetics,*John Wiley & Sons, 2005.
2. J. Raja Ram, and J. C. Kuriacose,*Kinetics and Mechanism of Chemical Transformations*, MacMillan Indian Ltd., New Delhi, 1993.

Supplementary Reading:

1. Richard I. Masel, *Chemical Kinetics & Catalysis*, Wiley-Interscience; 1st Edition, 2001.
2. K. K. Rohatgi-Mukherjee, *Fundamentals of Photochemistry*, Wiley, New York, 3rd Edition, 2002.

CY 533	**QUANTUM CHEMISTRY**	**4 Credits [3-1-0]**

Quantum Chemistry: Planck's quantum theory, wave – particle duality. Uncertainty Principle, operators and commutation relations; postulates of quantum mechanics and Schrodinger equation; free particle, particle in a box, degeneracy, harmonic oscillator, rigid rotator and the hydrogen atom. Angular momentum, eigenvalues of angular momentum operator, ladder operators, orbital and spin motion of electron, coupling of angular momenta including spin-orbit coupling, Time-independent perturbation theory, degenerate states, variational method, Hellmann-Feynman theorem. Spectra and structure of helium atom, term symbols for atoms, Hartree-Fock equations, self-consistent field method and coupling schemes. Born-Oppenheimer approximation, hydrogen molecule ion, hydrogen molecule: valence bond and molecular orbital methods, polyatomic molecules and hybridisation. The concept of groups, symmetry operations and symmetry elements in molecules, matrix representations of symmetry operations, point groups, irreducible representations and character tables.

Essential Reading:

1. D. A. McQuarrie, *Quantum Chemistry*, University Science Books, 1983.
2. A. K. Chandra*,Introductory Quantum Chemistry,* Tata McGraw Hill,1979.
3. P. W. Atkins, Molecular Quantum Mechanics, 2nd edition, Oxford University Press, 1983.

Supplementary Reading:

1. Eyring, Walter & Kimbel *,Quantum Chemistry,* John Willey,1953.
2. Fitts, D. Donald*, Principle of Quantum Mechanics,* Cambridge University Press, 1999.
3. I. N. Levine, *Quantum Chemistry*, 3rd edition, Allyn and Bacon, 1983.

CY 534	**PRINCIPLE OF HETEROGENEOUS CATALYSIS**	**3 Credits [3-0-0]**

Basic principles of catalysis, homogeneous and heterogeneous catalysis. Adsorptions: type of adsorption and their discrimination, adsorption isotherms, BDDT classification, surface area and pore size calculation, Enthalpy and entropy of adsorption, Langmuir, BET and other isotherms, Kelvin equation and capillary condensation. Kinetics: Kinetics of catalysed reaction, various types of reactions such as simple, parallel and consecutive reaction, order of reaction, energy of activation. Catalyst preparation: Selection, preparation and evaluation of a catalyst, Effect of promoter, carrier, stabilizer, poisioning effect. Catalyst site characterization: Types of catalyst based on active sites, acid-base and redox catalysts, methods of determination of active sites (titration, TPD, TPR, FTIR etc.). Mechanism of catalyst action: Mechanism of selected reactions on catalyst surfaces such as hydrogenation, dehydrogenation, dehydration, cracking etc. Applications to selected industrial processes- petrochemical industry-reforming and refining, environment protection, value added chemicals, autoexhaust catalysis, pharmaceuticals. Novel nanosize catalysts: Novel nanosize catalytic materials- clusters, zeolites, Mesoporous materials, clays, composite oxides etc.

Essential Reading:

1. M. Thomas and W. H. Thomas, *Introduction to the principles of heterogeneous catalysis*, Academic press, London 2007.
2. G. A. Somorjai, *Introduction to surface chemistry and catalysis*, John Wiley and Sons 2006.

Supplementary Reading:

1. L. Augustine, *Heterogeneous catalysis for the synthetic chemist*. Marcel Dekker Inc., New York, 1996

CY 535 ELECTROCHEMISTRY 3 Credits [3-0-0]

Inter ionic attraction theory, Derivation of Debye Huckel Onsager's conductance equation, its verifications and modifications and its present trend. Determination of degree of dissociation of electrolyte. Theoretical calculation of activity coefficient from ionic strength by Debye-Huckel theory, Determination of activity coefficient from Freezing Point method, EMF method and solubility method. Ion association, determination of thermodynamic dissociation, constant of weak electrolytes by Shedlovsky method, Reversible cells, chemical and construction cells, Liquid junction potential, single electrode potential, oxidation – reduction electrodes. Determination of (i) dissociation constant of weak monobasic acid (ii) hydrolysis constant of salts (iii) ionic product of water and (iv) solubility product of sparingly spoilable salts by EMF measurements. Factors effecting the EMF of half cells, Determination of pH. Electrode concentration cells, Electrolyte concentration cell. Electrochemical series and its significance,. Electrolytic polarization, over voltage.

Essential Reading:

1. S. Glasstone, *Text Book of Physical Chemistry*, MACMILLAN 1974.
2. G.M. Barrow , *Physical Chemistry*, TATA MCGRAW-HILL ,2007

Supplementary Reading:

1. Books and Reddy, *Modern Electrochemistry,* Vol – I .Springer,2000.
2. W.J. Moore, *Physical Chemistry*, Prentice Hall,1993

CY 536 COLLOIDS AND SURFACE CHEMISTRY 3 Credits [3-0-0]

The colloidal state: Introduction; Classification and colloidal systems; Properties of lyophillic and lyophobic colloidal solutions. Structural characteristics; Preparation and purification of colloidal systems. Kinetic properties: The motion of particles in liquid media; Brownian motion and translational diffusion; Osmotic pressure; Rotary Brownian motion. Optical properties: Optical and electron microscopy; Light scattering; Tyndall effect- turbidity. Liquid-gas and liquid-liquid interfaces; Surface and interfacial tensions; Adsorption and orientation at interfaces; Association colloids-micelle formation; spreading; Surface films and Langmuir-Blodgett films. Properties and aggregation of surfactants; The solid-gas interface: Adsorption of gases and vapours on solids; Capillary condensation; Langmuir adsorption isotherm; BET equation for multimolecular adsorption; Composition and structure of solid surfaces. The solid-liquid interface; Contact angles and wetting; Detergency; Adsorption from solution. Charged interfaces: The electric double layer; Electrokinetic phenomena; Electrokinetic theory. Colloid stability: Lyophobic sols; van der Waals forces between colloidal particles; Rheology: Introduction; Viscosity; Non-Newtonian flow; Viscoelasticity. Emulsions and foams: Oil-in-water and water-in-oil emulsions; Emulsifying agents and emulsion type; gels and Foams.

Essential Reading:

1. R. M. Pashley, and M. E. Karaman, *Applied Colloid and Surface Chemistry*, John Wiley & Sons Ltd., 2004.
2. D. Shaw, and B. Heinemann, *Introduction to Colloid and Surface Chemistry*, Butterworth Heinemann, 4^{th} Edition, 1992.

Supplementary Reading:

1. E. D. Shchukin, A. V. Pertsov, E. A. Amelina, and A. S.Zelenev, *Colloid and Surface Chemistry,*Elsevier, 2001.
2. F. Caruso (Editor),*Colloids and Colloid Assemblies: Synthesis, Modification, Organisation and Utilization of Colloid Particles*, Wiley, 2004.

CY 537 ADVANCED SOLID STATE CHEMISTRY 3 Credits [3-0-0]

Introduction, Crystal structure, Crystalline solids, Crystal systems, Metallic structure-Unit cells, Crystallographic directions and planes, linear and planar densities, close-packed crystal structures, Types of close packing-hcp and ccp, packing efficiency, Ceramics structure- radius ratio, structure types-NaCl, ZnS, Na_2O, $CdCl_2$, wurtzite, nickel arsenide, CsCl, CdI_2, rutile, Perovskite ABO_3 and Spinels AB_2O_4. Material preparation-Solid state reactions, precipitation, sol-gel route, precursor method, Ion exchange reactions, Intercalation/deintercalation reactions, soft chemical reactions and thin film preparation, Method of characterization-Powder X-ray diffraction, electron and Neutron diffraction, Thermal analysis, microscopic and spectroscopic techniques as tools for material characterization, Phase diagram and microstructure analysis- simple binary isomorphous, eutectic and congruent phase diagrams, Electronic properties-Developments, free electron theory, Band Theory, metals and their properties, Semiconducors- intrinsic and extrinsic, Hall Effect, Insulators-dielectric, ferroelectric, pyroelectric and Peizoelectric properties, Magnetic properties-Dia, para, ferro, ferri, antiferro and antiferri materials, Defects and dislocations-Vacancies and interstitials, dislocations and grain boundaries colour centers and reactivity, Amorphous materials-glasses and refractories, Superconductivity-Theory, discovery, various high Tc materials, Novel materials-Zeolites, Heteropoly acids, Mesoporous materials (MCM-41, MCM-48, SBA, TS), fullerenes, carbon nanotubes etc

Essential Reading:

1. A. R. West, *Solid state Chemistry and its applications,* Wiley Student Edition (John Wiley & Sons), 1988
2. C. N. R. Rao and J. Gopal Krishnan,New directions in solid state Chemistry, Cambridge press, 1990

Supplementary Reading:

1. A. F. Wells, *Structural Inorganic Chemistry,*Oxford University Press, USA; 5 Edition, 1984.

CY 538	**MOLECULAR SPECTROSCOPY**	**3 Credits [3-0-0]**

Interaction of matter with radiation, time dependent perturbation theory, Einstein coefficients. **Energy levels and transition probabilities** for the rigid rotor - harmonic oscillator model, potential energy surfaces in the ground and excited electronic states, Franck-Condon principle, spectroscopy of diatomic molecules (rotational, vibrational and electronic). Anharmonicity and centrifugal effects, Dunham expansion and Morse oscillator. **Rotational and vibrational spectroscopy** of polyatomic molecules, angular momentum operator matrix elements, energy levels and transition probabilities for symmetric and asymmetric top molecules, normal modes of vibration and their classification by group theory. Coupling between rotational and vibrational degrees of freedom: elementary introduction. Electronic spectra of polyatomic molecules: absorption and emission spectroscopy, charge transfer spectra, effect of solvent, Raman spectroscopy, Introduction to Mossbauer, photoelectron nuclear magnetic resonance spectroscopy. **Electron Spin Resonance Spectroscopy**: Electronic Zeeman and hyperfine interactions, hydrogen atom in a magnetic field, selection rules in ESR, anisotropy and hyperfine constants, hybridization, ESR of organic free radicals in solution, McConnell's relations.

Essential Reading:

1. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata- McGraw-Hill, 1994.
2. P. S. Sindhu, *Fundamentals of Molecular Spectroscopy*, New Age International (p) Limited, 2008.

Supplementary Reading:

1. Peter F. Bernath, *Spectra of Atoms and Molecul*es, Oxford University Press, 1995.
2. J. M. Hollas, *Modern Spectroscopy*, Wiley, 1992.
   D. C. Harris and M. D. Bertolucci, *Symmetry and Spectroscopy*, Dover, 1989.

CY 539	**BIOPHYSICAL CHEMISTRY**	**3 Credits [3-0-0]**

Hydrophobic and hydrophilic interactions in biological systems, biological relevance of chemical potential, protein solvent interactions-binding, hydration and exclusion, protein structure, stability, folding, unfolding and their spectroscopic and calorimetric studies. Protein ligand binding, equillibria across membranes, structure-function relationships.

Essential Reading:

1. R. B. Gregory, *Protein solvent interactions*, Marcel Dekker, Inc. 1995.
2. B. T. Nall and K. A. Dill, *Conformations and forces in protein Folding*, American Association for the Advancement of science, 1991.

Supplementary Reading:

1. C. R. Cantor and P. R. Schimmel, *Biophysical Chemistry Part-III*, Freeman and Co. 1980.

CY 541	CHEMISTRY OF HETEROCYCLIC COMPOUNDS	3 Credits [3-0-0]

Introduction, Structure and uses of heterocycles, Synthesis and Reactivity of furan, thiophene, pyrrole, pyridine, quinoline, isoquinoline, indoles, azines, purines, pteridines, azoles, benzo-fused ring systems including isobenzofuran, heteroisobenzofurans, compounds withoxygen and sulfur hetero atoms and small-ring heterocycles. Role ofheterocyclic compounds in biological systems.

Essential Reading:

1. T. L. Gilchrist, *Heterocyclic Chemistry*, Pearson Education, 3rd Ed. 2007.
2. J. A. Joule and G. F. Smith, *Heterocyclic Chemistry*, ELBS, 1978.

Supplementary Reading:

1. A. R. Katritzky and Pozharskii, *Handbook of Heterocyclic Chemistry* Academic Press; 2nd Ed. 2000.
2. J. A. Joule and K. Mills, *Heterocyclic Chemistry*, Wiley-blackwell; 4th Ed, 2000.

CY 542	METHODS INORGANIC SYNTHESIS	3 Credits [3-0-0]

The disconnection approach, chemoselective synthesis,C-C bond forming reactions, organometallic reagents in organic synthesis: Grignard reagents, organolithium reagents, organocadmium reagents, organocopper reagents, organosilicon compounds, organotin compounds, organoaluminum compounds, organoiron compounds, organochromium reagents, ylides of sulfur, phosphorous and nitrogen. Tebbe's reagent. Enolates, kinetic and thermodynamic enolates, enolate condensation reactions like Claisen, Dieckmann, Knoevenegal, Stobbe, Darzen glycidic ester. Umpolung reagents, definition of umpolung, acyl anion equivalent, equivalents of ketene, $RCOCH_2^+$, $RCOCH_2CH_2CH_2^+$, $RCOCH_2CH_2CH_2^-$ etc. Protecting groups: protection of hydroxyl, carboxyl, carbonyl, amino groups. Protection of carbon-carbon multiple bonds. Illustration of protection and deprotection in synthesis.

Essential Reading:

1. S. Warren, *Organic Synthesis: The Disconnection Approach*, Wiley Student Ed. 2007
2. J. Singh, L. D. S. Yadav, Organic Synthesis, Pragati Prakashan, 2007.
3. Michael B. Smith, *Organic Synthesis*, McGraw Hill, 2004.

Supplementary Reading:

1. S. Warren, *Designing Organic Synthesis*, John Wiley, 1978
2. S. G. Davies, *Organotransition Metal Chemistry, Application to Organic Synthesis*, Pergamon Press, 1982.
3. R. K. Mackie and D. M. Smith, *Guidebook to Organic Synthesis*, ELBS, 1982.

CY 543	MOLECULAR REARRANGEMENT	3 Credits [3-0-0]

Aldol Condensation, Claisen condensation, Dieckmann condensation, Curtius, Schmidt, Lossen and Wolff Reaction, Cope Reaction, Chugaev Reaction, Perkin, Stobb, Hofmann, Schidmt, Curtius, Reimer-Tiemann, Reformatsky, Diels-Alder reaction, Friedel-craft reaction, Wittig reaction, Meerwein-Pondroff-Verley reduction, Clemmenson reduction, Wolf-Kishner reduction, Birch reduction, Baylis-Hilman reaction, Barton reaction, Bamford-Stevans reaction, Shapiro reaction, Heck reaction, Demijanov, Pinacol-Pinacolone rearrangement, Favorski Rearrangement, Fries rearrangement, Wagner-Meerwein Rearrangement, Benzil-Benzilic Acid Rearrangement, Beckmann

Rearrangement, Claisen rearrangement, Bamberger rearrangement, Suzuki coupling, Stille coupling, McMurry coupling, Sonagashira coupling.

Essential Reading:

1. Parikh, Parikh and Parikh, *Name reactions in Organic Synthesis,* Foundation Books, 2006.
2. G. Brahmachari, Organic Name Reactions, Narosa Publishers, 2009.

Supplementary Reading:

1. Robert and Cassenio*, Basic Principles of Organic Chemistry,* Addison-Wesley Pub1977.
2. J. J. Li*, Name reactions in organic synthesis ,* 3rd Edition, SPRINGER 2006.
3. M. Smith, *Organic Synthesis,* Mc Graw Hill, 2nd Ed. 2004.

CY 544	INSTRUMENTAL METHODS OF ANALYSIS	3 Credits [3-0-0]

Basic principle, Instrumentation and application to chemist of the following instruments Atomic absorption spectroscopy, Flame emission spectroscopy, XRD, XRF. Polarography, Cyclic Voltametry, Basic principle and general analytical application of Thermal analysis, TGA and DTA, DSC Thermometric titration, Theory, instrumentation and complexation titrations dealing with EDTA., Principle, instrumentation and general application of Chromatography., Flow injection analysis, Recent development in the above technique.

Essential Reading:

1. A. S. Douglas, F. J Holler, S. R. Crouch, *Principles of Instrumental Analysis*, Thomson, 2007.
2. Willard, Merritt and Dean , *Instrumental Methods of Analysis*, AFFILIATED EAST-WEST, New Delhi, 2004

Supplementary Reading:

1. A. S. Douglas, F. J Holler, S R Crouch *Fundamentals of Analytical Chemistry*, Thomson, 2007.
2. R. S. Drago *Physical methods in inorganic chemistry*, AFFILIATED EAST-WEST, New Delhi, 1988.

CY 558	ORGANOMETALLIC CHEMISTRY	3 Credits [3-0-0]

General introduction, Structure and bonding, 18-Electron rule, Wades rule, Survey of organometallic complexes Preparation, properties and bonding of metal carbonyl complexes, Bonding in carbonyls, nitrosyls, tertiary phosphines, hydrides, alkene, alkyne, cyclobutadiene, cyclopentadiene, arene compounds and their M.O. diagrams. Metal-carbon multiple bonds. Fluxional organometallic compounds including ð-allyl complexes and their characterization. Metallocycles, unsaturated nitrogen ligands including dinitrogen complexes. Preparation and applications of organomagnesium compounds, Organolithium compounds, organocopper reagents, organozinc compounds, organolead compounds, organoaluminum compounds, organosilanes and organoboranes towards organic tranformations. Metal-Metal bond and transition metal cluster, Organometallic catalysis.

Essential Reading:

1. B. F.G. Johnson, *Transition metal cluster*, Wiley, 1980.
2. R. C. Mehrotra and A. Singh, *Organometallic Chemistry-A unified approach*, New age international(P)limited publisher, 2001.
3. C. Elschenbroich and A, Salzer, *Organometallic-A Concise introduction*, Weinheim, 1992.

Supplementary Reading:

1. R.H. Crabtree, *The organometallic chemistry of the transition metals*, Wiley-Interscience, 2005.
2. G. Wikinson, F.G.A. Stone, E. Abel, *Comprehensive Organometallic Chemistry*, Peramon, 1980.
3. P. Powell, *Principle of Organometalic Chemistry*, Kulwar, 1991.

CY 571 ORGANIC CHEMISTRY LABORATORY 6 Credits [0-0-9]

Elemental Analysis of Organic Compounds (C, H, N, O, S), Identification of organic compounds having at least two functional groups; Preparation of (a) p-Iodo tolune, (b) Benzaldehyde to Benzoin → Benzil → Benzilic acid, (c) Benzoic acid → o-Benzoyl Benozoic acid → Anthraquinone → Anthrone, (d) Ethylacetate → Ethylaceto acetate, (e) Anisole → Phenacetin; Synthesis of a simple dye and check, its purity by paper chromatography and extinction coefficient measurement; Estimation : (a) Methoxy group, (b) Acetyl group, (c) Nitrogen, (d) Carbon and hydrogen, (e) Spectrophotometric analysis of Keto group

Essential Reading:

1. V. K.Ahluwalia and R. Aggarwal, *Comprehensive practical organic chemistry*, University press. 2000
2. B. S. Furniss, *Vogel's Text Book of Practical Organic Chemistry*, ELBS Longman, 5th Edition, 1996.

Supplementary Reading:

1. D. S. Gupta , *Experimental Organic Chemistry, Qualitative and Quantitative*, TATA MCGRAW HILL 2004
2. A. Ault, *Techniques and Experiments for Organic Chemistry*, University Science Book.1998

CY 572 INORGANIC CHEMISTRY LABORATORY 6 Credits [0-0-9]

Qualitative Analysis of inorganic mixture containing not more than six radicals, any one of the following rare metal may be included, tungsten, molybdenum, titanium and vanadium. Organic radicals are excluded; Quantitative Analysis of major constituents of : Chrome iron ore, dolomite or Portland cement, Pyrolusite. Quantitative Analysis of major constituents of Bronze, Brass, solder, etc; Preparation and characterization of metal complexes

Essential Reading:

1. G. Svehla, *Vogel's qualitative inorganic analysis*, Harlow Longman, 2002.
2. A. I. Vogel, John Bassett, *Vogel's textbook of quantitative inorganic analysis: including elementary instrumental analysi*, Longman,2003

Supplementary Reading:

1. A. I. Vogel , *Qualitative Inorganic Analysis*, Orient Longman – 1979.

CY 573 PHYSICAL CHEMISTRY LABORATORY 6 Credits [0-0-9]

Conductometric titrations: Dissociation constant of weak acid, solubility product of sparingly soluable salt ($PbSO_4$, $BaSO_4$), Determination of strength of strong and weak acids in a given mixture conductrometrically, Determination of ratio of Potasium Dicromate, chromate in a supplied mixture. Potentiometric titration: Determination of Dissociation Constant of weak acid Determination of pH of an electrolyte. Polarimetricdetermination of Concentration of unknown sugar solution Inversion of cane sugar; Determination of Co-ordination number of copper in cupramine complex by distribution method, determination of Equilibrium constant of the reversible reaction $KI + I_2 = KI_3$, Kinetics of Easter Hydrolysis by acid and base; Determination of Molecular mass of volatile liquids by Victor Meyer Method. Determination of Molecular mass of inorganic solids by Rast's method, Determination of magnetic moment by Gouy's balance.

Essential Reading:

1. B. Behera *, Experimental Physical Chemistry, ,* Tata McGraw Hill 2000.

Supplementary Reading:

1. D. Alart, *Practical Physical Chemistry*, Longman, 1993.

CY 574 ENVIRONMENTAL CHEMISTRY LABORATORY 6 Credits [0-0-9]

Physico-chemicalanalysis of water and waste water analysis ; Analysis of Soil parameters ; Analysis of air & Noise

Essential Reading:

1. N. Manivaskam*, Physico-Chemical Examination of Water, sewage and Industrial Effluences,* Pragatiprakashan, 2000.

Supplementary Reading:

1. *Standard Methods for the Examination of Water and Waste Water,* APHA, AWWA, 6th Edition, 2002.

DEPARTMENT OF LIFE SCIENCES

DETAILED SYLLABI OF COURSES

LS 401	Microbiology	3-1-0	4
LS 402	Biochemistry	3-1-0	4
LS 403	Immunology	3-1-0	4
LS 404	Molecular Biology and Biotechnology	3-1-0	4
LS 405	Cell biology	3-1-0	4
LS 406	Fundamentals of Cell Biology	3-0-0	3
LS 410	Food Science	3-1-0	4
LS 411	Biophysics	3-1-0	4
LS 412	Advanced Microbial genetics	3-1-0	4
LS 413	Basic Biophysics	3-0-0	3
LS 414	Microbial Genetics	3-0-0	3
LS 420	Bioinformatics	3-1-0	4
LS 421	Radiation Biology	3-1-0	4
LS 422	Cell Signaling	3-1-0	4
LS 423	Advanced techniques	3-0-0	3
LS 424	Proteomics	3-1-0	4
LS 425	Introduction to Bioinformatics	3-0-0	3
LS 435	Microbial diversity and Extremophiles	3-0-0	3
LS 440	Physical Sciences and Instrumentation	3-1-0	4
LS 441	Bio-Statistics	3-1-0	4
LS 471	Microbiology Laboratory	0-0-3	2
LS 472	Biochemistry Laboratory	0-0-3	2
LS 473	Biotechnology Laboratory	0-0-3	2
LS 474	Molecular Biology Laboratory	0-0-3	2
LS 475	Immunology Laboratory	0-0-3	2
LS 501	Ecology and Environmental Sciences	3-1-0	4
LS 502	Advances in Structural Biology	3-1-0	4
LS 503	Recombinant DNA Technology	3-0-0	3
LS 507	Structural Biology	3-0-0	3
LS 511	Genetics	3-1-0	4
LS 512	Physiology &Developmental Biology	3-1-0	4
LS 513	Enzymology & Metabolism	3-1-0	4
LS 514	Fundamental of Genetics	3-0-0	4
LS 530	Aquatic biology and marine biotechnology	3-1-0	4
LS 531	Epigenetics	3-1-0	4
LS 532	Molecular Medicine	3-1-0	4
LS 533	Marine Biotechnology	3-0-0	3
LS 534	Introduction to Epigenetics	3-0-0	3
LS 535	Basics in Molecular medicine	3-0-0	3
LS 540	Research Methodology	3-0-0	3
LS 571	Ecology and Environmental Science Laboratory	0-0-3	2
LS 581	Cancer Biology	3-1-0	4
LS 582	Special Topics in Life Science – II	3-1-0	4
LS 583	Special Topics in Modern Biology – I	3-1-0	4
LS 584	Special Topics in Modern Biology – II	3-1-0	4
LS 585	Special Topics in Applied Life Science – I	3-1-0	4
LS 586	Special Topics in Applied Life Science – II	3-1-0	4

LS 591	Research Project – I	0-0-6	4
LS 592	Research Project – II	0-0-9	6
LS 593	Seminar and Technical writing – I	0-0-3	2
LS 594	Seminar and Technical writing – II	0-0-3	2
LS 595	Short-term Industrial/Research Experience	0-0-3	2
LS 596	Comprehensive Viva- Voce	0-0-0	2

LS 401 MICROBIOLOGY 4 credits [3-1-0]

Introduction to microbiology;Introduction to Microbiology; Discovery of the microbial world, controversy over spontaneous generation, Koch's postulate, development of pure culture methods. Microbial Taxonomy- low G+C gram positive bacteria; high G+C gram positive bacteria.Yeast and filamentous fungi, Viruses. Classification of prokaryotes and bacterial taxonomy: short description of different groups under Archaebacteria (Extremophiles: Thermophiles, Halophiles and Acidophiles), under Eubacteria (Myxobacteria, Mycoplasma, Actinomycetes, Rickettsias and Chlamydiae) and auxotrophs including Cyanobacteria. ; **Microbial nutrition**;Cultivation of bacteria – nutritional requirements of micro organism, physical requirements, different types of media & their preparations. Isolation of pure cultures, maintenance and preservation of the pure cultures.Culture characteristics – Bacterial growth – Growth curve, batch and continuous cultures diauxic and synchronous growth.Enumeration of cells by direct and indirect methods. ; **Control of microorganisms ;**Concept of sterilization and disinfection. Physical and chemical methods of control. Chemotherapeutics – mode of action of antibiotics, Penicillin, ampicillin, sulfonamide, vancomycin, streptomycine, tetracycline, chloramphenicol, antifungals, antiviral etc. Antibiotic resistance. ; **Microbial genetics** ;The basic principles of microbial DNA, replication, transcription and translation. Mutation and DNA repair- Types of mutations, molecular basis of mutation, spontaneous mutation, reverse mutations & suppressor mutations, Mutagens, mechanisms of DNA repair (Photo reactivation, Nucleotide excision repair, Mismatch correction, SOS repair). Extra chromosomal DNA structures. Different types of plasmids: F plasmids, R plasmids and Col plasmids. Importance of plasmids for bacterial survival and antibiotic resistance.Transposons, Genetic recombination and mechanisms of recombination processes. Horizontal gene transfer in bacteria: Transformation, conjugation and transduction. Lytic and lysogenic life cycles of bacteriophages.Operon systems for gene expressions in prokaryotes- lac and trp operon. ; **Recombinant DNA technology** ;Definition, importance and applications of recombinant DNA technology. Different kinds of vectors used in recombinant DNA technology [Plasmids, bacteriophages (Lambda and M13), phagemids, cosmids, artificial chromosomes (YAC, BAC)]. Restriction endonucleases, methyltransferase, ligase, polymerase, kinase, phosphatase, nuclease, transferase, reverse transcriptase, linkers, adapters- design of cloning strategy and stepwise experimental procedure. Polymerase chain reactions (PCR) and site directed mutagenesis. Restriction mapping. DNA sequencing (Maxam Gilbert, Sanger's and automated). Construction of cDNA and genomic libraries.DNA fingerprinting and its application in forensic science. ; **Medical microbiology**; Normal microflora of host -normal micro flora of skin, oral cavity, gastrointestinal tract, Respiratory tract; host-parasite relationship, entry of pathogens into the host, types of toxins (Exo, endo, entro) and their mode of actions; mechanisms of pathogenesis, and clinical manifestations associated with medically-important pathogenic microorganisms (bacteria, fungi, parasites, and viruses). ; Unit- 6: Environmental microbiology ; Role of microorganisms in the cycling of bioelements (carbon, nitrogen, phosphorus, sulphur, iron, manganese etc.); microbial degradation of pesticides and other recalcitrant chemicals, xenobiotics); microorganism in mineral recovery; microbial degradation of petroleum and hydrocarbons; biodeteriroration and control; microbial inoculants in agricultural: Biofertilizers- Biological Nitrogen fixation- symbiotic and asymbiotic, mass production by Rhizobium, Azotobacter and Cyanobacteria, nitrifying, ammonifying and photosynthetic bacteria; biological control.

Essential Reading:

1. M.J. Pelczar, E.C.S. Chan and N.R. Kreig, *Microbiology*, Tata McGraw Hill.
2. R.Y. Stanier, J.L. Ingraham, M. L. Wheelis and P.R. Painter, *General Microbiology*, Macmillian.

3. R.M. Atlas and R. Bartha,*Microbial ecology: Fundamentals and Applications*, 4 e Pearson Education.
4. L. Snyder and W. Champness,*Molecular genetics of bacteria*, 3 e, ASM Press.
5. B.D. Singh,*Biotechnology*, Kalyani Publishers.
6. T.A. Brown,*Gene cloning and DNA analysis: An introduction*, Blackwell Publishing.

Supplementary Reading:
1. P.V. Vandenmark and B.L. Batzing Benjamin Cummings, *The microbes – An Introduction to their Nature and Importance*.
2. Tortora, Funke and Chase*, Microbiology*, Benzamin & Cummings
3. Lansing M. *Microbiology*, 5th Edition, Prescott
4. M. Madigan, J. Martinko, Paul Dunlap, David Clark, *Brock biology of microorganisms*, 12th Edition Pearson Education.
5. S. R. Maloy, J.E. Cronan, Jr., D. Freifelder, *Microbial genetics*, Narosa Publishing House.

LS 402	BIOCHEMISTRY	4 credits [3-1-0]

Amino acids: Nomenclature, structure and properties of amino acids- Ninhydrin test. Proteins: Peptide bond, Conformation of proteins (Ramachandran plot, secondary, tertiary and quaternary structure; domains, motif and folds). Lipids, Membrane structure and function- Structure of model membrane, lipid bilayer and membrane protein diffusion, osmosis, ion channels, active transport, ion pumps, mechanism of sorting and regulation of intracellular transport, electrical properties of membranes. Concept of gene and genetics: Nucleic Acids, Structure of DNA and RNA, central dogma, central dogma reverse, genetic code. Principles of gene regulation: replication, transcription and translation. Carbohydrates: Structure of various sugars, including hexoses and pentoses. Concept of monosaccharides, disaccharides and polysaccharides, Glycolysis, TCA cycle and pentose phosphate pathway. ; Photosynthesis and Pigments of life: Chlorophyll, Haemoglobin and Cytochrome c. Tetrapyrroles are responsible, inter alia, for oxygen transport (haem), electron transport (cytochrome c) and, most fundamentally, photosynthesis (chlorophyll).

Essential Reading:
1. D. L. Nelson, M. M. Cox, *Lehninger Principles of Biochemistry*, Fourth Edition Hardcover: 1100 pages, Publisher: W. H. Freeman
2. Herpers *Review of Biochemistry*

Supplementary Reading:
1. D. Voet, *Biochemistry* by Hardcover: 1616 pages, Publisher: Wiley; 3 edition
2. L. Stryer, W.H. Freeman, *Biochemistry*
3. J. D. Rawan, N. Patterson, *Biochemistry*

LS 403	IMMUNOLOGY	4 Credits [3-1-0]

Basic concepts in immunology, components of the immune system, Innate immunity, principles of innate and adaptive immunity, Different lines and layers of defense, Pattern recognition in innate immune system. The complement system, Induced innate responses to infections, Antigen recognition by B-cells, The structure of a typical antibody molecule, Interaction between the antibody and specific antigen, Diversity of Immunoglobulins: VDJ Recombination; Antigen recognition by T cells, Antigen processing and presentation: MHC, Complement system, Development and survival of lymphocytes, Lymphocytes in bone marrow and thymus, Positive and negative selection of lymphocytes, Survival and maturation of lymphocytes, The Adaptive Immune Response, T Cell-Mediated Immunity and cytotoxicity, Macrophage activation by armed CD4 TH1 cells, Humoral Immune Response ; Adaptive Immunity to Infection: Infectious agents and how they cause disease? The course of the adaptive response against infection, The mucosal immune system, Immunological memory; Failures of Host Defense Mechanisms, Inherited immunodeficiency diseases, Acquired immune deficiency syndrome, Allergy and Hypersensitivity, Effector mechanisms in allergic reactions and IgE, Hypersensitivity diseases, Autoimmunity and Transplantation, Autoimmune responses are directed against self antigens.

Essential Reading:

1. Delves, Martin, Burton &Roitt, *Essential Immunology*, 11th Edition.
2. Richard A. Golds by, Thomas J. Kindt and Barbara A. Osborne, *Kuby Immunology* I. K. International Pvt Ltd.

Supplementary Reading:

1. Janeway, Travers, Walport, and Shlomchik, *Immunobiology, the immune system in health and disease,* Garland Science Publishing, 6th Edition, 2005,
2. L. M. Sompayrac, *How the Immune System Works,* Wiley-Blackwell; 3rd edition.

LS 404	**MOLECULAR BIOLOGY AND BIOTECHNOLOGY**	**4 credits [3-1-0]**

Properties and evolution of genetic material, flow of genetic information and Isolation of genes. DNA Replication: Models of Replication, Origin of replication, DNA polymerases, DNA topology, DNA damage and repair. Transcription: RNA-polymerases, RNA processing, regulation, post-transcriptional control and degeneration, gene silencing. Translation: Structure of Ribosome, tRNA and mRNA, protein synthesis and regulation in prokaryotes and eukaryotes, protein sorting, signal peptides. Biosignaling: signal perception, molecular mechanisms of signal transduction, regulation of signal transduction pathways in controlling gene expression. Transposons and retrotransposons: prokaryotic and eukaryotic transposable elements and their role in evolution. Linkage and crossing over, Genetic recombination and construction of genetic maps in Drosophila, Interference and coincidence, Cytological demonstration of crossing over in Drosophila, Mitotic recombination, Intragenic recombination, Inheritance of quantitative traits, Continuous and discontinuous variation, Polygenic inheritance, Genetic variance, heritability (narrow sense and broad sense). ; Concept and definition of biotechnology: Microbial biotechnology, Culture system (batch, fed batch and continuous culture), Fermentor, output optimization, concept of downstream processing for product recovery, stain development of microorganisms, fermentation of antibiotics, organic acids and amino acids, single cell protein, microbial fuel production, microbial pestisides and biofertilizers. ; Enzyme engineering: Commercial use of enzymes, immobilization techniques and its application, various methods of immobilization, enzyme sensors, enzyme reactor and there utility. ; Animal biotechnology: cell culture, Monoclonal antibody, gene therapy, hybridoma technology, methods of vaccination, gene therapy, Application of recombinant DNA technology in medicine and diagnosis. Animal cloning. ; Plant biotechnology: Transgenic plants, herbiside and insecticide resistant plants and there utility in modern day agriculture, chloroplast enginnering- production of moleculer H2 and chloroplast and photo voltaic system; Advantages of cynobacteria as possible commercial source of molecular H2.

Essential Reading:

1. B. Lewin, *Genes VIII* by Hardcover, Publisher: Prentice Hall
2. B.D. Singh, *Biotechnology* by Kalyani Publishers 2009.
3. R. C. Dubey, *A text book of Biotechnology* by S. Chand and Co., India
4. J. K. Pal and S. S. Ghaskadbi, *Fundamentals of molecular biology* by Oxford University Press.

Supplementary Reading:

1. L. Stryer, *Biochemistry*
2. S. Cummings*, Current Perspectives in Genetics: Insights and Applications in Molecular, Classical, and Human Genetics*, 2000 Edition Paperback: 170 pages, Publisher: Brooks Cole

LS 405	**CELL BIOLOGY**	**4 credits [3-1-0]**

Structure and Function of Cell and its Organelles: Cell as the unit of life- Development of cell theory, Cell types: prokaryotes vs. eukaryotes; from single cell to multi-cellular organism; Prokaryotic cells: Structure, cell-walls and related molecules, outer membrane, flagella, motivity, cell inclusion endospores, gas vesicles, capsules, slime layers. ; Cell Architecture: Cyto-skeletal components, microtubules and microfilaments, motility and motor motions, actomyosincomplex , Extra-cellular matrix. Membrane system: Biological membranes - architecture & kinetics (transport, ion channels, diffusion, Na-K pump, proton pump). Endomembrane system: endoplasmic reticulum, Golgi complex, endosomes, lysosomes. Cell nucleus, Chromatin structure, nucleolus, nucleoplasm. ; Cell Division: Mitosis, meiosis and cytokinetics, animal and yeast cell division, cell cycle control, programmed cell death. Cell cycle: G0/G1, S, G2 and M phages, duration of different phages and the methods for their determination, Cell cycle synchronization, arrest and delay in case of diseases. Protein localization: Synthesis of secretory &membrance protein, import into nucleus, mitochondria, chloroplast & peroxisome; Receptor-mediated endocytosis. Cellular communication: Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins. ; Cell Signaling: Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light signaling in plants, bacterial chemotaxis and quorum sensing. ; Specific pathways: Chromatin Regulation; Ras, MAPK and Ras-MAPK Signaling; Apoptosis/Autophagy, PI3K/Akt Signaling, Translational Control; Ca, cAMP& Lipid Signaling, Cell Cycle/Checkpoint, DNA Damage, Jak/Stat Pathway, NF-κB Signaling, TGF-β/Smad Signaling, Lymphocyte Signaling, Neuroscience, Tyrosine Kinase/Adaptors, Angiogenesis, Vesicle Trafficking, Cytoskeletal Signaling, Adhesion, Glucose Metabolism, Wnt/Hedgehog/Notch, Stem Cell/Lineage Markers, Nuclear Receptors.

Essential Reading:

1. B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, *Essential Cell Biology : An Introduction to the Molecular Biology of the Cell*, Garland Publishing Company
2. De Robertis, *Cell and Molecular Biology*, B .I. Publication Pvt. Ltd
3. H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaura, D. Baltimore and J. Danell, *Molecular Cell Biology*, W.H. Preeman and Company.
4. B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, *Essential Cell Biology : An Introduction to the Molecular Biology of the Cell*, Garland Publishing Company.
5. J. Nelson, *Structure and Function in Cell Signalling* by Wiley.
6. Ernst J. M. Helmreich, *The biochemistry of cell signalling* by Oxford Uni Press

Supplementary Reading:

1. E.B. Wilson, *Cell in Development and Inheritance*, Macmillan

LS 406	FUNDAMENTALS OF CELL BIOLOGY	3 credits [3-0-0]

Structure and function of cell and its organelles. Cell as the unit of life- Development of cell theory, Cell types: prokaryotes vs. eukaryotes; from single cell to multi-cellular organism; Prokaryotic cells: Structure, cell-walls and related molecules, outer membrane, flagella, motivity, cell inclusion endospores, gas vesicles, capsules, slime layers ; Cell architecture, cyto-skeletal components, microtubules and microfilaments, motility and motor motions, actomyosin complex. Membrane system: Biological membranes - architecture & kinetics (transport, ion channels, diffusion, Na-K pump, proton pump). Endomembrane system: endoplasmic reticulum, Golgi complex, endosomes, lysosomes. Cell signaling:- Membrane domains, Lipid rafts, messengers and receptors. Extra-cellular matrix, Cell nucleus, Chromatin structure, nucleolus, nucleoplasm. Energy Transduction and Bioenergetics: Mitochondria, ATP, Chemiosomes, ATPase, Gap junctions Chloroplast – photosynthetic electron transport, Calvin cycle. Anti-reductionism: Cell division: Mitosis, meiosis and cytokinetics, animal and yeast cell division, cell cycle control, programmed cell death. Cell cycle: G0/G1, S, G2 and M phages, duration of different phages and the methods for their determination, Cell cycle synchronization, arrest and delay in case of diseases. Protein localization: Synthesis of secretory &membrance protein, import into nucleus, mitochondria, chloroplast & peroxisome; Receptor-mediated endocytosis.

Essential Reading:

1. B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, Essential Cell Biology : *An Introduction to the Molecular Biology of the Cell*, Garland Publishing Company
2. De Robertis*, Cell and Molecular Biology*, B .I. Publication Pvt. Ltd
3. H. Lodish, A.Berk, S.L. Zipursky, P. Matsudaura, D. Baltimore and J. Danell, *Molecular Cell Biology*, W.H. Preeman and Company.
4. B. Alberts, D. Bray, A. Johnson, J. Lewis, M. Roff, K. Robert, P. Walter and K. Roberts, *Essential Cell Biology : An Introduction to the Molecular Biology of the Cell*, Garland Publishing Company

Supplementary Reading:

1. E.B. Wilson, *Cell in Development and Inheritance*, Macmillan

LS 410	**FOOD SCIENCE**	**4 credits [3-1-0]**

Unit- 1: Principles of food processing and preservation: Scope and importance of food processing: national and international perspectives, Principles of Preservation methods, fermentation methods for preservation, and chemical ; preservations of foods. Food preservation by low-temp: Refrigeration, freezing and freeze-drying. Food preservation by heating: drying, osmotic dehydration, blanching, canning, pasteurization, sterilization, extrusion cooking. Non-thermal preservation: Hydrostatic pressure, dielectric heating, microwave processing, hurdle technology, membrane technology, irradiation. ; **Unit- 2: Food chemistry** ;Food chemistry-definition and importance, Carbohydrates-chemical reactions, functional ; properties of sugars and polysaccharides in foods. Applications and preparations of sugars and polysaccharides. Protein and amino acids: structure, classifications, sources, denaturation and functional properties of proteins. Lipids: classification, and use of lipids in foods, physical and chemical properties, effects of processing on functional properties. Vitamins and Minerals, Effect of processing on vitamins and minerals.Enzymatic browning in foods and industrial applications of enzymes.Water in food, water activity and shelf life of food. ; **Unit- 3: Principles of food engineering** ; Unit operation in food engineering, Mass and energy balance, Fluid flow, fluid statics, fluid dynamics, fluid flow applications, Heat transfer-modes of heat transfer, conduction,convection, and radiation, heat exchangers and their designs. Thermal processing- vaporation and concentration, dehydration, drying, blanching, pasteurization, sterilization, distillation and crystallization. Mechanical separation-filtration, membrane concentration, sieving, centrifugation, sedimentation, Mechanical handling-conveying and elevation.Size reduction and classification-mixing, kneading, blending. ; **Unit- 4: Fermentation technology** ;Introduction to fermentation: Rate of microbial growth and death. Fermentation kinetics, Types of fermentation sub-merged/solid state, Batch /continuous fermentation. Fermenter design, operation, measurement and control in fermentation, Aeration and agitation in fermentation: Oxygen requirement, measurement of adsorption coefficients, sterilization of air and media; scale up in fermentation. Production of beer, wine and vinegar, Traditional fermented foods like idli and dosa. Principles of down stream processing and Product recovery.Production of alcohols, organic acids, enzymes and immobilization of enzymes.**; Unit- 5: Food quality and safety management** ;Objectives, importance and functions of quality control. Methods of quality, assessmentof food materials-fruits, vegetables, cereals, dairy products, meat, poultry, egg and processed food products.Sanitation and hygiene, GMP, GLP, Statistical quality control.Food laws and standard, PFA, AGMARK.Sampling and specification of raw materials and finished products, Concept of Codex Almentarious/ /USFDA/ISO 9000 series, rules and regulations for waste disposals.Food adulteration and food safety.HACCP, Sensory evaluation-introduction, panel screening, Sensory and instrumental analysis in quality control, IPR and patents.

Essential Reading:

1. Norman N. Potter and Joseph H. Hotchkiss, *Food Science*
2. Geoffrey Cambell-Platt, *New Text Book on Food Science and technology*, Editor Scientific publishers and Reviews

LS 411 BIOPHYSICS 4 credits [3-1-0]

Thermodynamic Principles: Laws of thermodynamics, Details of thermodynamic variables and functions. Application of there laws in Life Science with examples. Basic atomic and radiation physics.Electromanetic properties of light and basic molecular physics.Interaction of UV, VIS and IR radiation and LASER with bio-molecules and living system, Bio- and chemi-luminescence, photochemical reaction. Thermal changes in cells and tissues, thermal modeling in biological tissues, Biological transport processes, Nernst potential and Donnan potential – surface potential and potential across bio-membranes, biological energy conversion. Electromagnetic energy spectrum – their effects on the molecules and method of studying them, Raman, NMR, NOESY and TOCSY, ESR spectroscopy and Mass spectrometry, and their biological applications, optical rotatory dispersion, fluorescence, phosphorescence spectroscopy, circular dichroism, X-ray diffraction (structure of DNA, RNA and Proteins), ultrastructure determination, electron microscopy – transmission and scanning. Concept of liquid crystals, Principal component analysis, Matrices, analysis of spectral data with MetLab. Radioactivity: Radio emission, law of radioactive decay, production of radio isotopes for medical use, electromagnetic radiation, interaction of radiation with matter, exponential attenuation, half value thickness, photo electric, Compton and pair production process and their significance in radiology, radiation units, detection and measurements of radiation ; Introduction of ultrasonic wave: Ultrasonic wave motion, wave characteristics, intensity, and ultrasound properties in body. Use of ultrasound in biological field.

Essential Reading:

1. L. Stryer, W.H. Freeman and Co, *Biochemistry*
2. J. G. Morris, *A biologists physical chemistry* by Edward Arnold (Publishers) Ltd.

Supplementary Reading:

1. U. N. Dash, *Textbook of Biophysical Chemistry* by MacMillan
2. R.N. Roy, *A Textbook of Biophysics* by New Central Book Agency

LS 412 ADVANCED MICROBIAL GENETICS 4 credits [3-1-0]

Professor-in-charge: Dr. Bismita Nayak

Unit – 1: DNA Structure and Mutagenesis ; Historical developments in genetics, discovery of DNA and experimental evidence, Structure of Circular DNA molecule, Primary, Secondary, Tertiary and Quaternary structure of DNA, Watson and Crick model of double stranded DNA the law of DNA constancy and C value paradox and topological manipulations. ; DNA replication: DNA replication mechanism, enzymes involved in DNA replication and models of DNA replication. Molecular basis of spontaneous and induced mutations [physical and chemical mutagenic agents], types of mutation: point, frameshift, lethal, conditional lethal, inversion and deletion, null mutation, reversion of mutations, intra and intergenic suppression mutations. Environmental mutagenesis, toxicity testing and population genetics.Systems that safeguard DNA. DNA methylation and DNA repair mechanisms - excision, mismatch, SOS ,photoreactivation, recombination repair and glycocylase system. ; Unit – 2: Prokaryotic Transcription and Translation ; Organization of transcriptional units and regulation of gene expression Mechanism of transcription of prokaryotes-Structure and function of RNA polymerase, [DNA foot printing], termination and antitermination – N proteins and nut sites in DNA binding proteins, enhancer sequences and control of transcription, RNA processing (Capping, polyadenylation, splicing, introns and exons) Ribonucleoprotein, structure of mRNA, rRNA, tRNA. Direction of protein synthesis, RNA template, direction with experimental proof, tRNA as adaptor, ribosomes and their organization in prokaryotes, polycistronic mRNA in bacteria, initiation of translation in bacteria, small sub-units, its accessory factors, SD sequence in bacteria, initiator tRNA, elongation of translation, translocation and termination mechanisms. Post-translational modification. Salient features of genetic code. ; Unit – 3: Regulation of gene expression in prokaryotes ; Operon concept, co-ordinated control of structural genes, stringent response, catabolite repression, instability of bacterial RNA, positive regulation in E.coli [Arabinose operon] and negative regulation in E.coli [lac operon], inducers and repressors, regulation by attenuation by trp operon. ; Unit – 4: Genetic recombination ;Genetic recombination processes: Role of rec proteins in homologous recombination. Conjugation: Discovery, F+, F- and Hfr cells, types of Hfr; F+ and F- and Hfr and F- genetic crosses. Mechanism of conjugation.Sexduction, conjugational transfer of colicinogenic and resistance transfer factors.Genetic mapping. Plasmid Replication and Incompitability, Control of copy number. ; Transposons – Insertion sequences and composite transposons, phages as transposons, replicative, non-replicative and conservative transposition. Mutations i.e. deletions, inversions and frameshift due to transposition.Mechanism of transposition, controlling elements of maize – autonomous and non-autonomous elements.Types of transposons and their properties. ; Unit – 5: Phage Genetics ;T4 virulent phage: structure, life cycle, genetic map and DNA replication. Lamda temperate phage: Structure, genetic map, lytic and lysogenic cycle, lysogenic repression and phage immunity. [Lambda regulon] applications of phages in microbial genetics.

Essential Reading:

1. J. Dale and S. Park*, Molecular genetics of bacteria* by Wiley
2. S. R. Maloy, *Microbial genetics* by Jones and Bartlett Publishers Inc.

LS 413	**BASIC BIOPHYSICS**	**3 credits [3-0-0]**

Professor-in-charge: Dr. Samir K Patra

Thermodynamic Principles: Laws of thermodynamics, Details of thermodynamic variables and functions. Application of there laws in Life Science with examples. Basic atomic and radiation physics.Electromanetic properties of light and basic molecular physics.Interaction of UV, VIS and IR radiation and LASER with bio-molecules and living system, Bio- and chemi-luminescence, photochemical reaction. Thermal changes in cells and tissues, thermal modeling in biological tissues, Biological transport processes, Nernst potential and Donnan potential – surface potential and potential across bio-membranes, biological energy conversion. Electromagnetic energy spectrum – their effects on the molecules and method of studying them, Raman, NMR, NOESY and TOCSY, ESR spectroscopy and Mass spectrometry, and their biological applications, optical rotatory dispersion, fluorescence, phosphorescence spectroscopy, circular dichroism, X-ray diffraction (structure of DNA, RNA and Proteins), ultrastructure determination, electron microscopy – transmission and scanning. Concept of liquid crystals, Principal component analysis, Matrices, analysis of spectral data with MetLab. Radioactivity: Radio emission, law of radioactive decay, production of radio isotopes for medical use, electromagnetic radiation, interaction of radiation with matter, exponential attenuation, half value thickness, photo electric, Compton and pair production process and their significance in radiology, radiation units, detection and measurements of radiation ; Introduction of ultrasonic wave: Ultrasonic wave motion, wave characteristics, intensity, and ultrasound properties in body. Use of ultrasound in biological field.

Essential Reading:

1. L. Stryer, *Biochemistry* by W.H. Freeman and Co.
2. J. G. Morris, *A biologists physical chemistry* by Edward Arnold (Publishers) Ltd.

Supplementary Reading:

1. U. N. Dash, *Textbook of Biophysical Chemistry* by MacMillan
2. R.N. Roy, *A Textbook of Biophysics* by New Central Book Agency

LS 414	**MICROBIAL GENETICS**	**3 credits [3-0-0]**

Professor-in-charge: Dr. Surajit Das

Unit – 1: DNA Structure and Mutagenesis ; Historical developments in genetics, discovery of DNA and experimental evidence, Structure of Circular DNA molecule, Primary, Secondary, Tertiary and Quaternary structure of DNA, Watson and Crick model of double stranded DNA the law of DNA constancy and C value paradox and topological manipulations. ; DNA replication: DNA replication mechanism, enzymes involved in DNA replication and models of DNA replication. Molecular basis of spontaneous and induced mutations [physical and chemical mutagenic agents], types of mutation: point, frameshift, lethal, conditional lethal, inversion and deletion, null mutation, reversion of mutations, intra and intergenic suppression mutations. Environmental mutagenesis, toxicity testing and population genetics.Systems that safeguard DNA. DNA methylation and DNA repair mechanisms - excision, mismatch, SOS ,photoreactivation, recombination repair and glycocylase system. ; Unit – 2: Prokaryotic Transcription and Translation ; Organization of transcriptional units and regulation of gene expression Mechanism of transcription of prokaryotes-Structure and function of RNA polymerase, [DNA foot printing], termination and antitermination – N proteins and nut sites in DNA binding proteins, enhancer sequences and control of transcription, RNA processing (Capping, polyadenylation, splicing, introns and exons) Ribonucleoprotein, structure of mRNA, rRNA, tRNA. Direction of protein synthesis, RNA template, direction with experimental proof, tRNA as adaptor, ribosomes and their organization in prokaryotes, polycistronic mRNA in bacteria, initiation of translation in bacteria, small sub-units, its accessory factors, SD sequence in bacteria, initiator tRNA, elongation of translation, translocation and termination mechanisms. Post-translational modification. Salient features of genetic code. ; Unit – 3: Regulation of gene expression in prokaryotes ; Operon concept, co-ordinated control of structural genes, stringent response, catabolite repression, instability of bacterial RNA, positive regulation in E.coli [Arabinose operon] and negative regulation in E.coli [lac operon], inducers and repressors, regulation by attenuation by trp operon. ; Unit – 4: Genetic recombination ;Genetic recombination processes: Role of rec proteins in homologous recombination. Conjugation: Discovery, F+, F- and Hfr cells, types of Hfr; F+ and F- and Hfr and F- genetic crosses. Mechanism of conjugation.Sexduction, conjugational transfer of colicinogenic and resistance transfer factors.Genetic mapping. Plasmid Replication and Incompitability, Control of copy number. ; Transposons – Insertion sequences and composite transposons, phages as transposons, replicative, non-replicative and conservative transposition. Mutations i.e. deletions, inversions and frameshift due to transposition.Mechanism of transposition, controlling elements of maize – autonomous and non-autonomous elements.Types of transposons and their properties. ; Unit – 5: Phage Genetics ;T4 virulent phage: structure, life cycle, genetic map and DNA replication. Lamda temperate phage: Structure, genetic map, lytic and lysogenic cycle, lysogenic repression and phage immunity. [Lambda regulon] applications of phages in microbial genetics.

Essential Reading:

1. J. Dale and S. Park, *Molecular Genetics of Bacteria* by Wiley
2. S. R. Maloy, *Microbial genetics* by Jones and Bartlett Publishers Inc.

LS 420	BIOINFORMATICS	4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

Basic concepts, PubMed, OMIM and BLAST search tools. Definition and significance of Pairwise and Multiple Sequence Alignment, Methods and algorithms used in Pairwise alignment: Dot Matrix, Dynammic Programming Algorithm and k-tuple. Methods for doing MSA: CLUSTALW and PILEUP, Scoring MSA. Algorithms used in Database similarity searching: BLAST and FASTA. Definition of Profile and Pattern.PSI-BLAST and PHI-BLAST. Phylogenetic analysis: Concept and method: Distance based (Fitch and Margoliash& UPGMA) and character based methods (Parsimony). Introduction of protein structure prediction, and gene prediction.Ethical, legal and social implications of Biotechnological products.IPR and Patents.Genetically modified organisms and their acceptability.Concept of Object Oriented Programming (C++) and PERL and their application in Bioinformatics.Some basic commands of UNIX, Concept of DBMS and SQL.Commands of SQL for database management using Oracle.Scoring matrices: PAM and BLOSUM series.

Essential Reading:

1. D.W. Mount*, Bioinformatics: Sequence and Genome Analysis* by Cold Spring Harbor Laboratory Press
2. A.D. Baxevanis and B.F.F. Ouellette, *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* by Wiley-interscience.
3. T. Attwood and D. Parry-Smith*, Introduction to Bioinformatics*, Prentice Hall

Supplementary Reading:

1. J.M. Bower and H. Bolouri, *Computational Modeling of Genetic and Biochemical Networks* by MIT Press
2. P.A. Pevzner, *Computational Molecular Biology: An Algorithmic Approach* by MIT Press

LS 421	RADIATION BIOLOGY	4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

Basic concept of electromagnetic radiations, radiation dose and dosimetry. Photolysis of water, UV-radiation induced damage to DNA and various repair pathways. Rapidly accumulating advancement in the field of Radiobiology, Radio-oncology, Diagnostic Radiology.

Essential Reading:

1. Devi Nagarathnam and Rao, B. I. Churchil Livingstone, *Introduction to radiation biology*

LS 422	CELL SIGNALING	4 credits [3-1-0]

Professor-in-charge: Dr. Sujit K. Bhutia

A. Cell signaling: Hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component signaling systems, bacterial chemotaxis and quorum sensing. ; B. Cellular communication: Regulation of hematopoiesis, general principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation. ; C. Cancer : Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, interaction of cancer cells with normal cells, apoptosis, therapeutic interventions of uncontrolled cell growth. ; D. Specific pathways:- Chromatin Regulation; Ras, MAPK and Ras-MAPK Signaling; Apoptosis/Autophagy, PI3K/Akt Signaling, Translational Control; Ca, cAMP& Lipid Signaling, Cell Cycle/Checkpoint, DNA Damage, Jak/Stat Pathway, NF-κB Signaling, TGF-β/Smad Signaling, Lymphocyte Signaling, Neuroscience, Tyrosine Kinase/Adaptors, Angiogenesis, Vesicle Trafficking, Cytoskeletal Signaling, Adhesion, Glucose Metabolism, Wnt/Hedgehog/Notch, Stem Cell/Lineage Markers, Nuclear Receptors.

Essential Reading:

1. B. Alberts et al, *Molecular Biology of the cell* by Garland Science Com
2. Lodish et al, *Molecular cell Biology* by W H Freeman and Company
3. J. Nelson, *Structure and Function* in Cell Signalling by Wiley.
4. Ernst J. M. Helmreich, *The biochemistry of cell signalling* by Oxford Uni Press

LS 423	ADVANCED TECHNIQUES	3 credits [3-0-0]

Professor-in-charge: Dr. Surajit Das

Spectroscopy – Concepts of spectroscopy, Visible and UV spectroscopy, Laws of photometry. Beer-Lambert's law, Principles and applications of colorimetry, Mass Spectroscopy, LC-MS, LC-MS-MS, GC-MS-MS ; Chromatography – Dialysis, Principles of partition chromatography, paper, thin layer, ion exchange and affinity chromatography, gel permeation chromatography, HPLC and FPLC ; Centrifugation – Principles of centrifugation, concepts of RCF, different types of instruments and rotors, preparative, differential and density gradient centrifugation, analytical ultra-centrifugation, determination of molecular weights and other applications, subcellular fractionation ; Electrophoretic techniques – Principles of electrophoretic separation. Continuous, zonal and capillary electrophoresis, different types of electrophoresis including paper, cellulose, acetate/nitrate and gel. Electroporation, pulse field gel electrophoresis, EMSA, DNA fingerprinting, and foor printing. ; Molecular Biology techniques- Hybridization and blotting, PCR, RT-PCR, Real time PCR, RFLP, AFLP, Chromosome walking, chromosome jumping, DNA microarray, chips and RIA. Methods of DNA sequencing: Sangers sequencing, 454 sequencing. Analysis of SINES and LINES.Genomic insulators. ; Electron microscopy – Transmission and scanning, freeze fracture techniques, specific staining of biological materials. Spectroscopic techniques: Absorption, Florescence, ORD, CD, X-ray diffraction, X-ray absorption, and NMR. ; Advances in Viscosity and surface tension measurement– Viscosity of macromolecules, relationship with conformational changes.

Essential Reading:

1. K. Wilson and J. Walker, *Principles of Biochemistry and molecular biology* by Cambridge University Press.
2. D. A. Skoog and J. J. Leary, *Principles of Instrumental analysis* by Saunders College Publishing, Philadelphia

LS 424	PROTEOMICS	4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

Definition, classification, and scopes. The emergence of proteome concept: structural and functional proteomes, protein structure related to functional kinetics, e.g. prions, bridging genomics to proteomics. Transcriptomes: measurement of gene expression. Proteome analysis: by methods, 2-D PAGE including protein detection on electro-blot membrane, mass spectrometry and phosphorylation site analysis. Proteomics in relation to animal and plant health and welfare.

Essential Reading:

1. C Subramanian and N. Hazare, *A Textbook of Protein and Proteomics*, Dominant Pub.
2. A.Malcolm Campbell and Laurie J. Heyer, *Discovering Genomics, Proteomics and Bioinformatics* (2nd Edition).

LS 425	INTRODUCTION TO BIOINFORMATICS	3 credits [3-0-0]

Professor-in-charge: Dr. Samir K Patra

Basic concepts, PubMed, OMIM and BLAST search tools. Definition and significance of Pairwise and Multiple Sequence Alignment, Methods and algorithms used in Pairwise alignment: Dot Matrix, Dynammic Programming Algorithm and k-tuple. Methods for doing MSA: CLUSTALW and PILEUP, Scoring MSA. Algorithms used in Database similarity searching: BLAST and FASTA. Definition of Profile and Pattern.PSI-BLAST and PHI-BLAST. Phylogenetic analysis: Concept and method: Distance based (Fitch and Margoliash& UPGMA) and character based methods (Parsimony). Introduction of protein structure prediction, and gene prediction.Ethical, legal and social implications of Biotechnological products.IPR and Patents.Genetically modified organisms and their acceptability.Concept of Object Oriented Programming (C++) and PERL and their application in Bioinformatics.Some basic commands of UNIX, Concept of DBMS and SQL.Commands of SQL for database management using Oracle.Scoring matrices: PAM and BLOSUM series.

Essential Reading:

1. D.W. Mount*, Bioinformatics: Sequence and Genome Analysis* by Cold Spring Harbor Laboratory Press
2. A.D. Baxevanis and B.F.F. Ouellette,*Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* by Wiley-interscience.
3. T. Attwood and D. Parry-Smith*, Introduction to Bioinformatics*, Prentice Hall

Supplementary Reading:

1. J.M. Bower and H. Bolouri, *Computational Modeling of Genetic and Biochemical Networks* by MIT Press
2. P.A. Pevzner, *Computational Molecular Biology: An Algorithmic Approach* by MIT Press

LS 426 INTRODUCTION TO PROTEOMICS 3 credits [3-0-0]

Professor-in-charge: Dr. Samir K Patra

Definition, classification, and scopes. The emergence of proteome concept: structural and functional proteomes, protein structure related to functional kinetics, e.g. prions, bridging genomics to proteomics. Transcriptomes: measurement of gene expression. Proteome analysis: by methods, 2-D PAGE including protein detection on electro-blot membrane, mass spectrometry and phosphorylation site analysis. Proteomics in relation to animal and plant health and welfare.

Essential Reading:

1. C Subramanian and NandanHazare, *A Textbook of Protein and Proteomics*, Dominant Pub.
2. A.Malcolm Campbell and Laurie J. Heyer, *Discovering Genomics, Proteomics and Bioinformatics* (2nd Edition).

LS 435 MICROBIAL DIVERSITY AND EXTREMOPHILES 3 credits [3-0-0]

Professor-in-charge: Dr. Surajit Das

Unit – 1: Biodiversity ;Introduction to microbial biodiversity – distribution, abundance, ecological niche. Types-Bacterial, Archael and Eucaryal. ; Unit – 2: Characteristics and classification of Archaebacteria ;Thermophiles: Classification, hyperthermophilic habitats and ecological aspects. Extremely ThermophilicArchaebacteria, Thermophily, commercial aspects of thermophiles.Applications of thermozymes.Psychrophiles. Methanogens: Classification, Habitats, applications. ; Unit – 3: Alkalophiles and Acidophiles ;Classification, alkaline environment, soda lakes and deserts, calcium alkalophily Applications. Acidophiles: Classification, life at low pH, acidotolerence, applications. ; Unit – 4: Halophiles and Barophiles ;Classification, Dead Sea, discovery basin, cell walls and membranes – Purple membrane, compatible solutes. Osmoadaptation / halotolerence.Applications of halophiles and their extremozymes.Barophiles: Classification, high-pressure habitats, life under pressure, barophily, death under pressure. ; Unit – 5: Space Microbiology ;Aims and objectives of Space research. Life detection methods a] Evidence of metabolism (Gulliver) b] Evidence of photosynthesis (autotrophic and heterotrophic) c] ATP production d] Phosphate uptake e] Sulphuruptake .Martian environment (atmosphere, climate and other details).Antartica as a model for Mars. Search for life on Mars, Viking mission, Viking landers, and Biology box experiment. Gas exchange , Label release and pyrolytic release experiments. Monitoring of astronauts microbial flora: Alterations in the load of medically important microorganisms, changes in mycological autoflora, and changes in bacterial autoflora.

Essential Reading:

1. K. Horikoshi and W. D. grant, *Extremophiles: Microbial life in Extreme Environments* by Wiley Liss
2. C. Gerday and N. Glansdorff, *Physiology and biochemistry of Extremophiles* by ASM Press.

LS 440 PHYSICAL SCIENCES AND INSTRUMENTATION 4 credits [3-1-0]

Professors-in-charge: Dr. Samir K Patra (Physical Sciences) and Dr. Surajit Das (Instrumentation)

Physical sciences ; Reductionism vs. holistic view of living system, Debate on the definition of Life:- Molecular view: Koshland's concept – Seven Pillars of Life: Program, Improvisation, Compartmentalization, Energy, Regeneration, Adaptability, and Seclusion (PICERAS). Thermodynamics Principles: laws of thermodynamics, Details of thermodynamic variables and functions. Application of thermodynamics to biology. Structure of atoms, molecules and chemical bonds. Composition, structure and function of biomolecules (carbohydrates, lipids, proteins, nucleic acids and vitamins).Stablizing interactions (Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction, etc.). Water structure and polarity. Principles of biophysical chemistry (pH, buffer, reaction kinetics, thermodynamics, colligative properties). Stereochemistry: Configuration and conformation and stability; Elements of symmetry, Chirality; RS-, EZ, DL- and dl- system of nomenclature; Stereo-specific and stereo-selective reactions; Determination of relative configuration by asymmetric synthesis ; Instrumentation ;Unit- 1: Chromatography ; Paper, TLC, gel filtration, ion-exchange chromatography, affinity chromatography, HPLC and GLC ; Unit- 2: Microscopy; Optical microscopy, Bright field, Dark field, phase contrast and fluorescence microscopy. Electron microscopy: Transmission and scanning electron microscopy ; Unit- 3: Centrifugation ;Principle of centrifugation, rotors, different types of centrifuges, preparative and analytical centrifugation, ultra centrifugation ; Unit- 4: Electrophoresis ;Gel electrophoresis, SDS-PAGE, isoelectric focusing, two -dimensional electrophoresis, immuno electrophoresis, capillary electrophoresis ; Unit- 5: Spectroscopy ;Atomic Absorption, spectrophotometry, Mass spectrometry, NMR.

Essential Reading:

1. K. Wilson and J. Walker, *Principles of Biochemistry and molecular biology*, Cambridge University Press.
2. D. A. Skoog and J. J. Leary, *Principles of Instrumental analysis* by Saunders College Publishing, Philadelphia

LS 471	MICROBIOLOGY LAB	2 credits [0-0-3]

Professor-in-charge: Dr. Surajit Das

To study the guidelines for working in microbiology laboratory ; To acquaint with the instrument used in microbiology laboratory ; To study the various aseptic techniques used in microbial experiment ; To prepare various liquid and solid media used in microbiology experiment ; To isolate and count total heterotrophic bacteria in soil sample ; To isolate and count total heterotrophic microbes from air ; To isolate and count total heterotrophic bacteria in water sample ; To isolate pure culture from mixed culture by streak plate method ; To perform fungal staining for the study of fungal morphology ; To perform simple staining and to compare the morphological shape and arrangements' of bacteria cells ; To perform gram staining or differential staining to study the bacterial morphology and distinguish between gram positive and gram negative bacteria ; To test starch hydrolysis by amylase activity ; To test protein hydrolysis by gelatin degradation ; Preparation of agar slant ; To study catalase activity ; To study motility of bacteria by tube method: MPN ; Antibiotic sensitivity test ; IMViC test ; Isolation of Actinobacteria from soil samples.

LS 472	BIOCHEMISTRY LAB	2 credits [0-0-3]

Professor-in-charge: Dr. Samir K Patra

Estimation of blood glucose, detection of serum- (i) urea, (ii) uric acid, (iii) creatine, (iv) creatinine and (v) bile pigment ; Blood grouping (ABO – Rh) ; Determination of urine sample for (i) sugar, (ii) ketone bodies, (iii) protein ; Estimation of Hb concentration, total W.B.C and R.B.C count in blood ; Determination of lipid, total cholesterol, LDL and HDL and triglycerides ; Enzymology – purification of enzyme & its kinetics ; Study of the cell – (i) Cell culture, lymphocyte isolation & culture, growth rate studies, staining techniques (ii) Cell fractionation, homogenization of the tissue, centrifugation, marker enzyme assays (iii) Microscopy and microphotography ; Quantitative assays – (i) Enzyme assays (ii) RIA (iii) ELISA iv) DNA, RNA & proteins ; Protein fractionation – (i) Salting in and out, gel filtration, electrophoretic separation (ii) Gel filtration affinity based techniques (iii) SDS-PAGE (iv) Electrophoretic separation of LDH isoenzymes ; Absorption & fluorescence spectroscopy related experiments ; Determination of CMC of biological surfactants.

LS 473	BIOTECHNOLOGY LAB	4 credits [3-1-0]

Professor-in-charge: Dr. Surajit Das

Quantitation of nucleic acids (Spectrophotometric, Gel based and Saran wrap method) ; Analysis of DNA fragments and size determination by agarose gel electrophoresis ; Restriction digestion and ligation ; Restriction mapping ; Southern blotting ; Western blotting ; PCR and RT-PCR ; Optimization of gene expression in E.coli and analysis of expressed product ; Methods for enzyme immobilization

LS 474 MOLECULAR BIOLOGY LAB 2 credits [0-0-3]

Professor-in-charge: Dr. Samir K Patra

Determination of Isobestic points ; Determination of melting point of DNA (Calf thymus, Whale Sperm) ; Isolation of chromosomal DNA from E.coli and plants ; Isolation of RNA from mammalian cells (sources- horse, rat, rabbit etc.) ; SDS-PAGE of protein ; Isolation of plasmid DNA from E.coli ; Transformation of E.coli with plasmid ; UV induced mutagenesis in E. coli ; Tissue culture

LS 475 IMMUNOLOGY LAB 2 credits [0-0-3]

Professor-in-charge: Dr. Bismita Nayak

Study of Blood Groups ; Study of Antigen- Antibody pattern-ODD ; Immunoglobulin Y purification ; Immunoglobulin G purification ; Study of immunohistochemistry ; Study of Latex agglutination ; Study of haem agglutination ; Study of antibody-FITC conjugation

LS 501 ECOLOGY AND ENVIRONMENTAL SCIENCES 4 credits [3-1-0]

Professor-in-charge: Dr. Surajit Das

Unit- 1: Scope of ecology and environmental sciences;Definition, principles and scope of ecology. Human ecology and human settlement, Evolution- origin of life and speciation.Definition, principles and scope of Environmental Science.Earth, man and environment.Ecosystems- pathways in Ecosystems.Physico-chemical and Biological factors in the environment.Geographical classification and zones.Structure and composition of atmosphere, hydrosphere, lithosphere and biosphere. ; Unit- 2: Ecosystem structure and functions ;Ecosystems: Structure and functions, abiotic and biotic components, energy flows. Food chains, food web, ecological pyramids, types and diversity.Energy flow and mineral cycling (CNP); primary production and decomposition. Structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (fresh water, marine, estuarine). ; Unit- 3: Habitat and ecological components ;Habitat and niche: Concept of habitat and niche; niche width and overlap; fundamental and realized niche; resource partitioning; character displacement. ; Population ecology: Characteristics of a population; population growth curves; population regulation; life history strategies (r and K selection); concept of metapopulation – demes and dispersal, interdemic extinctions, age structured populations. ; Species interactions: Types of interactions, interspecific competition, herbivory, carnivory, pollination, symbiosis. ; Community ecology: Nature of communities; community structure and attributes; levels of species diversity and its measurement; edges and ecotones. ; Ecological succession: Types; mechanisms; changes involved in succession; concept of climax. ; Unit- 4: Biogeography and applied ecology ;Major terrestrial biomes; theory of island biogeography; biogeographical zones of India. Environmental pollution; global environmental change; biodiversity-status, monitoring and documentation; major drivers of biodiversity change; biodiversity management approaches. ; Unit- 5: Conservation biology ;Principles of conservation, major approaches to management, Indian case studies on conservation/management strategy (Project Tiger, Biosphere reserves).

Essential Reading:

1. E. P. Odum and G. W. Barrett, *Fundamentals of Ecology* by Cengage Learning
2. Peter Cotgreave, Irwin Forseth, *Introductory Ecology* by Wiley International.
3. S. C. Santra, *Environmental Science* by New Central Book Agency, India.
4. P. D. Sharma, *Ecology and Environment* by Rastogi Publications, India.

Supplementary Reading:

1. P. J. Russell, S. L. Wolfe, P. E. Hertz, C. Starr and B. McMillan, *Ecology* by Cengage Learning
2. J. L. Chapman and M. J. Reiss, *Ecology: Principles and applications* by Cambridge University Press.

LS 502 ADVANCES IN STRUCTURAL BIOLOGY 4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

A familiarity with the NMR, X-ray, and computational techniques used to study macromolecular structure, motions in macromolecules and the functional importance of dynamics, the basis for various types of macromolecular interactions including protein- protein and protein-nucleic acid interactions, evolutionary relationships of structural features, the determinants of protein structure and an understanding of the current views of protein folding, the chemical basis for interactions with enzyme inhibitors and other ligands. History of Structural Biology: X-ray crystallographic and NMR-structure of Proteins, and Nucleic acids. Proposition of DNA double helical structure in understanding the blue-print of life- Watson & Crick model.Fine structure of Proteins- fibrous, globular and membrane proteins, Nucleosome and Chromatin structure.Cytoskeleton structure and protein-protein Network, Muscle proteins.Structure of Heart, Lung and Brain.

Essential Reading:

1. Anders Lilgas, Lars Lilgas, JuiPiskur et al, *Textbook of Structural biology* by World Scientific Publisher
2. S. K. Malhotra (Editor), *Advances in structural biology* by Elsevier.
3. Mary Luckey, *Membrane structural biology* by Barnes and Noble Publisher.

LS 503 RECOMBINANT DNA TECHNOLOGY 3 credits [3-0-0]

Professor-in-charge: Dr. Surajit Das

Unit- 1: Introduction to the subject and the tools used in RDT ;Restriction endonuclease, methyltransferase, ligase, polymerase, kinase, phosphatase, nuclease, transferase, reverse transcriptase, linkers, adapters DNA, RNA and protein markers. ; Unit- 2: Overview of cloning vectors ;Plasmids, bacteriophages (Lambda and M13), phagemids, cosmids, artificial chromosomes (YAC, BAC). ; Unit- 3: Blotting techniques. hybridization and Nucleic acid amplification ; Southern, Northern and Western blotting techniques. Radioactive and non-radioactive probes. Basics of PCR, site directed mutagenesis. ; Unit- 4: Cloning and selection of clones ; Basic cloning experiment: Design of cloning strategy and stepwise experimental procedure including application of tools introduced in module I. Complementation, colony and plaque hybridization, restriction, PCR, plus-minus screening, immunoscreening. ; Unit- 5: Heterologous gene expression ;Overview of expression vectors (Bacteria and yeast), vector engineering (fusion tags, antibiotic markers), codon optimization, host engineering ; Unit- 6: DNA Libraries ; Purpose of constructing DNA libraries. Construction of cDNA and genomic libraries. ; Unit- 7: Advanced techniques in RDT ; Primer extension mapping, S1 mapping, RNase protection assay, two and three hybrid systems, subtractive hybridization, gel retardation assay, DNasefootprinting, in vitro transcription and translation, phage display, DNA sequencing (Maxam Gilbert, Sanger's and automated), protein engineering.

Essential Reading:

1. R.W. Old and S. B Primrose, *Principles of Gene Manipulation: An Introduction to Genetic Engineering*, Blackwell Science Inc.
2. D.M. Glover and B.D. Hames, *DNA Cloning: A Practical Approach*, IRL Press.
3. J. Sambrook, E.F. Fritsch and T. Maniatis, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor, Laboratory Press.

Supplementary Reading:

1. B.R. Grick and J.J. Pasternak, *Molecular Biotechnology: Principles and Applications of Recombinant DNA*, ASM Press
2. P.B Kaufman, W. Wu, D. Kim and C.J. Cseke, *Molecular and Cellular Cells Methods in Biology and Medicine*, CRC Press.
3. J.A. Bavies and W.S. Reznikoff, *Milestones in Biotechnology: Classic Papers on Genetic Engineering*, Butterworth Heinemann.

LS 507	STRUCTURAL BIOLOGY	3 credits [3-0-0]

Professor-in-charge: Dr. Samir K Patra
A familiarity with the NMR, X-ray, and computational techniques used to study macromolecular structure, motions in macromolecules and the functional importance of dynamics, the basis for various types of macromolecular interactions including protein- protein and protein-nucleic acid interactions, evolutionary relationships of structural features, the determinants of protein structure and an understanding of the current views of protein folding, the chemical basis for interactions with enzyme inhibitors and other ligands. History of Structural Biology: X-ray crystallographic and NMR-structure of Proteins, and Nucleic acids. Proposition of DNA double helical structure in understanding the blue-print of life- Watson & Crick model.Fine structure of Proteins- fibrous, globular and membrane proteins, Nucleosome and Chromatin structure.Cytoskeleton structure and protein-protein Network, Muscle proteins.Structure of Heart, Lung and Brain.

Essential Reading:
1. Anders Lilgas, Lars Lilgas, JuiPiskur et al, *Textbook of Structural biology* by World Scientific Publisher
2. S. K. Malhotra (Editor), *Advances in structural biology* by Elsevier.
3. Mary Luckey, *Membrane structural biology* by Barnes and Noble Publisher.

LS 511	GENETICS	4 credits [3-1-0]

Professor-in-charge: Dr. Sujit K. Bhutia
Introduction to Genetics: Mendelism, Mendel and his experiments, Law of segregation, Law of independent assortment, Application of laws of probability (product rule, sum rule), Chromosomal basis of segregation and independent assortment. ; Extensions of Mendelism: Codominance, incomplete dominance, gene interactions, pleiotropy, genomic imprinting, penetrance and expressivity, phenocopy, linkage and crossing over, sex linkage, sex limited and sex influenced characters. ; Gene mapping methods: Linkage maps, tetrad analysis, mapping with molecular markers, mapping by using somatic cell hybrids, development of mapping population in plants. ; Extra chromosomal inheritance: Inheritance of Mitochondrial and chloroplast genes, maternal inheritance. ; Mutation: Types, causes and detection, mutant types – lethal, conditional, biochemical, loss of function, gain of function, germinal verses somatic mutants, insertional mutagenesis. Deletion, duplication, inversion, translocation, ploidy and their genetic implications. Homologous and non-homologous recombination including transposition ;Evolutionary genetics-Properties and evolution of genetic material flow of genetic information. Molecular tools in phylogeny, classification and identification; Protein and nucleotide sequence analysis; origin of new genes and proteins; Gene duplication and divergence. Populations, Gene pool, Gene frequency; Hardy-Weinberg Law; concepts and rate of change in gene frequency through natural selection, migration and random genetic drift; Adaptive radiation; Isolating mechanisms; Speciation; Allopatricity and Sympatricity; Convergent evolution; Sexual selection; Co-evolution.

Essential Reading:
1. E J Gardner, *Principles of Genetics*, John Wiley & Sons Inc.
2. D.P. Snustad& M.J. Simmons, *Principles of Genetics*, John Wiley and Sons Inc.
3. Alan G. Atherly, Jack R. Girton, John F. McDonald, *The Science of Genetics*, Saunders College Pub.

Supplementary Reading:
1. L. Hartwell, Leroy Hood, Michael Goldberg, Ann Reynolds, Lee Silver, RuthVeres*Genetics: From Genes to Genomes* by publisher: McGraw-Hill.
2. Lynn B. Jorde, John C. Carey, Michael J. Bamshad and Raymond L. White, *Medical genetics*

LS 512 PHYSICAL & DEVELOPMENTAL BIOLOGY 4 credits [3-1-0]

Professor-in-charge: Dr. Bismita Nayak

Basic Concepts of Development: Potency, commitment, specification, induction, competence, determination and differentiation; morphogenetic gradients; cell fate and cell lineages; stem cells, Gametogenesis, fertilization and early development: cell surface molecules in sperm-egg recognition in animals; embryo sac development and double fertilization in plants; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis, and establishment of symmetry in plants; seed formation and germination. ; Cell Aggregation and Differentiation; Axes and pattern formation in Drosophila, amphibia and chick; organogenesis, development and regeneration in vertebrates; metamorphosis; environmental regulation of normal development. ; Morphogenesis and Organogenesis in Plants: Organization of shoot and root apical meristem; shoot and root development, Programmed cell death, aging and senescence. Embryonic development, cellular differentiation, organogenesis, metamorphosis.; Animal Physiology: Comparative physiology, the respiratory system: Comparison of respiration in different species, anatomical considerations, transport of gases, exchange of gases, waste elimination, neural and chemical regulation of respiration, circulatory system: cardiac cycle, heart as a pump, blood pressure, neural and chemical regulation, digestive system: Digestion, absorption, energy balance, BMR, the nervous system: Neurons, action potential, gross neuroanatomy of the brain and spinal cord, central and peripheral nervous system, neural control of muscle tone and posture, the excretory system, the endocrine system and reproductive system: Endocrine glands, basic mechanism of hormone action, hormones and diseases; reproductive processes, neuroendocrine regulation, the skeletal system. ; Plant Physiology: Osmoregulation, Solute transport and photoassimilate translocation; Photosynthesis: Light harvesting complexes; mechanisms of electron transport; CO2 fixation, Respiration and photorespiration: Citric acid cycle, plant mitochondrial electron transport and ATP synthesis, alternate oxidase, photorespiratory pathway; Plant hormones and Sensory photobiology; Responses of plants to biotic (pathogen and insects) and abiotic (water, temperature and salt) stresses.

Essential Reading:

1. S.F. Gilbert, *Developmental Biology* by Sinauer Associates Inc.
2. Lincoln Taiz and Eduardo Zeiger, *Plant Physiology*, Sinauer Associates Inc.

LS 513 ENZYMOLOGY AND METABOLISM 4 credits [3-1-0]

Professor-in-charge: Dr. Sujit K Bhutia

Enzymology: Concept of Enzyme and mechanism of action. Classification of enzumes (OTHLyILi) and nomenclature. Kinetics: derivation of Michaelis-Menten equation, L-B plot, Regulation of enzyme activity, binding site and active site, Factors affecting the rate of enzymatic reaction, Enzyme kinetics for mono- and bi-substrate reactions, Inhibitions –competitive, uncompetitive mixed and non-competitive type, Allosteric regulation, covalent modifications, Isozymes, ribozymes, abzymes. Enzyme inhibition and Mechanisms of inhibitors action ;General Metabolism: Biogenetics and ATP, Oxidative and photo phosphorylation; Carbohydrate: Glycolysis, TCA, Gluconeogenesis, Pentose phosphate pathway: Mechanism of selective reactions, Radioisotope distribution study and regulation. Glycogen metabolism: Break down, synthesis, hormonal control and regulation. Amino acids and protein: Catabolism of proteins and amino acids, Urea cycle, Fate of carbon skeleton of amino acids, Mechanism of selective reactions. Biosynthesis of amino acids: Nitrogen fixation, Biosynthesis of essential amino acids, and Mechanism of selective reactions, Regulation. Biomolecules obtained from amino acids. Fatty acids: oxidation (Even, odd, saturated and unsaturated) and Biosynthesis of fatty acids, tri-glycerides, phospholipids and sterols. Regulation of fatty acid metabolism.Introduction, hydrolysis of tri-acylglycerols, α-, β-, ω- oxidation of fatty acids.Oxidation of odd numbered fatty acids – fate of propionate, role of carnitine, degradation of complex lipids.Fatty acid biosynthesis, Acetyl CoA carboxylase, fatty acid synthase, ACP structure and function.Lipid biosynthesis, biosynthetic pathway for tri-acylglycerols, phosphoglycerides, sphingomyelin and prostaglandins.Metabolism of cholesterol and its regulation.Energetics of fatty acid cycle. Nucleic Acids: Biosynthesis and degradation of purine and pyrimidine, nucleotides, Mechanism of selective reactions and regulation.

Essential Reading:

1. *Methods in Enzymology*, Academic Press.
2. Donald Voet, *Biochemistry* by Hardcover: 1616 pages, Publisher: Wiley
3. David L Nelson; Albert L Lehninger; Michael M Cox , *Lehninger Principles of Biochemistry*; New York : W.H. Freeman

LS 514	FUNDAMENTAL OF GENETICS	4 credits [3-0-0]

Professor-in-charge: Dr. Sujit K. Bhutia

Introduction to Genetics: Mendelism, Mendel and his experiments, Law of segregation, Law of independent assortment, Application of laws of probability (product rule, sum rule), Chromosomal basis of segregation and independent assortment, Chi-square test and its application in analysis of genetic data ; Extensions of Mendelism: Allelic variation and gene function- Dominance relationships, basis of dominant and recessive mutations, Multiple allelism, allelic series, Testing gene mutations for allelism: complementation test, intragenic complementation, Visible, sterile and lethal mutations, Genotype to phenotype: effect of the environment on phenotype development- Penetrance and expressivity, phenocopy, Gene interactions and modifying genes, Pleiotropy ; Sex-linked inheritance, Linkage and crossing over, Genetic recombination and construction of genetic maps in Drosophila, Interference and coincidence, Cytological demonstration of crossing over in Drosophila, Mitotic recombination, Intragenic recombination, Inheritance of quantitative traits, Continuous and discontinuous variation, Polygenic inheritance, Genetic variance, heritability (narrow sense and broad sense), Cytoplasmic inheritance, maternal effects, inheritance due to parasites and symbionts, Properties and evolution of genetic material, flow of genetic information.

Essential Reading:

1. E J Gardner, *Principles of Genetics*, John Wiley & Sons Inc
2. D.P. Snustad& M.J. Simmons, *Principles of Genetics*, John Wiley and Sons Inc

Supplementary Reading:

1. L. Hartwell, Leroy Hood, Michael Goldberg, Ann Reynolds, Lee Silver, Ruth Veres , *Genetics: From Genes to Genomes*
2. publisher: McGraw-Hill
3. Lynn B. Jorde, John C. Carey, Michael J. Bamshad and Raymond L. White, *Medical genetics*

LS 530	AQUATIC BIOLOGY AND MARINE BIOTECHNOLOGY	4 credits [3-1-0]

Professor-in-charge: Dr. Surajit Das

Unit 1: Aquatic ecosystems ;Definition, principles and scope of ecology in relation to aquatic ecosystem. Abiotic and biotic factors. Freshwater ecology- physico-chemical characteristics of freshwater, Marine ecology- physico-chemical characteristics of marine environment, classification, thermal stratification, marine communities. Estuarine and coastal ecology- Characteristics of estuaries, classification, horizontal stratification, estuarine communities, adaptations. Mangrove ecosystems: special features of mangrove habitats and distribution of plants and animals in mangrove ecosystems. ; Unit 2: Productivity and benthos ;Primary productivity- gross and net productivity; methods employed for measuring productivity; general account of productivity in different oceans. Factors affecting primary production: nutrients, light, temperature, organic micro nutrients and inhibitors, grazing. ; Plankton- role in aquatic ecosystem in relation to fisheries; qualitative and quantitative analysis of plankton; eutrophication; red tide; phytoplankton – zooplankton relationships. ; Benthos- classification and identification of major types and their role in aquatic production. ; Unit 3: Aquatic microbiology and public health ;Types of microbes- bacteria, fungi and viruses. Isolation and culture techniques, identification of bacteria and fungi and maintaining their cultures. Methods of studying the marine microorganisms-methods of collection, enumeration (total and viable counts), isolation, culture & identification based on morphological, physiological and biochemical characteristics. ; Diseases of cultivable organisms: signs, symptoms, prophylaxis and treatment. ; Microbiology of fresh and processed fish; handling of fish- spoilage of fish and shellfish. ; Unit- 4: Marine pharmacology ;Marine Pharmacology: current status and prospects. Bioactive compounds from marine environment: isolation, purification and identification of compounds. ; Unit- 5: Fouling and boring organisms ;Biofouling – biofilm, biocorrosion, corrosion process and control of marine structures. Bioinvasion and ballast water.Marine fouling and boring organisms - their biology, adaptation - factors influencing the settlement of macrofoulers.; Unit- 6: Aquaculture and fisheries technology ; Application of microbial biotechnology in culture ponds-bioaugmentation, bioremediation for soil and water quality improvement; nutrient cycling; probiotics, prebiotics and immunostimulants. ; Tools for disease diagnosis in cultivable organisms - Enzyme immuno assays - Dot immunobinding assay - Western blotting - Latex agglutination test - Monoclonal antibodies - DNA based diagnosis. ; Reproductive biotechnology- breeding biology and endocrine control of reproduction in fin fishes and shell fishes. ; Fish cytogenetics- application of genetics in aquaculture, hybridization of fishes, recent trends and techniques in hybridization, selective breeding, cross breeding, development of disease resistance and high quality new strains, transgenic fish production. ; Chromosome manipulation- role in aquaculture, androgenesis, gynogenesis, sex reversal and polyploidy. Cryopreservation.

Essential Reading:

1. Nicholas V. C. Polunin, *Aquatic Ecosystems: Trends and global prospect*s by Cambridge University Press.
2. Paul J. B. Hart, John D. Reynolds, *Handbook of Fish Biology and Fisheries*: 2 Volume Set by Wiley.
3. S. J. Ennion, G. Goldspink, *Gene Expression and Manipulation in Aquatic Organisms* by Cambridge University Press
4. Stickney, R.R., *Encyclopedia of Aquaculture* by John Wiley Sons Inc.

Supplementary Reading:

1. R. S. K. Barnes, K. H. Mann, *Fundamentals of Aquatic Ecology* by Wiley
2. Y. Le Gal, Y. Le Gal and H. O. Halvorson, *New developments in marine biotechnology* by Springer US
3. P. Lazarovici*, Biochemical aspect of marine pharmacology* by Alaken Inc.

LS 531	EPIGENETICS	4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

Epigenesis and development, Concept of epigenetics, Epigenetic mechanisms and regulation of gene expression; DNA-Methylation, Epigenome, Methylome. Histone Code: histone modifications (acetylations, methylations, phosphorylations, sumoylations, uniquitylation etc.) and enzymatic mechanisms. DNA-methyltransferases, Histone acetylases, histone deacetylases, (Histone) protein arginine methyltransferases and demethylases, (Histone) protein lysine methyltransferases and demethylases. Transcriptional silencing by polycomb group proteins and regulation by trithorax group proteins.Histone variants, chromosome inheritance, X-chromosome inactivation. Genomic imprinting, germ line and pluripotent stem cells. Epigenetics of human disese and epigenetic determinants of cancer.Nuclear transplantation and the reprogramming of the genome.RNA interference and regulation of gene expression (RNAi, microRNA, heterochromatin assembly). Position-effect Variegation, heterochromatin formation and gene silencing in Drosophila

Essential Reading:

1. C. David Allis, Thomas Jenuwein, Danny Reinberg and Marie-Laure Caparros, *Epigenetics* by *Cold Spring Harbor Laboratory Press*, CSH Press, NY, USA.
2. JörgTost (Editor), *Epigenetics* by, Caister Academic Press.

LS 532	MOLECULAR MEDICINE	4 credits [3-1-0]

Professor-in-charge: Dr. BismitaNayak

Overview of Drug Design; Drug targets and vaccine delivery, Cell differentiation, Proliferation and gene expression; junctional components targeted by disease causing micro-organisms; diseases associated with intercellular junctions including multiple sclerosis, type 1 diabetes, inflammatory bowel diseases. ; Introduction to Metabolic Disorders; Reproductive disorders, Cardiovascular diseases, Disorders in hormonal action: Insulin dependent and independent diabetes, Importance of intracellular trafficking and its related pathogenesis, Molecular endocrinology in health and disease. ; Diseases; Current topics in fungal, parasitic, bacterial and viral diseases; Introduction to metabolic disorders and metabolic profiling; Cancer; Basic biology and pathology of cancer, various types of cancers, Molecular epidemiology and genetic susceptibility; Cell proliferation, transformation and cancer progression.

Essential Reading:

1. Ronald J. Trent, *Molecular Medicine: An Introductory Text* by Elsevier.
2. *Science in Medicine: The JCI Textbook of Molecular Medicine American Society* for Clinical Investigation

LS 533	MARINE BIOTECHNOLOGY	3 credits [3-0-0]

Professor-in-charge: Dr. Surajit Das

Unit 1: Aquatic ecosystems ;Definition, principles and scope of ecology in relation to aquatic ecosystem. Abiotic and biotic factors. Freshwater ecology- Physico-chemical characteristics of freshwater, Marine ecology- Physico-chemical characteristics of marine environment, classification, thermal stratification, marine communities. Estuarine and coastal ecology- Characteristics of estuaries, classification, horizontal stratification, estuarine communities, adaptations. ; Unit 2: Productivity and benthos ;Primary productivity, gross and net productivity. Plankton and their role in aquatic ecosystem in relation to fisheries; qualitative and quantitative analysis of plankton.Biomass , food webs, energy flow. Benthos- classification and identification of major types and their role in aquatic production.Methods of collection, preservation and identification of dominant types from different water habitats. ; Unit 3: Aquatic microbiology and public health ;Types of microbes, bacteria, fungi and viruses. Isolation and culture techniques, identification of bacteria and fungi and maintaining their cultures. Methods of studying the marine microorganisms-methods of collection, enumeration (total and viable counts), isolation, culture & identification based on morphological, physiological and biochemical characteristics. Microbiology in relation to fish and prawn production.Biological factors of water-self purification. Technical means of controlling microbial population in water. ; Unit- 4: Marine pharmacology ;Marine Pharmacology: Prospects – Bioactive compounds from marine environment: isolation, purification and identification of compounds. ; Unit- 5: Fouling and boring organisms ;Biofouling - Biofilm formation. Marine fouling and boring organisms - their biology, adaptation - Factors influencing the settlement of macrofoulers. Antifouling and Anti boring treatments.Corrosion Process and control of marine structures.; Unit- 6: Aquaculture and fisheries ;Application of microbial biotechnology in culture ponds, bioaugmentation, bioremediation for soil and water quality improvement - nutrient cycling, bio-fertilization. Probiotics – Immunostimulants. Regulation of bacterial growth.; Tools for disease diagnosis in cultivable organisms - Enzyme immuno assays - Dot immunobinding assay - Western blotting - Latex agglutination test - Monoclonal antibodies - DNA based diagnosis. ; Hybridization of fishes, recent trends and techniques in hybridization, selective breeding, cross breeding, development of disease resistance and high quality of new strains, transgenic fish production. Chromosome manipulation, its role in aquaculture, androgenesis, gynogenesis, sex reversal and tripoidy.Cryopreservation.

Essential Reading:

1. Nicholas V. C. Polunin, *Aquatic Ecosystems: Trends and global prospects* by Cambridge University Press.
2. J. B. Hart, John D. Reynolds, *Handbook of Fish Biology and Fisheries*: 2 Volume Set by Paul Wiley.
3. S. J. Ennion, G. Goldspink, *Gene Expression and Manipulation in Aquatic Organisms* by Cambridge University Press
4. Stickney*, Encyclopedia of Aquaculture* by R.R., John Wiley Sons Inc.

Supplementary Reading:

1. R. S. K. Barnes, K. H. Mann, *Fundamentals of Aquatic Ecology* by Wiley
2. Y. Le Gal, Y. Le Gal and H. O. Halvorson, *New developments in marine biotechnology* by Springer US
3. P. Lazarovici, *Biochemical aspect of marine pharmacology* by Alaken Inc.

LS 534	INTRODUCTION TO EPIGENETICS	3 credits [3-0-0]

Professor-in-charge: Dr. Samir K Patra

Epigenesis and development, Concept of epigenetics, Epigenetic mechanisms and regulation of gene expression; DNA-Methylation, Epigenome, Methylome. Histone Code: histone modifications (acetylations, methylations, phosphorylations, sumoylations, uniquitylation etc.) and enzymatic mechanisms. DNA-methyltransferases, Histone acetylases, histone deacetylases, (Histone) protein arginine methyltransferases and demethylases, (Histone) protein lysine methyltransferases and demethylases. RNA interference and regulation of gene expression (RNAi, microRNA ETC)

Essential Reading:

1. C. David Allis, Thomas Jenuwein, Danny Reinberg and Marie-Laure Caparros, *Epigenetics* by Amazon Publishers.
2. Jörg Tost (Editor), *Epigenetics* by Caister Academic Press.

LS 535	BASICS IN MOLECULAR MEDICINE	3 credits [3-0-0]

Professor-in-charge: Dr. Bismita Nayak

Principles of protein and nucleic acid structure.Overview of drug design and drug targets.Molecular modelling in drug discovery. Computer representations of Molecules, chemical databases, cell differentiation, proliferation and gene expression; junctional components targeted by disease causing micro-organisms; diseases associated with intercellular junctions including multiple sclerosis, type 1 diabetes, inflammatory bowel disease, and cancers of the breast, prostate and colon. ; Introduction to metabolic disorders and metabolic profiling. Reproductive disorders.Cardiovascular diseases.Disorders in hormonal action.Insulin dependent and independent diabetes. Ligand induced signalling and gene expression in eukaryotic cells. Importance of intracellular trafficking and its related pathogenesis.Molecular endocrinology in health and disease.Cancer and cell cycle. ; Current topics in fungal, parasitic, bacterial and viral diseaes.Introduction to metabolic disorders and metabolic profiling. Reproductive disorders.Cardiovascular diseases.Disorders in hormonal action.Insulin dependent and independent diabetes. Ligand induced signalling and gene expression in eukaryotic cells. Importance of intracellular trafficking and its related pathogenesis.Molecular endocrinology in health and disease.Cancer and cell cycle.Basic biology and pathology of cancer, multifactorial etiology of cancer.Molecular epidemiology and genetic susceptibility.Cell proliferation, transformation and cancer progression.

Essential Reading:

1. Ronald J. Trent, *Molecular Medicine: An Introductory Text* by Elsevier.
2. *Science in Medicine: The JCI Textbook of Molecular Medicine American Society for Clinical Investigation*.

LS 540	RESEARCH METHODOLOGY	3 credits [3-0-0]

Professor-in-charge: Dr. Surajit Das

Bio-Statistics ;Unit 1: Collection and presentation of data ; Statistics- definition, function, scope and limitations. Collection of biological data – sampling, aim, techniques, random sampling and non-random sampling.Classification of data- frequency distribution and tabulation.Tabulation of data and graphical representation- bar diagram, pie diagram, frequency curve, histogram, Ogive. ; Unit 2: Statistics of location and dispersion ;Measures of central value- Mean, Median, Mode. Measures of dispersion- standard deviation, standard error, coefficient of variation.Normal distribution, Skewness and Kurtosis. ; Unit 3: Sampling statistics and testing of hypothesis ;Sampling distribution, Sampling error, standard errors, degrees of freedom. Test of significance based on large samples- procedure for testing hypothesis. ; Unit 4: Correlation and regression ; Use of correlation in biological science – purpose, positive correlation, negative correlation, calculating correlation coefficient, significance, other types of correlation. Use of Regression in Biological Sciences – purpose, regression coefficient Y, Regression line. ; Unit 5: 't' test, Chi square and ANOVA ; Student 't' test for mean, Chi-square test, Analysis of variance- One-way and Two-way ANOVA. ; Unit 6: Use of computers in Bio-statistics ;Use of computer in Bio-Statistics- Computation of Median, Variance, Standard Deviation, and Correlation Coefficient etc. Application of statistical packages- MS Excel, SPSS etc. ;Bio-Instrumentation ; Unit 1: Chromatography ; Paper, TLC, gel filtration, ion-exchange chromatography, affinity chromatography, HPLC and GLC ; Unit 2: Microscopy ; Optical microscopy, Bright field, Dark field, phase contrast and fluorescence microscopy. Electron microscopy: Transmission and scanning electron microscopy. ; Unit 3: Centrifugation ;Principle of centrifugation, rotors, different types of centrifuges, preparative and analytical centrifugation, ultra centrifugation ; Unit 4: Electrophoresis ; Gel electrophoresis, SDS-PAGE, isoelectric focusing, two -dimensional electrophoresis, immuno electrophoresis, capillary electrophoresis ; Unit 5: Spectroscopy ; Atomic Absorption spectrophotometry, Mass spectrometry, NMR.

Essential Reading:

1. S.C. Gupta, *Fundamentals of statistics* by Himalaya Publishing House
2. J. H. Zar, *Biostatistical analysis* by Prentice Hall.
3. K. Wilson and J. Walker, *Principles of Biochemistry and molecular biology* by Cambridge University Press.
4. D. A. Skoog and J. J. Leary, *Principles of Instrumental analysis by Saunders College* Publishing, Philadelphia

Supplementary Reading:

1. Grafen and R. Hails, *Modern statistics for the Life Sciences* by Oxford University Press
2. Thomas Glover and Kevin Mitchell, *An Introduction to Biostatistics* by Waveland PrInc

LS 571	CELL BIOLOGY	2 credits [0-0-3]

Cell biology laboratory
Introduction to microscopy and cell culture ; Measurement of cell diameter ; Determination of Cell surface hydrophobicity ; Determination of doubling time of prokaryotes ; Determination of doubling time of eukaryotes ; Cell lysis, fractionation and preparation of cellular component ; Transfection of eukaryotic cell with DNA and analysis of the foreign component ; Detection Fluorescent proteins as reporters in eukaryotic cells ; Detection of apoptosis, autophagy and senescence in eukaryotic cells ; Visual observation of cell division in microscope

LS 572	ENZYMOLOGY LAB	4 credits [3-1-0]

Professor-in-charge: Dr. Samir K Patra

Isolation of Enzymes from plant and microbial sources ; Enzyme assay; activity and specific activity – determination of amylase, nitrate reductase, cellulose, protease ; Purification of Enzyme by ammonium sulphate fractionation ; Enzyme Kinetics: Effect of varying substrate concentration on enzyme activity ; Effect of Temperature and pH on enzyme activity ; Production of enzyme on industrial scale using solid and state fermentation ; Enzyme immobilization

LS 581	CANCER BIOLOGY	4 credits [3-1-0]

Professor-in-charge: Dr. Sujit K Bhutia

Introduction to mammalian cell culture and applications; what is Cancer? Profile of a Cancer Cell; How Cancers Spread; Identifying the causes of Cancer: Chemicals and Cancer , Radiation and Cancer , Infectious Agents and Cancer, Heredity and Cancer; Oncogenes, Tumor Suppressor Genes and Cancer Overview; Chromosome heterogeneity, micro satellite instability, Epigenetic basis of cancer, DNA-methylation and histone modifications associate to cancer; Cancer stem cell: identification, property and therapeutic implication; tumor evolution, escape from non-immune and immune surveillance. Immunoediting, role of immunological ignorance and tolerance in tumor escape, Regulatory lymphocytes in cancer; Cancer Screening, Diagnosis, and Treatment; Preventing Cancer.

Essential Reading:

1. Lewis J. Kleinsmith*, Principles of Cancer Biology*: International Edition; Pearson Higher Education
2. Sharmila A. Bapat, *Cancer Stem Cells: Identification and Targets*, Wiley
3. George C. Prendergast and Elizabeth M. Jaffee, *Cancer immunotherapy: immune suppression and tumor growth*, Academic Press.

DEPARTMENT OF MATHEMATICS

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
MA 101	Differential Equations	3-1-0	4
MA 102	Matrix theory, Vector Calculus and Fourier Analysis	3-1-0	4
MA 201	Probability, Statistics and Numerical Methods	3-1-0	4
MA 202	Complex Analysis and Partial Differential Equations	3-1-0	4
MA 205	Calculus	3-1-0	4
MA 206	Introduction to Complex Analysis and PDEs	3-1-0	4
MA 207	Introduction to Numerical Analysis	3-1-0	4
MA 208	Analysis-I	3-1-0	4
MA 270	Numerical Methods Laboratory	0-0-3	2
MA 301	Algebra-I	3-1-0	4
MA 311	Linear Algebra	3-0-0	3
MA 312	Real Analysis	3-0-0	3
MA 313	Complex Analysis and Transform Techniques	3-0-0	3
MA 321	Discrete Mathematics	3-0-0	3
MA 322	Linear Programming	3-1-0	4
MA 332	Probability	3-1-0	4
MA 372	Statistics Laboratory	0-0-3	2
MA 373	Laboratory Works on Latex, and Matlab	0-0-3	2
MA 402	Measure Theory	3-1-0	4
MA 403	Linear Algebra	3-1-0	4
MA 404	Functions of a Complex Variable	3-1-0	4
MA 405	Partial Differential Equations	3-1-0	4
MA 407	Topology	3-1-0	4
MA 413	Analysis-II	3-1-0	4
MA 423	Discrete Mathematics	3-0-0	3
MA 424	Operations Research	3-0-0	3
MA 425	Elementary Stochastic Processes with Applications	3-0-0	3
MA 431	Mathematical Methods	3-0-0	3
MA 432	Finite Difference Methods	3-0-0	3
MA 433	Finite Element Methods	3-0-0	3
MA 438	Dynamical Systems	3-1-0	4
MA 470	Lab works on Real Life Problems-I	0-0-3	2
MA 471	Object Oriented Programming Practice Lab.	0-0-3	2
MA 472	Research Paper Review	0-0-3	2
MA 481	Departmental Seminar – I	0-0-3	2
MA 482	Departmental Seminar – II	0-0-3	2
MA 501	Abstract Algebra	3-1-0	4
MA 502	Functional Analysis	3-1-0	4
MA 503	Theory of Rings and Fields	3-1-0	4
MA 504	Differential Geometry	3-1-0	4
MA 510	Calculus of Several Variables	3-1-0	4
MA 511	Differential Geometry	3-1-0	4
MA 512	Fourier Analysis	3-1-0	4
MA 513	Differential Topology	3-1-0	4
MA 514	Rings and Modules	3-1-0	4
MA 515	Homotopy Theory	3-1-0	4
MA 516	Operator Theory	3-1-0	4

MA 517	Lie Algebra	3-1-0	4
MA 518	Advanced Complex Analysis	3-1-0	4
MA 519	Multi-Linear Algebra	3-1-0	4
MA 520	Automata Theory	3-1-0	4
MA 521	Combinatorics	3-1-0	4
MA 522	Operations Research	3-1-0	4
MA 523	Discrete Mathematics	3-1-0	4
MA 524	Statistical Methods	3-1-0	4
MA 525	Elementary Stochastic Processes with Applications	3-1-0	4
MA 527	Fractuals	3-1-0	4
MA 529	Information Theory	3-1-0	4
MA 531	Boundary Layer Theory	3-1-0	4
MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4
MA 534	Geometry of Robotics	3-1-0	4
MA 540	Singular Homology Theory	3-1-0	4
MA 542	Tensor Analysis	3-1-0	4
MA 544	Category Theory	3-1-0	4
MA 546	Differentiable Manifolds	3-1-0	4
MA 548	Field Theory	3-1-0	4
MA 549	Algebraic Geometry	3-1-0	4
MA 550	Coding Theory	3-1-0	4
MA 551	Numerical Analysis	3-1-0	4
MA 552	Fuzzy logic and Set Theory	3-1-0	4
MA 553	Optimization Techniques	3-1-0	4
MA 554	Graph Theory	3-1-0	4
MA 555	Stochastic Processes	3-1-0	4
MA 556	Number Theory	3-1-0	4
MA 558	Sampling Techniques	3-1-0	4
MA 560	Mathematical Methods	3-1-0	4
MA 561	Lie Groups & Applications to ODEs & PDEs	3-1-0	4
MA 562	Finite Volume Methods for Hyperbolic PDEs	3-1-0	4
MA 563	Wavelets and Applications	3-1-0	4
MA 564	Integral Transforms	3-1-0	4
MA 565	Fractional Order models (a,b,d,f)	3-1-0	4
MA 566	Fractional Differential Equations (c,e,g,h)	3-1-0	4
MA 567	Theory of Vibrations	3-1-0	4
MA 568	Mathematics of Soft Computing	3-1-0	4
MA 569	Perturbation Methods	3-1-0	4
MA 571	Statistical Methods Lab.	0-0-3	2
MA 572	Lab. Works on Real Life Problems-II	0-0-3	2
MA 574	Laboratory Works on NSPDE	0-0-3	2
MA 591	Research Project – I	0-0-6	4
MA 592	Research Project – II	0-0-9	6
MA 593	Seminar and Technical Writing – I	0-0-3	2
MA 594	Seminar and Technical Writing – II	0-0-3	2
MA 595	Short term Industrial/Research Experience	0-0-3	2
MA 596	Comprehensive Viva Voce	0-0-3	2

MA 101	DIFFERENTIAL EQUATIONS	4 credits [3-1-0]

Differential equations: First-order differential equations: Basic concepts and ideas, Separable equations, Exact equations, Integrating factors, Linear differential equations, Bernoulli equation, Orthogonal trajectories of curves. Applications to physical problems, Linear differential equations of second and higher order: Homogeneous linear equations of second order, Euler-Cauchy equation, Solution by undermined coefficients and variation of parameters, Higher order linear differential equations. Applications to physical problems. ***Series solutions of differential equations and special functions***: Power series method, Legendre's equations and functions, Frobenius method, Bessel's equation and functions, Sturm-Liouville problems, Orthogonal functions, Orthogonal eigen-function expansions, Applications to physical problems. ***Laplace transforms***: Laplace transform, Inverse Laplace transforms, Solution of differential equations, Differentiation and integration of transforms, Integral equations.

Essential Reading:

1. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007 Chapters: Chapter 1 (excluding 1.9), 2, 3, 4, 5.

MA 102	MATRIX THEORY, VECTOR CALCULUS AND FOURIER ANALYSIS	4 credits [3-1-0]

Matrix theory: Linear Systems and equations, Gauss elimination, Rank of a matrix, Linear independence, Vector space, Solutions of linear systems, Existence, uniqueness, Cramer's rule, Inverse of a matrix, Gauss-Jordon elimination, Vector spaces, Inner product spaces, Linear transformations. Eigen values, Eigen vectors, Symmetric, skew-symmetric and orthogonal matrices, Complex matrices: Hermitian, skew- Hermitian, and unitary matrices, Similarities of matrices, Basis of eigenvector, Diagonalisation ; ***Vector calculus***: Vector differential calculus: Grad, div, curl, Vector algebra in 2-space and 3-space, Inner product (dot product), Vector product (cross product), Vector and scalar functions and fields, Derivatives, Curves, tangents are length, Velocity and acceleration, Curvature and torsion of a curve, Gradient of a scalar field, Directional derivative, Divergence of a vector field, Curl of a vector field. Vector integral calculus: Line integrals, Line integral independent of path, Double Integrals, Green's theorem in the plane, Surfaces and surface integrals, Triple integrals: Divergence theorem of Gauss, Further applications of the divergent theorem, Stoke's theorem ; ***Fourier Analysis***: Fourier series, Integrals and transforms: Fourier series, Functions of any period $p = 2L$, Even and odd functions: Half-range expansions, Complex Fourier series, Forced oscillations, Approximation by trigonometric polynomials, Fourier integrals, Fourier cosine and sine transforms, Fourier transform.

Essential Reading:

1. E. Kreyszig *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007 Chapters : 6 (6.3 – 6.8), 7, 8, 9, and 10.

MA 201	PROBABILITY, STATISTICS AND NUMERICAL METHODS	4 credits [3-1-0]

Probability and Statistics: Probability theory: Probability, Random variables, Probability distributions, Mean and variance of distributions, Binomial, Poisson and Hyper-geometric distributions, Normal distribution, Distributions of several random variables, Mathematical statistics, Random sampling, Estimation of parameters, Confidence intervals, Testing of hypothesis, Decisions, Quality control, Acceptance sampling, χ^2-test for goodness of fit, Nonparametric tests, Regression analysis, Fitting of straight lines, Correlation analysis. ***Numerical Methods***: Numerical methods in general: Floating point, Round-off, error, Propagation of error, Interpolation, Splines, Numerical integration and differentiation. Numerical methods in linear algebra: Gauss elimination, LU-Factorization, Matrix inversion, Linear systems: Solution by iteration, Linear systems: Ill-conditioning, Norms, Method of least squares, Matrix eigen value problems, Inclusion of matrix eigen values, Eigen values by iteration (Power method), Tridiagonalization and QR-factorization, Numerical methods for differential equations: Methods for first-order differential equations, Multistep methods, Methods for systems and higher order equations, Methods for elliptic partial differential equations, Methods for parabolic and hyperbolic equations.

Essential Reading:

1. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007Chapters: 17, 18,19, 22 (excluding 22.4), 23.

MA 202	**COMPLEX ANALYSIS AND PARTIAL DIFFERENTIAL EQUATIONS**	**4 credits [3-1-0]**

***Complex Analysis*:** Derivative. Analytic function, Cauchy Riemann equations, Laplace's equation, Geometry of analytic functions, Exponential function, Trigonometric functions, Hyperbolic functions, Logarithm, General power, Conformal mapping, Linear fractional transformations. Complex integration, Line integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral Formula, Derivative of Analytic functions, Power series, Taylor series, Sequences, Series, Convergence tests, Functions Given by power series, Taylor series and Maclaurin series, Uniform convergence. Laurent series, Residue integration, Laurent series, Singularities and zeros infinity, Residue integration methods, Evaluation of real integrals. ***Partial Differential Equations*:** Basic concepts, Modeling of vibrating string, Wave equation, Separation of variable, Use of Fourier series, D'Alembert's solution of the wave equation, Heat equation, Solution by Fourier Series, Solution by Fourier integral and transforms, Modeling: Membrane, Two-dimensional wave equation, Rectangular membrane. Use of double Fourier series, Laplacian in polar coordinates, Circular membrane, Use of Fourier–Bessel series, Laplace's equation in cylindrical and spherical coordinates, Potential, Solution by Laplace transforms.

Essential Reading:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007
   Chapters: 11, 12 (12.3 – 12.9), 13,14, 15.

MA 205	**CALCULUS**	**4 credits [3-1-0]**

Real numbers, Real sequences, Convergence of sequences and series of real numbers, Limits, Continuity of functions, Differentiability, Rolle's theorem, Mean value theorem, Taylor's theorem, Maxima, Minima, Points of inflection, Asymptotes and curvature, Definite integral as limit of a sum, Properties of definite integrals, Application of definite integrals, Power series, Test of convergence, Alternating series, Absolute convergence, Partial derivatives, Gradient and directional derivatives, Chain rule, Lagrange multipliers.

Essential Reading:

1. G.B. Thomas and R.L. Finney, *Calculus and Analytical Geometry (9th Edition),* ISE Reprint, Addison-Wesley, 1998.

Supplementary Reading:

1. N. Piskunov, *Differential and Integral Calculus*, GK Publishers, 1996.

MA 206	**INTRODUCTION TO COMPLEX ANALYSIS AND PDES**	**4 credits [3-1-0]**

***Complex Analysis*:** Derivative. Analytic function, Cauchy Riemann equations, Laplace's equation, Geometry of analytic functions, Exponential function, Trigonometric functions, Hyperbolic functions, Logarithm, General power, Conformal mapping, Linear fractional transformations. Complex integration, Line integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral Formula, Derivative of Analytic functions, Power series, Taylor series, Sequences, Series, Convergence tests, Functions Given by power series, Taylor series and Maclaurin series, Uniform convergence. Laurent series, Residue integration, Laurent series, Singularities and zeros infinity, Residue integration methods, Evaluation of real integrals.

***Partial Differential Equations*:** Classification of integrals, Linear equations of PDEs, Charpits method, Jacobi method, Method of Characteristics, Quasi linear PDEs, Nonlinear first order PDEs, Classification of second order PDEs, Methods for Wave equation, Heat equation and Laplace equation

Essential Reading:

1. R. V. Churchil and Brown**, Complex variables and applications, Tata McGraw Hill, 1990.**
2. T. Amaranath, An Elementary course in Partial Differential Equations, Narosa, 2009.

MA 207	INTRODUCTION TO NUMERICAL ANALYSIS	4 credits [3-1-0]

Definition and sources of errors, Propagation of errors, Backward error analysis, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors. Nonlinear equations, Bisection method, Newton's method and its variants, Fixed point iterations, Convergence analysis. Newton's method for non-linear systems. Finite differences, Polynomial interpolation, Hermite interpolation, Spline interpolation, B-splines. Numerical integration, Trapezoidal and Simpson's rules, Newton-Cotes formula, Gaussian quadrature, Richardson Extrapolation IVP: Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, Multistep methods, Predictor-Corrector method Accuracy and stability,

Essential Reading:

1. S. D. Conte and Carl de Boor, *Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edition*, McGraw Hill, 1980.

Supplementary Reading:

1. K. E. Atkinson, *Introduction to Numerical Analysis*, 2nd Edition, John Wiley, 1989.

MA 208	ANALYSIS -I	4 credits [3-1-0]

Metric spaces: Open sets, Closed sets, Continuous functions, Completeness, Cantor intersection theorem, Baire category theorem, Compactness, Totally boundedness, Finite intersection property.

Functions of several variables: Differentiation, inverse and implicit function theorems. Rlemann-Stieitjes integral: Definition and existence of the integral, Properties of the integral, Differentiation and integration.

Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuity, Ascoli's Theorem.

Essential Reading:

1. W.Rudin, *Principles of Mathematical Analysis*, McGraw-Hill, 1986.
2. H.L. Royden, *Real Analysis*, Macmillan, 1988.

MA 270	NUMERICAL METHODS LABORATORY	2 credits [0-0-3]

Experiments to be handled using FORTRAN/C ++/JAVA

1. Bisection Method
2. Method of false position and secant method
3. Newton-Raphson method

4. Method of successive approximation
5. Gaussian elimination method
6. Gauss-Seidel iterative method
7. Inversion of a matrix
8. Eigen values and eigen vectors
9. Lagrange's interpolation
10. Newton's forward and backward interpolation
11. Everette's formula
12. Numerical differentiation
13. Trapezoidal rule of integration
14. Simpson's one-third rule
15. Simpson's three-eighth rule
16. Euler's method
17. Improved Euler's method
18. Runge-Kutta second and fourth order methods
19. Predictor-corrector methods
20. Taylor series method

MA 301 GROUP THEORY 4 credits [3-1-0]

Groups, Subgroups, Centralizers, Normalizers, Stabilizers, Kernels, Cyclic groups, Subgroups generated by a subset of a group, Quotient groups, Lagrange's theorem, Homomorphisms, Isomorphism theorems, Composition series, Solvable groups, Nilpotent groups, Symmetric group, Alternating group, Group actions, Permutation representations, Automorphisms, p-groups, The Sylow theorems, Simplicity of the Alternating group, Direct products of groups, Fundamental theorem of finitely generated abelian groups, Groups of small orders, Rings, Ring homomorphisms, Ideals, Ring of fractions, The Chinese remainder theorem, Euclidean domains, Principal domains, Unique factorization domains, Matrix rings, Polynomial rings, Irreducible Criteria, Eisenstein's criterion.

Essential Reading:
1. D. S. Dummit & R. M. Footee, *Abstract Algebra*, Wiley, 2008

Supplementary Reading :
1. N. Herstien, *Topics in Algebra*, Wiley, 2008
2. J. J. Rotman, *An Introduction to the Theory of Groups*, Springer, 1999.

MA 311 LINEAR ALGEBRA 3 credits [3-0-0]

Vector spaces, Bases and dimensions, Change of bases and change of coordinates, Sums and direct sums, Quotient spaces. Linear transformations, Representation of linear transformations by matrices, Dual spaces, Invariant subspaces, Direct-sum decomposition, Cyclic subspaces and Annihilators, The minimal polynomial, The rational and Jordan canonical forms, Inner product spaces, Orthonormal bases, Gram-Schmidt process. Adjoint operators, Normal, unitary, and self-adjoint operators, Spectral theorem for normal operators.

Essential Reading:
1. K. Hoffman and R. Kunze, *Linear Algebra*, Prentice Hall of India, 1996.

Supplementary Reading:
1. G. Schay, *Introduction to Linear Algebra* , Narosa, 1997.
2. G. C. Cullen, *Linear Algebra with Applications*, Addison Wesley, 1997.

MA 312 REAL ANALYSIS 3 credits [3-0-0]

The real number system : Elementary logic, The field axioms, the axiom of order, geometric representation of real numbers.

Metric sets and limits : Metric sets, Interior points and boundary points of a set, open sets and closed sets, limit point of a set, sequences, monotonic sequences, Cauchy sequences, limit of a function.

Continuity and Differentiation: Continuous functions, uniform continuity, mean value theorem for derivatives, the total differential, the directional derivative.

Integration : Step functions, upper and lower integral of a bounded function, integral of a bounded function, interchange of limits, the fundamental theorem of differential and integral calculus.

Essential Reading :

1. J.M. Howie, *A First Course in Real Analysis*, Springer, 2001

MA 313 COMPLEX ANALYSIS AND TRANSFORM TECHNIQUES 3 credits [3-0-0]

Analytic functions, Line integral, Cauchy's integral theorem and integral formula, Taylor and Laurent series, Residue theorem and applications, Bilinear transformations, Fourier transformations , Fourier transforms (exp, sin, cos), Laplace transforms , Inversion integrals, Convolution, Applications.

Essential Reading:

1 R. V. Churchil and Brown**, Complex variables and applications, Tata McGraw Hill, 1990.**

Supplementary Reading:

1 Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007.

2 I.N. Sneddon, The use of integral transforms, Tata MCGraw Hill, New Delhi, 1974.

MA 321 DISCRETE MATHEMATICS 4 credits [3-1-0]

The language of sets: The concept of a set, Operations with sets, Computer operations with sets, The cardinality of a set, Recursively defined sets.

Functions and Matrices: The concept of a function, Special functions, Properties of functions, The pigeonhole principle, Composition of functions, Matrices.

Induction and algorithms: The division algorithm, Divisibility properties, Mathematical Induction, Algorithm correctness, The growth of functions,

Recursion: Recursively defined functions, Solving recurrence relations, Generating functions, Recursive algorithms.

Combinatorics and Discrete probability: The fundamental counting principles, Permutations, derangements, Combinations, Permutations and combinations with repetitions, The binomial theorem, The generalized inclusion and exclusion principle, Discrete probability.

Relations: Boolian matrices, Relations and digraphs, Computer representations of relations, Properties of relations, Operations on relations, The connectivity relations, Equivalence relations, Partial and total orderings.

Graphs: Computer representation of graphs, Paths, cycles and circuits, Eulerian and Hamiltonian graphs, Planner graphs, graph colouring, Trees: Spanning trees, Binary trees, Binary search trees.

Boolean algebras and combinatorial circuits: Boolean algebras, Boolean functions, Logic gates, Combinatorial circuits.

Essential Reading :

1. T. Koshy, *Discrete Mathematics with Applications*, Academic Press (An Imprint of Elsevier) First Indian Reprint 2005

MA 322	LINEAR PROGRAMMING	4 Credits [3-1-0]

Linear Programming : Lines and hyperplanes, convex sets, convex hull and their properties - Formulation of a Linear Programming Problem - Theorems dealing with vertices of feasible regions and optimality - Graphical solution - Simplex method (including Big M method and two phase method); infeasible and unbounded LPP's, alternate optima - Dual problem and duality theorems - Dual simplex method and its application in post optimality analysis - Revised simplex method - Sensitivity analysis - parametric programming .

Transportation problem: Introduction - existence of solution - degeneracy - MODI method (including the theory) - Assignment problem - Hungarian method for solving assignment problems - travelling salesman problem.

Integer Programming : Gomory's cutting plane method for an integer linear programming problem and a mixed integer linear programming problem.

Theory of Games: Introduction – Minimax (maximin) – Criterion and optimal strategy – Solution of games with saddle points – Rectangular games without saddle points – 2 X 2 games – dominance principle – m X 2 & 2 X n games –graphical method.

Dynamic programming : Multistage decision process - Concept of sub optimization - Principle of optimality - Computational procedure in dynamic programming -Application to problems involving discrete variables, continuous variables and constraints involving equations and inequalities - application to linear programming problem

Essential Reading :

1. H.A.Taha, *An Introduction to Operations Research* , PHI

Supplementary Reading:

1. Kambo, *Mathematical Progamming Techniques*, East-West Publi., Delhi
2. Kanti Swarup et. al., *Operations Research*, Sultan Chand and Co.,
3. S.D.Sharma , *Operations Research*, Kedarnath.
4. J.K.Sharma, *Operation Research*, MacMilan.
5. Hiller and Libermann, *Introduction to Operation Research*, TMH.
6. Wayne L.Winston, *Operation Research*, Thomson BrooCole.

MA 332	PROBABILITY	4 Credits [3-1-0]

Axiomatic definition of probability, Theorems on probability. Conditional probability and independence. Bayes's theorem, Geometric probability. Random variables, their properties. Some standard discrete and continuous variables. Mathematical expectation, variance, moments, moment generating function. Chebyshev's inequality. Functions of a r.v., their distributions and moments. Joint, marginal and conditional distributions, independence of random variables. Law of large numbers, Central limit theorem, Correlation and regression: Simple, multiple and partial. Sampling distributions. Estimation of parameters : Maximum likelihood and method of moments. Properties of best estimates. Testing of hypotheses, Neyman-Pearson Lemma, standard tests for one and two sample problems.

Essential Reading:

1 V.K. Rohatgi and A.K. Md Ehsanes Saleh*, An Introduction to Probability and Statistics, John Wiley and sons*

Supplementary Reading:

1 S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistics* , Sultan Chand and Sons, New Delhi.
2 W.J. DeCoursey**,** *Statistics and Probability with Engineering Application, John Wiley and Sons Ltd.s*
3 T.T.Soong, *Fundamentals of Probability and Statistics for Engineers*, John Wiely and Sons Ltd
4 Douglas C. Montgomery, George C. Runger, *Applied Statistics and Probability for Engineers*, Third Edition

MA 342	**DIFFERENTIAL GEOMETRY**	**4 Credits [3-1-0]**

Vector Fields: height of the level set, level curves, Integral curve, smooth vector field, The tangent Space: tangent to the level set, gradient, **Surfaces:** Hyperplane, Lagrange multiplier, Vector Fields on Surfaces, maximal integral curve, orientation and its consistency, Osculating plane, Serret Frenet formula, Singular points and their classification Gauss, The Gauss map spherical image, one-sheeted hyperboloid, **Geodescis:** maximal geodesic, great circle, Parallel Transport, covariant derivative and acceleration, Fermi derivative, The Weingarten Map: shape operator, geodesic flow, **Curvature of plane curves:** center of curvature, radius of curvature, Isometries, Intrinsic differentiation, Gauss-Kronecker curvature, translation, rotation, Funda-mental theorem on curves, **Riemannin metrics:** Hyperbolic metric, Stereographic projection, Poincare metric, affine and Riemannian connection and covariance derivation, Applications of differential geometry in engineering and sciences.

Essential Reading:

1. J. A. Thorpe, *Elementary Topics in Differential Geometry* (Springer), 2004.

MA 372	**STATISTICS LABORATORY**	**2 Credits [0-0-3]**

1. Classification of raw data
2. Computation of arithmetic mean by different methods
3. Computation of geometric mean and harmonic mean for ungrouped and grouped data
4. Computation of quartiles, deciles and percentiles
5. Computation of mean deviation and quartile deviation
6. Computation root mean square deviation and standard deviation
7. Computation of raw moments and central moments
8. Computation of Karl Pearson’s coefficient of correlation
9. Testing if the mean of a normal population is equal to a given value
10. Testing the equality of two population means
11. Testing if the variance of a normal population is equal to a given value
12. Testing the equality of two population variances

MA 373	**LABORATORY WORKS ON LATEX AND MATLAB**	**2 Credits [0-0-3]**

Introduction to Latex- Latex symbols- Type setting- Figures and Tables inserting – Formatting. **Introduction to Mathematica and Matlab**- Matrix computation using Matlab- Solving algebraic and differential equations using Mathematica and Matlab. Plotting graphs .

MA 401 REAL ANALYSIS 4 Credits [3-1-0]

Numerical sequences and series: Convergent sequences, Subsequences and Cauchy sequences, Special sequences, Upper and lower limits, Series of non-negative terms, Root and ratio tests, Summation by parts, Absolute convergence, Rearrangements, *Continuity*: Continuity and compactness and connectedness, Monotonic functions, *Differentiation*: The Mean value theorem, Continuity of derivatives, L'Hospital's rule, Taylor's Theorem, Differentiation of Vector-valued functions, *The Riemann-Stieltjes integral*: Definition, existence and properties, Integration and differentiation, Integration of vector-valued function, *Sequence and series of functions*: Uniform convergence and continuity, Differentiation and integration, Equi-continuous family of functions, The Stone-Weierstrass theorem, *Functions of several variables*: Linear transformations, Differentiation, The contraction principle, The inverse and implicit function theorems, The rank theorem, Derivatives of higher order, Differentiation of integrals

Essential Reading:

1. W. Rudin, Principles of Mathematical Analysis, McGraw Hill, 1986.

Supplementary Reading:

1. F. Morgan, Real Analysis, AMS Bookstore, 2005.

MA 402 MEASURE THEORY 4 Credits [3-1-0]

Outer measure, Measurable sets and Lebesgue measure, Nonmeasurable sets, Measurable functions, Littlewood's three principles, The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, The integral of a nonnegative function, The general Lebesgue integral, Convergence in measure, Differentiation of monotone functions, Functions of bounded variation, Differentiation of an integral, Absolute continuity, Convex functions, The L^p spaces, The Minkowski and Holder inequalities, Convergence and completeness, Approximation in L^p, Bounded linear functionals on the L^p spaces.

Essential Reading:

1. E. D. Benedetto, *Real Analysis: Foundations and Applications*, Springer, 2002
2. H. L. Royden, *Real Analysis (Third Edition)*, Macmillan Publishing Company, 1988
3. G. De. Barra, *Measure Theory and Integration*, Horwood Publishing Corporation, 2003.

MA 403 LINEAR ALGEBRA 4 credits [3-1-0]

Vector spaces, Bases and dimensions, Change of bases and change of coordinates, Sums and direct sums, Spanning sums and independence, The dimension of a vector space, The complexification of a real vector space, Quotient spaces. Linear transformations, The kernel and image of a linear transformation, The rank and nullity theorem, Change of bases for linear transformations, Linear functionals, Representation of linear transformations by matrices, Dual spaces, Second dual, Reflexive spaces, Invariant subspaces, Direct-sum decomposition, Cyclic subspaces and Annihilators, The minimal polynomial, The rational and Jordan canonical forms, Inner product spaces, Orthonormal bases, Gram-Schmidt process. Adjoint operators, Normal, unitary, and self-adjoint operators, Spectral theorem for normal operators.

Essential Reading:

1. K. Hoffman and R. Kunze, *Linear Algebra*, PHI, 1971.
2. S. roman, *Advanced Linear Algebra*, Springer, 2007.

MA 404 FUNCTIONS OF A COMPLEX VARIABLE 4 credits [3-1-0]

Spherical representation of extended complex plane, Analytic functions, Branches of multiple-valued functions, Cauchy's theorem, Singularities, The Argument principle, Calculus of residues, Harmonic functions, Poisson's formula, The reflection principle, Conformal mappings, Geometry of Mobius transformations, Open mapping theorem, The Maximum modulus theorem, Schwarz's lemma, Partial fractions and factorization, Stirling's formula, Jensen's formula, Hadamard's theorem.

Essential Reading:

1. L. V. Ahlfors, *Complex Analysis* (McGraw Hill International), 1979
2. J. B. Conway, *Functions of One Complex Variable* (Springer), 1978
3. W. Rudin, *Real and Complex Analysis* (McGraw-Hill), 1986

MA 405 PARTIAL DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

Origin of first order partial differential equations, Cauchy's problem, Linear equations, Integral surfaces passing through a given curve, Surfaces orthogonal to a given system of surfaces, Nonlinear partial differential equations of the first-order, Cauchy's method of characteristics, Compatible systems of first-order equations, Charpit's method, Special types of first-order equations, Solutions satisfying given conditions, Jacobi's method, Origin of second order partial differential equations , Second and higher order equations in physics, Linear partial differential equations with constant coefficients, Equations with variable coefficients, Characteristic curves of second-order equations, Characteristics of equations in three variables, Solution of linear hyperbolic equations, Separations of variables, Integral transforms method, Nonlinear equations of second-order. Laplace's equation: The occurrence of Laplace's equation in physics, Elementary solutions of Laplace's equations, Family of equipotential surfaces, Boundary value problem, Problems with axial symmetry, Kelvin inversion theorems , theory of green's function for Laplace equation.

Essential Reading:

1. N. Sneddon: *Elements of Partial Differential Equations*, Dover, 2006

MA 407 TOPOLOGY 4 credits [3-1-0]

Topological spaces and continuous functions: Topological spaces, Basis for a topology, Order topology, Product topology, Subspace topology, Closed sets and limit points, Continuous functions, Homeomorphism, Metric topology, Quotient topology, Connectedness and compactness: Hausdorff spaces, Connected spaces, Connected subspaces of the real line, Compactness and local connectedness, Compact spaces, Compact subspaces of the real line, Limit point compactness, Local compactness, Countability and separation axioms: Countability axioms, Separation axioms, Normal spaces, Regular spaces, Completely regular spaces, Urysohn lemma, Urysohn metrization theorem, Tietze extension lemma, The Tychonoff theorem: Compactification, One-point compactification, The Stone-Cech compactification, Metrization theorems and paracompactness, Local finiteness, Complete metric spaces and function spaces: Compactness in metric spaces, Pointwise and compact convergence, Ascoli,s theorem, Baire's spaces and dimension theory, A nowhere differentiable function, Applications of topology in engineering and sciences.

Essential Reading:

1. J. R. Munkres: *Topology*: (Pearson Prentice Hall), 2005

MA 413 ANALYSIS-II 4 credits [3-1-0]

Functions on Euclidean spaces, continuity, differentiability; partial and directional derivatives, Chain Rule, Inverse Function Theorem, Implicit Function Theorem. Riemann Integral of real-valued functions on Euclidean spaces, measure zero sets, Fubini's Theorem. Partition of unity, change of variables. Integration on chains, tensors, differential forms, Poincare Lemma, singular chains, integration on chains, Stokes' Theorem for integrals of differential forms on chains. (general version). Fundamental theorem of calculus. Differentiable manifolds (as subspaces of Euclidean spaces), differentiable functions on manifolds, tangent spaces, vector fields, differential forms on manifolds, orientations, integration on manifolds, Stokes' Theorem on manifolds.

Essential Reading:

1. V. Guillemin and A. Pollack, *Differential Topology*, Prentice-Hall Inc., Englewood Cliffe, New Jersey, 1974.

Supplementary Reading:

1. W. Fleming, *Functions of Several Variables*, 2nd Ed., Springer-Verlag, 1977.
2. J.R. Munkres, *Analysis on Manifolds*, Addison-Wesley, 1991.
3. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGraw-Hill, 1984.
4. M. Spivak, *Calculus on Manifolds, A Modern Approach to Classical Theorems of Advanced Calculus*, W. A. Benjamin, Inc., 1965.

MA 423	**DISCRETE MATHEMATICS**	**3 credits [3-0-0]**

The language of sets: The concept of a set, Operations with sets, Computer operations with sets, The cardinality of a set, Recursively defined sets: *Functions and Matrices*: The concept of a function, Special functions, Properties of functions, The pigeonhole principle, Composition of functions, Matrices. *Induction and algorithms*: The division algorithm, Divisibility properties, Mathematical Induction, Algorithm correctness, The growth of functions, *Recursion*: Recursively defined functions, Solving recurrence relations, Generating functions, Recursive algorithms, *Combinatorics and Discrete probability*: The fundamental counting principles, Permutations, derangements, Combinations, Permutations and combinations with repetitions, The binomial theorem, The generalized inclusion and exclusion principle, Discrete probability. *Relations*: Boolian matrices, Relations and digraphs, Computer representations of relations, Properties of relations, Operations on relations, The connectivity relations, Equivalence relations, Partial and total orderings. *Graphs*: Computer representation of graphs, Paths, cycles and circuits, Eulerian and Hamiltonian graphs, Planner graphs, graph colouring, Trees: Spanning trees, Binary trees, Binary search trees. *Boolean algebras and combinatorial circuits*: Boolean algebras, Boolean functions, Logic gates, Combinatorial circuits.

Essential Reading:

1. T. Koshy, *Discrete Mathematics with Applications*, Academic Press (An Imprint of Elsevier) First Indian Reprint 2005

MA 424	**OPERATIONS RESEARCH**	**3 credits [3-0-0]**

Convex sets, Supporting and separating hyperplanes, Convex polyhedron and polytope, Convex functions, , Linear programming model, Graphical solution, The simplex method, Artificial variables, The Big-M method, Degeneracy and cycling, Dual of an LPP, The dual simplex method, *Transportation and assignment Problems*: Balanced transportation problem, Unbalanced transportation problem, Basic feasible solution by north-west corner rule, Row minima and column minima methods, Vogel's approximation method, Solution of TP, Assignment problem, Hungarian method of assignment, *Queuing Theory*: Introduction, Components of a queuing problem, Classification of queues, Steady, Transient and explosive states of a queue, Roles of Poisson process and exponential distribution in queuing theory, Queuing models, $(M/M/1:\infty/FIFO)$ Model, Distribution of waiting time and time spent by an unit in the system, $(M/M/1:N/FIFO)$ model, $(M/M/c:\infty/FIFO)$ model, $(M/M/c:N/FIFO)$ model, $(M/E_k/1:\infty/FIFO)$ model, $(M/E_k/1:\infty/FIFO)$ model, $(M/E_k/1:1/FIFO)$ model, Real life examples of queuing models.

Essential Reading:

1. H.A. Taha, *Operations Research,* Prentice Hall, 1997

Supplementary Reading:

1. N. S. Kambo*, Mathematical Programming Techniques*, East West Press, 1997.

MA 425	ELEMENTORY STOCHASTIC PROCESS WITH APPLICATIONS	3 credits [3-0-0]

(Prerequisite: MA-201)

Definition and examples of stochastic processes, Classifications of stochastic processes, Markov chains, Definition and examples, Transition Probability matrices, Classification of states of a Markov chain, Determination of higher order transition probabilities, stability of a Markov chain, Graph theoretic approach, Markov chains with denumerable number of states, Reducible Markov Chains, Markov chains with continuous state spaces, General pure birth and death processes, Renewal processes, Renewal processes in continuous time, renewal equation, Renewal theorems, Residual and excess lifetime, Renewal reward processes, Regenerative renewal processes, Stochastic processes in queuing, General concepts of queuing systems, Steady state and transient behavior, Birth and death process in queuing theory, Network of Markovian queuing systems.

Essential Reading :

1. J. Medhi, *Stochastic Processes*, New Age Publishers, 2007.

MA 431	MATHEMATICAL METHODS	3 credits [3-0-0]

Bessel Equation: General solution of Bessel equation, Recurrence relations, Orthogonal sets of Bessel functions, Modified Bessel functions, Applications.

Legendre equation: General solution of Legendre equation, Legendre polynomials, Associated Legendre polynomials, Rodrigues formula, Orthogonality of Legendre polynomials, Application.

Green's function: Concept and calculation of Green's function, Approximate Green's function, Green's function method for differential equations.

Fourier Series, Generalized Fourier series, Fourier Cosine series, Fourier Sine series, Fourier integrals. Fourier transform, Laplace transform, Z-transform, Hankel transform, Mellin transform. Solution of differential equation by Laplace and Fourier transform methods.

Essential Reading:

1. G. N. Watson, *A Treatise on the Theory of Bessel Functions*, Cambridge University Press, 1944.
2. G. F. Roach, *Green's Functions*, Cambridge University Press, 1995.
3. A.D. Poularikas, *The Transforms and Applications Handbook*, CRC Press, 1996.
4. J. W. Brown and R. Churchill, *Fourier Series and Boundary Value Problems*, McGraw Hill, 1993.

MA 432	FINITE DIFFENCE METHODS	3 credits [3-0-0]

Iterative methods for linear systems: Classical iterative methods (Jacobi, Gauss-Seidel and successive overrelaxation (SOR) methods), Krylov subspace methods; GMRES, Conjugate-gradient, biconjugate-gradient (BiCG), BiCGStab methods, preconditioning techniques, parallel implementations.

Finite difference method: Explicit and implicit schemes, consistence, stability and convergence, Lax equivalence theorem, numerical solutions to elliptic, parabolic and hyperbolic partial differential equations.

Essential Reading:

1. D.S. Watkins, *Fundamentals of Matrix Computations, Second Edition*, Wiley-interscience, New York, 2002.
2. Joe D. Hoffman, *Numerical methods for Engineers and Scientist*, McGrow-Hill, 1993.
3. A. Quarteroni and A. Valli, *Numerical Approximation of Partial Differential Equations*, Springer, 1994.
4. K. Atkinson and W. Han, *Theoretical Numerical Analysis: A Functional Analysis Frame-work*, Springer-Verlag, New York, 2001.

MA 433	FINITE ELEMENT METHODS	3 credits [3-0-0]

Basic concept of the finite element method, Integral formulations and variational methods, The Lax-Milgram theorem, The abstract Galerkin method, Piecewise polynomial approximation in Sobolev spaces, Finite elements, Numerical quadrature, Applications to autonomous and non-autonomous problems, Optical error bounds in energy norms, Variational crimes, Apriori error estimates. The discontinuous Gaterkin methods, Adaptive finite element, The Autin-Nitscte duality argument, A posteriori error analysis.

Essential Reading:

1. C. Johnson, *Numerical Solution of Partial Differential Equations by the Finite Element Method*, Cambridge Universityh Press, 1987.
2. J. N. Reddy, *An Introduction to Finite Element Method*, McGraw Hill, 1993

Supplementary Reading :

1. P. G. Ciarlet, *The Finite Element Method for Elliptic Problems*, North-Holland, Amsterdam, 1978.
2. K. Erikssen et al., *Computational Differential Equations*, Cambridge University Press, 1996.
3. C. A. J. Fletcher, *Computational Galerkin Methods*, Springer-Verlag, New-York inc, 1984.

MA 438	DYNAMICAL SYSTEMS	4 credits [3-1-0]

Review of stability for linear systems. Flow defined by nonlinear systems of ODEs, linearization and stable manifold theorem. Hartman-Grobman theorem. Stability and Lyapunov functions. Planar flows: saddle point, nodes, foci, centers and non-hyperbolic critical points. Gradient and Hamiltonian systems. Limit sets and attractors. Poincare map, Poincare Benedixson theory and Poincare index.

Essential Reading:

1. L. Perko, *Differential Equations and Dynamical Systems*, Springer Verlag, NY, 1991.

Supplementary Reading:

1. V.I. Arnold, *Ordinary Differential Equations*, Prentice Hall of India, New Delhi, 1998.
2. M.W. Hirsch and S. Smale, *Differential Equations, Dynamical Systems and linear Algebra*, Academic Press, NY, 1974.

MA 470	LABORATORY WORKS ON REAL LIFE PROBLEMS-I	2 credits [0-0-3]

MA 471	OBJECT ORIENTED PROGRAMMING PRACTICE LABORATORY	2 credits [0-0-3]

Computational works are to be done on the following 12 topics.

1. Finding all topologies from a 4-point set
2. Income tax calculation

3. Calculation of quintiles
4. Drawing all random samples from a given population and finding the unbiased estimate of the population mean and the variance
5. Calculation of central moments
6. Computations of roots of algebraic and transcendental equations by four methods
7. Interpolation by four methods
8. Numerical integration and numerical solution of differential equations
9. Listing all primes and twin primes up to certain number
10. Listing all divisors of certain numbers
11. Finding the determinant and inverse of a matrix
12. Finding eigen values and eigen vectors of a given matrix

MA 501 ABSTRACT ALGEBRA 4 Credits [3-1-0]

Groups, Subgroups, Centralizers, Normalizers, Stabilizers, Kernels, Cyclic groups, Subgroups generated by a subset of a group, Quotient groups, Lagrange's theorem, Homomorphisms, Isomorphism theorems, Composition series, Solvable groups, Nilpotent groups, Symmetric group, Alternating group, Group actions, Permutation representations, Automorphisms, p-groups, The Sylow theorems, Simplicity of the Alternating group, Direct products of groups, Fundamental theorem of finitely generated abelian groups, Groups of small orders, Rings, Ring homomorphisms, Ideals, Ring of fractions, The Chinese remainder theorem, Euclidean domains, Principal domains, Unique factorization domains, Matrix rings, Polynomial rings, Irreducible Criteria, Eisenstein's criterion.

Essential Reading:

1. D. S. Dummit & R. M. Footee, *Abstract Algebra*, Wiley, 2008

Supplementary Reading:

1. I. N. Herstien, *Topics in Algebra*, Wiley, 2008
2. J. J. Rotman, *An Introduction to the Theory of Groups*, Springer, 1999

MA 502 FUNCTIONAL ANALYSIS 4 Credits [3-1-0]

Normed spaces, Banach spaces, Further properties of normed spaces, Finite dimensional normed spaces and subspaces, Compactness and finite dimension, Bounded and continuous linear operators, Linear functionals, Linear operators and functionals on finite dimensional spaces, Normed spaces of operators, Dual spaces, Inner product spaces, Hilbert spaces, Further properties of inner product spaces, Representation of functionals on Hilbert spaces, Hilbert-adjoint operator, Self-adjoint, unitary and normed operators, Fundamental theorems for normed and Banach spaces: Zorn's lemma, Hahn-Banach theorem, Hahn-Banach theorem for complex vector spaces and normed spaces, Adjoint operators, Reflexive spaces, Topological vector spaces.

Essential Reading:

1. Y. Eidelman, V.D. Milman, A. Tsolomitis, Functional *Analysis: An Introduction*, AMS Bookstore, 2004
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Willey, 1978

MA 503 ALGEBRA- II 4 Credits [3-1-0]

Simple groups and solvable groups, nilpotent groups, simplicity of alternating groups, composition series, Jordan-Holder Theorem. Semidirect products. Free groups, free abelian groups.

Rings, Examples (including polynomial rings, formal power series rings, matrix rings and group rings), ideals, prime and maximal ideals, rings of fractions, Chinese Remainder Theorem for pairwise comaximal ideals.

Euclidean Domains, Principal Ideal Domains and Unique Factorizations Domains. Poly-nomial rings over UFD's.
Fields, Characteristic and prime subfields, Field extensions, Finite, algebraic and finitely generated field extensions, Classical ruler and compass constructions, Splitting fields and normal extensions, algebraic closures. Finite fields, Cyclotomic fields, Separable and inseparable extensions.

Galois groups, Fundamental Theorem of Galois Theory, Composite extensions, Examples (including cyclotomic extensions and extensions of finite fields). Norm, trace and discriminant. Solvability by radicals, Galois' Theorem on solvability. Cyclic extensions, Abelian extensions, Trans-cendental extensions.

Essential Reading:

1. M. Artin, *Algebra*, Prentice Hall of India, 1994.
2. D.S. Dummit and R. M. Foote, *Abstract Algebra*, 2nd Ed., John Wiley, 2002.
3. J.A. Gallian, *Contemporary Abstract Algebra*, 4th Ed., Narosa, 1999.
4. N. Jacobson, *Basic Algebra I, 2nd Ed*., Hindustan Publishing Co., 1984, W.H. Freeman, 1985.

MA 504	DIFFERENTIAL GEOMETRY	4 Credits [3-1-0]

Vector Fields: height of the level set, level curves, Integral curve, smooth vector field, The tangent Space: tangent to the level set, gradient, **Surfaces:** Hyperplane, Lagrange multiplier, Vector Fields on Surfaces, maximal integral curve, orientation and its consistency, Osculating plane, Serret Frenet formula, Singular points and their classification Gauss, The Gauss map spherical image, one-sheeted hyperboloid, **Geodescis:** maximal geodesic, great circle, Parallel Transport, covariant derivative and acceleration, Fermi derivative, The Weingarten Map: shape operator, geodesic flow, **Curvature of plane curves:** center of curvature, radius of curvature, Isometries, Intrinsic differentiation, Gauss-Kronecker curvature, translation, rotation, Funda-mental theorem on curves, **Riemannin metrics:** Hyperbolic metric, Stereographic projection, Poincare metric, affine and Riemannian connection and covariance derivation, Applications of differential geometry in engineering and sciences.

Essential Reading:

1. J. A. Thorpe, *Elementary Topics in Differential Geometry* (Springer), 2004.

MA 510	CALCULUS OF SEVERAL VARIABLES	4 credits [3-1-0]

Euclidean Space: Vector space, Definition of euclidean space, Orthinormal basis, The dual and second dual, Norms in the dual, The space L(E, F), Open sets, Closed sets, Completeness, Borel covering theorem, Equivalence of norms, Connected open sets.

Mappings and their duals: Continuous mappings, Definition of differentials, Differentiability implies continuity, Special cases, Function of class C^1, Mappings of class C^1, Composition of differentiable mappings, Higher differentials.

Mappings into reals: Taylor's theorem for one variable, Taylor's theorem for n variables, Absolute maxima and minima, Volume of a set, Integral on a closed interval, Condition for integrability, Integral on an open set, Iterated integral, Volume of n-ball, Interchange of order of integration with differentiation.

Main theorems on mappings: Regular elements in L(E, F), Inverse of a mapping, Implicit function theorem, Determinant, Oriented volume, Change of variables in integration.

Essential Reading:

1. S. Salas and G.J. Etgen, *Calculus: Several Variables*, John Wiley, 2003

T. P. Dick, C. M. Patton, *Calculus of Several Variables*, PWS Pub. Co., 1995

MA 511 DIFFERENTIAL GEOMETRY 4 credits [3-1-0]

Vector Fields: height of the level set, level curves, Integral curve, smooth vector field, The tangent Space: tangent to the level set, gradient, Surfaces: Hyperplane, Lagrange multiplier, Vector Fields on Surfaces, maximal integral curve, orientation and its consistency, Osculating plane, Serret Frenet formula, Singular points and their classification Gauss, The Gauss map spherical image, one-sheeted hyperboloid, Geodescis: maximal geodesic, great circle, Parallel Transport, covariant derivative and acceleration, Fermi derivative, The Weingarten Map: shape operator, geodesic flow, Curvature of plane curves: center of curvature, radius of curvature, Isometries, Intrinsic differentiation, Gauss-Kronecker curvature, translation, rotation, Funda-mental theorem on curves, Riemannin metrics: Hyperbolic metric, Stereographic projection, Poincare metric, affine and Riemannian connection and covariance derivation, Applications of differential geometry in engineering and sciences.

Essential Reading:

1. J. A. Thorpe, *Elementary Topics in Differential Geometry* (Springer), 2004.

MA 512 FOURIER ANALYSIS 4 credits [3-1-0]

Fourier series and integral: Fourier coefficient and series, Criteria for point-wise convergence, Fourier series of continuous functions, Convergence in norm, Summability methods, The Fourier transforms of L^1 functions, The Fourier transform on L^p, $p > 2$, The convergence and summability of Fourier integrals. *The Hardy-Littlewood maximal functions*: Approximation of the identity, Weak-type inequalities and almost everywhere convergence, The Marcinkiewicz interpolation theorem, The Hardy-Littlewood maximal function, The dyadic maximal function. *The Hilbert transform*: The conjugate Poisson kernel, The theorems of M. Riesz and Kalmogrov, Truncated integrals and point-wise convergence, Multipliers

Essential Reading:

1. J. Duoandikoetxea, *Fourier Analysis*: AMS Bookstore, 2001.

MA 513 DIFFERENTIAL TOPOLOGY 4 credits [3-1-0]

Manifolds and Smooth Maps: Derivatives and tangents, The inverse function theorem and immersions, submersions, transversability, homotopy and stability, Sard's theorem and Morse functions, embedding manifolds into Euclidean spaces, Simplicial surfaces: Simplices, Simplicial complexes, Simplicial surfaces, The Euler characteristic, Proof of the classification of compact and connected surfaces, Smooth surfaces, Tangent and normal vectors, First fundamental forms, Directional derivatives. Coordinates free, Dirtectional derivatives-coordinates, Length and area, Isometries, Transversality and interactions: Manifolds with boundaries, one-manifolds and some consequences, Transversality and interaction theorem mod 2, winding numbers and the Jordan-Brouwer separation theorem, Oriented interaction theorem: Motivation, orientation, oriented interaction number, Lefschetz fixed-point theory, Vector fields and the Poincare-Hopf theorem, The Hopf degree theorem, The Euler characteristic and triangulations, Intergration on manifolds: Introduction, exterior algebra, differential forms, interior of manifolds, exterior derivatives, cohomology with forms, Stokes' theorem, Integration and mappings, the Gauss-Bonnet theorem.

Essential Reading:

1. D. B. Gauld, *Differential Topology: An Introduction*, Dover Publication 2006.

MA 514 RINGS AND MODULES 4 credits [3-1-0]

Ring of continuous functions, matrix rings, polynomial rings, power series rings, Laurent rings, Boolean rings, Direct products, local rings, prime fields, Euclidean domains, PID, Unique factorization domains, Eisenstein's criteria, modules, direct sum, free modules, quotient modules, simple modules, homomorphisms, module's over PID's, Artinian modules, Noetherian modules, Artian rings, Noetherian rings, Nil Radicals, Jacobson radicals.

Essential Reading:

1. C. Musili, *Introduction to Rings and Modules*, Narosa,

MA 515	**HOMOTOPY THEORY**	**4 credits [3-1-0]**

Brouwer Fixed point theorem, categories, Functors, Natural transformations, Natural equivalence, Homtopy, Convexity, Contrctibility, Mapping cylinder and cones, Paths and path connected spaces, Affine spaces, Affine maps, Homotopy as equivalence relation, Contractible Spaces, Homotopy of maps, Homotopy classes, Homotopically equivalent spaces with examples, Fundamental Groups, Induced maps and homomorphisms, Lifting property, Calculation of first homotopy groups, Function spaces, Group objects and cogroup objects, Loop space and suspension, Exact sequence of homotopy groups, Homotopy lifting propert, Homotopy extension property, Fibrations and cofibrations, CW-complexes and their examples, attaching of maps, Homotopy groups of CW-complexes, The effect on the homotopy groups of a cellular extension, Spaces with prescribed homotopy groups, Weak homotopy equivalences and CW-approximation Homotopy extension and classification theorems, Study of some cases where homotopy theory is applied in electrical engineering.

Essential Reading:

1. J. Rotman, *Algebraic Topology*, Springer-Verlag, 2004

MA 516	**OPERATOR THEORY**	**4 credits [3-1-0]**

Banach Spaces: The Banach space of continuous functions, Abstract Banach spaces, The conjugate space of continuous linear functionals, Examples of Banach spaces: c_0, l^1 and l^∞, Weak topologies on Banach spaces, The Alaoglu theorem, The Hahn-Banach theorem, The conjugate space of C([0,1]). The open mapping theorem, The Lebesgue spaces: L^1 an L^∞, The Hardy spaces: H^1 and H^∞, Banach algebras: The Banach algebra of continuous functions, Abstract of Banach algebras, Abstract index in a Banach algebra, The space of multiplicative linear functions, The Gelfand transform, The Gelfand-Mazur theorem, The Gelfand theorem for commutative Banach algebras, The spectral radius formula, The Stone-Weirstrass theorem, The generalized Stone-Weirstrass theorem, The disk algebra, The algebra of functions with absolutely convergent Fourier series, The algebra of bounded measurable functions, Geometry of Hilbert space: Inner product spaces, The Cauchy-Schwarz inequality, The Pythagorian theorem, Hilbert spaces, Examples of Hilbert Spaces: C^n, l^2, L^2, and H^2. The Riesz-Representation Theorem, The existence of orthogonal bases, The dimension of Hilbert spaces, Operators on Hilbert space and C^*-algebras: The adjoint operators, Normal and self-adjoint operators, Projections and subspaces, Multiplication operators and maximal abelian algebras, The bilateral shift operators, C^*-algebras.

Essential Reading:

1. R. G. Douglas: *Banach Algebra Techniques in Operator Theory*, Springer, 1998

MA 517	**LIE ALGEBRA**	**4 credits [3-1-0]**

Definitions and example, Solvable and nilpotent Lie algebras, Simple and semi-simple Lie algebras, Levi's theorem, Idealizer and centralizer, Derivation of a Lie algebra, Structure constant, Special linear algebra, Lie groups and Lie algebras, Classical groups and their Lie algebras, Cartan-Killing form, Root-space decomposition of a Semi-simple Lie algebra, Properties of root space, Simple root system and classification of finite dimensional complex Semi-simple Lie algebra, Cartan matrix, root diagrams, Dynkin diagrams, Weyl group of a root system, Weyl reflection, Real forms of Lie algebras and their classification through Satake and Vogan diagram, Applications of Lie groups and Lie algebras to robotics, Genetic coding, Control theory, Computer vision, Particle physics.

Essential Reading:
1. K. Erdmann, M. J. Wildon, *Introduction to Lie Algebras*, Springer 2006

MA 518 ADVANCED COMPLEX ANALYSIS 4 credits [3-1-0]

Compactness and Convergence in the space of analytic functions, Riemann mapping theorem, Reflection principle, Weierstrass factorization theorem, The Reimann zeta function, Runge's theorem, Simple connectedness, Picard's little theorem and Picard's big theorem, Normal families, Equicontinuity, Arzela's theorem, Normality and continuity, Conformal mapping of polygons, The Schwarz-Christiffel formula, Harnock's of harmonic functions, Diridhlet's principle, The Weierstrass P-function, Analytic continuation, The Monodromy theorem, Picard's theorem, Lacunary values.

Essential Reading:
1. L. V. Ahlfors, *Complex Analysis* (Mc-Graw Hill International)

Supplementary Reading:
1. J. B. Conway, *Functions of One Complex Variable* (Narosa).
2. M. Rao & H. Stetkaer, *Complex Analysis: An Invitation* (World Scientific)

MA 519 MULTI LINEAR ALGEBRA 4 credits [3-1-0]

Tensor product: Multilinear mappings of vector spaces, Existence and universal property of the tensor product, Commutativity and associativity of the tensor product, The tensor product in terms of coordinates, Tensor products and spaces of linear mappings, Tensor algebras: Covariant, contravariant and mixed tensors, Classical definition and notation of a tensor in terms of coordinates, Structure tensor of an algebra, Mixed tensor algebra, Universal property of the tensor algebra, symmetry and alteration, Exterior algebra: Exterior powers and p-vectors, Alternation operator, Exterior powers of linear mappings, Exterior algebra, Duality and p-forms, Exterior algebra, duality in exterior algebra, applications to vector space bundles, exterior differentiation, Tensor products and standard algebras: Graded vector spaces, graded algebra, the graded tensor algebras, commutative algebra, the exterior algebra of a finite dimensional vector spaces, Grassman algebras: Alternate k-linear functions, exterior multiplications, homogeneous elements, decomposable elements, Recent developments.

Essential Reading:
1. R. Merris, *Multilinear Algebra*, (CRC Press) 1997

MA 520 AUTOMATA THEORY 4 credits [3-1-0]

Finite Automata, Regular expressions, equivalence of finite automata and expressions, Moore and Mealy Machines, Properties of regular sets: Pumping lemma, closure properties and decision algorithms, Minimizing finite automata, Context-free grammars, Pushdown automata

Essential Reading:
1. J. E. Hopcroft & J. D. Ullman, *Introduction to Automata theory, Languages and computations* (Narosa)

MA 521 COMBINATORICS 4 credits [3-1-0]

Graphs, Trees, Colorings of graphs and Ramsey's theorem, The addressing problem for graphs, The principle of inclusion and exclusion, inversion formulae, Permanents, Elementary counting, Stirling numbers, Recursions and generating functions, Partitions, (0,1)-matrices, Latin squares, Hadamard matrices, 1 Designs, Codes and designs, Strongly regular graphs and partial geometries, Orthogonal Latin squares, Projective and combinatorial geometries, Gaussian numbers and q-analogues, Lattices and Möbius inversion, Combinatorial designs and projective geometries.

Essential Reading:

1. V. K. Balakrishnan, *Theory and Problems of Combinatorics*, McGraw Hill, 1994
2. J. H. Van Lint and R.M. Wilson, *A Course in Combinatorics*, Cambridge University Press, 2001.

MA 522	OPERATIONS RESEARCH	4 credits [3-1-0]

Nonlinear programming problem: Kuhn-Tucker optimality conditions and convex programming: Kuhn-Tucker first order optimality conditions, Second order optimality conditions, Lagrange's method, Convex programming problem, Sufficiency of Kuhn-Tucker conditions, Lagrangian saddle-point and duality, Duality of convex programs - Quadratic programming (Wolfe's and Beale's methods)

Network analysis: Preliminaries - min cost flow problem - max flow problem - CPM/PERT. Scheduling and sequencing.

Queuing theory: Queuing theory: Introduction, Components of a queuing problem, Classification of queues, Steady, transient and explosive states of a queue, Roles of Poisson process and exponential distribution in queuing theory, Queuing models, (M/M/1:∞/FIFO) model, Distribution of waiting time and time spent by an unit in the system, (M/M/1:N/FIFO) model, (M/M/c:∞/FIFO) model, (M/M/c:N/FIFO) model, (M/E_k/1:∞/FIFO) model, (M/E_k/1:∞/FIFO) model, (M/E_k/1:1/FIFO) model, Examples of queuing models.

Inventory Control: Introduction, Inventory control for single commodity - deterministic inventory models (without and with shortages) - Probabilistic inventory (both discrete and continuous) control models.

Essential Reading:

1. H.A.Taha, *An Introduction to Operations Research* , PHI, 2002

Supplementary Reading:

1. H.M.Wagner : *Principles of Operations Research*, Prentice Hall of India, Delhi. , 1996
2. J.C. Pant, *Introduction to Optimisation*, Jain Brothers, Delhi, 2000.
1. F. S. Hillier & G. J. Lieberman, *Introduction to Operations Research*, Tata McGraw-Hill, 2005.
2. N.S. Kambo: *Mathematical Programming Techniques*, Affiliated East-West Press Ltd, 1984.

MA 523	DISCRETE MATHEMATICS	4 credits [3-1-0]

Functions and matrices: Special functions, Properties of functions, pigeonhole principle, Composition of functions.

Induction and algorithms: The division algorithm, Divisibility properties, Mathematical induction, Algorithm correctness, The growth of functions, Complexities of algorithms.

Recursion: Recursively defined functions, Solving recurrence relations, Generating functions, Recursive algorithms, Correctness of recursive algorithms, Complexities of recursive algorithms.

Combinatorics and discrete probability: The fundamental counting principles, The generalized inclusion and exclusion principle, Discrete probability.

Relations: Boolian matrices, Relations and digraphs, Computer representations of relations, Properties of relations, Operation on relations, The connectivity relations, Equivalence relations, Partial and total orderings.

Graphs: Computer representation of graphs, Isomorphic graphs, Paths, cycles and circuits, Eulerian and Hamiltonian graphs, Planner graphs, graph colouring.

Trees: Spanning trees, Minimal spanning trees, Rooted trees, Binary trees, Binary search trees.

Boolean algebras and combinatorial circuits: Boolean algebras, Boolean functions, Logic gates, Combinatorial circuits, Minimization of combinatorial circuits, Recent developments.

Essential Reading:

1. T. Koshy, *Discrete Mathematics with Applications*, Academic Press (An Imprint of Elsevier) First Indian Reprint 2005.

Supplementary Reading:

1. R. Johnsonbaugh, *Discrete Mathematics*, Pearson Prentice Hall, 2008

MA 524	**STATISTICAL METHODS**	**4 credits [3-1-0]**

Random variables: Distribution functions, Properties of distribution functions, Discrete random variables and probability mass functions, Continuous random variables and probability density functions, Two dimensional random variables: Joint, marginal and conditional distributions, Independence, Mathematical expectations: Mathematical expectation of function of a random variable, Linearity of mathematical expectation, Expectation in joint distributions, Conditional expectation and conditional variance, Moments, cumulants and their generating functions, Conditional expectations and conditional variance, Theoretical discrete distributions: Binomial, Poisson, hyper-geometric, Negative binomial and multinomial distributions, Recurrence relations for probabilities and moments, Theoretical continuous distributions: Exponential, gamma, beta and normal distributions, Applications of normal distribution, Chi-square distribution: Test for goodness of fit and population variance, t-distribution: Test for single mean and difference of two means, F-distribution: Test for equality of two population variances, Law of large numbers: Chebyshev’s inequality, Weak law of large numbers, De-Moivre Laplace theorem, Central limit theorems.

Essential Reading:
1. J. E. Freund, *Mathematical Statistics with Applications*, Miller 2003.

Supplementary Reading:
1. J. Medhi, *Statistical Methods, An Introductory Text*, New Age, 1992
2. K. Knight, *Mathematical Statistics*, CRC Press, 1999

MA 525	**ERGODIC THEORY**	**4 credits [3-1-0]**

Measure preserving transformation, Isomorphism and spectral invariants, Measure preserving transformation with pure point spectrum, Entropy.

Essential Reading:

1. P. Walters, *Ergodic Theory*, Springer Verlag, 1981

MA 527	**FRACTALS**	**4 credits [3-1-0]**

Fractal examples: the Traidic Cantor dust, the Sierpinski Gasket, A space of strings, Turfle graphics, Sets defined recursively, number system, Metric topology, Uniform convergence, The Hausdorff metric, Metrics for strings, Topological dimension, Small and large inductive dimension, Two dimensional euclidean space, Other topological dimensions.

Essential Reading:
1. G. A. Edger, *Measure, Topology and fractal Geometry*, Springer Verlag.
2. M. Barnsley, *Fractals Everywhere*, Morgan Kaufmann, 2000.
3. H. O. Peitgen, *Chaos and Fractals*, New Frontiers of Science, Springer, 2004

MA 529	INFORMATION THEORY	4 credits [3-1-0]

Information Theory and Source Coding: Introduction to information theory, Uncertainty and information, Average mutual information and entropy, Information measures for continuous random variables, Source coding theorem, Huffman coding, The Lempel-Ziv algorithm, Tun length encoding and PCX format, Rate distortion function, Optimum quantizer design, Introduction to image compression, The Jpeg standard for lossless compression, The Jpeg standard for Lossy compression, Channel Capacity and Coding: Channel models, Channel capacity, Channel coding, Information capacity theorem, The Shannon limit, Random selection of codes, Cryptography: Introduction to cryptography, An overview of encryption techniques, Operations used by encryptions algorithm, Symmetric (secret key) cryptography, Data encryption standards (DES), International data encryption algorithm (IDEA), RC ciphers, Assymmetric (public key) algorithms, Way hashing, Other techniques, Secure communication using chaos functions, Cryptanalysis, Politics of cryptography, Recent developments.

Essential Reading:
1. H. S. M. Coxeter, *Elements of Information Theory*, John Wiley, 2005.

Supplementary Reading:
1. R. Bose, *Information Theory Coding and Cryptography*, Tata McGraw-Hill, 2003
2. S. Goldman, *Information Theory*, Dover, 2005

MA 531	BOUNDARY LAYER THEORY	4 credits [3-1-0]

Outline of viscous flows: Real and perfect fluids, viscosity, Reynolds number, Laminar and turbulent flows, Asymptotic behavior at large Reylonds numbers, Fundamentals of boundary-layer theory: Boundary-layer concept, Laminar boundary-layer on a flat plate at zero incidence, Separation of the boundary-layer. Field equations for flows of Newtonian fluids: Continuity equation, Momentum equation, General stress state of deformation bodies, General state of deformation of flowing fluids, Relation between stresses and rate of deformation, Stokes hypothesis, Navier-Stokes equations, Energy equations, Equations of motion in different coordinate systems. Exact solutions of the Navier-Stokes equations: Couette-Poiseuille flows, Plane stagnation point flow, Flow at a wall suddenly set into motion, Stokes first problem, Flow at an oscillation flow, Stokes second problem, Unsteady plane stagnation-point flow. Boundary-layer equations in plane flow: Setting the boundary-layer equations, Wall friction, separation and displacement, Dimensional representation of the boundary layer equations, Plate boundary- layer. Thermal boundary- layer: Boundary layer equations for the temperature field, Effect of the Prandtl number.

Essential Reading:
1. H. Schlichting and K. Gersten, *Boundary-Layer Theory*, Springer, 2003.

MA 532	NUMERICAL SOLUTIONS OF PARTIAL DIFFERENTIAL EQUATIONS	4 credits [3-1-0]

Parabolic equations in one space dimension, Explicit and implicit formula, Convergence and stability, Derivative boundary conditions, Parabolic equations in three dimensions, Explicit methods and their stability, Alternating direction implicit methods, nonlinear equations, Elliptic equations in two dimensions, Laplace equation in a square, the Nuemann problem, Mixed boundary conditions, Non-rectangular regions, Alternative method for constructing difference formula, Properties of difference formula, The solution of elliptic difference equations, Direct factorization methods, Successive over relaxation, A.D.I methods, Conjugate gradient and related methods, First order hyperbolic equations, Explicit and implicit schemes and their stability.

Essential Reading:

1. A.R. Mitchel & D.F. Grifflts: *The Finite Difference Methods in Partial Differential Equations*, Willey, 1980

MA 533	**MODERN THEORY OF PARTIAL DIFFERENTIAL EQUATIONS**	**4 credits [3-1-0]**

Theory of distributions: support, test functions, regular and singular distributions, generalized derivatives,

Sobolev spaces: Definition and basic properties, approximation by smooth functions, dual spaces, trace and imbedding results

Eliptic boundary value problems: abstract variational problems, Lax-Milgram lemma, weak solutions and wellposedness with examples, regularity result, maximum principles, eigen value problems.

Semigroup theory and applications: exponential map, C-semigroups, Hille-Yosida and Lummer-Phillips theorems, applications to heat and wave equations

Essential Reading:

1. S Kesavan, Topics in Functional Analysis, Wiley Eastren Ltd, New Delhi, 1989.

Supplementary Reading:

1. L C Evans, Partial Differential Equations, AMS, Providence, 1998.

2. M Renardy and RC Rogers, An introduction to Partial Differential Equations, 2^{nd} edition, Springer, New York, 2004.

MA 534	**GEOMETRY OF ROBOTICS**	**4 credits [3-1-0]**

Robotics: An introduction, Theoretical robotics, Mathematical ingredients: Lie groups, subgroups, the Proper Euclidean group, Chasle's theorem, SE(3), Reuleaux's lower pairs, Lie algebras, Commutators, Exponential mapping, Robots Jacobian and Derivatives, Robot Kinematics: Inverse kinematics for 3-R wrists, 3-R Robots and planar motion, Planar 4-bar, Line geometry, Plucker coordinates, Inverse robots Jacobian, Representation SO(3), Screw systems, Clifford algebra, Dual quarternions, Euclidean geometry, Pieper's theorem, the T3 Robot, the PUMA, Statics: Gripping, Friction, Dynamics: Lagrangian and Hamiltonian Dynamics of Robots. Robot equation of motion, Constrained dynamics, trees and stars, Serial robot with end effector constraints, Biped walking, Differential geometry, Controlling of Robots, Hybrid control, Non linear control and Lie brackets.

Essential Reading:

1. J.M. Seling, *Geometric Fundamentals of Robotics*, Springer (2005)

Supplementary Reading:

1. R M Murray, S. Sastry, Li Z, *A mathematical introduction to robotic manipulation*, CRC press, Boca Raton, Florida

MA 535 CALCULUS OF VARIATIONS AND INTEGRAL EQUATIONS 4 credits [3-1-0]

Calculus of Variations: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations.

Integral equations : Classification of Liner Integral Equations: Fredholm, Volterra, Integro-Differential Equations, Singular Integral Equations, Converting Volterra Equation to ODE, Conversion of IVP to Volterra equation Conversion of BVP to Fredholm Equation ; Fredholm Integral Equations - Decomposition method, Direct Computation method, successive approximation method, method of successive substitutions, Homogeneous Fredholm Equations, Comparison between Alternative methods ; Volterra Integral Equation – Adomian Decomposition methods, Series Solution method, converting Volterra Equation to VIP, Successive Approximation method, successive substitution method, comparison between alternative methods ; Intergro-Differential Equations – Introduction, Direct Computation method, Adomian Decomposition Method. Conversion to Fredholm integral Equation. Volterra Intego-Differential equation Series Solution, Decomposition Method, Conversion to IVP.

Essential Reading:

1. A. S. Gupta, *Calculus of Variations*, Prentice-Hall Of India Pvt. Ltd., 2004
2. M. L. Krasnov, A. I. Kiselev, and G. I. Makarenko, *Problems and Exercises in Integral Equations*, Mir Publ., Moscow, 1971.

Supplementary Reading:

1. J. N. Reddy, *An introduction to the Finite Element Method*, McGraw Hill, NY, 2006.
2. Shanti Swarup, *Linear Integral Equations*, Krishna Prakashan Media (Pvt.) Ltd., 2003.
3. J. Kondo, *Integral Equations*, Clarendon Press, Oxford, 1997.
4. C. Corduneanu, *Integral Equations and Applications*, Cambridge Univ.Press, Cambridge–New York, 1991.
5. A. C. Pipkin, *A Course on Integral Equations*, Springer-Verlag, New York, 1991.
6. A.W. Wazwaz, *A First Course in Integral Equation*, World Scientific, 1997.
7. A.J. Jerri, *Introduction to Integral Equation with Application*, Wiley Interscience, 1999.

MA 536 NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

Introduction. Runge-Kutta methods -derivation, error bounds and error estimates. Weak stability theory for Runge-Kutta methods. Order and convergence of the general explicit one-step methods. Linear multi-step methods -derivation, order consistency, zero-stability and convergence. Weak stability theory for general linear multi-step methods. Predictor-Corrector methods. Stiff systems.

Essential Reading:

1. J. C Butcher, *Numerical Methods for Ordinary Differential Equation*, Wiley publisher, 2008.

MA 537 NUMERICS OF SINGULARLY PERTURBED DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

First-order Initial-Value Problems: Continuous problem, classical difference schemes, necessary conditions, uniformly convergent exponentially fitted schemes, artificial viscosity, constant fitting factors, optimal error estimates, Fitted mesh methods in one dimension, Convergence of fitted mesh methods for Reaction-diffusion problem and convection-diffusion problems.

Essential Reading:

R.E. O'Malley, Singular Perturbation Methods for Ordinary Differential Equations, Springer-Verlag, New York, 1991.

1. J.J.H Miller, E.O. Riordan, G.I Shishkin, *Fitted Numerical Methods for Singular Perturbation Problems*, World Scientific, Singapore, 1996.

Supplementary Reading:

1. P.A. Farrell, A.F. Hegarty, J.J.H Miller, E.O. Riordan, G.I Shishkin, *Robust Computational Techniques for Boundary Layers*, Chapman & Hall/CRC Press, Boca Raton, FL, 2000.
2. E.P. Doolan, J.J.H. Miller, and W.H.A. Schildres. *Uniform Numerical Methods for Problems with Initial and Boundary Layers*. Boole Press, Dublin, 1980.

MA 538	FLUID DYNAMICS	4 credits [3-1-0]

Review of gradient, divergence and curl. Elementary idea of tensors. Velocity of fluid, Streamlines and path lines, Steady and unsteady flows, Velocity potential, Vorticity vector, Conservation of mass, Equation of continuity. Equations of motion of a fluid, Pressure at a point in fluid at rest, Pressure at a point in a moving fluid, Euler's equation of motion, Bernoulli's equation. Singularities of flow, Source, Sink, Doublets, Rectilinear vortices. Complex variable method for two-dimensional problems, Complex potentials for various singularities, Circle theorem, Blasius theorem, Theory of images and its applications to various singularities. Three dimensional flow, Irrotational motion, Weiss's theorem and its applications. Viscous flow, Vorticity dynamics, Vorticity equation, Reynolds number, Stress and strain analysis, Navier-Stokes equation, Boundary layer Equations

Essential Reading:

1. G. K. Batchelor, *An Introduction to Fluid Dynamics*, Cambridge University Press, 1993.

Supplementary Reading:

1. N. Curle and H. Davies, *Modern Fluid Dynamics*, Van Nostrand Reinhold, 1966.
2. F. Chorlton, *A Text Book of Fluid Dynamics*, Von Nostrand Reinhold/CBS, 1985.
3. L. M. Milne Thomson, *Theoretical Hydrodynamics*, Macmillan and Co., 1960.
4. A. R. Patterson, *A First Course in Fluid Dynamics*, Cambridge University Press, 1992.

MA 539	SCIENTIFIC COMPUTATING	4 credits [3-1-0]

Errors; Iterative methods for nonlinear equations; Polynomial interpolation, Spline interpolations; Numerical integration based on interpolation, quadrature methods, Gaussian quadrature; Initial value problems for ordinary differential equations - Euler method, Runge-Kutta methods, multi-step methods, predictor-corrector method, stability and convergence analysis; Finite difference schemes for partial differential equations - Explicit and implicit schemes; Consistency, stability and convergence; Stability analysis (matrix method and von Neumann method), Lax equivalence theorem; Finite difference schemes for initial and boundary value problems (FTCS, Backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme).

Essential Reading:

1. D. Kincaid and W.Cheney, *Numerical Analysis:Mathematics of Scientific Computing, 3rd Ed.*, AMS, 2002.
2. G. D. Smith, *Numerical Solutions of Partial Differential Equations, 3rd Ed.*, Calrendorn Press, 1985.

Supplementary Reading:

1. K. E. Atkinson, *An Introduction to Numerical Analysis*, Wiley, 1989.
2. S. D. Conte , C. de Boor, *Elementary Numerical Analysis, An Algorithmic Approach*, McGraw-Hill, 1981.
3. R.Mitchell and S.D.F.Griffiths, *The Finite Difference Methods in Partial Differential Equations*, Wiley, 1980.

MA 540	SINGULAR HOMOLOGY THEORY	4 credits [3-1-0]

General Homology Theory: Axioms of homology theory, Singular homology theory, Affinely independent, Ordered simplex: Standard n-simplex, Singular n-simplex, singular n-chain, Free abelian group, Singular chain complex, nth singular homology group of a topological space, boundary operator, Induced homomorphism of singular homology groups, Connecting homomorphism, Brouwer fixed point theorem: Brouwer degree, Jordan-Brouwer separation theorem, Brouwer theorem on the invariance domain, Inverse system and direct system of abelian groups, Attaching spaces with maps, Singular homology groups of standard projective spaces: Excision theorem, Reduced singular homology groups, Strong deformation retract, Relative homeomorphim theorem, Verification Eilenberg-Steenrod axioms, Calculation of singular homology groups using Eilenberg-Steenrod axioms, Products: Kunneth formula, Acyclic model Theorem, Homology external product, Alexander-Whitney diagonal approxi-mation, Homology theory of CW-complxes, Some cases application of singular homology groups in electrical engineering.

Essential Reading:

1. J. Rotman: *An Introduction to Algebraic Topology* (Springer-Verlag) 2004

MA 541	COMMUTATIVE ALGEBRA	4 credits [3-1-0]

Dimension theory of affine algebras: Principal ideal theorem, Noether normalization lemma, dimension and transcendence degree, catenary property of affine rings, dimension and degree of the Hilbert polynomial of a graded ring, Nagata's altitude formula, Hilbert's Nullstellensatz, finiteness of integral closure.

Hilbert-Samuel polynomials of modules : Associated primes of modules, degree of the Hilbert polynomial of a graded module, Hilbert series and dimension, Dimension theorem, Hilbert-Samuel multiplicity, associativity for-mula for multiplicity, Complete local rings: Basics of completions, Artin-Rees lemma, associated graded rings of filtrations, completions of modules, regular local rings Basic Homological algebra: Categories and functors, derived functors, Hom and tensor products, long exact sequence of homology modules, free resolutions, Tor and Ext, Koszul complexes. Cohen-Macaulay rings: Regular sequences, quasi-regular sequences, Ext and depth, grade of a module, Ischebeck's theorem, Basic properties of Cohen-Macaulay rings, Macaulay's unmixed theorem, Hilbert-Samuel multiplicity and Cohen-Macaulay rings, rings of invariants of finite groups.

Essential Reading:

1. D. Eisenbud, Commutative Algebra (with a view toward algebraic geometry) Graduate Texts in mathematics 150, Springer-Verlag, Berlin, 2003.

Supplementary Reading:

2. H. Matsumura, Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press, Cambridge, 1980.

3. W. Bruns and J. Herzog, Cohen-Macaulay Rings, (Revised edition) Cambridge Studies in Advanced Mathematics No. 39, Cambridge University Press, Cambridge, 1998.

MA 542 TENSOR ANALYSIS 4 credits [3-1-0]

Tensor analysis: Transformation of coordinates, The summation convention, Contravariant vectors, Invariants, Covariant vectors, Tensors, The Christofell 3-index symbols and their relations, Riemann symbols and the Riemann tensor, The Ricci tensor, Quadratic differential forms, The equivalence of symmetric quadratic differential forms, Covariant differentiation with respect to a tensor g_{ij}, Introduction to a metric: Definition of a metric, N-tuply orthogonal systems of hypersurfaces in a V_n, Metric properties of a space V_n immersed in a V_m, Geodesics, Riemannian, Normal and geodesic coordinates, Geodesic form of the linear element, Finite equations of geodesics, Curvature of a curve, Parallel displacement and the Riemann tensor, Fields of parallel vectors, Associate directions, Curvature of V_n at appoint, The Bianchi identity, The theorem of Schur, Isometric correspondence of spaces of constant curvature, Conformal spaces, Spaces conformal to flat space, Orthogonal ennuples: The Frenet formulas Principal directions determined by a symmetric covariant tensor of the second order, The Ricci principal tensors, Condition that a congruence of an orthogonal ennuple be normal, N-tuply orthogonal systems of hypersurfaces, N-tuply orthogonal systems of hypersurfaces in a space conformal to a flat space, Congruence canonical with respect to a given congruence, Recent developments.

Essential Reading:

1. L.P. Lebedev: *Tensor Analysis* (World Scientific) 2003.

MA 543 COMPLEX DYNAMICS 4 credits [3-1-0]

1. Introduction and definitions
2. Newton's method
3. Critical points, classification of fixed points, periodic points
4. The Fatou and Julia sets
5. Properties of the Julia set
6. Repelling and parabolic fixed points
7. Connectedness, density of orbits
8. Classification of components of the Fatou set
9. No wandering domains
10. Attracting basins, rotation domains
11. Bottcher's theorem
12. Shishikura's theorem
13. Quadratic polynomials
14. The special case of polynomials, quadratic polynomials
15. The structure of the Fatou sets
16. The Mandelbrot set (the parameter space)- Definition and properties, Proof that its complement is simply connected (time permitting), Its interior structure; combinatorics

Essential Reading:

1. Iteration of rational functions, Alan F. Beardon

MA 544 CATEGORY THEORY 4 credits [3-1-0]

Categories and Functors: The definition of a category, Covariant and contravariant functors, Natural transformations, Natural equivalence, Examples from from different topics of engineering and sciences, The duality principle, The construct of small categories, Reflective subcategories, Coma category, Full and faithful functors, Limits and colimits: Products and coproducts, Limits, colimits, equalizer, coequaliser, pullback, pushout, Universal and couniversal properties, Equivalence of equalizer and pullback in presence of products, Equivalence of coequalizer and pushout in presence coproducts, Limits in terms of products and equalizers, Limits in terms of products and pullback, Colimits in terms of coproducts and coequalizers, Colimits in terms of coproducts and pushout, Adjoint functors: Left adjoint, Right adjoint, Adjoint functor theorem, Preservation of limits by adjoint functors, Representable functors, Representing objects, Tensor products of categories.

Essential Reading:

1. S. Awodey: *Category Theory* (Oxford University Press) 2006

MA 545 CONVEX ANALYSIS AND MONOTONE OPERATORS 4 credits [3-1-0]

Convex set, convex function and its properties in Banach spaces and R^n, Subdifferential, Normal and tangent cones and its application to optimization, Fenchel duality, Clarke subdifferential, cone and its properties, Regular normal cone, subdifferential, subderivatives and its calculus rule in R^n.

Monotone operators: definitions, examples, properties, Fitzpatrick's function: definition and properties, Linear maximal monotone operators, Maximal monotonicity of sums and compositions involving maximal monotone operators in reflexive spaces and non reflexive spaces, Introduction of different types of maximal monotone operators and its relationship, Enlargements of monotone operators.

Essential Reading:

1. Rockafellar and Wets, *Variational Analysis* , Springer, Chapter-: 2 (A, B, D,E, F), 6(A,B) and 8(A,B,C).

Supplementary Reading:

1. J. M. Borwein and A. S. Lewis, *Convex Analysis and Nonlinear Optimization Theory and Applications*, Springer, Chapter-: 3 and 6
2. F H Clarke, *Optimization and Nonsmooth analysis*, Chapter-: 1.1,1.2,2.1,2.2 and 2.3.
3. S Simons, *Hahn Banach to Monotonicity*, Springer, Chapter-: IV, VI and VII

MA 546 DIFFERENTIABLE MANIFOLDS 4 credits [3-1-0]

Differentiable Manifolds: Topological manifolds, Chart, Atlas, Maximal atlas, Differentiable structures, Differentiable functions, Diffeomorphisms, Germs of local smooth functions, Algebra of smooth germs, Derivation, Tangent and cotangent spaces, Differential of smooth map, Immersion, Vector bundles, Examples of smooth vector bundles, Differential forms: Alternate k-linear functions, Grassmann algebras, Universal property of exterior algebra, Differential forms, Differential k-forms, Exterior multiplication, Exterior differentiation, De Rham cohomolgy groups, Induced transformations, Poincare’s lemma, Riemannian manifolds: Innerproducts, Riemannian structures, Riemannian metric, Riemannian connection, Geodesics, Convex neighborhoods, De Rahm’s theorem: Singular homology groups, Real singular cohomology groups, De Rham’s theorem.

Essential Reading:

1. L. Conlon: *Differentiable Manifolds* (Springer-Verlag): 2001

MA 547 GEOMETRY OF NORMED SPACES 4 credits [3-1-0]

Geometric form of Hahn-Banach theorem, w-w* topologies, James characterization of reflexivity, Strict convexity, Uniform convexity, Duality between strict convexity and smoothness, Differentiability of the norm, Drop theorem, Bishop- Phelp theorems, Krein-Milman theorem and Radon-Nikodym property

Essential Reading:

1 M. Fabian, P. Habala, P. Hajek, V.M. Santalucia, J. Pelant and V. Zizler, Functional analysis and infinite dimensional geometry, Canadian Mathematical Society, 2001

Supplementary Reading:

1. J. B. Conway, *A course in functional analysis*. Graduate Texts in Mathematics, 96. Springer-Verlag, 1990.

2. K. Yosida, *Functional Analysis*, Springer-Verlag (1980).

MA 548 FIELD THEORY 4 credits [3-1-0]

Algebraic Extensions, Algebraic closed fields, Splitting fields, Normal extensions, Multiple Roots, Finite fields, Separable extensions, Galois theory: Automorphism groups and fixed firelds, Fundamental theorem of Galois theory, Fundamental theorem of algebra, Applications: Roots of unity and cyclotomic polynomials, cyclic extensions, Polynomoals solvable by radicals, Symmetric functions, Ruler and compass construction

Essential Reading:

1. S. Lang: *Algebra* (Addison-Wesley)
2. T. W. Hungerford: *Algebra* (Springer)

MA 549 ALGEBRAIC GEOMETRY 4 credits [3-1-0]

Regular Functions and Maps: The Zariski topology, Regular functions on an affine variety, Projective varieties, Regular maps, The Veronese map, Determinantal representation of Veronese varieties, Subvarieties of Veronese varieties, The Segre maps, Subvarieties of Segre varieties, Products of varieties, Graphs, Fiber products, Combinations of Veronese and Segre maps, Cones, Projections and More about Products: Cones, Quadrics, Projections, More cones, More projections, Constructible sets, Families and parameter spaces: Families of varieties, The universal hyperplane, The universal hyper section, Parameter spaces of hypersurfaces, Universal families of hypersurfaces, A family of lines, Rational functions and rational maps: Rational functions, Rational Maps, Graphs of Rational Maps, Birational Isomorphism, The Quadric Surface, Hypersurfaces, Degree of a rational map, Blow-ups, Blowing up points, Blowing up subvarieties, The quadric surface again, The cubic scroll in $\mathbb{P}^4$, Unirationality.

Essential Reading:

1. J. Harris, *Algebraic Geometry A First Course*, Springer, 1992

MA 550 CODING THEORY 4 credits [3-1-0]

Block codes, Linear codes, Hamming codes, Weight enumerators, Binary Golay code, Ternary Golay code, Constructing codes from other codes, Ree-Muller codes, Cyclic codes: Generator matrix and check polynomial, Zeros of a cyclic code, BCH codes, Reed-Solomon codes, Binary cyclic codes of length 2n (n odd).

Essential Reading:

1. J. H. van Lint, *Introduction to Coding Theory*, Springer, 1998.
2. F. Blake & R. C. Mullin, *An introduction to Algebraic and Combinatorial Coding theory,* Academic press, 1976.

MA 551 NUMERICAL ANALYSIS 4 credits [3-1-0]

Sources of errors, Propagation of errors, Stability in numerical analysis, Root finding of nonlinear for equations: Aitken extrapolation for linearly convergent sequences, Error tests, The numerical evaluation of multiple roots, Brent's root finding algorithm, Hermite interpolation, Piecewise polynomial interpolation, The minimax and near minimax approximations, The Remes algorithms, Numerical integration: Patterson's method, Asymptotic error formulas and their applications, Adaptive numerical integration, Singular integrals, Umerical methods for differential equations: Multistep method, Derivation of higher-order multistep methods, Numerical solutions of system of linear equations: The residual correction method, Error prediction and acceleration, The numerical solution of Poisson's equation.

Essential Reading:

1. K. E. Atkinsan, *An Introduction to Numerical Analysis*, Willey, 1978
2. E. Süli, D. F. Mayers, *An Introduction to Numerical Analysis*, Cambrige University Press, 2003

MA 552	**FUZZY LOGIC AND SET THEORY**	**4 credits [3-1-0]**

Fuzzy sets, Support, Membership function, Fuzzy union and intersection, Fuzzy product, Fuzzy topological spaces, Fuzzy continuity, Fuzzy compactness, Fuzzy connectedness, Fuzzy groups, Fuzzy normal Subgroups, Fuzzy ideals, Fuzzy maximal ideals.

Essential Reading:

1. H. J. Zimmermann, *Fuzzy Set Theory and Its Applications*, Kluwer Academic Publishers, 1998.

MA 553	**OPTIMIZATION TECHNIQUES**	**4 credits [3-1-0]**

Dynamic programming: Introduction, The recursive equation approach, Computational proce-dure in dynamic programming, Solution of LPP by dynamic programming, Application of dynamic programming to a minimum path problem, Goal programming: Goal programming problem, Generalized goal programming models, Chebyshev norm model, Network optimization problem: The shortest-path problem, The mimimun spanning tree problem, Maximum flow problem, Minimum cost flow problem, Network simplex method, Simulation: Various Methods of Sample Collection, Simulated sampling (Monte-Carlo method), Definition of simulation, Steps in simulation procedure, Simulation model, Application of simulation method, Simulations here Monte-Carlo methods are useful, General procedure of Monte Carlo methods, Advantages and disadvantages of Monte Carlo methods, Problem of Replacement: Replacement models and their solutions, Concept of present value, Replacement of items whose efficiency deteriorates with time, Replacement of items whose maintenance cost increases with time and the value of money remains the same, Replacement of items when value of money also changes, Replacement of items that fail completely, Group replacement method, Inventory control: Economic lot size models, EOQ with uniform rate of demand, Economic lot size with different rates of demand in different cycles, Determination of buffer stock, ABC analysis of inventory, Game theory: Solving simple games, Games with mixed strategies, Graphical solution procedure, Solution by linear programming.

Essential Reading:

1. F. S. Hillier & G. J. Lieberman, *Introduction to Operations Research*, Tata McGraw-Hill, 2005

Supplementary Reading:

1. N.S. Kambo, *Mathematical Programming Techniques*, Affiliated East-West Press Ltd, 1984.

MA 554	**GRAPH THEORY**	**4 credits [3-1-0]**

Path and circuits, Trees and fundamental circuits, Cut sets and cut vertices, Planner and dual graphs, Vector spaces of a graph, Directed graphs.

Essential Reading:

1. N. Deo, *Graph Theory with Applications to Engineering and Computer Science,* PHI, 1974

MA 555	**STOCHASTIC PROCESSES**	**4 credits [3-1-0]**

Stochastic Processes: Definition and examples of stochastic processes, Classifications of stochastic processes, Markov chains: Definition and examples, Transition Probability matrices, Classification of states of a Markov chain, Determination of higher order transition probabilities, Stability of a Markov chain, Graph theoretic approach, Markov chains with denumerable number of states, Reducible Markov chains, Markov Chains with continuous state spaces, Non-homogeneous Markov Chains, Markov chains in continuous time: General pure birth and death processes, Birth and death processes with absorbing states, Renewal processes: Renewal processes in continuous time, renewal equation, Renewal theorems, Residual and excess lifetime, Renewal reward processes, Regenerative renewal processes, Regenerative inventory systems, Generalization of the classical renewal theory, Stochastic processes in queuing and reliability: General concepts of queuing systems, Steady state and transient behavior, Birth and death process in queuing theory, Network of Markovian queuing systems, Reliability, Introduction to Brownian motion: Wiener processes, Differential equations for a Wiener process, Kalmogrov's equations, The first passage time distribution for a Wiener process. Recent developments.

Essential Reading:

1. J. Medhi, *Stochastic Processes*, New Age Publishers, Second Edition, Reprint 2007.

Supplementary Reading:

1. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, Academic Press, 1975.

MA 556	NUMBER THEORY	4 credits [3-1-0]

Basis representation: Principles of mathematical induction, The basis representation theorem, *The fundamental theorem of arithmetic*: Euclid's division lemma, Divisibility, The linear Diophantine equation, The fundamental theorem of arithmetic, Combinatorial and computational number theory: Fermat's little theorem, Wilson's theorem, Generating functions, The use of computers in number theory, *Fundamentals of congruences*: Basic properties of congruences, Residue systems, Riffling, *Solving congruences*: Linear congruences, The theorems of Fermat and Wilson revisited, The Chinese remainder theorem, Polynomial congruences, Arithmatic functions: Combinatorial study of $\varphi(n)$, Formulae for d(n) and $\sigma(n)$, Multiplicative arithmetic functions, The Mobius inversion formula, *Primitive roots*: Properties of reduced residue systems, Primitive root modulo p.

Essential Reading:

1. G. E. Andrews, *Number Theory*, Courier Dover Publications, 1994.

MA 557	STATISTICAL INFERNECE(PARAMETRIC)	4 credits [3-1-0]

Parametric models, parameters, random sample and its likelihood, statistic and its sampling distributions, problems of inference. Examples from standard discrete and continuous models such as Bernoulli, Binomial, Poisson, Negative Binomial, Normal, Exponential, Gamma, Weibull, Pareto etc. Concept of sufficiency, minimal sufficiency, Neyman factorization criterion, Fisher information, exponential families. Maximum likelihood estimators, method of moment estimators, percentile estimators, least squares estimators, minimum mean squares estimators, uniformly minimum variance unbiased estimators, Rao-Blackwell theorem, Cramer-Rao lower bond, different examples.

Statistical Hyptheses-simple and composite, statistical tests, critical regions, Type-I and Type-II errors, size and power of a test, Neyman Pearson lemma and its different applications. Most powerful test, uniformly most powerful test, unbiased test and niformly most unbiased test. Likelihood ratio test. Interval estimation, confidence intervals, construction of confidence intervals, shortest expected length confidence interval, most accurate one sided confidence interval and its relation to UMP test.

Essential Eeadings:

1. R. L. Berger and G. Casella, *Statistical Inference.*
2. E. L. Lehmann, *Theory of Point Estimation*

Supplementary Readings:

1. T. S. Ferguson, *Statistical Decision Theory.*
2. E. L. Lehmann, *Testing of Statistical Hypotheses.*
3. P. J. Bickel and K. A. Doksum, *Mathematical Statistics.*
4. J. O. Berger, *Statistical Decision* Theory.

MA 558 SAMPLING TECHNIQUES 4 credits [3-1-0]

Basic concept of sample surveys: Census and sample surveys, Advantages and disadvantages, Probability and non-probability sampling, Sampling unit, Sampling frame, Sampling and non-sampling error, Simple random sampling and Stratified random sampling: Procedure for selecting a random sample, Estimation of population parameters, Estimation of population Proportion, Confidence limits, Estimation of sample size, Principle of stratification, Advantages of stratification, Estimation of population mean and variance, Allocation of sample size in different strata, Relative precision of stratified random sampling over simple random sampling, Estimation of gain in precision due to stratification, Systematic random sampling: Sample selection procedure, Advantages and disadvantages, Estimation mean and its sampling variance, Comparison of simple random sampling with stratified random sampling in some specified populations, Cluster sampling: Equal cluster sampling, Estimator of mean and its variance, Relative efficiency of cluster sampling, Optimum cluster size, Cluster sampling for proportions.

Essential Reading:

1. R.K.Som, *Practical Sampling Techniques*, CRC Press, 1995

Supplementary Reading:

1. S.K. Thompson, *Sampling*, John Wiley, 1992.

MA 559 STATISTICAL DECISION THEORY 4 credits [3-1-0]

Games and statistical games, statistical decision problem, decision funcion, risk function, prior and posterior distribution, Bayes risk and Bayes rules, least favourable prior, minimaxity, admissibility and complete classes, admissibility of Bayes rules, existence of minimal complete class and Bayes rules, the supporting and separating hyperplane theorems, essential completeness of the class of nonrandomized rules, minimax and complete class theorems, solving for minimax rules, essential completeness of class of rules based on suffiecient statistics, continuity of risk functions, invariant decision problems, admissible and minimax invariant decision rules.

Essential Readings:

1. T. S. Ferguson, *Statistical Decision Theory.*
2. E. L. Lehmann, *Theory of Point Estimation.*

Supplementary Readings:

1. J. O. Berger, *Statistical Decision* Theory.

MA 560 MATHEMATICAL METHODS 4 credits [3-1-0]

Asymptotic expansions, Watson's lemma, method of stationary phase and saddle point method. Applications. to differential equations. Behaviour of solutions near an irregular singular point, Stoke's phenomenon, Method of strained coordinates and matched asymptotic expansions. Variational principles, Lax-Milgram theorem and applications to boundary value problem, Calculus of variations and integral equations. Volterra integral equations of first and second kind. Iterative methods and Neumann series.

Essentials Reading:

1. C.M. Bender and S.A. Orszag, *Advanced Mathematical Methods for Scientists and Engineers*, McGraw-Hill Book Co., 1978.

Supplementary Reading:

1. J. Kevorkian and J.D. Cole, *Perturbation Methods in Applied Mathematics,* Springer Verlag, Berlin, 1985

MA 561 LIE GROUPS AND APPLICATIONS TO ODEs AND PDEs 4 credits [3-1-0]

Lie group of transformations, Infinitesimal transformations, Extended transformations, Multiparameter, Lie group of Transformations, Invariance of Ordinary Differential Equations, Invariance of ODEs under multi-parameter groups, Applications to Boundary Value problems, Invariance of Partial Differential Equations.

Essential Reading:

1.G.W. Bluman and S. Kumei, *Symmetries and Differential Equations*, Springer Verlag, New York, 1989

Supplementary Reading:

2.N.H. Ibragimov, *Transformation groups applied to mathematical physics*, Reidel, Dordrecht, 1985

MA 562 FINITE VOLUME METHODS FOR HYPERBOLIC PDEs 4 credits [3-1-0]

Conservation Laws and Differential Equations, Characteristics and Riemann Problems for Linear Hyperbolic Equations, Finite volume methods, Necessary components for convergence, CFL Condition, Lax-Friedrichs Method, The Richtmyer Two-Step Lax-Wendroff Method, Upwind Methods, Godunov's Method, Flux-Difference vs. Flux-Vector Splitting, Roe's Method, The Lax-Wendroff Method, The Beam-Warming Method.

Essential Reading:

1. R.J. LeVeque, *Finite volume methods for hyperbolic problems*, Cambridge University Press, Cambridge, UK 2002.

Supplementary Reading:

1. E. F. Toro, *Rieman solvers for numerical methods for fluid dynamics*, Springer-Verlag, Berlin, 1999.

MA 563 WAVELETS AND APPLICATIONS 4 credits [3-1-0]

Fourier transform on L^1 (R) and L^2 (R) and basic properties and examples; Motivation and definition of Windowed Fourier Transform and examples, Time frequency localization, the reconstruction formula; Motivation and Definition of the wavelet transform and examples, Basic properties, The reconstruction formula, Frequency localization, Scaling functions and wavelets, orthogonal bases of compactly supported wavelets, orthonormal Wavelets; Definition of Multiresolution Analysis and examples, Properties of scaling functions and orthonormal wavelets bases, Construction of orthonormal wavelets.

Essential Reading:

1. L. Debnath, *Wavelet Transforms and Their Applications*, Birkhäuser, 2002.

Supplementary Reading:

1. G. Bachman, L. Narici, and E. Beckensterin, *Fourier and Wavelet Analysis*, Springer-Verlage, 2000.

2. C.K. Chui, *An Introduction to Wavelets*, Academic Press, 1992.

MA 564 INTEGRAL AND DESCRETE TRANSFORMS 4 credits [3-1-0]

Laplace Transform : Definition - Functions of exponential order and examples - Transforms of elementary, transcendental and special functions - transforms of derivatives and integrals and periodic function, unit step function and impulse function - The inverse transform - Convolution theorem - solution of differential equations by the use of the transform - Laplace inverse integral - Solution of Laplace equation (in two dimensions), one dimensional heat equation and one dimensional wave equation.

Fourier transform : The Fourier transform, Inverse Fourier transform, Fourier transform properties, Convolution integral, convolution theorem, correlation, correlation theorem, Parseval's theorem, Wave from sampling, sampling theorem, frequency sampling theorem, Solution of one dimensional heat equation. Discrete Fourier Transform : Fourier transform of sequences, Discrete Fourier transform, transfer function. The Fast Fourier Transform : Intuitive Development, Theoretical development of Base 2, FFT algorithm.

Z transform : Z transform, inverse Z transform, Z transform properties, solution of linear difference equations by using z-transform.

Mellin Transforms: Definition, properties and evaluation of transforms, Convolution theorem for Mellin transforms, Application to integral equations.

Essential Reading :

1. Churchill, *Operational Mathematics*, McGraw Hill, Tokyo, 1972.
2. Hildebrand, *Methods of Applied Mathematics*, Prentice Hall Inc., New Jercy, 1960.
3. E.O.Brigham, *The Fast Fourier Transforms*, Prentice Hall, 1988.
4. E.J.Jerry, *Theory and applications of Z transform method*, 1996.

MA 565	FRACTIONAL ORDER MODELS (a,b,d,f)	4 credits [3-1-0]

(a) Special Functions of the Fractional Calculus: Gamma Function. Mittag-Leffler Function. Wright Function. **(b) Fractional Derivatives and Integrals:** Grunwald-Letnikov, Fractional Derivatives. Riemann-Liouville Fractional Derivatives. Some Other Approaches. Geometric and Physical lnterpretation of Fractional lntegration and Fractional Differentiation ; Sequential Fractional Derivatives. Len and Right Fractional Derivatives. Properties of Fractional Derivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms of Fractional Derivatives. Mellin Transforms of Fractional Derivatives ; **(d) Fractional Green's Function :** Definition and some properties. One Term Equation. Two Term Equation, Three-Term Equation, Four-Term Equation. General Case: n-term equation ; **(f) Numerical Evaluation of Fractional Dervative:** Approximation of Fractional Derivatives. The "Short-Memory" Principle. Calculation of Heat Load Intensity Change in Blast Furnace Walls. Order of Approximation. Computation of Coefficients. Higher order Approximations.

Essential Reading:

1. Podlubny, *Fractional Differential Equations*, San Diego, Academic Press, 1999.

Supplementary Reading:

1. Miller KS, Ross B, *An Introduction to the fractional calculus*, New York, John Wiley 1993.
2. Oldham KB, Spanier J, *The Fractional Calculus*, New York, Academic Press: 1974.
3. Podlubny, *Geometric and physical interpretation of fractional integration and fractional differentiation, Fractional Calculus and Applied Analysis*, vol, 5, no. 4, 2002, 367-386.
4. Carpinteri A, Mainardi F, Editors. *Fractals and fractional calculus in continuum mechanics*. CISM Courses and Lectures no. 378. International Center for Mechanical Sciences. New York: Springer Verlag Wien: 1997.

MA 566	FRACTIONAL DIFFERENTIAL EQUATIONS (c,e,g,h)	4 credits [3-1-0]

(c) Linear Fractional Differential Equations: Fractional Differential Equation of a General Form. Existence and Uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. ; The Laplace Transforms methods standard fractional differential equations. Sequential Fractional Differential Equations ; **(e) Other Methods for the solution of fractional order equations:**

Power Series Method ; Babenko's Calculus method. Method of Orthogonal Polynomials. The Mellin Transform Method; **(g) Numerical Solution of Fractional Differential Equations:** Intial Conditions: Which problem to solve? Numerical solution. Examples of Numerical Solution. The "Short Memory" Principle in Initial Values problem for Fractional Differential Equations. Matris approach to discrete fractional calculus. Numerical solution of nonlinear problem. **(h) Applications:** Fractional order systems and controllers.

Essential Reading:

1. Inman D.J 1994. *Engineering Vibrations*. Prentice Hall, Englewood Cliffs, NJ.
2. Timoshenk S., Young D.H. and Weaver W. 1990. *Vibrations Problems in Engineering* 5th ed. Wiley, New York., NY.
3. Rao J.S. *Advanced Theory of Vibration*. New York, NY1991.
4. Chakraverty S. *Vibration of Plates*, Taylor and Francis, Boka Raton2008.
5. Meirovitch L. *Elements of Vibration Analysis*. 2nd Ed. McGraw Hill, New York, NY1986.

MA 567	THEORY OF VIBRATIONS	4 credits [3-1-0]

Theory of Vibrations: Vibrations Basics, One Degree of Freedom Systems, Two Degree of Freedom System, Multi-Degree of Freedom Systems, Continuous Systems: String, Rod, Beam, Membrane, Plate, Equation of Motion Through application of energy method, Approximate methods for Vibrations problems, Rayleigh methods, Rayleigh-ritz methods, Non-Linear Vibarion.

Essential Reading:

1. Inman D.J 1994. *Engineering Vibrations*. Prentice Hall, Englewood Cliffs, NJ.
2. Timoshenk S., Young D.H. and Weaver W. 1990. *Vibrations Problems in Engineering* 5th ed. Wiley, New York., NY.
3. Rao J.S. *Advanced Theory of Vibration*. New York, NY1991.
4. Chakraverty S *Vibration of Plates*, Taylor and Francis, Boka Raton. 2008.
5. Meirovitch L. *Elements of Vibration Analysis*. 2nd Ed. McGraw Hill, New York, NY1986.

MA 568	MATHEMATICS OF SOFT COMPUTING	4 credits [3-1-0]

Introduction to soft computing, Fuzzy set theory, Fuzzy logic and control, gradient descent optimization: least squares methods, genetic algorithms, swarm optimization, support vector machines, neural networks: supervised and unsupervised learning: Hopfield nets, perceptrons, gradient descent, multilayer nets, backpropagation, overfitting, hybrid systems: neuro-fuzzy, neuro-genetic, GA tuned Fuzzy system.

Essential Readings:

1. J-S.R Jang, C-T. Sun, E. Mizutani, Neuro-Fuzzy and soft computing" Prentice Halls, 1997.
2. Ross T J., Fuzzy Logic with engineering applications, John Wiley & Sons 2007.
3. RA Aliev & RR Aliev Soft Computing and its applications, World Scientific, 2001.
4. JM Zurada, Introduction to Artificial Neural Systems. West Pub. Company, 1992
5. John Shawe-Taylor & Nello Cristianini, Support Vector Machines and other kernel – based learning methods- Cambridge University Press, 2000.

MA 569	PERTURBATION METHODS	4 credits [3-1-0]

Asymptotic expansion and approximation, asymptotic solution of algebraic and transcendental equations, regular and singular perturbations for first and second-order ordinary differential equations, physical examples, initial-value problems, multiple scales, two-scale asymptotic approximation, averaging technique, composite asymptotic expansions, initial layers - matching by Van Dyke rules. Two-point boundary-value problems: Boundary layers -exponential and cusp layers, matched asymptotic expansions, composite asymptotic expansions, WKB (Wentzel, Kramers, Brillouin) expansion method, conditions for validity of the WKB approximation, patched asymptotic approximations, WKB solution of inhomogeneous ordinary differential equations. Perturbation methods for linear eigen value problems, Rayleigh-Schrodinger theory, singularity structure of eigen values as functions of complex perturbing parameter, level crossing. Nonlinear eigen value problems, direct error estimation, oscillatory phenomena - free conservative and free self-sustained oscillations, harmonic resonance, shock and transition layers.

Essential Readings:

1. C.M. Bender, S.A. Orszag, *Advanced Mathematical Methods for Scientists and Engineers*, Springer, New York, 1999.
2. W. Eckhaus, *Asymptotic Analysis of Singular Perturbations*, North-Holland, Amsterdam, 1979.
3. J. Kevorkian, J.D. Cole, *Perturbation Methods in Applied Mathematics*, Springer- Verlag, New York, 1981.
4. P.A. Lagerstrom, *Matched Asymptotic Expansions*, Springer-Verlag, New York, 1988.
5. J. A. Murdock, *Perturbations -Theory and Methods*, SIAM -Classics in Applied Mathematics, Vol. 27, SIAM, Philadelphia, 1999.
6. A.H. Nayfeh, *Introduction to Perturbation Techniques*, John Wiley & Sons, New York, 1981.
7. R.E. O'Malley, *Singular Perturbation Methods for Ordinary Differential Equations*, Springer-Verlag, New York, 1991.

MA 571	STATISTICAL METHODS LABORATORY	2 credits [0-0-3]

Computational works are to be done on the following topics.

1. Calculation of A.M., G.M., H.M., median and mode
2. Calculation of quartiles, deciles and percentiles
3. Calculation of range, quartile deviation, mean deviation, standard deviation and root mean square deviations
4. Calculation of central moments from raw moments, calculation of skewness and kurtosis
5. Calculation of raw moments from central moments, calculation of moments about one point from moments about another point
6. Flitting of binomial distribution
7. Flitting of Poisson distribution
8. Flitting of normal distribution
9. Tasting of hypothesis based on normal distribution
10. Tests based on chi-square distribution
11. Tests based on t-distribution
12. Tests based on F-distribution

MA 572	LABORATORY WORKS ON REAL LIFE PROBLEMS-II	2 credits [0-0-3]

MA 574	LABORATORY WORKS ON NSPDE	2 credits [0-0-3]

Finite difference methods for Parabolic, Elliptic and Hyperbolic equations using explicit and Implicit Schemes - Consistency, Stability and Convergence analysis.

DEPARTMENT OF PHYSICS

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
PH 101	Physics – I	3-1-0	4
PH 102	Physics - II	3-1-0	4
PH 170	Physics Laboratory	0-0-3	2
PH 201	Thermodynamics	3-1-0	4
PH 202	Electricity & Magnetism	3-1-0	4
PH 271	Thermal Laboratory	0-0-3	2
PH 272	Electricity & Magnetism Laboratory	0-0-3	2
PH 301	Wave and Oscillations	3-1-0	4
PH 302	Properties of Matter	3-1-0	4
PH 303	Optics	3-1-0	4
PH 304	Introduction to Mechanics	3-1-0	4
PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3
PH 312	The Physics of Quantum World	3-0-0	3
PH 321	Physics of Semiconducting Materials	3-0-0	3
PH 331	World of LASERS	3-0-0	3
PH 332	Physics of the Universe	3-0-0	3
PH 341	Treatise of Einstein Work and Beyond	3-0-0	3
PH 351	Science of Nano-materials	3-0-0	3
PH 352	X-Ray techniques for Structure Evaluation	3-0-0	3
PH 371	Waves and Optics Laboratory	0-0-3	2
PH 372	Properties of Matter Laboratory	0-0-3	2
PH 401	Mathematical Methods in Physics	3-1-0	4
PH 402	Numerical Techniques in Physics	3-1-0	4
PH 403	Classical Mechanics	3-1-0	4
PH 404	Electrodynamics	3-1-0	4
PH 405	Statistical Mechanics	3-1-0	4
PH 406	Condensed Matter Physics	3-1-0	4
PH 407	Quantum Mechanics - I	3-1-0	4
PH 408	Quantum Mechanics - II	3-1-0	4
PH 409	Introduction to Spectroscopy	3-1-0	4
PH 422	Theory & Simulation of Nanostructures	3-0-0	3
PH 431	Non-linear systems & Chaos	3-0-0	3
PH 462	Vacuum Science and Applications	3-0-0	3
PH 471	General Physics Laboratory	0-0-3	2
PH 472	Solid State Physics Laboratory	0-0-3	2
PH 473	Spectroscopy Laboratory	0-0-3	2
PH 481	Research Project – I	0-0-6	4
PH 482	Research Project – II	0-0-6	4
PH 507	Nuclear & Particle Physics	3-1-0	4
PH 508	Atomic & Molecular Physics	3-1-0	4
PH 511	Advanced Quantum Mechanics	3-1-0	4
PH 512	Advanced Statistical Mechanics	3-1-0	4
PH 513	Density Functional Theory and its Recent Applications	3-1-0	4
PH 514	Advanced Condensed Matter Physics	3-1-0	4
PH 522	Physics of Semiconductors : from Bulk to quantum dots	3-1-0	4
PH 523	Semiconductor Spintronics & Quantum Computation	3-1-0	4
PH 524	Computational Condensed Matter Physics	3-1-0	4
PH 525	Electronic Structure of Disordered Alloys	3-1-0	4

PH 531	Non-Linear dynamics, Chaos & its recent applications	3-1-0	4
PH 532	Physics of Macromolecules	3-1-0	4
PH 533	Synchronizations & its recent applications in Chaotic Systems	3-1-0	4
PH 535	LASER Physics	3-1-0	4
PH 538	Special Topics in Condensed Matter Physics - I	3-1-0	4
PH 539	Special Topics in Condensed Matter Physics - II	3-1-0	4
PH 541	Dielectric & Magnetic Properties of Materials	3-1-0	4
PH 542	Physics & Applications of Dielectric Materials	3-1-0	4
PH 543	Bio-Ceramic Materials & Applications	3-1-0	4
PH 544	Polymer Physics	3-1-0	4
PH 551	Crystal Symmetry & Crystal Physics	3-1-0	4
PH 553	Advanced X-rays structure analysis	3-1-0	4
PH 554	Physics of Thin Film Technology	3-1-0	4
PH 555	Physics of material synthesis & Charaterization	3-1-0	4
PH 556	X-rays and Nano-Science	3-1-0	4
PH 558	Special Topics in Functional Materials – I	3-1-0	4
PH 559	Special Topics in Functional Materials – II	3-1-0	4
PH 561	Physics of Microelectronic and Photonic Devises	3-1-0	4
PH 562	Superfluidity and Superconductivity	3-1-0	4
PH 563	Physical Phenomena at Low Temperature	3-1-0	4
PH 564	Magnetism – Principles & Applications	3-1-0	4
PH 565	Defects in Solids	3-1-0	4
PH 568	Special Topics in Low Temperature Physics – I	3-1-0	4
PH 569	Special Topics in Low Temperature Physics – II	3-1-0	4
PH 571	Instrumentation Laboratory	0-0-3	2
PH 572	Advanced Material Synthesis Laboratory	0-0-3	2
PH 573	Computational Physics Laboratory	0-0-3	2
PH 574	Advanced Characterization Techniques Laboratory	0-0-3	2
PH 581	Research Project – III	0-0-6	4
PH 582	Research Project – IV	0-0-9	6
PH 591	Research Project – I	0-0-6	4
PH 592	Research Project – II	0-0-9	6
PH 593	Seminar & Technical Writing – I	0-0-3	2
PH 594	Seminar & Technical Writing – II	0-0-3	2
PH 595	Short Term Industrial / Research Experience	0-0-0	2
PH 596	Comprehensive Viva-Voice	0-0-0	2

PH 101 PHYSICS - I 4 Credits [3-1-0]

Optics: (i) Inference: Condition for interference, division of wave front (two beam interference). Young’s double slit experiment, fringe pattern on transvers and longitudinal planes, intensity distribution, Fresnel’s biprism, displacement of fringes, division of amplitude (two beam interference), cosine law, Newton’s rings experiment, Michelson Interferometer, fringes of equal inclination and equal thickness. (ii) Diffraction: Fraunhofer diffraction pattern and intensity distribution. (iii) Polarisation: Polarized and un polarized light, production of polarized light, Malu’s law, superposition of two disturbances, phenomena of double refraction interference of polarized light, quarter and half wave plates, Nicole prisam. (iv) Electromagnetic Waves: Maxwell’s equations in vacuum & medium, eletro magnetic waves and its transverse nature**Relativity:** Reference frames, inertial frames, Michelson-Morley experiment, speed of light, Galilean relativity and transformation, simultaneous events and simultaneity, postulates of relativity, Lorentz transformation, length contraction and time dilation, velocity addition, relativistic momentum, relativistic mass and mass-energy relation.**Quantum Mechanics:** (i) Particle nature of wave, Black body radiation, photoelectric effect, x-ray diffraction, Compton effect, pair production, photon and gravity. (ii) Wave nature of particle, De Broglie waves, matter waves as group waves, phase velocity & group velocity, particle diffraction & Davison-Germer experiment, uncertainty principle and its application. (iii) Wave equation: probability & wave function, time dependent and time independent Schrodinger equation, eigen value & eigen functions, boundary conditions on wave function, application of Schrodinger equations to one dimensional problem.

Essential Reading:

1. A. Ghatak, *Optics*, Tata-McGraw Hill (2004)
2. A. Beiser, *Concept of Modern Physics (or Perspective of Modern Physics)*, Tata-McGraw Hill) (2005)

Supplementary Reading:

1. R. Resnick, *Relativity*, Wiley Eastern Pvt. Ltd. (2007)
2. Jenkin & White, *Fundamentals of Optics*, McGraw-Hill, 4th Edition
3. D.J. Griffith, *Introduction to Quantum Mechanics* , Pearson (2007)
4. D. J.Griffith, *Introduction to Electrodynamics*, Pearson (2007)

Prerequisite:

PH 102	PHYSICS – II	4 Credits [3-1-0]

Statistical Mechanics: Statistical distributions, Max-B statistics, molecular energies in ideal gas, quantum statistics: B-E & F-D statistics, Rayleigh-Jeans formula, Planck's radiation law, specific heats of solids, free electrons in metals, electron-energy distribution, dying stars. ; **Spectroscopy:** quantum theory of hydrogen atom, quantum number for three dimensions : principal, orbital & magnetic quantum numbers (space quantization), electron probability density, radiative transitions, selection rules, Zeeman effect. Electron spin, exclusion principle, symmetric & anti-symmetric wave functions, atomic structures, spin-orbit coupling, total angular momentum, X-ray spectra. LASER: Coherent time & length (temporal coherence), Line width, spatial coherence(Michelson stellar Interferometer), optical beats, Fourier analysis of Coherence time and line width, visibility in Young's double slits experiment, Fourier transform spectroscopy (introduction). Spontaneous & stimulated emission, metastable states, optical pumping, population inversion, Einstein approach of stimulated emission, Einstein coefficient, components of laser: optical cavity & resonator, optical amplification, Fiber laser, Ruby & He-Ne lasers. ; **The Solid State :** Crystalline & amorphous solids, Crystal structure, Bravais lattice, packing fraction, atomic radius, point defect, dislocations, reciprocal lattice & Brilloin zones, wide & small angles X-ray- crystellography: crystal planes, Bragg's diffraction & diffraction condition in reciprocal lattice, Ionic, metallic, covalent and Van der Waals bonds, nano-tubes. Band theory of solids : formation of allowed & forbidden bands due to periodicity, Kronig-Peny model for periodic potential. Origin of resistivity, effective mass of electron, classification of solids on the basis of band theory, impurity in semiconductors. Dielectric (including ferroelectric & piezoelectyric) & Magnetic properties of solids (dia-, para and ferromagnetism), Langevin theory, Weiss theory of ferromagnetism, hysteresis, superconductivity: zero resistence, type-I & type-II superconductors, magnetic properties of superconductors (Meissner effect), flux quantization & Josephson junction, vacuum science and its application. ; **Nuclear Physics :** Nuclear structure, atomic masses, mass spectrograph, nuclear properties, stable nuclei, binding energy, nuclear models: liquid drop and shell models, meson theory of nuclear forces, cross section, nuclear reactions, nuclear fissions, nuclear reactors, fusion in stars, fusion reactors: energy source for future, constituents of nuclear particles: quarks, hadrons, Glons.

Essential Reading:

1. Ghatak, *Optics*, Tata-McGraw Hill (2004)
2. Beiser, *Concept of Modern Physics (or Perspective of Modern Physics)*, Tata-McGraw Hill) (2005)

Supplementary Reading:

1. C.Kittel, *Introduction to Solid State Physics*, Wiley & Sons (2004)
2. D. J.Griffith, *Introduction to Quantum Mechanics*, Pearson (2007)

Prerequisite: First level Physics course

EC 201	ANALOG ELECTRONICS	4 Credits[3-1-0]

Bipolar Junction Transistor: Review of BJT operation and DC biasing, small signal model, BJT biasing for discrete circuit design, single stage amplifier analysis, complete static characteristic, internal capacitances and second order effect. ***Field-Effect Transistor:*** Review of JFET, depletion and enhancement MOSFET operation, characteristic and DC biasing, MOSFET as amplifier, biasing of MOS amplifier circuits, single stage IC MOS amplifiers, CMOS logic inverter, MOSFET as analog switch, small signal model of MOSFET for high and low frequencies, spice model and analysis of FET circuits. ***Frequency Response Analysis***: S-domain analysis, bode plot, amplifier transfer function, low frequency and high frequency response of common-source and common drain amplifiers, frequency response analysis of other single stage transistor amplifier configuration. ***Feedback Amplifier***: General feed-back structures, negative feedback, the 4 basis feedback topologies and their analysis, close loop gain calculation, amplifier stability analysis using Bode plot.***Output stage and Power Amplifier:*** Classification of output stages, class A, class B, class AB amplifiers, power BJT, IC power transistors and MOS power transistors. ***Differential and Multistage Amplifier:*** BJT differential amplifier, small signal operation of BJT differential amplifier, non-ideal characteristics of differential amplifier, biasing of BJT ICs, multistage amplifiers, spice model and analysis of all circuits.

Essential Reading:

1. A.S. Sedra and K.C. Smith, Microelectronic Circuits, Oxford University Press; 2005.

Supplementary Reading:

1. Spencer and Ghausi, Introduction to Electronic Circuit Design, Pearson Education, 2003
2. A. Dutta, Semiconductor Devices and Circuits, Oxford University Press, ND 2008

PH-201	THERMODYNAMICS	4 Credits[3-1-0]

Concept of thermodynamic state, extensive and intensive variables, Zeroth Law of thermodynamics, measurement of temperature, heat and work, internal energy function and the first law of thermodynamics, ideal gas and gas equations, ideal engine and Carnot cycle, concepts of entropy and temperature as conjugate pair of variables, second law of thermodynamics, entropy maximum and energy minimum principles, entropy, multiplicity and disorder, Maxwell's demon, applications to pure substances, thermodynamic potentials, conditions of equilibrium, concepts of stability, Maxwell's relations, metastable and unstable equilibrium, open systems, components and phases, Joule-Thomson expansion, Gibbs-Duhem relations, first order phase transitions and Clausius-Clapeyron equation, critical phenomena and higher order phase transition, applications for magnetic, dielectric and superconducting systems, heat engines and black body radiation, chemical equilibrium and ideal gas reactions, heterogeneous systems, thermodynamics of irreversible processes, entropy production, kinetic theory of gases, transport phenomena.

Essential Reading:

1. M. W. Zemansky, Heat and Thermodynamics, McGraw-Hill Ltd., 7th Edition, 2007.
2. R. Bowley and M. Sanchez, Introductory Statistical Mechanics, Oxford Press, 2007.

Supplementary Reading:

1. H. B. Callen, Thermodynamics and Thermostatistics, John Wiley & Sons 2nd Ed.
2. L. A. Girifalco, Statistical Mechanics of Solids, Oxford University press, 2000.

3. A. Bieser, Perspective of Modern Physics / Concept of Modern Physics, Tata McGraw-Hill, 2005.

EC-202	DIGITAL ELECTRONICS	3 Credits[3-0-0]

Prerequisites: EC 100: Basic Electronics

Design Concepts: Digital Hardware, Design Process, Hardware, Logic Circuit Design, Theory and Practice; Introduction To Logic Circuits: Variables and Functions, Inversion, Truth Tables, Logic Gates and Networks, Boolean Algebra, Systhesis using AND, OR AND NOT Gates, Design Examples, Introduction to Cad Tools, Introduction to VHDL.; ***Implementation Technology***: Transistor Switches, NMOS Logic Gates, CMOS Logic Gates, Negative Logic System, Standard Chips, Programmable Logic Devices, Custom Chips, Standard Cells and Gate Arrays Practical Aspects, Transmission Gates, Implementation details for FPGAs.; Optimized Implementation of Logic Functions: Karnaugh Map, Strategy for Minimization, Minimization of Product-of-Sums Forms, Incompletely Specified Functions, Multiple-Output Circuits, NAND and NOR Logic Networks, Multi-Level Systhesis, Analysis of Multi-Level Circuits, CAD Tools. ; ***Number Representation and Arithmetic Circuits:*** Positional Number Representation, Addition of Unsigned Numbers, Signed Numbers, Fast Adders, Design of Arithmetic Circuits Using Cad Tools. ; ***Combinational Circuit Building Blocks:*** Multiplexers, Decoders, Encoders, Code Copnverters, Arithmetic Comparison Circuits, VHDL for Combinational Circuits. ; ***Flip-Flops, Registers and Counters, A Simple Processor:*** Basic Latch, Gated SR Latch, Gated D Latch. Master-Slave and Edge-Triggered D Flip-Flops, T Flip-Flop, JK Flip-Flop, Registers, Counters, Reset Synchronization, Other Types of Counters, Using Storage Elements with Cad Tools, Using Registers and Counters With Cad Tools, Design examples. ; Synchronous Sequential Circuits: Basic Design Steps, State Assignment Problem, Meanly State Model, Design of Finite State Machines using CAD Tools, Serial Adder Example, State Minimization, Design of a Counter using the Sequential Circuit Approach, FSM as an Arbiter Circuit, Analysis of Synchronous Sequential Circuits.

Essential Reading:

1. S. Brown and Z. Vranesis, Fundamental of Digital Logic with VHDL design Tata Mc GRAW-Hill, 2003

Supplementary Reading:

1. F. Vahid: Digital Design: Wiley Student Edition, 2006
2. J. F. Wakerly, Digital Design Principles and Practices, Fourth Edition, Prentice-Hall, 2005.
3. R. L. Tokheim, Digital electronics, Principles and applications, 6th Edition, Tata McGraw Hill Edition, 2003

PH-202	ELECTRICITY AND MAGNETISM	4 Credits[3-1-0]

Vectors: Scalar and vector, triple products, differentiation of a vector, ∇ operator, gradient, divergence and curl of a vector, Gauss divergence theorem, Stoke's theorem. ***Electrostatics:*** Charges and forces, charge quantization, Coulomb’s law, electric field, electric potential, application of Coulomb’s law, potential and field due to one, two and three-dimensional charge distributions, electric dipole and quadrupole, Gauss’s theorem and its applications, electrostatic energy, electrostatics in a dielectric medium, capacitors, parallel plate capacitor, cylindrical and spherical capacitors, capacitors in parallel and series circuit, moving charges, electric currents, current density, Ohm’s law, Kirchhoff’s law. ***Magneto-statics:*** Magnetic field, magnetic force, field and potential due to a magnetic dipole, torque on the dipole in an external magnetic field. ***Electrodynamics:*** Current carrying conductors, magnetic induction, Biot-Savart law, magnetic dipole moment, vector and scalar potential, Ampere’s circuital law, induction and inductance, magnetic circuits, Faraday’s law, Lenz’s law, self and mutual induction, magnetic force between two circuits, alternating current, LCR circuits with DC and AC sources, dc motor, ac motor, dynamo, Helmholtz coil, Maxwell’s equations

Essential Readings:

1. Fundamentals of Physics, Resnick, Halliday and Walker, 6th edition, Wiley
2. Fundamentals of Electricity and Magnetism, Arthur F. Kip, McGraw Hill

Supplementary Readings:

1. University Physics, Sears and Zemansky, 10th edition, Addison – Wesley series
2. Introduction to electrodynamics, D.J. Griffiths, 3rd edition, Prentice Hall
3. Electricity and magnetism, A.S. Mahajan and A. A. Rangwala, McGraw Hill

PH-301 WAVES AND OSCILLATIONS 4 Credits[3-1-0]

Oscillations: Equilibrium, concept of potential well, small oscillations, linear and transverse oscillations of a mass between two springs, diatomic molecule, damped oscillations, critical damping, Q of an oscillator, forced oscillator with one degree of freedom, transient and steady state oscillations, resonance energy, low and high frequency responses, two dimensional oscillator, normal modes, longitudinal and transverse oscillation of coupled masses, energy transfer between modes, coupled pendulum. ***Fourier analysis:*** Fourier series and Fourier coefficients, exponential representation for harmonic oscillations, expression for Fourier coefficients, non-periodic disturbance, Fourier integral, Fourier transform wave-train of finite length, constancy of $\Delta x \cdot \Delta k$ (uncertainty product), applications. ***Waves:*** Classical wave equation, wave velocity, boundary conditions and normal modes, dispersion relations, dispersive waves, acoustic and optical modes, Waves in continuous media, speed of transverse waves on a uniform string, speed of longitudinal waves in a fluid, energy density and energy transmission in waves, typical measurements, dispersion in waves, group and phase velocity, superposition of waves, linear homogeneous equations and the superposition principle, interference in space and energy distribution, beats and tones, Doppler effect. ***Ultrasonic:*** Production, detection and applications of ultrasonic waves. ***Electromagnetic Waves:*** Maxwell’s equations, propagation of plane em wave in matter, energy flow and Poynting vector.

Essential Readings:

1. Vibrations and Waves by A. P. French.(CBS Pub. & Dist., 1987)
2. Waves: BERKELEY PHYSICS COURSE (SIE) by Franks Crawford (Tata McGrawHill, 2007).

Supplementary Readings:

1. The Physics of Waves and Oscillations by N.K. Bajaj (Tata McGraw-Hill, 1988)
2. Fundamentals of Waves & Oscillations By K. Uno Ingard (Cambridge University Press, 1988)
3. Schaum's Outline of Mechanical Vibrations by S. Graham Kelly (McGraw-Hill; 1st edition, 1996)

PH-302 PROPERTIES OF MATTER 4 Credits[3-1-0]

Elasticity: Stress and Strain, Hooke's Law, Young’s modulus, Poisson's Ratio, work done in stretching and twisting a wire, twisting couple on a cylinder and wire, rigidity modulus by static torsion, torsional pendulum, rigidity modulus and moment of inertia, bending of beams, bending moment, uniform and non uniform bending, Koenig's method, Searle’s method, determination of Young's modulus using microscope. ***Fluid dynamics:*** Stream line and turbulent flow, Bernoulli’s theorem, Euler’s equation, viscosity, Stoke’s law, Poiseullie’s equation, determination of coefficient of viscosity using - Stroke’s method and Rankine’s method, variation of viscosity of a liquid with temperature. ***Surface Tension:*** Surface energy, relation between surface tension and surface energy, equilibrium conditions at the interface between two liquids and at the liquid-solid interface, pressure under a curved surface, capillary effects, variation of surface tension with temperature, Jaegar's method. ***Low Pressure:*** Production and measurement of low pressure, molecular pump, rotary pump, diffusion pump, McLeod gauge, Bourdon spiral guage, Pirani guage, Ionization gauge, Knudsen gauge,

Essential Readings:

1. F. H. Newman and V. H. L. Searle, The general properties of matter (Edward Arnold, fifth ed., 1985).
2. Elements of properties of matter – D.S.Mathur (S.Chand & Co., 2001)

Supplementary Readings:

1. Fundamentals of Physics by D.Halliday, R. Resnick and J. Walker. (Wiley, 6th Edition, 2001)

PH-303	**OPTICS**	**4 Credits[3-1-0]**

Geometrical Optics: Introduction to geometrical and physical opticss, Fermat's principle of least action, reflection, refraction, refraction through spherical surfaces, conjugate foci for refraction at a spherical surface, transverse magnification of a spherically refracting surface, Lagrange and Helmholtz Laws of magnification, refraction through convex lens, deviation produced by a thin lens, cardinal points, lenses separated by a finite distance and equivalent focal length, graphical construction of images using cardinal points, aberration, optic centre of a lens, spherical aberrations, minimizing spherical aberration, chromatic aberration, condition for achromatism, coma, astigmatism, curvature of the field, Huygen's and Ramsden's eye pieces. ***Interference:*** Air wedge, determination of diameter of a thin wire by air wedge, test for optical flatness, Haidinger's fringes, multiple beam interference, Febry-perot interferometer and Febry-perot fringes, Jamin's & Rayleigh's interferometers, stationary waves in light, color photography, holography, temporal and spatial coherence, theory of partial coherence, coherence time and coherence length, purity of a spectral line, .***Diffraction***: Fresnel diffraction, Fresnel's assumption, explanation for rectilinear propagation of light, theory of zone plate, multiple foci of a zone plate, diffraction due to Circular aperture, opaque circular disc, straight edge, narrow wire, Rayleigh's criterion for resolution, resolving power of microscope, telescope, prism, grating. dispersive power of plane diffraction grating ***Fiber Optics:*** Propagation of light in fibers, numerical aperture, single mode and multi mode fibers, attenuation in optical fibers, spot size in fundamental mode, pulse dispersion in optical fibers, ray dispersion in step index fibers, parabolic- index fibers & material dispersion, applications of fiber optics;

Essential Readings:

1. Fundamentals of Optics by Jenkins A Francis and White E. Harvey, (Tata McGraw Hill Inc., 2011).
2. Optics by Ajoy Ghatak (Tata GcGraw Hill, 2008)

Supplementary Readings:

1. Optical Physics by S.G. Lipson, H. Lipson, and D.S. Tannhauser, (Cambridge University press,1995).
2. Fundamentals of Physics by D.Halliday, R. Resnick and J. Walker. (Wiley, 6th Edition, 2001)
3. Optics by N. Subramaniam & Brij Lal, (S. Chand & Co. Pvt. Ltd., New Delhi, 1990).

PH-304	**INTRODUCTION TO MECHANICS**	**4 Credits[3-1-0]**

Classical Mechanics: Dynamics of system of particles, center of mass, conservation of momentum, impulse, momentum of variable mass system, motion of rocket, **w**ork and energy theorem, conservative and non conservative forces, potential energy, energy diagram, stable and unstable equilibrium, gravitational potential energy, elastic potential energy, work done by non conservational forces, law of conservation of energy, elastic and inelastic collisions between particles, centre of mass and laboratory frames, rotational dynamics, angular momentum of a particle and system of particles, torque, conservation of angular momentum, rotation about a fixed axis, moment of inertia, parallel and perpendicular axis theorem, kinetic energy of rotation, motion involving both translation and rotation, law of gravitation, inertial and gravitational mass, potential and field due to spherical shell and solid sphere, motion of particle under central force field, two body problem and its reduction to one body problem and its solution, energy equation and energy diagram, Keppler's laws, orbits of artificial satellites. ***Quantum Mechanics:*** Inadequacies in Classical Physics, basic postulates, energy, momentum and Hamiltonian operators, wave function and its physical significance, probability density, Schrodinger equation, normalization, linearity and superposition of wave functions, Eigen values and Eigen functions, expectation Values, Schrodinger equations for particle in a box and potential well. ***Statistical Mechanics:*** Limitations of classical mechanics, review of Statistical distributions (Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics) and their application, entropy and thermodynamic probability, microscopic and macroscopic states of a system, μ and Γ- space, ensembles (micro-canonical, canonical and grand canonical), Liouville's theorem, equal a priori probability.

Essential Reading:

1. An introduction to mechanics by D. Kleppner, Robert J. Kolenkow (Tata-McGraw Hill 2007)
2. Concept of Modern Physics by A. Beiser (Tata-McGraw Hill, 2005).

Supplementary Reading:

1. Fundamentals of Physic: Resnick, Halliday, & Wlaker, John Wiley & Sons Inc., 2004.
2. Fundamentals of Statistical and Thermal Physics by Frederick Reif (Tata McGraw-Hill, 2010)

PH 311	**FUNDAMENTALS OF THERMAL & STATISTICAL PHYSICS**	**3 Credits [3-0-0]**

Concept of thermodynamic state, extensive and intensive variables; heat and work, internal energy function and the first law of thermodynamics; ideal engine and Carnot cycle, concepts of entropy and temperature as conjugate pair of variables; second law of thermodynamics, entropy maximum and energy minimum principles. Entropy: multiplicity and disorder, Maxwell's demon ; Thermodynamic potentials; conditions of equilibrium, concepts of stability, Maxwell's equations, metastable and unstable equilibrium; components and phases, Gibbs-Duhem relations; first order phase transitions and Clausius-Clapeyron equation; critical phenomena, some chosen applications from magnetic, dielectric and superconducting; heat engines and black body radiation. Thermodynamics of irreversible processes: entropy production; Elementary kinetic theory of gases; transport phenomena; Introduction to statistical mechanics and distribution functions. occupation probability in M-B, B-E, F-D statistics, distribution functions, criteria for applicability of classical statistics, specific heat of classical gas, Fermi gas, Fermi energy, electronic contribution to specific heat of metals, energy bands in conductors, insulators and semiconductors, modifications at metal-metal contact, p-n junction, details of tunnel diode.

Essential Reading:

1. M. W. Zemansky, *Heat and Thermodynamics*, McGraw-Hill Ltd., 6th Edition, 1999.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Supplementary Reading:

1. H. B. Callen, *Thermodynamics and Thermostatistics*, John Wiley & Sons 2nd Ed.
2. L. A. Girifalco, *Statistical Mechanics of Solids*, Oxford University press, 2000.
3. A. Bieser, *Perspective of Modern Physics / Concept of Modern Physics*, Tata McGraw-Hill, 2005.

Prerequisite:

PH 312	**PHYSICS OF QUANTUM WORLD**	**3 Credits [3-0-0]**

Historical background of quantum theory, wave function and its Born interpretation, relation with measurement of dynamical variables, double slits experiments with em wave and matter wave; Delta-function as definite position and plane wave as definite momentum wave function, wave-packet as superposition of delta-functions and of plane waves, uncertainty principle, Gaussian wave packets, applicability of classical physics on the basis of uncertainty product, observables and operator formulation, eigenvalue and eigenstates, Schrodinger equation for time evolution, stationary states, spread of free particle wave packets, time energy uncertainty, natural line width of spectral lines, probability currents and their relation with the flux in beams of particles; Square well potentials (finite & infinite) and their applications, double, well potentials and examples like ammonia inversion, delta function potentials and examples like electron sharing in covalent bonds; Kronig-Penney model of 1-d crystals. Linear harmonic oscillator, outline of getting stationary states, molecular vibrations and spectroscopy. barrier tunneling, examples of alpha-decay, scanning tunneling microscope, principle of tunnel diode etc; Angular momentum operators, eigenvalues and eigenfunctions, spin angular momentum, hydrogen atom using coulomb interaction, structure of H-line due to L-S interaction (derivation not needed), J-J coupling, fine structure and hyperfine structure, space quantization; Quatum statistics and its applications to metals, semiconductors etc.

Essential Reading:

1. A. Bieser, *Concept of Modern Physics*, Tata-McGraw Hill, 2005.
2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Reading:

1. R. P. Feynman, *Lectures on Physics, V*ol.III, Narosa Publishing, 2008.
2. C. Cohen-Tannoudji, *Quantum Mechanics*, John Wiley & Sons, 2005.
3. C. Kittel, *Introduction to Solid State Physics*, John Wiley & Sons 7^{th} Ed., 2004.
4. R. Bowley & M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Prerequisite: First level Physics course

PH 321	PHYSICS OF SEMICONDUCTING MATERIALS	3 Credits [3-0-0]

Crystal structure, periodic lattice and reciprocal lattice, application of quantum mechanics to periodic potentials, Bloch's theorem, band energies and band gap. Properties of metals, Fermi surface and transport properties, density of states, metal surface states and work function, bulk semiconductors and semiconducting devices, effective mass theory of band energy, tight binding model; Novel materials: super lattices, quantum well, quantum DOT and quantum wires, superconductivity, high Tc superconductors and their applications, polymers and optical materials; Density functional theory and properties of bulk and small clusters of atoms, Carr- Perinello method of molecular dynamics.

Essential Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.
2. S. Dimitrijev, *Principles of Semiconductor Devices*, Oxford University, 2006.

Supplementary Reading:

1. J. Singh, *Semiconductor Devices: Basic principles*, Wiley India, 2008.
2. P.Y. Yu and M.Cardona, *Fundamentals of Semiconductors Physics & Material Properties*, Springer Verlag, 1999.
3. Y. D. Jiles, *Introduction to Magnetism and Magnetic Materials*, Chapmean and Hall. (2^{nd} edition)
4. J.M. Haile, *Molecular Dynamics*, John Wiley & sons, 1997.

Prerequisite: First level Physics course

PH 331	WORLD OF LASERS	3 Credits [3-0-0]

Brief history of LASER; Wave nature of light, interaction of electromagnetic radiation with matter, coherence; Particle nature of light, quantum theory of atomic energy level; Radiative and non radiative transition; Radiation and thermal equilibrium; Stimulated absorption, Spontaneous and stimulated absorption; Population inversion, gain and gain saturation, Active medium, Optical amplification; Pumping mechanism, three and Four level pumping mechanism, Optical resonator, laser oscillation; Metastable state, Q-stitching and mode locking. ; Properties of Laser, monochromaticity, coherence, directionality, bright ness, short pulse duration; Different types of LASERS: gas LASER, solid State LASER, fiber optic LASER, pulsed LASER, excimer LASER ; Applications of LASERS, principle of holography, application in holography, LASER application in modern industries, material technology, in medical science, in science and technology, in optical communication

Essential Reading:

1. Willam T. Silfvast, *LASER Fundamentals*, Cambridge University Press, 2nd Ed, 2004.
2. Orazio Svelto and David C. Hanna, *Principles of LASERS,* Springer, 4th Ed, 1998.

Supplementary Reading:

1. John F. Ready, *Industrial Applications of LASERS*, Academic Press, 2nd Ed, 1997.
2. Markolf H. Niemz, *LASER –Tissue interaction: Fundamentals and Applications*, Springer, 3rd Ed, 2007.
3. Ronald W. Waynant, *LASERS in Medicine*, CRC Press, 2002
4. A.K. Ghatak and K. Thyagarajan, *LASERS: Theory and Applications*, Macmillan Publishers India, 2000
5. LASERS: Principles, *Types and Applications*, New Age Instruments, 2004.

PH 332	**PHYSICS OF THE UNIVERSE**	**3 Credits [3-0-0]**

Astronomy and physics, photometry, observational instruments, stellar spectra, stellar evolution, classification of stars, star clusters and binary stars, nucleo-synthesis and formation of elements, galaxies and observed universe. Evolution of galaxies and their origin, quasars and active galaxies; Theories of the universe: from Newtonian cosmology to modern cosmology: Big-Bang theory and early universe, the universe and the arrow of time, confrontation between theories and observations.

Essential Reading:

1. E. Harrison, *Cosmology*, Cambridge University Press. 2^{nd} Ed., 2000.
2. J. Narliker, *Introduction to Cosmology*, Cambridge University Press. 3^{rd} Ed., 2002.

Supplementary Reading:

1. J. Narlikar, *Structure of the Universe*, Prentice Hall (Indian Edition)
2. Bormer and Gerhard, *The early Universe*, Springer Verlag, Berlin, 2003.
3. *The early Universe and Observational Cosmology*, Lecture Notes in Physics (vol.646), Springer Verlag, 2007.

Prerequisite:

PH 341	**A TREATISE ON ALBERT EINSTEIN WORK & BEYOND**	**4 Credits [3-1-0]**

Photon: From quantum paradox to quantum reality.
The concept of photon & Einstein' photoelectric effect, EPR paradox Schrodinger's cat paradox, quantum well, quantum wire, quantum dot, Bell inequality, Quantum computation, quantum cryptography, Grover and Shor's Algorithm ; **Brownian motion**, From pollen grain's to protein chain. ; Theory of Brownian motion (random walk model) Einstein's theory of Brownian motion, Langevin's theory of Brownian motion. ; **Special theory of relativity**: From discreteness to continuity. ; Relativistic world, Space time and relativity, *Definition of simultaneity , Moving rigid body and moving clock, Visualizing proper time in special relativity* ,Salient features of Einstein's paper on special theory of relativity.

Essential Reading:

1. J.Stachel, *Einstein's Miraculous year: Five papers that changed the face of physics* , Princeton University press, 1998
2. Neilson & Choung - *Quantum computation and quantum information*

Supplementary Reading:

1. N.D Mermin – *space and time in special relativity*, McGraw-Hill New york, Second edn

2. WT Coffey, Yu P kalmykov *The Langevin equation second edition*, World scientific, 2004.
3. Special issues of Physics teacher Vol- 46, no- 2 On Photon.
4. Special issues of Physics teacher Vol- 47, no- 4 On Special theory of relativity.
5. Special issues of Physics teacher Vol- 48,

PH 351	**SCIENCE OF NANO MATERIALS**	**3 Credits [3-0-0]**

Introduction to nano science and nano technology, nano structure and it's manipulation, nano particles and nano materials, Applications of nano functional material in different fields of science and technology, Different experimental techniques for evaluation of nano ordered structures in materials(XRD,SAXS,TEM etc); Introduction to biological macromolecules and their characterization with special emphasis to Small Angle X-ray Scattering (SAXS) ; Introduction to synthesis of nano particles and their characterization, physics of nano particles and their composites.

Essential Reading:

1. G. L. Hornyak, H. F. Tibbals, J. Dutta, H. F. Tibbals, *Introduction to nanoscience*, Taylor and Francis Inc, 2008.
2. Z. L. Wang, Y. Liu, Z. Zhang, *Handbook of Nanophase and nano structured materials Vol-I Synthesis*, Klwer Academic Publications, 2002.

Supplementary Reading:

1. T. Pradeep, *Nano: The essentials: Understanding Nanoscience &Nanotechnology*, McGraw-Hill professional publishing (1^{st} Edn).
2. T. Chakraborty, F. Peeters, U. Sivan, *Nano-physics & Bio-electronics: A new Odyssey*, Elsevier Publications, 2002.

PH 352	**X-RAY TECHNIQUES FOR STRUCTURE EVALUATION**	**3 Credits [3-0-0]**

Production, properties and applications of x-rays, x-ray absorption and its roll in stricture evaluation, x-ray detectors, real and reciprocal space, structure factor, form factor, X-ray diffraction (XRD) and its applications, x-ray scattering and its applications, introduction to small Angle X-ray Scattering (SAXS) and its advantage in structure evaluation; Introduction to X-ray spectroscopy, Moseley's law and its applications, x-ray fluorescence (XRF), energy dispersive x-ray (EDX), particle induced x-ray emission (PIXE) and their applications; Introduction to medical x-ray and x-ray techniques (radiography, radiotherapy, CT scanning etc.)

Essential Reading:

1. J. A. Nielson and D. McMorrow, *Elements of Modern X-ray physics*, John Wiley&sons, 2001.
2. G. V. Pavlinsky, *Fundamentals of x-ray physics*, Cambridge International sci Pub, 2008.

Supplementary Reading:

1. A. K. Singh, *Advanced X-ray Techniques in Research and Industry*, Capital Publishing Company, 2006.
2. N. Kasai, M. Kakudo, *X-ray diffraction by macromolecules*, Springer, 2005.

Prerequisites: fundamentals of modern physics

PH 401	**MATHEMATICS METHODS IN PHYSICS**	**4 Credits [3-1-0]**

Curvilinear coordinates systems, Vector algebra and vector analysis, Vector & function spaces, Hilbert spaces, expansion of state vector, operators in infinite vector space. Determinants & matrices, eigenvalues and eigenfunctions, Vector calculus, gradient, divergent and curl, Tensors and linear algebra; Polynomials, generalized functions, Dirac delta function, gamma function, Fourier series & transform, Legendre functions and Transformation; Function of complex variable and complex analysis; Elementary group theory

Essential Reading:

1. G. B. Arfken and H. J. Weber, *Mathematical methods for Physicists*, Elsevier Academic Press, 6th Ed., 2005.
2. M. L. Boas, *Mathematical Method in Physical Science*, John Willy & Sons, 3rd Ed., 2006.

Supplementary Reading:
1. J. Mathews and R. L. Walker, *Mathematical Methods of Physics*, Pearson Education, 2005.
2. S. D. Joglekar, *Mathematical Physics*, Universities Press, 2005.
3. R. V. Churchil and J. W. Brown, *Complex Variables &Applications*, 7th Ed., 2003.

Prerequisite: First level Mathematics course

PH 402	**NUMERICAL TECHNIQUES IN PHYSICS**	**4 Credits [3-1-0]**

Ordinary differential equations & partial differential equations, Green's functions, Calculus of variations. Solutions of differential equations by various numerical techniques: Numerical techniques: finite difference calculus, interpolation & extrapolation, solution of simultaneous linear equations & roots of equations, least square curve fitting, numerical integration, matrix eigenvalue problems; Probability: random variables, binomial distribution, Poisson distribution & Gauss/normal distribution. Monte Carlo simulation: random walk problem, random number generators, magnetization at a finite temperature, diffusion & percolation problems.

Essential Reading:
1. G. B. Arfken and H. J. Weber, *Mathematical methods for Physicists*, Elsevier Academic Press, 6th Ed., 2005.
2. J. Mathews and R. L. Walker, *Mathematical Methods of Physics*, Pearson Education, 2005.

Supplementary Reading:
1. S. D. Joglekar, *Mathematical Physics*, Universities Press, 2005.
2. R. V. Churchil and J. W. Brown, *Complex Variables &Applications*, 7th Ed., 2003.
3. M. L. Boas, *Mathematical Method in Physical Science*, John Willy & Sons, 3rd Ed., 2006.
4. S. C. Chapra, *Numerical Methods for Engineers*, Tata-McGraw-Hill. 5th Ed, 2007.

Prerequisite: PH 501: Mathematical Methods in Physics - I

PH 403	**CLASSICAL MECHANICS**	**4 Credits [3-1-0]**

Review of Newton's and conservation laws, system of particles, constraint, de-Alembert principle, generalized coordinates & Lagrangian equations, variational & Principle of least action and Hamilton principles and Lagrangian formalism, Hamilton equation of motions, Canonical transformations and Hamilton-Jacobi theory; The two-body central force problem, collisions and scattering by central force. The kinematics of rigid body motion and non-inertial frames, rigid body equation of motion; Liouvile's theorem, small oscillations, general wave motion, phase and group velocities, dispersion; Lagrangian and Hamiltonian formalisms for continuous systems and fields; Special theory of Relativity

Essential Reading:
1. H. Goldstein, *Classical Mechanics*, Addison Wesley, Pearson Education, 2007.
2. R. D. Gregory, *Classical Mechanics*, Cambridge University Press, 2006.

Supplementary Reading:
1. L. D. Landau and E. M. Lifshitz, *Course of Theoretical Physics- Mechanics*, (vol.-1), 3rd Ed., Pergamon Press.
2. R. P. Fynman, *Lectures on Physics (vol-1)*, Narosa Publishing, 2008.
3. D. Morin, *Introduction to Classical mechanics (with problems & solutions)*, Cambridge University Press, 2008.
4. T. W. B. Kibble and F. H. Berkshire, *Classical Mechanics*, 5th Ed., Imperial College Press, 2004.

5. N. C. Rana and P. S. Joag, *Classical Mechanics*, Tata-McGraw-Hill, 1991.

Prerequisite: Knowledge of Newtonian Mechanics & first level of mathematics course

PH 404	**ELECTRODYNAMICS**	**4 Credits [3-1-0]**

Potential formulation, Laplace & Poisson equations, Boundary value problems, method of images, multipole expansion, dielectrics and magnetic properties of materials; Time-varying fields, continuity equation, Maxwell's correction and equations, Poynting theorem, conservation of energy and momentum in of em fields, electromagnetic potentials, gauge invarience and transformations; Electromagnetic waves & its propagation in conducting and non-conducting media. Wave guides. Interference, diffraction and polarizations, coherence; Relativistic formulation of electrodynamics, co-variant form of Maxwell's equations, Gauge invariance and four potential, electromagnetic energy momentum tensor; Electrodynamics of a charged particle, radiation from a accelerated charge particle, retarded & Lienard-Weichert potentials, bremsstrahlung & synchrotron radiation, scattering by charged particles, applications to wave guides, fibres and plasmas.

Essential Reading:
1. D. J. Griffth, *Introduction to Electrodynamics*, Pearson Education. 3rd Ed., 2007.
2. D. Jackson, *Classical Electrodynamics*, Wiley and sons Ltd. 3rd Ed., 1998.

Supplementary Reading:
1. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundation of Electromagnetic theory*, Addison Wesley Company / Narosa Publishing. 4th Ed., 2008.
2. A. Ghatak, *Optics,* Tata McGraw-Hill, 2004.
3. R. P. Feynman *Lectures on Physics (vol.II),* Addison Wesley, Narosa, 2008.

Prerequisite: 2nd level of electricity & magnetism course and 1st level of mathematics course

PH 405	**STATISTICAL MECHANICS**	**4 Credits [3-1-0]**

Review of thermodynamics - Laws of thermodynamics, entropy, thermodynamic potentials & Maxwell's relations, chemical potential & phase equilibria; Equilibrium statistical mechanics- phase space, micro-states, macrostates, micro-canonical, canonical & grand-canonical ensembles & and partition functions; Maxwell-Boltzmann, Fermi-Dirac & Bose-Einstein distributions, applications of statistical mechanics to ideal quantum gas, interacting systems, theories of phase transitions etc; Elementary concepts of non-equlibrium statistical mechanics.

Essential Reading:
1. H. B. Callen, *Thermodynamics & Thermostatistics*, John Wiley & Sons. 2nd Ed.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Supplementary Readings:
1. M. W. Zemansky, *Heat & Thermodynamics*, McGraw-Hill, 1999.
2. L. Landau and E.M. Lifshitz: course in theoretical physics vol.5 (part-I) & vol.9 (part-II) - Statistical Mechanics, 3rd ed., Pergamon Press.
3. B. B.Laud, *Fundamentals of Statistical mechanics*, New Age Publication, 2007.
4. J. K. Bhattacharya, *Statistical Mechanics*, Allied Publishers Ltd., 1996.
5. L. E. Reichl, *A modern course in Statistical Physics*, Wiley & Sons, 2nd Ed., 1997.

Prerequisite: 1st level of thermodynamics course & elementary knowledge of Probability theory.

PH 406	**CONDENSED MATTER PHYSICS**	**4 Credits [3-1-0]**

Crystal systems & reciprocal lattice, Bragg's Law in reciprocal Lattice. Free & nearly free electron models & Fermi surface for metals, electron in periodic potential, Bloch's theorem and energy bands, tight binding model for band structure, density of states. Bondings in crystals, van-der walls, ionic, & covalent solids, electron in DC electric field; Transport properties - electrical & optical, effective mass, holes in semiconductors, laws of mass action, intrinsic & extrinsic semiconductors, electron & holes mobilities, impurity level & p-n junctions; Lattice vibrations, phonons, adiabatic & harmonic approximations, lattice heat capacity, Einstein and Deby models, dielectric-polarization mechanism, Piezo, Pyro & ferro electricity; Magnetism: exchange interaction, dia-magnetism, para-magnetism, ferro-magnetism & anti-ferromagnetism, Hund's rule, Pauli magnetism, Heisenberg model, giant & colossal magneto-resistance, Hall effect; Superconductivity-basic phenomology, Meissner effect, Type-I & II super- conductors, BCS pairing mechanism.

Essential Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & sons, 8th Ed., 2004.
2. Ashcroft and Mermin, *Solid State Physics*, Thomson Learning, 2007.

Supplementary Reading:

1. J. Callaway, *Quantum Theory of Solid*, Academic Press, 2nd Ed.
2. D. Craik, *Magnetism Principles and Applications*, John Wiley, 2003.
3. F. Duan and J. Guojun, *Introduction to Condensed Matter Physics*, World Scientific, 2005.
4. L. Mihali and M. C. Martin, *Solid State Physics*, John Wiley & Sons, 1996.

Prerequisite: Basic quantum mechanics & electrodynamics

PH 407	**QUANTUM MECHANICS - I**	**4 Credits [3-1-0]**

Historical perspective and origin of quantum theory, wave mechanics, group waves and wave packets, uncertainty principle, motion and spread of wave packets. Schrodinger equation, application to one-dimensional problems, central potentials-hydrogen atom; Hilbert space formalism, state space and Dirac,s notation, mathematical formulation. Commutation relations and commutating observables. Creation and anhilation operators. Schrodinger, Heisenberg and interaction pictures, symmetries in quantum mechanics; General treatment of angular momentum, various commutations relations of angular mementum. Spin- Stern - Garlach experiment. Application of general theory to orbital and spin angular momentum. Identical particles, Pauli exclusion principle.

Essential Reading:

1. C. Cohen-Tannoudji, *Quantum Mechanics (vol.1),* John Willey & sons, 2005.
2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Reading:

1. A. Bieser, *Perspective of Modern Physics / Concept of Modern Physics*, McGraw-Hill, 2005.
2. R. P. Feynman, *Lectures on Physics (vol.III),* Narosa Publishing, 2008.
3. L. Landau and E. M. Lifshitz, *Course in theoretical physics vol.3-Quantum Mechanics (non-relativistic),* 3rd Ed.

1. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson Education, 2005.

Prerequisite: 2nd level mathematics and wave mechanics courses

PH 408	**QUANTUM MECHANICS - II**	**4 Credits [3-1-0]**

Addition of angular momenta. Clebs-Gordan coefficients; Approximate methods: WKB approximation, variational method. Bound state perturbation theory, application to fine structure, anharmonic oscillators and Zeeman Effect, time-dependent perturbation theory. Interaction with classical radiation fields; Scattering theory- Scattaring cross section, unbound states; EPR paradox & Bell's inequality, quantum teleportation, idea of quantum computation & informations.

Essential Reading:

1. C. Cohen-Tannoudji, *Quantum Mechanics (vol.2),* John Willey & sons, 2005.

2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Readings:

1. R. P. Feynman *Lectures on Physics (vol.III)*, Narosa Publishing, 2008.
2. L. Landau & E. M. Lifshitz, *Course in theoretical physics vol.3-Quantum Mechanics (non-relativistic),* 3rd Ed.
3. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson Education, 2005.
4. M. A. Nielsen and I. L. Chuang, *Quantum Computation & Quantum Information,* Cambridge University Press, 2002.

Prerequisite: PH 511: Quantum mechanics-I

PH-409	**INTRODUCTION TO SPECTROSCOPY**	**4 Credits[3-1-0]**

Atomic structure, Rutherford scattering, electron orbits, Bohr atom model, energy levels and atomic spectra, e/m of the electron, correspondence principle, nuclear motion, atomic excitation, Frank-Hertz experiment, spectra of hydrogen atom, quantum numbers, electron probability density, excitation and ionization of atoms, spectrum of singly ionized helium, spectrum of many electron atoms. vector atom model, orbital angular momentum, magnetic moment of an orbital electron, space quantization of an atom, radiative transitions, selection rules, Stark effect, normal Zeeman effect, Stern-Gerlach experiment, concept of spin, magnetic moment due to spin, Larmor's theorem, Larmor's precession, gyromagnetic ratio and Bohr Magneton, coupling schemes, selection rules, spin-orbit coupling, spectral notation, fine structure of spectral lines, D lines of sodium, anomalous Zeeman effect, Paschen-Back effect, discovery of deuterium, alkali and alkaline earth spectra. discovery of x-rays, continuous and characteristic x-rays and their spectra, x-ray diffraction – Bragg's law & Laue diffraction, Moseley's law, Moseley's law on the basis of Bohr's atom model.

Essential Reading:

1. Fundamentals of Molecular Spectroscopy by C. N. Banwell and E. M. McCash (Tata McGraw-Hill, 2007)
2. Introduction to Atomic Spectra, by H.E. White (Tata McGraw-Hill, 1984)

Supplementary Reading:

1. Concept of Modern Physics by A. Beiser (Tata-McGraw Hill, 2005).
2. Physics of Atoms and Molecule by B. H. Bransden, C. J. Joachain (Prentice Hall, 2003)
3. Physical Chemistry by P. Atkins, J. D. Paula, Atkins (Oxford University Press, Indian 8th Edition, 2008).

PH 422	**THEORY & SIMULATION OF NANOSTRUCTURES**	**3 Credits [3-0-0]**

Inter atomic Potentials: Potential energy surface, pair potential approximation, phenomenological potentials, Buckingham, Morse, Lenard-Jones and Berker potentials, Pseudo potentials, Many-body potentials; Molecular Dynamics: Models for MD calculations, initial value, isothermal equilibrium, boundaries, nano-design and nano-construction, solution of the equation of motion, Verlet, Gear-Predictor, and other methods, efficient force field computation, force derivation, list method, cell algorithm, scalable parallel method, Tight-binding MD, Carr-Perrinello MD; Characterization: Thermal stability, material properties, wear at nanometer level, mean values and correlation functions; Nano-engineering: Functional nanostructures, nano-machines, nano-clusters, influence of initial conditions, temperature, crystalline structure, etc. Simulated nano structure transformations.

Essential Reading:

1. M. A. Ratner and D. Ratner, *Nanotechnology: A Gentle Introduction to the next Big Idea,* Pearson, 2002.
2. J. M. Haile, *Molecular Dynamics*, John Wiley & sons, 1997.

Supplementary Reading:
1. M. Rieth, *Nano Engineering in Science and Technology: An Introduction to the world of Nano-Design,* World-Scientific, 2003.
2. C. Delerve and M. Lannoo, *Nanostructures-Theory & Modeling*, Springer Verlag, 2004.

Prerequisite: First level physics course

PH 431	**NONLINEAR SYSTEM & CHAOS**	**3 Credits [3-0-0]**

Dynamical systems with nonlinearity, phase portraits and flow in one, two and three dimensions, fixed point, limit cycle motions, bifurcation. Stability of fixed point, limit cycles; Deterministic chaos and strange attractors: Population growth, logistic maps etc., routes to chaos-period doubling, intermittancy, quasi periodicity. Concept of universality and renormalization, measure of Chaos-Poincare section, Lyapunov exponent; Idea of Fractal geometry and dimension: Euclidean and topological dimensions, Cantor set and Koch curves, Fractal boundaries, determination of fractal geometry, Hausdor exponent, Self affinity, Hurst exponent. Examples from physics, Engineering, biology and chemistry.

Essential Reading:
1. Paul. S. Addison, *Fractals and Chaos*, Overseas Press, 2005.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.

Supplementary Reading:
1. G. L. Baker and J. P. Gollub, *Chaotic dynamics-An Introduction*, Cambridge University Press, 1996.
2. F. Verhulst, *Nonlinear differential equations and dynamical systems,* Springer, 2nd Ed, 1999.
3. T. Kapitaniak, *Chaos for Engineers*, Springer, 1998.
4. D. W.Jordan and P. Smith, *Nonlinear Ordinary Differential Equations*, Oxford Univ. Press, 4th Ed., 2007.

Prerequisite: First level mathematics course

PH 462	**VACUUM SCIENCE AND APPLICATION**	**3 Credits [3-0-0]**

Vacuum and its necessity. Gas flow in vacuum systems, Pumping speed and through put; *Creation of Vacuum:* Rotary vane pump, Roots blower pump, Diffusion pump, Ionization pump, Diaphragm pump, Adsorption pump, Turbo molecular pump; *Measurement of Vacuum:* Pirani/Thermocouple gauge, Penning/Ionization Gauge (hot cathode and cold cathode), Capacitance gauge, Bourdon gauge, McLeod gauge; *Quality of vacuum:* Residual gas analyzer, Leak detection. Material selection and vacuum chamber; *Application of Vacuum in thin film deposition:* Thermal evaporation, DC and RF sputtering, Molecular beam epitaxy (MBE), Pulsed LASER deposition (PLD).

Essential Reading:
1. V. V. Rao, T. B. Ghosh and K. L. Chopra, *Vacuum Science and Technology*, Allied Publishers – 1998.
2. *N. Harris, Modern Vacuum Practice [Freely available on net] (*www.modernvacuumpractice.com/editor/user_DocView.asp?DocumentID=18*)*

Supplementary Reading:
1. D. M. Hoffman, B. Singh & J. H. Thomas, *Handbook of Vacuum Science and technology,* Academic press: 2005.
2. J. M. Lafferty, *Foundations of Vacuum science and Technology*, John Wiley and Sons, New York, 1998.
3. A. Chambers, R. K. Fitch & B. S. Halliday, *Basic Vacuum technology*, 2nd Ed, Overseas press, New Delhi -2005 or CRC press – 1998.

Prerequisite:

PH 507	**NUCLEAR & PARTICLE PHYSICS**	**4 Credits [3-1-0]**

Properties of Nuclei, nuclear two-body problem, nuclear force, binding energy and stability of nuclei. Nuclear models : Liquid drop and Shell models; Nuclear decay, nuclear kinematics & classification of nuclear reactions, fusion & fission reactions; Brief overview of ion-beam applications for materials (various types of detectors); Elementary particles and their properties, fundamental forces.

Essential Reading:
1. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles,* Wiley India Pvt. Ltd., 2006.
2. Pehodgson, E. Gadioi , E. Gadioli-Erba, *Introductory Nuclear Physics*, Clarendon Press, 1997.

Supplementary Reading:
1. D. J. Griffith, *Introduction to Elementary particles*, John Wiley & sons. 2nd Ed., 2008.
2. D. H. Perkins, *Introduction to High Energy Physics*, 4th edition, Cambridge University Press, 2000.

Prerequisite: Quantum Mechanics courses

PH 508	**ATOMIC & MOLECULAR PHYSICS**	**4 Credits [3-1-0]**

Review of atomic structure of H, two electron systems, alkali system, Hartree-Fock method, density functional theory based Khon Sham equation, models for exchange co-relation functional, L-S coupling, JJ-coupling, fine structure & hyperfine structure. Zeeman, Stark & Paschen-Back effects. Auger & X-rays transitions; Molecular binding, LCAO, LCMO, molecular spectra (electronic, vibrational, rotational etc.); Principles of NMR, ESR, Raman spectra, LASERS.

Essential Reading:
1. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles,* Wiley India Pvt. Ltd., 2006.
2. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill Publishing Company limited, New Delhi, 2007.

Supplementary Reading:
1. B. H. Bransden, C. J. Joachain, *Physics of Atoms and Molecule*, Prentice Hall, 2003.
2. P. W. Atkin and R. S. Friedman, *Molecular Quantum Mechanics*, Oxford University Press, Indian Edition, 2004.
3. D. A. McQuarrier, *Quantum Chemistry*, Viva Books Private Limited, Indian Edition, 2007.
4. P. Atkins, J. D. Paula, *Atkins' Physical Chemistry*, Oxford University Press, (Indian Edition), 8th Edition, 2008.
5. H. E.White, *Introduction to Atomic Spectra*, McGraw-Hill.

Prerequisite: Quantum Mechanics courses

PH 511	**ADVANCED QUANTUM MECHANICS**	**4 Credits [3-1-0]**

Integral formulation of Quantum mechanics, Path Integral Integral, Relativistic wave equations, field quantization & particle processes, second quantization, interaction picture, S-matrix, many particle Green's functions and diagrametric methods, Feynman diagrams, many body physics, relativistic quantum mechanics of spin-1/2 particles, quantum theory of radiation, co-variant of perturbation theory, elements of quantum electrodynamics. Applications in condensed matter physics.

Essential Reading:
1. J. J. Sakurai, *Advanced Quantum Mechanics*, Pearson Education, 2007.

2. P. Strange, *Relativistic Quantum Mechanics: with Applications in Condensed Matter & Atomic Physics,* Cambridge University press, 1st Ed., 1998.

Supplementary Reading:

1. L. D. Landau and E. M. Lifshitz, *Quantum Electrodynamics (vol.4),* 3rd Ed. Pergamon Press.
2. S. Doniach and E. H. Sondheimer , *Green's Functions for Solid State Physicists*, Imperial College Press, 1998.
3. E. N. Economou, *Green's Functions in Quantum Physics*, Springer, 3rd Ed., 2006.

Prerequisite: Quantum mechanics courses.

PH 512	ADVANCED STATISTICAL MECHANICS	4 Credits [3-1-0]

Review of equilibrium statistical mechanics and its applications, theory of phase transition, critical phenomena, critical points and order parameter, thermodynamic properties and exponents, fluctuation of the order parameter, mean field theory .The renormalization group: the definition, fixed points and exponents, RG in selected models, perturbation expansion and dynamics. Ising Model and magnetism, correlation functions, superconductivity, superfluidity, Bose-Einstein condensation, fluctuation problems. Percolation problems; Kadona transformations, Ginzberg-Landau form. The correlation length and scaling hypothesis, scale transformation and dimensional analysis; Non-equilibrium statistical mechanics, ergodic hypothesis and basic postulates, Langevin equations, Focker-Planck equations, diffusion equation, entropy from trajectory of motion, instability of a trajectory

Essential Reading:

1. L. E. Reichl, *A modern course in Statistical Physics*, Wiley & Sons, 2nd Ed., 1997.
2. R. Zwanzig, *Nonequilibrium Statistical Mechanics*, Oxford University Press, 2001.

Supplementary Reading:

1. L. Landau and E. M. Lifshitz, *Course in theoretical physics vol.5 (part-I) & vol.9 (part-II) - Statistical Mechanics,* 3rd Ed., Pergamon Press.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.
3. V. Balakrishnan, *Elements of Nonequilibrium Statistical Mechanics*, CRC Press, 2008.
4. D. S. Lemons, *An Introduction to Stochastic process in Physics*, John Hopkins Univ. Press, 2002.

Prerequisite: Statistical mechanics course

PH 513	DENSITY FUNCTIONAL THEORY & ITS RECENT APPLICATIONS	4 Credits [3-1-0]

Origin : Thomas-Fermi Theory, Electron Density, Potential Relation, Minimum Energy Principle and Chemical Potential, Exchange energy from Fermi hole, Hartree-Fock Method, Exchange energy in atoms, Correlations in Thomas Fermi Framework; Hohenberg-Kohn Theorem, v-Representability, derivative discontinuity, Spin Polarised systems, Density Matrix Functional, Basic Kohn-Sham equations, Variational principle and self consistent equations, Extension to magnetic and multi-component systems, approximations for exchange correlation energies, applications to atoms, molecules and solids; Relativistic and time dependent density functional theory and its application to excited states problems.

Essential Reading:

1. R. E. Nalewajski, *Density Functional Theory (Relativistic & Time Dependent),* Springer Verlag, 1996.
2. R. M. Dreizder and E. K. U. Gross, *Density Functional Theory*, Plenum Press, 1995.

Supplementary Reading:

1. M. Marques, C. A. Ullrich, C. A. F. Nogueira, A. Rubio, K. Burke, K. E. K. U. Gross, (Eds.) ,Springer, 2006.
2. R. M. Martin, *Electronic Structure: Basic Theory and Practical Methods*, Cambridge University Press, 2004.
3. J. Kohanoff, *Electronic Structure Calculations for Solids and Molecules: Theory and Computational Methods,* Cambridge University Press, 2006.
4. C. Fiolhais, F. Nogueira, M. Marques (eds.), *A Primer in Density Functional Theory*, Springer-Verlag, 2003.

Prerequisite: quantum mechanics and condensed matter physics courses.

PH 514	ADVANCED CONDENSED MATTER PHYSICS	4 Credits [3-1-0]

Second quantization, Fermi liquid, electron-electron interaction, electron-hole interaction in semiconductors, elementary excitation, electron-phonon interaction, polarons; Density functional theory and advanced band structure calculations, approximation in exchange potentials, molecular dynamics; Cooperative phenomena, paramgnetism, ferromagnetism, Ising model, superconductivity, BCS and Ginzberg-Landau theories, Bose-Einstein condensation, Dynamical mean field theory.

Essential Reading:

1. W. G. Aulbur, L. Jonsson, and J. W. Wilkins, *Quasiparticle Calculations in Solids, Solid State Physics Vol.54*, Academic Press, 2000
2. G. D. Mahan, *Many Particle Physics (Physics of Solids and Liquids)*, Springer, 3rd Ed., 2007.

Supplementary Reading:

1. F. Duan and J. Guojun, *Introduction to Condensed Matter Physics*, World Scientific, 2005.
2. R. M. Dreizder and E. K. U. Gros, *Density Functional Theory*, Plenum Press, 1995.
3. Avella, Adolfo; Mancini, Ferdinando (Eds.), *Lectures on the Physics of Strongly Correlated Systems X*I, (Eleventh Training Course in the Physics of Strongly Correlated Systems) Springer, 2006.
4. S. Doniach and E. H. Sondheimer , *Green's Functions for Solid State Physicists*, Imperial College Press, 1998.
5. H.Bruus and K. Flensberg, *Many-Body Quantum Theory in Condensed Matter Physics: An Introduction,* Oxford University Press, 2004.

Prerequisite: Condensed matter physics course

PH 522	PHYSICS OF SEMICONDUCTORS: FROM BULK QUANTUM DOTS	4 Credits [3-1-0]

Crystal structure of Bulk semiconductors, theories of band structure, effective mass theory, k-p method etc. Band gap tailoring, doping with tri- and penta-valent elements, electron and holes, Fermi- Dirac statistics and electron & holes charge concentrations. Computational Method of band structure calculation, preparation of bulk and low dimensional semiconductors; Transport properties: Transport phenomena in bulk semiconductors : quantum mechanical theories of the interaction of photon with matter and first principle techniques for the calculation of transport properties, applied electric field and drift velocity, carrier mobility and ohm's law, Diffusion and diffusion current equations , diffusion coefficient, Einstein relation, continuity equation, generation and recombination mechanism, minority carrier life time and diffusion length; Semiconductor heterostructures and their novel properties. Low dimensional semiconductors: two, one and zero dimensional semiconductors. Effect of quantum confinement. Semiconductor nono-structures and nano-tubes: the band structure and ground state properties. Dilute magnetic semiconductors: magnetic properties of doped semiconductors with magnetic impurities.

Essential Reading:

1. P. Y. Yu, and M. Cardona, *Fundamentals of Semiconductors Physics & Material Properties,* Springer Verlag, 1999.
2. J. Singh, *Semiconductor Devices: Basic principles*, Wiley India, 2008.

Supplementary Reading:

1. S. Dimitrijev, *Principles of Semiconductor Devices,* Oxford University, 2006.
2. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.
3. S. M. Sze, *Semiconductor Devices: Physics and Technology*, John Willey and Sons-2004.
4. Y. Fu and M. Wilander, *Physical Models of Semiconductor Quantum Devices*, Kluwar Academics, 1999.

Prerequisite: Quantum mechanics courses and basic knowledge of solid state physics

PH 523	SEMICONDUCTOR SPINTRONICS & QUANTUM COMPUTATION	4 Credits [3-1-0]

Properties of ferromagnetic semiconductor heterostructures, spin dependent scattering and tunneling, magneto-resistance, spin injection in ferromagnetic semiconductor heterostructures, spin injection and transport properties of micro- and nanoscale devices; Towards a semiconducting spin transistor, spin dynamics in semiconductors; coherent ensembles of spins, spin coherence in bulk and nanostructure semiconductors; Optical manipulation, transport and storage of spin coherence in semiconductors. Spin in quantum information processing. Electron spins in quantum; dots as Qubits for quantum information processing.

Essential Reading:

1. D. D. Awschaldm, *Semiconductor Spintronics & Quantum Computation*, Springer Verlag, 2002.
2. M. A. Nielsen and I. L. Chuang, *Quantum Computation & Quantum Information*, Cambridge University Press, 2002.

Supplementary Reading:

1. E. L. Nagaev, *Colossal Magneto-Resistance and phase separation in magnetic semiconductors,* World Scientific, 2002.
2. P. Kaye, R. Laflamme, M. Mosca, *An Introduction to Quantum Computing,* Oxford University press, 2007.
3. S. Bandyopadhyay and M. Cahay, *Introduction to Spintronics*, CRC Press, 2008.
4. S. Maekawa, *Concepts in Spin Electronics*, Oxford University Press, 2006.

Prerequisite: quantum mechanics & condensed matter physics courses

PH 524	COMPUTATIONAL CONDENSED MATTER PHYSICS	4 Credits [3-1-0]

Review of linear methods of band structure calculation. Density functional theory, Time dependent density functional theory, Pseudopotential, tight binding, KKR, augmented plane wave methods for band structurecalculations; Greens' function method-GW approximation coupled with density functional theory for first principle calculations. Calculation of transport properties. Application to bulk materials; Molecular Dynamics: Simulation of nano materials and their properties, tight binding and Carr-Perrinello molecular dynamics(Emphasis would be given to numerical calculations and development of computer codes.)

Essential Reading:

1. R. M. Martin, *Electronic Structure: Basic Theory and Practical Methods*, Cambridge University Press, 2004.
2. J. Kohanoff, *Electronic Structure Calculations for Solids and Molecules: Theory and Computational Methods,* Cambridge University Press, 2006.

Supplementary Reading:

1. R. M. Dreizder and E. K. U. Gros, *Density Functional Theory*, Plenum Press, 1995.
2. R. E. Nalewajski, *Density Functional Theory (Relativistic & Time Dependent),* Springer Verlag, 1996.
3. I. Turek, V. Drchal, J. Kudrnovsky, M. Sob, P. Weinberger, *Electronic Structure of disordered alloys, structure & interfaces,* Kluwar Academic Publishers, 1997.
4. V. V. Nemoshkalenko and V. N. Antonov, *Computational Methods in Solid State Physics,* CRC Press, 1998.
5. D. Hugues(ed), *Electronic Structure & Physical Properties of Solids (lecture notes*), Springer, 1998.

Prerequisite: Quantum mechanics & condensed matter physics courses.

PH 525	**ELECTRONIC STRUCTURE OF DISORDERED ALLOYS**	**4 Credits [3-1-0]**

Green's function method for solids, density of states using Green's function method. ; Method of configurational averaging. Virtual crystal approximation, coherent potential approximation, KKR-CPA equation. ; Augmented space formalism and its application to the study of averaged quatities of density of states and transport properties. Cluster coherent potential approxmation within augmented space formalism. ; Recursion method, Augmented space recursion for efficient calculation. First principle techniques for the study of disordered systems: bulk, surfaces and interfaces.

Essential Readings:

1. I.Turek, V.Drchal, J.Kudrnovsky, M.Sob, P.Weinberger, *Electronic Structure of disordered alloys, structure & interfaces*, Kluwar Academic Publishers. (1997)
2. A.Mookerjee, D.D.Sarma, *Electronic Structures of Alloys, Surfaces and Clusters,* Taylor & Francis (2003)

Supplementary Readings:

1. D.Hugues(ed), *Electronic Structure & Physical Properties of Solids (lecture notes)*, Springer (1998)
2. Wolfgang Pfeiler, *Alloy Physics*, Wiley VCH (2007)

PH 531	**NON-LINEAR DYNAMICS, CHAOS & RECENT APPLICATIONS**	**4 Credits [3-1-0]**

Introduction to non-linear dynamics, Chaos & Fractals. One Dimensional Flow: Fixed points and Stability, Bifurcations, flow on the circle. Two Dimensional Flow: Linear systems, Phase plane, Limit cycles, bifurcation in two dimensional systems. Chaos: Chaos on a strange attractor, Lorenz map, Periodic windows, Liapunov exponents, universality, Renormalization. Strange attractors: Henon map, Rossler system. Spatio-Temporal Chaos in extended system; Synchronization in nonlinear and chaotic systems. Fractals. (With examples from physics, chemistry, biology, fluid dynamics and electronic circuits.)

Essential Reading:

1. D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations,* Oxford Univ. Press, 4th Ed., 2007.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.

Supplementary Reading:

1. G. L. Baker and J. P. Gollub, *Chaotic dynamics-An Introduction*, Cambridge University Press, 1996.
2. F. Verhulst, *Nonlinear differential equations and dynamical systems,* Springer, 2nd Ed, 1999.
3. T. Kapitaniak, *Chaos for Engineers*, Springer, 1998.
4. P. S. Addison, *Fractals & Chaos,* Overseas Press, 2005.
5. D. Kaplan and L..Glass, *Understanding Nonlinear Dynamics,* Springer, 1998.

Prerequisite: Good knowledge of Partial differential equations and algebra

PH 532	PHYSICS OF MACROMOLECULES	4 Credits [3-1-0]

Variety of macromolecules, synthetic, natural and biopolymers, synthesis of macromolecules, molecular weight, concept of mono dispersity and poly dispersity, review of mathematical statistics, distribution of molecular weight, Review of thermodynamics for small molecules, thermodynamics of macromolecules, entropy of mixing, the Flory-Huggins lattice theory, enthalpy and free enthalpy of mixing, partial molar quantities, partial specific volume, chemical potential, static's and dynamics of dilute of polymer solution, Rouse model, Zimm model, Chain conformations and configurations, single ideal chain, mean square end to end distance, radius of gyration, freely joined chain, worm like chain, the random flight model, excluded volume, solvent quality, theta temperature, semi-dilute and concentrated polymer solutions, chain cross-over and chain entanglement; Experimental techniques: Macromolecular structure, principles of x-ray diffraction, x-ray diffraction by macromolecules. Viscosity, intrinsic viscosity, viscoelasticity. Osmotic pressure, determination of molecular weight by osmometer, second virial coefficient. Diffusion, Fick's first and second law, Einstein equation of diffusion. Light scattering, Rayleigh scattering, Fluctuation theory, determination of molecular weight, radius of gyration, second virial coefficient, diffusion coefficient and hydrodynamic radius of macromolecules; Some concepts of electrolytes and polyelectrolytes, Debye-Huckle theory, Donnan equilibrium, flexible plyelectrolytes, polypeptides, proteins, nucleic acid, self-assembly, colloids, surfactants, micelles. Scaling and universality.

Essential Reading:
1. S. F. Sun, *Physical Chemistry of Macromolecules,* John Wiley & Sons, 2004.
2. P. Munk and T. M. Aminabhavi, *Introduction to Macromolecular Science*, Wiley-Interscience, 2002.

Supplementary Reading:
1. G. Pattersom, *Physical Chemistry of Macromolecules*, CRC Press, 2007.
2. M. Doi and H. See, *Introduction to Polymer Physics*, Oxford University Press, 1996.
3. M. Doi, S. F. Edwards, *The Theory of Polymer Dynamics*, Clarendon Press, 1999.
4. A. E. Tonelli, *Polymers from Inside Out:In introduction to Macromolecules*, John Wiley-Interscience, 2001

Prerequisite: Basic Mathematics and statistics, basic thermodynamics.

PH 533	SYNCHRONIZATIONS AND ITS RECENT APPLICATION IN CHAOTIC SYSTEMS	4 Credits [3-1-0]

Synchronization in historical perspective. The basic notions: the self sustained oscillators and its phase, self sustained oscillators in nature, synchronization of a driven periodic oscillators, phase and frequency locking; Synchronization of higher order and Arnold tongues, synchronization of relaxor oscillators. Synchronization of two and many periodic oscillators, frequency locking, chains, lattices and oscillatory media; Synchronization in chaotic oscillators: Lorentz, Rossler, Marhieu oscillators; phase synchronization of chaotic oscillators, synchronization in the presence of noise, populations of globally coupled oscillators.

Essential Reading:
1. A. Pikovsky, M. Rosenblum and J. Kurths, *Synchronization: A Universal Concept in Nonlinear Science,* Cambridge University Press, 2002.
2. S. H. Strobatz, *SYNC: How Order Emerges From Chaos In the Universe, Nature, and Daily Life,* Hyperion, 2004.

Supplementary Reading:

1. G. V. Osipov, J. Kurths and C. Zhou, *Synchronization in Oscillatory Networks* (Springer Series in Synergetics), Springer, 2007.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.
3. Y. Kuramoto, *Chemical Oscillations, Waves, and Turbulence,* Dover Publications, 2003.
4. A. T. Winfree, *The Geometry of Biological Time*, Springer, 2001.

Prerequisite: Good knowledge of differential equations and linear algebra.

PH 535	LASER PHYSICS	4 Credits [3-1-0]

Brief history of LASER, wave nature of light, wave-particle duality, Electromagnetic radiation, interaction of light with matter, Black body radiation, General Physical principles behind amplification: Spontaneous emission. Stimulated absorption, Stimulated emission, Einstein coefficient and amplication, Line broadening, Ideas about line-width, Laser rate equations: The three level system, The four level system, Semi classical theory of LASER, active medium, population inversion, pumping mechanism, Role of feedback mechanism, Optical resonator, Modes of a rectangular cavity, Transverse and Longitudinal modes, The quality factor, Q- switching, Mode locking. CW operation, Pulsed operation.
Properties of LASER: Coherence, Directionality and Monochromacity

Different types of LASERS: Gas LASER, Solid state LASER, Liquid state LASER, Excimer LASER, Fiber optic LASER

Essential Readings:

1. William T. Silfvast, LASER Fundamentals, Cambridge University Press, 2^{nd} Edition, 2004.
2. Anthony E. Siegman, LASERS, University Science Books, 1986.

Supplementary Readings:

1. A.K. Ghatak and K.Thyagarajan, LASERS: Theory and applications, Macmillan Publishers India, 2000.
2. K.R. Nambiar, LASERS: Principles, Types and Applications, New Age Instruments, 2004.
3. Orazio Svelto and David C. Hanna, Priniciples of LASERS, Springer, 4^{th} Ed, 1998

PH 541	DIELECTRIC & MAGNETIC PROPERTIES OF MATERIALS	4 Credits [3-1-0]

Review of crystallography: - Symmetry, point groups, Miller indices, Laue's condition, Reciprocal lattice, Brillouin zones; **Magnetic Properties and magnetic materials**: - Van Vleck paramagneism Quantum theory of paramagnetism and Ferromagnetism. Temperature dependence spontaneous magnetization, magnetic domain, hystersis, Exchange interaction. Molecular field theory(Weiss law). Technological application of magnetic materials & multilayers in memory device, sensors, magnetic bubbles; **Phenomenological theories of magnetic order**- Interaction of atomic spins at large distance, molecular field theory, Spin waves, Ising model, Magnetic phase transition; **Di electric material :-** Classical & Quantum, theory of electronic polarisability and ionic polarisability spontaneous polarization , Hysteresis, Frequency dependent polarization, Piezoelectricity; **An introduction to relaxor ferroelectricity**. Pervoskite crystal structure, Ferroelectric phases and domains , Curie Weiss behavior, Diffuse phase transition, Physics of Relaxor ferroelctricity , ABO3 relaxors, Application of ferroelectricity.

Essential Reading:

1. S. Blundell*, Magnetism in condensed matter*, Oxford university press, 2001.
2. A. Aharoni, *Introduction to the theory of ferromagnetism,* Oxford university press, 2001.

Supplementary Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.

2. Y. D. Jiles*, Introduction to magnetism and magnetic materials*, Chapmean and Hall. (2nd edition).
3. Ashcroft/ Mermin, *Solid state physics*, India edition IE, Thomsom books, Reprint, 2007.
4. L. L. Hench, J. K. West, *Principles of electronic ceramics*, John Wiley and sons,1995.

Prerequisite: 5th level condensed matter physics and quantum mechanics courses

PH 542	PHYSICAL & APPLICATION OF DIELECTRIC MATERIALS	3 Credits [3-0-0]

Maxwell Equations & Polarization, Macroscopic Electric Field, Local Electric Field at an Atom, Chemical Bond in Dielectrics, Structure of Dielectrics, Electrical Conduction in Dielectrics, Polarization Mechanisms in Dielectrics, Dielectric Relaxation, Ferro-electricity: Theory of Ferroelectrics, Domain, Imperfections & Polarization Reversals, Experimental Study of Thermodynamic Properties, Oxygen Octahedron, Order Disorder Ferroelectric, Critical Phenomena, Size Limit on Ferro-electricity, Applications of Ferroelectric Materials: Ferroelectric Ceramics Applications, Applications of Piezoelectric Ceramics, Ferroelectric Thin Films Applications, Electro-optic Applications.

Essential Reading:

1. A. J. Moulson and J. M. Herbert, *Electroceramics: Materials, Properties and Applications,* Wiley; 2nd Edition, 2003.
2. K. Uchino, *Ferroelectric Devices*, New York: Marcel Dekker, 2000.

Supplementary Reading:

1. M. E. Lines and A. M. Glass, *Principles and Applications of Ferroelectric and Related Materials,* Clarendon Press, Oxford, 2007.
2. Y. H. Xu, *Ferroelectric Materials and Their Applications*, Noth-Holland, 1991.
3. C. Kittel, *Introduction to Solid State Physics*, 8th Ed. John Wiley & Sons Pvt. Ltd, 2004.

Prerequisite: Basic knowledge of Electrostatics, Magnetostatics & Dielectric Materials

PH 543	BIO CERAMIC MATERIALS & APPLICATIONS	3 Credits [3-0-0]

Overview of structure and properties of materials: crystal structure, bonds in solid, crystal defect, surface property: surface tension & diffusion, and surface improvement, mechanical property, strengthening mechanism, thermal treatment and sterilization etc. ; Overview of bio implanting materials : synthetic polymers (polyethylene, polypropelyne), Acrylic polymer(PMMA),bio polymer(Collagens, elastin) metal alloys(steel, metal-chromium, platinum, titanium) , ceramics (Alumina, hydroxyapatite) , composite (fibers matrices) etc. Structure property relationship & mechanical properties of biological materials ; soft tissues and hard tissues. Orthopedic implants Materials: composition & mechanical strength of bone, Hydroxy Apatite ceramic for use in implantation, mechanical testing of ceramic materials for bone and joint replacement, Knee and hip joint replacement, Apatite morphology. ; Dental materials : Implant type, physical mechanical properties Dental materials, Biocompatibility of dental materials, Dental ceramics, zinc oxide and poly-Acrylic cements, methods of strengthening ceramics, Filling and metal – ceramic restoration, Dental ceramic for bonding , restoration application, chemical attack of dental ceramic. ; Analysis of human bone and teeth by PIXE, EDXRF, XRD, TGDTG and synthesis of Hydroxyapaptite by ion implantation

Essential Readings:

1. G.W. Hastings and D.F.Williams, *Mechanical properties of Biomaterials*, John Willey 1980
2. Sujata V.Bhat, *Bio- materials* second edition, Narosa , 2007

Supplementary Readings:

1. G.D. Winter, J.L.Leray, Klassde Groot, *Evaluation of Bio materials*, John Wiley, 1980.
2. Ph.d thesis of Tapas Ranjan Routray, *Characterisation & and Analysis of gallstone and hydroxyapaptite*, submitted to NIT, Rourkela

PH 544 POLYMER PHYSICS 4 Credits [3-1-0]

Polymer fundamentals: basic concept, nomenclature, classification of polymer, specific features of polymer, configurational states and chain conformations in polymer, ; Synthesis of Polymers: Polymerization and polycondensatation. ; Theory of polymer solution: Basic concept, Regular solution, Flory-Huggins theory, The solubility parameter concept, Equation of state theory, Polymer-polymer blend ; The rubber elastic state: Thermoelastic behavior and thermodynamics, The statistical mechanical theory of rubber, Swelling of rubbers in solvents. The glassy amorphous state, the molten state, Crystalline Polymer, Phase transitions of polymers, Crystallization, melting and glass transition, Theory of glass transition and Free volume, Liquid crystalline polymers, Polymer crystallization, ; Polymer characterization: Methods of investigation of polymer structure such as SAXS, WAXS, Thermal analysis, Microscopy, Vibrational Spectroscopy, Mechanical properties, ; Electrical properties of polymer: Dielectric properties and relaxation phenomena in polymer, Piezoelectric, and ferroelectric polymer. ; Polymer electrolyte: Fundamentals and classifications, Different generations of polymer electrolytes, Physics of polymer electrolyte, Thermodynamics, Structure and morphology, Ion transport mechanism in polymer electrolyte, Phenomenological concept and empirical relations, application of polymer electrolytes for electrochemical devices.

Essential Reading:

1. U. W Gedde; *Polymer Physics,* Chapman & Hall, New York, 1996 (Reprint).
2. D. I. Bower, *An Introduction to Polymer Physics*, Cambridge University Press, 1st Edition, (2005).

Supplementary Reading:

1. A. Tager, *Physical Chemistry of polymer*, Mir Publishers, Moscow, New Age International (P) Ltd. 2nd Edition (1978) Reprint.
2. M. Rubinstein and R. H. Colby, *Polymer Physics*; Oxford, New York: Oxford University Press, (2003).
3. F. M. Gray, *Solid Polymer Electrolytes*, VCH, New York (1991).

Prerequisite: Basic statistical mechanics and condensed matter physics

PH 551 CRYSTAL SYMMETRY & CRYSTAL PHYSICS 4 Credits [3-1-0]

The development of structure and types of matter: liquid, amorphous and crystalline states. Crystal structure: lattice, basis, unit cell. Concepts of crystal symmetry: point symmetry, translational symmetry, Bravais lattices, crystal systems, point groups, space groups Examples of structures such as NaCl, CsCl, the diamond structure, cubic perovskite structure. ; Fundamental principle of x-ray diffraction, Scattering of x-ray by electron and atoms, Structure factor and Intensity. Typical crystal structure determinations from x-ray powder diffraction data. Determination of crystallite size and strain from x-ray diffraction pattern. ; Crystal physics: Crystal symmetry and macroscopic physical properties, Symmetry of higher rank tensors and their applications to crystal properties: pyroelectricity, ferroelectricity, electrical conductivity, piezoelectricity, magnetic succiptibility and elasticity tensors.

Essential Reading:

1. J. F. Nye; *Physical properties of crystals: their representation by tensors and matrices*, Oxford Science Publication, Oxford University Press: New York, 2004 (Reprint).
2. H. P. Klug, L. E. Alexander, *X-ray diffraction procedures for crystalline and amorphous materials*, A Wiley Interscience Publication, 2nd Edition (1974). (both the above books are available in Library)

Supplementary Reading:

1. A. R. Verma and O. N. Srivastava, *Crystallography Applied to Solid State Physics*, New Age International (P) Ltd. 2nd Edition (2005) Reprint.
2. B. E. Warren, *X-ray diffraction*, Addison-Wesley Publishing Company, London, 1969.

3. C. Suryanarayana, M. Grant Norton, *X-ray diffraction: A practical approach*, Plenum Press, New York, 1998.

Prerequisite: Basic Mathematical Physics mainly matrix and tensor analysis.

PH 553	ADVANCED X- RAYS SRUCTURE ANALYSIS	4 Credits [3-1-0]

Introduction to x-rays, Introduction to X-ray diffractiontechniques, Qualitative and quantitative analysis of XRD data, prerequirements of Sample preparation for XRD data, Measurement of line intensities, Various factors effecting XRD intensities, Quantitative methods based on intensity ratios, The absorption diffraction method, Internal standard method, General RIR method, Normalized RIR method, Constrained XRD phase analysis, Detection limit issues Preliminary idea about XRF, PIXE, SAXS, GISAXS, EDX and their applications to characterize the materials with limitations of the techniques. X-ray spectroscopy and its application in characterization of materials. Advantages and disadvantages of the above mentioned techniques; Introduction to Medical application of X-rays and different equipments used for diagnosis purposes.

Essential Reading:

1. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction*,Pearson, 3rdEdn, 2001.
2. A. R. Verma, O. N. Srivastava, *Crystallography Applied to Solid State Physics*, New New Age International Publication, 2001.

Supplementary Reading:

1. A. K. Singh*, Advanced X-ray Techniques in Research and Industry*, Capital Publishing Company, 2006.

Prerequisites: Elementary knowledge on modern physics.

PH 554	PHYSICS OF THIN FILM TECHNOLOGY	4 Credits [3-1-0]

Physical vapor deposition (PVD):- Physical fundamentals and technical aspects Theories of film growth and applications, Sputtering(RF &DC), Pulse laser deposition and Molecular beam epitaxy; **Chemical vapor deposition (CVD):-** Physical fundamentals and technical aspects Theories of film growth and applications; Ferro Magnetic, dielectric and superconducting thin film and multilayers; **Langumuir Blodgett thin film:-** Technical details, Isotherm, Applications to organic electronics sensors etc Self assembly; **Sol-gel Spin coating:-** Technical details-hydrodynamics of spin coating (Newtonian and non-Newtonian behavior), dip coating; **Thin film characterizing technique:-** Surface Plasmon resonance spectroscopy , Ellipsometry, Atomic force Microscopy, and Tunneling electron microscopy, Transmission electronmicroscopy

Essential Reading:

1. Milton Ohring, *Material science of thin film deposition and structure*, academic press, John Wiley New york, 2006.
2. Maissel L I, Glang R *Hand book thin film technology* Mc Graw Hill 2 nd edition.

Supplementary Readi:

1. R. Sahu, *Physics of solid, nuclei and particle*, Narosa publishing house, 2006.
2. K. L. Chopra,*Thin film phenomena* , Mcgraw- Hill book company latest Edition.
3. C. C Julian, *Introduction of electron Scanning Tunneling Microscopy*, Coulombia university press, 2006

Prerequisite: condensed matter physics and quantum mechanics courses

PH 555	PHYSICS OF MATERIAL SYNTHESIS AND CHARACTERIZATION	4 Credits [3-0-0]

Bulk Materials Synthesis Techniques: Powders synthesis method; mechanical methods, hydrothermal synthesis of ceramic oxide powders, chemical methods, synthesis of nano-scale ceramic powders, powder characterization, particle size, shape, surface area, chemical composition, crystal structure and phase composition. **Thin Film Synthesis Techniques:** Physical vapor deposition, Chemical vapor deposition, Pulsed LASER Deposition, Sol-Gel, Molecular Beam Epitaxy, **Characterization Techniques:** X-Ray Diffraction Methods, X-Ray Fluorescence, Electron Dispersion Spectroscopy, Thermo gravimetric Analysis, Differential Thermal Analysis, Differential Scanning Calorimetery, Electron Microscopy-Transmission and Scanning Electron Microscopy, STM and AFM, Compositional analysis employing AES, ESCA and Electron Probe Microanalysis. Fourier Transform Infrared Spectroscopy.

Essential Reading:
1. M. Ohring, *The materials Science of Thin films*, Amazon, 2001.
2. M. N. Rahaman, *Ceramic Processing*, CRC Press, Taylor & Francis Group, FL, 2007.

Supplementary Reading:
1. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental Analysis*, 5th Ed., Hartcourt College Publishers, 1998.
2. *Lecture notes of AICTE Short term Winter School on Advanced Techniques for Characterization of Materials*, Feb. 12-23, 1996, IIT Delhi.
3. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction* ,Pearson, 3rdEdn, 2001.

Prerequisite: Basic knowledge of Quantum Mechanics

PH 556	X- RAY AND NANO- SCIENCE	4 Credits [3-1-0]

Production and properties of X-rays. Introduction to Nanoscience, Roll of X-ray in Nanoscience. Real and reciprocal space, application of reciprocal space to diffraction, Ewald's sphere, X-ray crystallography including space group and symmetries, scattering of X-ray by free and bound electrons, scattering by liquids; Introduction to Small Angle X-ray Scattering (SAXS), postulates of SAXS theory, Idea of different systems (ideal, non-ideal, monodisperse, polydisperse, dilute and dense systems). Overview of experimental SAXS system, Calculation of scattered intensity from a single particle & many particle systems, Refinement of SAXS data. Characterization of nano materials using SAXS data. General application of SAXS technique.

Essential Reading:
1. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction*, Pearson, 3rdEdn, 2001.
2. P. Linder, Z. Th. Neutron, *X-ray and Light: scattering methods applied to soft condensed matter,* Elsevier Science, 2002.

Supplementary Reading:
1. G. V. Paulinsky, *Fundamentals of x-rays*, Cambridge international science, 2008.
2. N. Kasai, M. Kakudo, *X-ray diffraction by Macromolecules*, Springer, 2005.
3. E. J. Mittemeijer, P. Scardi, Diffraction Analysis of microstructure of materials, Springer, 2003.

Prerequisites: Elementary knowledge on physics.

PH 561	PHYSICS OF MICROELECTRONIC AND PHOTONIC DEVICES	4 Credits [3-1-0]

The course introduces carrier transport in materials, physics of phenomena in semiconductors and optical fiber communications. This course provides basic idea to carry research in the area of semiconductors and photonics; Carrier Drift, Drift velocity, Carrier mobility, Carrier Diffusion, Generation and Recombination Process, Diffusion and diffusion current equations, Diffusion coefficient, Einstein relation, Continuity equation, Thermionic Process, Tunneling Process, High Field Effects; Thermal equilibrium condition, Depletion region, Depletion capacitance, Current voltage characteristics, Junction breakdown, Heterojunction, junction potential; Behaviour of charged particles in conducting, insulating and semiconductor materials - thin film phenomena - Transport properties of thin films - Epitaxial growth - Microelectronics - Lithography and etch techniques - Microelectronic devices for Magnetic, dielectric, conductive and optical memory applications; Radiative Transition and optical absorption, Light emitting Diode, Semiconductor Laser, Laser Diodes, Optical Modulators, optical fibers, couplers, electro-optic devices, magneto-optic devices, Photo detector, Solar cell.

Essential Reading:

1. B. G. Streetman *and S. Banerjee , Solid State electronic devices,, 5th edition,* Prentice Hall of India *Private Limited, New Delhi, 2000.*
2. S. M. Sze, *Semiconductor Devises (Physics and Technology),* John Wiley & Sons Inc. 2nd Edition 2002

Supplementary Reading:

1. C. Kittel, *Introduction to solid state physics*, 7th Edition, Wiley Student Edition Reprint 2006.
2. Jean-pierre Colionge, C. A. Colinge, *Physics of SemiconductorDevices,* Klumer Acamedic Publication, 2002.
3. N. D. Gupta, *Amitav Das Gupta, Semiconductor Devices Modelling and Technology*, Prentice Hall of India,2004.
4. S. Dimitrijeo, *Principle of Semiconductor Devices,* Oxford University 2006.
5. Jia- Ming Liu, *Photonic Devices*, Published by Cambridge University Press, 2005.

Prerequisites: Knowledge in elementary solid state Physics and semiconductor properties**.**

PH 562	**SUPERFLUIDITY AND SUPERCONDUCTIVITY**	**4 Credits [3-1-0]**

Introduction to Superfluidity, 4He and 3He and their properties, Claussius-Clapeyron relation, Properties of solids at low temperature, Superdiamagnetism, Bose-Einstein Condensate, Supersolid, Superfluid film,gauge symmetry breaking, Thermodynamics of Superconductivity, ; Phenomenology of superconductivity, review of basic properties, thermodynamics of superconductors, Meissner effect, London equations, Cooper pairs, coherence length, Ginzburg-Landau theory, BCS theory, Josephson effect, SQUID, excitations and energy gap, magnetic properties of type-I and type-II superconductors, flux lattice, Quantum vortex ; Introduction to high-temperature superconductors, Inhomogeneities, Superconducting order parameter fluctuation. Experimental Techniques for Low-Temperature Measurements, Material Properties and Superconductor Critical-Current Testing.

Essential Reading:

1. C. Kittel, *Introduction to Solid State Physics*. John Wiley & Sons 7th edition (2004) Reprint 2006
2. D. R Tilley and J. Tilley , *Superfluidity and superconductivity*, 3rd ed-- New Delhi: Overseas Press, 2005

Supplementary Reading:

1. N.W. Ashcroft and N.D. Mermin ,*Solid State Physics*, Thomson India, Edition, 4th Indian Reprint 2007
2. M. Tinkham, *Introduction to Superconductivity*. 2nd Edition Dover, 2004 (2nd edition of the work first published by McGraw-Hill Book Co., New York, in 1975)
3. Hagen Kleinert, *Gauge Fields in Condensed Matter*, Vol-I SUPERFLOW AND VORTEX LINES,
4. G. Deutscher, *New Superconductors : From Granular to High Tc*, World Scientific, 2006
5. Jack Ekin, *Experimental Techniques*, Oxford Uni.Press,2006

Prerequisites: knowledge in elementary solid state Physics and Statistical Mechanics.

PH 563 PHYSICAL PHENOMENON AT LOW TEMPERATURE 4 Credits [3-1-0]

Introduction with brief history, Need for low temperature, Techniques of attaining low temperature and its measurements, Ultra low temperatures (dilution refrigerator, adiabatic demagnetization, nuclear demagnetization and their measurements). Experimental determination of physical properties at low temperature (Electrical conductivity, thermal conductivity, Specific heat capacity, magnetic properties, thermoelectric power, etc), Magnetic field in addition to low temperature, Effect of magnetic field on the physical properties, Sources of magnetic fields. Measurements involving high magnetic field (Electron spin resonance, Nuclear magnetic resonance, SQUID).

Essential Reading:

1. Frank Pobell*, Matter and Methods at Low Temperatures* (Springer, 2007)
2. G. K. White and Philip J. Meeson, *Experimental Techniques in Low Temperature Physics*, (Oxford, 2002)

Supplementary Reading:

1. T. H. K. Barron and G. K.white, *Heat Capacity and Thermal Expansion at Low Temperature* (Kluwer academic, 1999)
2. Jack W. Ekin, Experimental *Techniques for Low Temperature Measurements* : *Cryostat Design, Material and Superconductor Critical Current Testing* (Oxford university press, 2006)
3. D.R. Tilley& John Tilley, *Superfluidity and Superconductivity* (Institute of Physics, 2003)

Prerequisite: Elementary Condensed Matter Physics

PH 564 MAGNETISM – PRINCIPLES & APPLICATIONS 4 Credits[3-1-0]

Basic concepts: Introduction, sources of magnetic field, electromagnetics, magnetic materials. *Magnetic measurements:* neutron diffraction, magnetoresistance, Hall effect, dc magnetization, ac susceptibility, magnetic scanning microscopy. *Interactions in magnetic material:* Molecular field theory, direct and indirect exchange interaction, band theory, spin waves, RKKY interaction, Kondo effect. *Relaxation & resonance in magnetic materials:* Electron spin resonance, nuclear spin resonance, Mossbauer effect, De-Haas-Van Alphen effect, cyclotron resonance. *Application of magnetism:* Refrigeration, magnetoelectric, magnetoeleastic, magnetic sensors. *Magnetic nanostructures:* Thin films, multilayers and nanoparticles. Superparamagnetism.

Suggested Readings:

1. *Nicola A Spladin,* **Magnetic Materials**, Cambridge University Press.
2. *Stephen Blundell,* **Magnetism in Condensed Matter**, Oxford University Press
3. *Ralph Skomski,* **Simple Models of Magnetism**, Oxford University Press
4. *B.D.Cullity & C.D.Graham,* **Introduction to Magnetic Materials**, IEEE press
5. *K.H.J.Buschow & F.R.de. Boer,* **Physics of Magnetism and Magnetic Materials**, Kluwer, Academic Press
6. *A. Morrish,* **The Physical Principles of magnetism**, IEEE Press

PH-565 DEFECTS IN SOLIDS 4 Credits[3-1-0]

Defects in lattice: point defects, linear crystal defects, localization, ion implantation, radiation damage, surface defects, defect dynamics. *Defect in metals:* Alloys, intermetallic compounds, quantum interference and weak localization. *Defects in semiconductors:* Lightly and heavily doped semiconductors, Impurity levels, localization of electronic states, hopping conduction, magnetic semiconductors, quantum hall effect. *Defects in superconductors:* vortices and its pinning, pinning effect on critical current capacity, artificial and natural pinning centers in superconductors, magnetic and non-magnetic pinning centers. *Defect related studies:* Positron annihilation spectroscopy, Photoluminescence spectroscopy, Electrical transport.

Suggested Readings:

1. *A. Kelly, G.W.Groves & P.Kidd* **, Crystallography and Crystal Defects**, John Wiley & Sons
2. *J.P.Hirth & J Lothe,* **Theory of Dislocations**, John Wiley Sons
3. *B.I.Shklovskii & A.L.Efros,* **Electronic Properties of Doped Semiconductors**, Springer-Verlag
4. *M. Tinkham,* **Introduction to Superconductivity**, Dover Publications
5. *J.S.Dugdale,* **The Electrical Properties of Disordered Metals**, Cambridge University Press.
6. *D.K.Schroder,* **Semiconductor Material and Device Characterization**, Wiley-IEEE Press

DETAILED SYLLABI OF LABORATORY COURSES

PH170	Physics Laboratory	0-0-3	2
PH 271	Thermal Laboratory	0-0-3	2
PH 272	Electricity & Magnetism Laboratory	0-0-3	2
PH 371	Waves and Optics Laboratory	0-0-3	2
PH 372	Properties of Matter Laboratory	0-0-3	2
PH 471	General Physics Laboratory	0-0-3	2
PH 472	Solid State Physics Laboratory	0-0-3	2
PH 473	Spectroscopy Laboratory	0-0-3	2
PH 571	Instrumentation Laboratory	0-0-3	2
PH 572	Advanced Synthesis Laboratory	0-0-3	2
PH 573	Computational Physics Laboratory	0-0-3	2
PH 574	Advanced Characterization Laboratory	0-0-3	2

PH 170 PHYSICS LABORATORY 2 Credits[0-0-3]

Error & error analaysis, graph drawing, least square fitting

List of Experiments

1. Bar pendulum,
2. Lee’s Disc,
3. Young’s modulus,
4. Newton’s rings,
5. Diffraction grating(spectrometer),
6. Optical rotation,
7. Carry Foster’s bridge,
8. Band gap of semiconductor-Four probe method,
9. Visocty of water by Stoke’s Method
10. Surface Tension by Capillary Rise
11. Diode Characterstics
12. Comparision of Magnetic Moments

Reference: 1. Laboratory Manual,

Prerequisite

PH 271 THERMAL PHYSICS LABORATORY 2 Credits[0-0-3]

1. Heating Efficiency of Electrical Kettle
2. Thermo electric effect (see beck effect)
3. Peltier Effect
4. Determination of Stefan’s Constant
5. Conversion of Mechanical Energy in to heat energy

6. Thermal conductivity of a poor conductor (Lees method)
7. Thermal conductivity of a good conductor (Searles method)
8. Heat Capacity
9. Thermal Expansion of Solids
10. Gas laws: Boyles law
11. Gas laws: Charles law
12. Joule Thomson effect of Metal

Reference: 1. Laboratory Manual,

Prerequisite

PH 272	**ELECTRICITY & MAGNETISM LABORATORY**	**2 Credits[0-0-3]**

1. Resistance of Galvanometer by Kelvin's method
2. Resonance in LCR Circuit
3. Electromagnetic induction and Faraday's law
4. To Study capacitance of capacitor by coulomb meter
5. I-V relationship in RL series circuit
6. Magnetic Hysteresis
7. Mutual induction by deflection method
8. Field Characteristics of Helmholtz-coil
9. Rise & decay of current in inductive circuit
10. Determination of ballistic constant of a b.g.
11. Frequency of ac supply & capacitance using electrical vibrator
12. Mutual inductance by Carey Foster's method
13. L & C by Maxwell's bridge
14. Capacitance using Schering Bridge

Reference: 1. Laboratory Manual,
Prerequisite

PH 371	**WAVES AND OPTICS LABORATORY**	**2 Credits[0-0-3]**

1. NEWTON'S RINGS – Determination of refractive index of liquids
2. Michelson Interferometer
3. Fresnel Biprism,
4. Advanced Spectroscopy,
5. To determine the wavelength of light using Fabry-Perot Etalon.
6. Measurement of Refractive Index of Dielectric Material using BREWSTER ANGLE METHOD
7. Resolving limit of a telescope system
8. Use of diffraction grating and its resolving limit
9. Potential energy curves of a i-double system and oscillations in if for various amplitudes
10. Study of oscillations of a mass under different combinations of springs
11. Speed of waves on a stretched string
12. To verify the existence of different harmonics and measure their relative amplitudes in complex wave

Reference: 1. Laboratory Manual,
Prerequisite

PH 372	**PROPERTIES OF MATTER LABORATORY**	**2 Credits[0-0-3]**

1. Study of laws of parallel and perpendicular axes for moment of inertia
2. Study of a compound pendulum
3. Study of bending of a cantilever

4. Study of torsion of a wire (static and dynamic methods)
5. Vertical oscillations of a spring with mass
6. Fly wheel
7. Study of oscillations under a bifilar suspension
8. KUNDT'S TUBE – Determination of Velocity of Sound in Air
9. COUPLED OSCILLATOR – Measurement of Normal Mode Frequencies
10. SONOMETER – Resonance Modes of a Stretched String & Velocity of Wave Propagation
11. Determination of Coefficient of Viscosity by Poiseuilles Method
12. Determination of Rigidity Modulus by Static and Dynamic Methods.

Reference: 1. Laboratory Manual,

Prerequisite

PH 471	GENERAL PHYSICS LABORATORY	2 Credits[0-0-3]

List of Experiments:

1. To determine fundamental charge by Milliken's oil drop expt.,
2. To determine Plank's constant by Black body radiation,
3. Measurement of e/m,
4. Measurement of Hall coefficient,
5. To obtain B-H loop,
6. Measurement of different noise level using sound level meter,
7. Franck-Hertz Experiment,
8. Refractive Index of medium by Michelson interferometer,
9. Current balance,
10. Variation of magnetic field by Helmholtz coil

Reference: Laboratory Manual

Prerequisite : 1st level physics courses

PH 472	SOLID STATE PHYSICS LABORATORY	2 Credits[0-0-3]

List of Experiments:

1. Band gap of semiconductor crystal by four-probe arrangement,
2. Magneto resistance of a given sample,
3. Measurement of Dielectric constant & Curie temperature,
4. Dispersion relation of mono & diatomic lattice,
5. Tc & Jc of superconducting sample,
6. Young's modulus by Piezoelectric oscillator,
7. Mass susceptibility by Guoy balance,
8. Lande's g factor by ESR spectrometer in MHz range,
9. V vs I of semiconductor by varying temperature(low),
10. Refractive Index of transparent solid media at different temperature,
11. Study of Hysteresis loop of Ferroelectric/Ferromagnetic materials & estimate the energy.

Reference : Laboratory Manual

Prerequisite : 1st level physics courses

PH 473	SPECTROSCOPY LABORATORY	2 Credits[0-0-3]

List of Experiments:

1. Determination of wavelength of x-ray radiation from diffraction pattern of the given cubic crystal system,
2. Study of absorption lines of Na vapour,
3. Determination of wavelength of the given LASER source with the aid of grating,
4. Obtain and analyze the U-V spectra of an unknown system for different types of bonds,
5. Investigation of hyperfine structure of organic/inorganic/ionic radicals using EPR(ESR) spectrometer,
6. Optical microscopic studies of treated and untreated systems,
7. To obtain holographic image of a given object using LASER source

8. Diffraction of LASER by a narrow wire,
9. Wavelength of LASER source by Michelson interferometer,
10. To determine the resolution of gamma-ray spectrometer.

Reference: Laboratory Manual

Prerequisite : 1st level physics courses

PH 571	INSTRUMENTATION LABORATORY	2 Credits[0-0-3]

List of Experiments:

1. Microprocessor based Physics experiments
2. AD/DA converter circuits for interfacing
3. Creation of low temperature and its measurement
4. Measurement of Resistance of material at low temperature
5. Design of temperature sensor using commertial circuit resister and diods.
6. Design of power supply using IC
7. Design of power supply having + and –ve voltage supply to be used in OPAMP
8. Design and fabrication of a constant current source.
9. Demonstration of group wave using sound waves.

Reference : Laboratory Manual

PH 572	ADVANCED MATERIALS SYNTHESIS LABORATORY	2 Credits [0-0-3]

Synthesis of Nanomaterials, thin films, hydrogel, colloids, electroceramics etc. in research laboratories.

PH 573	COMPUTATIONAL PHYSICS LABORATORY	2 Credits [0-0-3]

Programming for numerical calculations using various numerical techniques- roots of a equation, matrix eigenvalue problems, solving differential equations, use of Monte-Carlo simulation for statistical problems, etc., with Fortran & C languages application of MATLAB & OCTAVE.

Essential Reading:

1. S. C. Chapra, *Numerical Methods for Engineers*, Tata-McGraw-Hill. 5th Ed., 2007.
2. V. Rajaraman, *Programming in Fortran 77*, PHI, 4th Ed., 2003.

Supplementary Reading:

1. S. Chandra, *Computer Applications in Physics*, Narosa Publications, 2003.
2. S. J. Chapman, *MATLAB Programming for Engineers*, Thomson Learning.

Prerequisite: Knowledge of C-programming

PH 574	ADVANCED CHARACTERISTICS TECHNIQUES LABORATORY	2 Credits [0-0-3]

Use of Characteristics techniques like XRD, SEM, Particle Size Analyzer, etc.

DEPARTMENT OF HUMANITIES AND SOCIAL SCIENCES

MA (Development Studies)

DETAILED SYLLABI OF COURSES

Sub Code	Subject	L-T-P	Credit
CS 171	Computing Laboratory - I	0-0-3	2
HS 500	Research Methodology	3-1-0	4
HS 501	Advanced Research Methodology	3-1-0	4
HS 511	Technical and Business Communication	3-1-0	4
HS 512	Literary Foundations: Methods and Genres	3-1-0	4
HS 513	Post-Colonial Consciousness and Development	3-1-0	4
HS 514	Mapping the Other: Theories for Alterity	3-1-0	4
HS 515	History of Ideas: The Modern Period	3-1-0	4
HS 522	Social Psychology and Its Application	3-1-0	4
HS 523	Educational Psychology	3-1-0	4
HS 524	Cognitive Development and Assessment	3-1-0	4
HS 525	Psychometrics	3-1-0	4
HS 526	Clinical Paradigms, Psychological Disorders and Therapeutic Interventions	3-1-0	4
HS 527	Corporate Social Responsibility	3-1-0	4
HS 531	Social Institutions and Development	3-1-0	4
HS 532	Planning and Policy: Issues in India	3-1-0	4
HS 533	Development: Social, Anthropological and Political Perspective	3-1-0	4
HS 534	Natural Resource Management and Sustainable Development	3-1-0	4
HS 535	Gender and Development	3-1-0	4
HS 536	Trends and Issues in Tribal Studies	3-1-0	4
HS 537	Development Issues in Orissa	3-1-0	4
HS 538	Urban Governance and Development	3-1-0	4
HS 541	Economics of Development	3-1-0	4
HS 542	Measurement of Poverty, Inequality and Human Development	3-1-0	4
HS 543	Global Issues in Development	3-1-0	4
HS 544	Environment and Development	3-1-0	4
HS 545	Indian Financial System	3-1-0	4
HS 546	Population Dynamics and Development	3-1-0	4
HS 548	Demographic Transition and Health Policies in Developing World	3-1-0	4
HS 570	Advanced Language Laboratory	0-0-6	4
HS 572	Statistical Laboratory	0-0-3	2
HS 591	Research Project – I	0-0-6	4
HS 592	Research Project – II	0-0-9	6
HS 593	Seminar & Technical Writing – I	0-0-3	2
HS 594	Seminar & Technical Writing – II	0-0-3	2
HS 595	Short Term Industrial/Research Experience	0-0-3	2
HS 596	Comprehensive Viva -Voce	0-0-3	2
HS 550	Special Topics in Development Studies – I		3/4
HS 551	Special Topics in Development Studies – II		3/4
HS 552	Special Topics in Development Studies – III		3/4
HS 553	Special Topics in Development Studies – IV		3/4

HS 500	**RESEARCH METHODOLOGY**	**4 credits (3-1-0)**

Objective: The paper aims at equipping students with methods and designs they can apply in systematic examination and measurement of socio-economic phenomena. ; **Contents:** Introduction to Social Science Research; Types of Research Designs and Methods; Qualitative Research; Case Study, Observation, Interview, Genealogy, Questionnaires and Schedules.

Essential Reading:

1. Gupta, S. C. and Kapoor, V. K., *Fundamentals of Mathematical Statistics*, Sultan Chand and Sons, New Delhi.
2. Bruce E. Wampold and Difford J. Drew, *Theory and Application of Statistics*, McGraw-Hill International Editions.

Supplementary Reading:

1. Donald L. Haruett& James L. Mwrphy*, Introductory Statistics Analysis*, Addison-Wesley Publishing Compnay.
2. Goon, A. M., Gupta, M. K. and Dasgupta, B., *An Outline of Statistical Theory*, Vol. 1, The World Press Private Limited, Calcutta, 1985.

HS 501	**ADVANCED RESEARCH METHODOLOGY**	**4 credits [3-1-0]**

Objective: These papers will expose students to quantitative methods in social science research. Use of statistical methods and basic econometrics can help them in data analysis.
Contents: Multivariate Significance Tests;The Normal Probability Curve**:** Properties and Applications, Logic of Hypothesis Testing, Type I and Type II Errors, Power of Statistical Tests, Linear Correlation and Regression, Factors Influencing Correlation Coefficients,Multiple Correlation and Regression; Computer Applications, Content Analysis, Special Analysis, Factor Analysis, stakeholder analysis and social audit.

Essential Reading:

1. Cramer, Duncan, *Advanced quantitative data analysis. Maidenhead*: Open University Press, 2003.
2. Creswell, John W. *Research design: qualitative, quantitative, and mixed methods approach*. 3rd ed. Thousand Oaks: Sage, 2009.
3. Neuman, William Lawrence. *Basics of Social Research: qualitative and quantitative approaches*. 2nd ed. Boston: Pearson/Allyn and Bacon, 2007.

Supplementary Reading:

1. Dane, Francis C. *Research methods*. Pacific Grove: Brooks/Cole, 1990.
2. Devlin, Ann Sloan. *Research methods: Planning, Conducting and Presenting Research*. Belmont, Calif.: Thomson /Wadsworth, 2006.

HS 511	**TECHNICAL AND BUSINESS COMMUNICATION**	**4 credits (3-1-0)**

Objective: The course aims at exposing students to various aspects of organisational communication. ; **Contents:** Communication: Aspects and Issues, Verbal and Non-verbal Communication, Creativity in Communication, the Johari Window. Interpersonal and Impersonal Communication, Communication in Professional contexts, Formal & Informal Communication in Organisations; Essentials of Grammar, Tricky Grammatical Choices; Effective Pronunciation, Loan Words, Foreign Words, Word-Formation, Vocabulary Building Exercises. Varieties of English; Speech Styles, the Job Process, Focus of Job Interviews; Report Writing, Guidelines for Preparing a Good CV, Drafting a Job Application Letter, Comprehension Skill Testing, Paragraph Writing.

Essential Reading:

1. Ivor Williams, *English for Science and Engineering*, Cengage Learning, First Indian Reprint 2007.

2. S. Stevenson and S. Whitmore,*Strategies for Engineering Communication*, John Wiley & Sons (Asia) Pvt. Ltd. 2002

Supplementary Reading:

1. S. Clark and G. Pointon, *Word for Word*, OUP, 2004
2. M. Nurnberg and M. Rosenblum, *All About Words: An Adult Approach to Vocabulary Building*, W.R. Goyal Publishers & Distributors, New Delhi,2000
3. Straus, Jane, *The Blue Book of Grammar and Punctuation*. (Available online at http://www.grammarbook.com)
4. *Guide to Grammar and Writing,* Web Pages available at http://grammar.ccc.commnet.edu/grammar/ and "The Online Writing Lab at Purdue" (OWL) WebPages available at http://owl.english.purdue.edu/

HS 512 LITERARY FOUNDATIONS: METHODS AND GENRES 4 credits [3-1-0]

Objective: The course aims to sensitize students to the richness and beauty of English literature and to foster a deeper understanding of people's way of life as reflected through literature. Students will be exposed to a variety of periods and genres that will develop their critical thinking processes, the ability to analyse and reason carefully, the ability to organise and present materials coherently both in written and oral forms, and the ability to understand and manage other people-all practical skills that allow scope for improved professional communication. ; **Contents:** The four principal genres to be discussed are drama, fiction, verse novel and short stories.W. Shakespeare: *Macbeth;* H. Lee: *To Kill a Mocking bird;* Vikram Seth*: The Golden Gate;* Jhumpa Lahiri: *Interpreter of Maladies.*

Essential Reading:

1. W. Shakespeare, *Macbeth.*John Wiley & Sons; The Manga edition, 2008
2. H. Lee, *To Kill a Mockingbird*. Warner Books; 1st edition, 1988.
3. Vikram Seth, *The Golden Gate*. New Delhi: Penguin Books India (Pvt.) Ltd, 1986
4. Jhumpa Lahiri, *Interpreter of Maladies*. Delhi: Harper Collins India, 2000

Supplementary Reading:

1. J. L. Badaracco**,** *Questions of Character: Illuminating the Heart of Leadership through Literature,*Harvard Business School Press, 2006
2. A.Simmons**,** *The Story Factor: Inspiration, Influence, and Persuasion through the Art of Storytelling***,** Basic Books: US.2002
3. R. Lebow and R. Spitzer, *Accountability: Freedom and Responsibility without Control ,* Berrett-Koehler Publishers Inc. 2002
4. *William Shakespeare's 'Macbeth' (Modern Critical Interpretations*) (Hardcover). Harold Bloom (editor), 1987

HS 513 POST-COLONIAL CONSCIOUSNESS AND DEVELOPMENT 4 credits [3-1-0]

Objective: The course will offer students an understanding of the contemporary multicultural world that needs to have reconciliation between indigenous settlers and the migrants. Students will understand questions of racial and ethnic prejudices and will locate their role as individuals/institutions towards a collective goal of nation building. ; **Contents:** Navigation and Cultural/Racial Encounters; Impact of Colonization and Colonial Consciousness; Western mode of Education, National Consciousness, Freedom Struggle and Independence; Postcolonial Development and Nation Building; Writing back.

Essential Reading:

1. Ashcroft, William D., Gareth Griffith, and Helen Tiffin, eds. *The Post-Colonial Studies Reader*. London: Routledge, 1995.
2. Barthes, Roland. *Empire of Signs*. London: Jonathan Cape, 1970.
3. Fanon, Frantz. *Black Skin, White Masks*. New York: Grove P, 1967
4. Fanon, Frantz. *Studies in Dying Colonialism*. New York: Grove P, 1965.
5. Memmi, Albert. *The Colonizer and the Colonized*. New York: Orion Books, 1965.
6. Said, Edward. *Orientalism*. New York: Pantheon Books, 1978.

Supplementary Reading:

1. Barker, Francis, Peter Hulme, and Margaret Iversen, eds. *Europe and Its Others*. U of Essex P, 1985.
2. Barlow, Tani, ed. *Colonial Modernity*. Durham, NC: Duke UP, 1993.
3. Blunt, Allison, and Gillian Rose, eds. *Writing Women and Space: Colonial and Postcolonial Geographies*. New York: Guilford P, 1994.
4. Butler, Judith. Gender Trouble: *Feminism and the Subversion of Identity*. London: Routledge, 1990.
5. Fanon, Frantz. *The Wretched of the Earth*. New York: Grove P, 1961.
6. Ferro, Marc. *Colonization: A Global History*. London: Routledge, 1997.

HS 514	MAPPING THE OTHER: THEORIES FOR ALTERITY	4 credits [3-1-0]

Objective: The course will introduce students to critical/theoretical writings that concern the idea of the Self, the other and the Society and the way multiple identity categories are framed and categorised in a world where questions of 'legitimacy' are of concern. ; **Contents:** Multiculturalism, Postmodernism and the Debate of Plurality; Concept of Alterity and Identity, Centre and Periphery, Debate of Alternative Identities.

Essential Reading:

1. Nealon, Jeffrey. *Alterity Politics: Ethics and Performative Subjectivity*. Duke University Press: Durham, 1998.
2. Foucault, Michel. *The Order of Things*. London: Tavistock, 1970.
3. Corbey, Raymond & Joep Leerssen. *Alterity, Identity, Image: Selves and Others in Society and Scholarship*. Amsterdam & Atlanta: Rodopi, 1991.

Supplementary Reading:

1. Geertz, Clifford. *Interpretation of Cultures*. Basic Books: New York. 1973.
2. Agamben, Giorgio, Daniel Heller-Roazen (Translation). *Homo Sacer: Sovereign Power and Bare Life*. Stanford University Press. Stanford, June 1998.
3. Guha, Ranajit. *Dominance without Hegemony: History and Power in Colonial India*. Harvard: HUP. 1997.

HS 515	HISTORY OF IDEAS: THE MODERN PERIOD	3 Credits [3-1-0]

This introductory course will survey the most important intellectual themes of the modern period. The focus of the course will be on different concepts from Psychoanalysis, Marxism, Existentialism, Postcolonialism and Poststructuralism. From Freud's 'oedipal complex' to Nietzsche's 'death of God', there will be discussions on concepts such as 'modernism', 'empire', 'imperialism', 'nation' and 'development' as expressed in some of the major cultural texts of the modern period. Comparative elements from the Indian subcontinent will be brought in to our weekly discussions.

Objectives:

1. The course will introduce students to a few primary texts on the key socio-cultural concepts of the modern period.
2. Students will have a theoretical understanding of binary distinctions and concepts such as Orient and Occident, representation and appropriation, etc.
3. Students will be able to understand social conditionings from the perspective of theoretical development of the modern period.

Course Description and Content:

It is a professional course in Development Studies Programme and special emphasis will be given to development of multiple thoughts, viz., gender and feminist thought, development of ethnic consciousness and identity, encounter with the other, subalternity, significance of existential subjectivism versus scientific objectivism, and queer centralism. The major theoretical portions for discussion are categorised under the following broad periods: World War I: (Impact on faith and progress; special focus on Sigmund Freud) ; Inter-War Era: (Communist and Fascist ideas; Utopian ideals; special focus on Marx) ; Post-World War II Syndrome (Existentialism; special focus on Nietzsche)

Essential Reading:

1. Beauvoir, Simone de. “Introduction: Woman as Other” in *The Second Sex* (1989).
2. Foucault, Michel. “We Other Victorians” in *The History of Sexuality* (1990).
3. Freud, Sigmund. ‘Selections’ from *Totem and Taboo* (1913) and *Civilization and Its Discontents* (1930).
4. Jacques Derrida, “Difference” from *Margins of Philosophy* (1972).
5. Marx, Karl. ‘Selection’ on India and from *The Portable Karl Marx*. Ed. by E. Kamenka (1983).
6. Nietzsche, Friedrich. “An Attempt at Self-Criticism” from *The Birth of Tragedy* (1886).
7. Said. Edward W. “Introduction.” *Orientalism* (1977).
8. Sartre, Jean Paul. *‘Selections’ from Being and Nothingness* (1943).
9. Spivak, Gayatri Chakravorty. “Can the Subaltern Speak?” in *Marxism and the Interpretation of Culture*. Eds. Cary Nelson and Lawrence Grossberg (1988).

Supplementary Reading:

1. Guha**,** Ranajit**.** ***“****On Some Aspects of the Historiography of Colonial India****”*** *in Subaltern Studies I***.** 1999**.**
2. Millet**,** Kate**.** *Sexual Politics* **(**1968**).**
3. Pollock**,** Sheldon**. “**Is There an Indian Intellectual History? Introduction to **‘**Theory and Method in Indian Intellectual History**”** in *Journal of Indian Philosophy***.** Volume 36**,** Numbers 5**-**6**,** 533**-**542.
4. Stromberg**,** Roland N**.** *European Intellectual History since 1789***,** 6th Edition**,** 1994**.**

HS 522	**SOCIAL PSYCHOLOGY AND ITS APPLICATIONS**	**4 credits (3-1-0)**

Objective: The course aims at making students aware of social issues ranging from individual to group and organizational concerns. ; **Contents:** Social Issues in Aggression, Mass Communication, Consumer Behaviour, Diversity, Environment, Health Care, Legal Issues; Activism for Social Change; Influencing Public Policy.

Essential Reading:

1. S. Oskamp and P. W. Schultz: *Applied social psychology*, 2nd ed, Upper Saddle River, NJ: Prentice Hall, 1998.

Supplementary Reading:

1. L.Brahnan and J.Feist: *Health Psychology: An Introduction to Behavior and Health*, 5th edition, Wadsworth Thomson 2004
2. R. Baron and D. Byrne *: Social Psychology,* 10th Ed, Pearson Education, 2004
3. F.M. Moghaddam: *Social Psychology: Exploring Universals Across Cultures*, New York, W.H. Freeman and Company, 1998

HS 523	**EDUCATIONAL PSYCHOLOGY**	**4 credits [3-1-0]**

Objective: The course aims to appraise students about the teaching and learning process to reflect upon the mental abilities and related issues involved in educational settings. ; **Contents:** Learner Differences and Learning Needs; Modifying Students’ Behaviour; Principles of Behaviourism, Measuring Cognitive Ability; Motivation in Teaching and Learning; Teaching-Learning process; Standardised Testing , Assessment and Evaluation of Performance.

Essential Reading:

1. A. Woolfolk: *Educational Psychology*. 9th edition, Pearson Education, 2004

Supplementary Reading:
1. N.L. Gage and D.C. Berliner: *Educational Psychology* (6th Eds.), New York: Haughton Mifflin, 1998
2. Ormrod, *J.E: Educational Psychology*. N.J.: Prentice-Hall, 1998
3. G.R Lefrancois: *Psychology for Teaching*, USA: Wadsworth, 1999

HS 524	COGNITIVE DEVELOPMENT AND ASSESSMENT	4 credits [3-1-0]

Objective: Cognitive Development and Assessment aims at providing a primary level understanding of various developmental milestones achieved by the child, the methods to assess them, typical and atypical developments, delays in development and its implications for psychological development along with possible intervention and prevention strategies to deal with such issues. **Content:** Concept and Theories of Development, Infant Perceptual Development (Visual and Auditory), Understanding Objects and Space, Understanding Number, Categorical Development, Memory Development, Causal Knowledge, Theory of Mind (Perception, Intentionality, Thinking, Belief and Pretending), Assessment of IQ and other developmental milestones.

Essential Reading:
1. Flavell, J.H., Patricia, H. M. & Miller, S.A. (2001). *Cognitive Development* (4th Edn.). Prentice Hall.
2. Mcclelland, J.L., Siegler, R.S. (2001). Mechanisms of Cognitive Development: Behavioral and Neural Perspectives. Lawrence Erlbaum Associates

Suggested Reading:
1. Singer, D.G., Revenson, T. (1996). *A Piaget Primer: How A Child Thinks* (Revised Edition). Plume Books.

HS 525	PSYCHOMETRICS	4 credits [3-1-0]

Objective: The course aims at orientating students on designing and developing psychological tests, understanding psychological theories behind test construction and standardization. **Content:** the concept, theories, measurement and interpretation of psychological attributes like intelligence, personality, attitude etc., reliability and validity, steps in test construction and standardization.

Essential Reading:
1. Anastasi A. & Urbina S. (2009). *Psychological Testing* (7th Ed.). Phi Learning.
2. Murphy, K.R., & Davidshofer, C.O. (2004).Psychological Testing: Principles and Applications (6th Ed.). Prentice Hall.

Suggested Reading:
1. Bacharach, V.R., Furr, R. M., Furr, M. (2007). *Psychometrics: An Introduction*. Sage Publication.

HS 526	CLINICAL PARADIGMS, PSYCHOLOGICAL DISORDERS AND THERAPEUTIC INTERVENTIONS	4 credits [3-1-0]

Objective: To provide students the preliminary ideas regarding psychological disorders and maladaptive behaviour as well as basic approaches to deal with them. ; **Contents:** Current Paradigms in Psychopathology and Therapy; Stress Coping and Maladaptive Behaviour; Anxiety, Personality and Mood Disorders; Juvenile Delinquency; Therapeutic Interventions and Outcomes**;** Rehabilitation Issues and Community Participation.

Essential Reading:
1. Geoffrey Kramer, Douglas Bernstein and Vicky Phares : *Introduction to Clinical Psychology*, 7th Edition, Pearson Education, 2009

Supplementary Reading:

1. J.O.P., Diaz, R.S., Murthy, and R. Lakshminarayana: *Disaster Mental Health in India*. Indian Red Cross Society: New Delhi, 2004
2. G.C. Davison and J.M Neale: *Abnormal Psychology*. New York: John Wiley & Sons. 2001
3. Sarason, I.G and B.R. Sarason : *Abnormal Psychology*, New Delhi: Pearson Education, 2002

HS 527	CORPORATE SOCIAL RESPONSIBILITY	4 credits (3-1-0)

Objective: The course will cover the key characteristics of Corporate Social Responsibility (CSR) in the context of present-day management. The course aims to apprise students regarding business decision-making which is informed by ethical values and respect for people communities and the environment. The course also aims to make students aware of creating a strategic plan that enables an organization to reach out to its internal and external stakeholders with consistent messages. ; **Content:** Responsible business: a myriad of terms and concepts; How does CSR fit into the overall corporate strategy and why has CSR become so important; Drivers and constraints of corporate responsibility; The emerging sustainable value creation concept; The stakeholder corporation vs. the shareholder corporation; The natural environment of the business: employees. customers, investors, communities, business partners, governments, etc. Ethical programmes as instruments to gain a competitive advantage as well as make a positive contribution to the well-being of society; Corporate Responsibility indicators, standards and reporting (SA 8000, AA 1000, GRI, Global Compact, ISO 26000 etc); How to draw up your CSR report: case study; Critical issues in corporate responsibility in India; Public Policy on CSR in India.

Essential Reading:

1. William B. Werther Jr. and David Chandler, *Strategic Corporate Social Responsibility: Stakeholders in a Global Environment,* Second Edition, Sage Publications, 2011
2. Sanjay K Agarwal, *Corporate Social Responsibility in India,* Sage Publications, 2008

Supplementary Reading:

1. Mark S. Schwartz, *Corporate Social Responsibility: An Ethical Approach,* Broadview Press, 2011
2. Paul Hohnen and Jason Potts, *Corporate Social Responsibility: An Implementation Guide for Business*, The International Institute for Sustainable Development, ISBN 978-1-895536-97-3, 2007
3. George Pohle and Jeff Hittner, *Attaining Sustainable Growth through Corporate Social Responsibility*, IBA Global Business Services, 2008

HS 531	SOCIAL INSTITUTIONS AND DEVELOPMENT	4 credits (3-1-0)

Objective: The course aims at introducing the nature of rural and social Institutions of Indian Society to the students. ; **Contents:** Institutions and Social Development: Culture, Community, Organisation and Society, Caste, Class and Power; Kinship and Descent; Family, Marriage, Religion and its Changing Perspectives; Agrarian Social Structure and Jajmani Relation; Technology and Rural Institutions.

Essential Reading:

1. Milton Singer& Bernard S. Cohn, *Structure and Change in Indian Society*, Rawat, Jaipur, 1996
2. D.N.Majumdar & T.N.Madan, *An Introduction to Social Anthropology*, Mayoor Paperbacks, 1994
3. Harry M. Johnson, *Sociology: A Systematic Introduction*, Allied Publishers Private Limited, New Delhi, 1986

Supplementary Reading:

1. Harry M. Johnson, *Sociology: A Systematic Introduction*, Allied Publishers Private Limited, New Delhi, 1986
2. David G. Mandelbaum, *Society in India*, Popular Prakashan, Bombay, 1984

3. J.L.Kachroo & Vijaya Kachroo, *Society in India*, Bookhive Publication, New Delhi, 1957

HS 532	PLANNING AND POLICY ISSUES IN INDIA	4 credits [3-1-0]

Objective: This course aims at providing the theoretical background related to the various economic aspects of the study of technique of economic planning. ; **Contents:** Need for and Role of Planning and Futures of Planning in Capitalist, Socialist and mixed economies. Types of Planning, Basic Components of plan model, Decentralized and Centralized Planning; Requisites for and Strategic for planning; Balanced and Unbalanced growth; Key Sectors, Choice of Technique; Resource mobilization, Sectoral allocation of resources; Technique of Planning Models; Consistency Conditions and optimization; Static and Dynamic inter-industry models; Linear programming and econometric methods; Shadow prices and macro and micro planning level; Indian Planning Exercises.

Essential Reading:
1. Lange, Oskar, *Essays on Economic Planning*, Bombay, Asia Publishing House
2. Lewis, W, Arthur, *Development Planning*, New York, Harper and Row Publishers
3. Agrawal, A.N and KundanLal, “*Economic Planning*”, Vikash Publishing House, New Delhi

Supplementary Reading:
1. Tadaro and Smith, *Economic Development*, Prentice Hall
2. Uma Kapila, *Indian Economy Since Independence*, ISBN: 81-7188-326-5
3. Myrdal, Gunnar, *Asian Drama:an inquiry into the Poverty of Nations*, New York: Twentieth Century Fund
4. Sen, A.K, *Choice of Technique*, Blackwell

HS 533	DEVELOPMENT: SOCIAL, ANTHROPOLOGICAL AND PSYCHOLOGICAL PERSPECTIVES	4 credits [3-1-0]

Objective: Developmental issues are closely tied to socio-economic and anthropological context. Motivational, attitudinal and behavioural aspects are also involved. The paper aims to provide interdisciplinary and comprehensive view of the concept of development. ; **Contents:** Defining Development; Role of Anthropology in Development Planning and Social Change; Diffusion of Innovations; Process of Innovation; Role of Advocates and Advocate assets; Novelty characteristics; Acceptors and Rejecters of innovations; Culture content of social change; Socio-cultural and Psychological Barriers to Change; Psychological approaches to Cultural Studies: Culture and Personality: Benedict and Mead; Basic Personality and the Concept of Institutions: Kardiner; Modal Personality: Cora Du Bois; Development of Morality and Gender Roles, Social Perception, Prejudice and Attribution errors.

Essential Reading:
1. C.K., Sigelman, and E.A. Rider*: Life-Span Human Development*, Thomson and Wardsworth Publishers, 4th Ed, 2003
2. Ram Ahuja, *Social Problems in India*, Rawat, Jaipur, 1992.
3. Satish Kedia & John Van Willigen, *Applied Anthropology: Domains of Application*, PRAEGER Publisher, Westport, Connecticut, London, 2005.
4. S C Dube, *Understanding Change: Anthropological and Sociological Perspectives*, Vikas Publishing House Pvt. Ltd, New Delhi, 1993.

Supplementary Reading:
1. T.S. Saraswathi and Baljit Kaur : *Human Development and Family Studies in India: an Agenda for Research and Policy*, Sage Publications,1993
2. Mahendra Dev, *Inclusive Growth in India: Agriculture, Poverty, and Human development*, Oxford, New Delhi, 2008.

HS 534	NATURAL RESOURCE MANAGEMENT AND SUSTAINABLE DEVELOPMENT	4 credits [3-1-0]

Objective: The aim of the course is to highlight the importance of measures towards sustainable development in the wake of depletion of natural resources and environmental concerns. ; **Contents:** Concepts on NRM, CPR, Livelihood, Culture and Sustainable Development; Cultural ecology and Ethno-ecology; Theoretical and Methodological Approaches in NRM; Climate Change, Natural Calamity and Social Adaptation; Indigenous Knowledge and Natural Resource Management; Depletion of Natural Resources and Livelihood; Policy and Natural Resource Management: Water, Forest and Land; Gender and Livelihood.

Essential Reading:

1. Kartar Singh, *Managing Common Pool Resources: Principles and Case Studies*, Oxford, New Delhi, 1994.
2. G.P. Mishra &B.K. Bajpai, *Community Participation in Natural Resource Management*, Rawat publication, Jaipur, 2001.
3. G. Palanithurai, M.A. Thirunavukkarasu & G. Uma, *Planning at Grassroots*: *Government's Participation in People's Plan*, Concept, New Delhi, 2008.
4. Sumi Krishna, *Livelihood and Gender*, Sage, New Delhi, 2004.

Supplementary Reading:

1. Ram Prasad Panda, *Eco-conservation and Tribal development*, Sonali Publication, New Delhi, 2005.
2. S.K Agarwal & P.S. Dubey*, Environmental Controversies*, APH Publishing Corporation, New Delhi, 2002.

HS 535	GENDER AND DEVELOPMENT	4 credits [3-1-0]

Objective: This course aims at providing students an insight to various dimensions of globalization, gender and development and linkages between them. ; **Contents:** Conceptual clarity on Globalization, Gender and Development; Linkage between Globalization, Gender and Development. Structural impact of Globalization, Gendered impact of Globalization; Globalization and its Consequences on Women; Feminization of poverty, Feminization of Labour, Feminization of Violence; Incorporation of Gender into Development Analysis and Practice; Indicators of Gender Inequality and the Status of Women; Gender and Development Policy and Practice.

Essential Reading:

1. Agnihotri, S.B.: *Sex ratio in Indian Population: A Fresh Exploration*.
2. Boserup E.*: Women's Role in Economic Development.*
3. Desai, N. and M.K. Raj. (Eds.): *Women and Society in India*.

Supplementary Reading:

1. *Government of India: Towards Equality —– Report of the Committee on the Status of Women in India*, Department of Social Welfare, Ministry of Education and Social Welfare, New Delhi.
2. ILO: *Women's Participation in the Economic Activity of Asian Countries.*

HS 536	TRENDS AND ISSUES IN TRIBAL STUDIES	4 credits [3-1-0]

Objective: The course aims at enhancing the awareness of students regarding important trends and issues in Tribal Studies. ; **Contents:** Definition of Tribe, Cultural Continuity between Tribal and Non-tribal Populations in India; Scheduled Tribes in India: Distribution, Classification: Racial and Linguistic; Social, Political and Economic Organisations and Tribal way of Life. Tribal problems in India: Land Alienation and Indebtedness, Education, Health, Forest Degradation, Cultivation, Impact of liberalization, Industrialization and Urbanization, Displacement and Rehabilitation; Tribal Administration and Constitutional Safe-guards for tribes in India; Tribes and Problems of National Integration; Tribal Movements in Post-Independent India.

Essential Reading:

1. L.P. Vidyarthi & B.K. Rai, *The Tribal Culture of India*, Concept, New Delhi, 1985.
2. R.C. Verma, *Indian Tribes through Ages, Ministry of Information and Broad Casting*, Govt. of India, New Delhi, 1995.
3. Nadeem Hasnain, *Tribal India*, Palaka Prakashan, Delhi, 1992.

Supplementary Reading:

1. Apoorva Pandit& Ms. Sunanda Bhagwat, *Tribal Culture and Technology*, Inter India Publication, New Delhi, 2006.
2. Devendra Thakur & D.N. Thakur, *Tribal Development and Planning*, Deep & Deep Publication, New Delhi, 1997.
3. Pariyaram M. Chacko & K.S. Singh, *Tribal Community and Social Change*, Sage, New Delhi, 2005.

HS 537	DEVELOPMENT ISSUES IN ORISSA	4 Credits (3-1-0)

Objective: This course will provide a clear picture about the various issues in Orissa such are development policies, its economy, culture, health status, natural resources. It will help students to have a better understanding about the development scenario of a state and its vision in development. **Content:** State of Maternal and Child Health in Orissa, Trends in infant and Child Mortality, Causes of Infant and Child Mortality, Causes of Malaria, Demand and Access factor for Health Care Services, Health Infrastructure, Health expenditure, regional inequality in maternal and child health in Orissa, Interrelationship between socio-economic inequality and health status, Programmatic improvement achieved under the umbrella cover of NRHM, ICDS, and various state and national health programs. A Macro Economy Glance of Orissa's Economy including Income, Employment, Consumption expenditure and cost of living**,** Agriculture and Allied Sectors-the industrial sector, service sector, Infrastructure, poverty, social sector and public finance, Federal Finance-centre and state relationship, Culture and festivals, Displacement issues, Government policies on natural resource management, disaster mitigation, mining, forest and water resources.

Essential Readings:

1. Mishra, P.K. (ed). 1997. *Comprehensive History and Culture of Orissa*, Vol.2, Part 2, New Delhi: Kaveri Books.
2. Das, K. 1991. *Folklore of Orissa*, Bhubaneswar: Orissa Sahitya Academy.
3. Das, K and L. K. Mahapatra. 1993. *Folklore of Orissa*, New Delhi: National Book Trust of India.
4. Directorate of Economics and Statistics, Government of Orissa. 2005–06 to 2008–09. Economic Survey. Planning and Coordination Department, Government of Orissa.
5. Finance Department, Government of Orissa. 1996–2008. Demand for Grants of Health and Family Welfare Housing and Urban Development, Rural Development, Labour and Employment and Women and Child Development Departments. Government of Orissa.
6. Health and Family Welfare Department. 2002. Orissa State Integrated Health Policy-2002, Government of Orissa.

Supplementary Readings:

1. International Institute for Population Sciences (IIPS). 2007–08. DLHS 3, Orissa. Mumbai: IIPS.
2. International Institute for Population Sciences (IIPS) and Macro International. 2008. National Family Health Survey (NFHS-3), India, 2005–06: Orissa. Mumbai: IIPS.
3. Patnaik, D. 1982. *Festivals of Orissa*, Bhubaneswar: Orissa Sahitya Academy.

HS 538	URBAN GOVERNANCE AND DEVELOPMENT	4 Credit (3-1-0)

Objectives: The course has both academic and practical objectives. As the principal academic objective, students should gain an understanding of how cities, suburbs, and their metropolitan areas function and are governed. As the principal practical objective, students should gain a sense of how the problems of urban areas might be better addressed by both elected policy makers and appointive public administrators. At the end of the semester, students should be better prepared to assist in solving such problems themselves. **Contents:** Urban demography, Rural urban continuum, Urban local governance, Urban planning, Poverty, Problems with slum areas, Urbanisation and its impact; origin patterns, structure, functions - Urban local institutions; constitutional framework, Urban laws - decentralization and autonomy – Wards Committee.

Essential Readings:

1. Basu, D.D, 1985, *Introduction to the Constitution of India*, New Delhi, Prentice Hall of India
2. Singh. I.B, 1997, *Administrative System in India*, IPH, New Delhi
3. Barthwal. C.P, 2002, *Understanding Local Government*, Bharat Book, Lucknow.
4. Arora. R.K, 1999, *District Administration*, Aalekh Pub., Jaipur.
5. Hoshiar Singh, 1997, *Local Government*, Kitab Mahal, Allahabad

Supplementary Readings:

1. Harrigan, John J., and Ronald K. Vogel. *Political Change in the Metropolis*, 6th ed. Addison-Wesley Longman, 2000, paper.
2. Bissinger, Buzz. *A Prayer for the City*. Vintage Books, 1997, paper.

HS 541	ECONOMICS OF DEVELOPMENT	4 credits (3-1-0)

Objective: This course will introduce students to the field of development economics by providing an in-depth knowledge of economic growth and development with primary focus on the growth model and its applicability in India. ; **Contents:** Economics of Development: Concepts and Approaches; Growth Model; Development Theories; Domestic and International Measures for Economic Development; Role of State in Economic Development; Population Growth and Economic Development; Poverty and Unemployment.

Essential Reading:

1. Taneja Mayer, *Economic Growth and Development*, Indian Publisher.
2. Benjamin Higgins, *Economic Development: Problems, Principles and Policies*, UBS Publishers
3. Debraj Ray, *Development Economics*, Oxford India Paperbacks

Supplementary Reading:

1. Brown, M.: *On the Theory and Measurement of Technical Change*.
2. Chenery, H.B. et. al. (Eds.): *Redistribution with Growth*.
3. C.P. Kindleberger, *Economic Development*, W.W. Norton & Co.; Second Edition edition
4. Maurice Dobb, *Some Aspect of Economic Development*

HS 542	MEASUREMENT OF POVERTY, INEQUALITY AND HUMAN DEVELOPMENT	4 credits [3-1-0]

Objective: This course aims at equipping students with the technical and substantive dimensions of various measures of poverty, inequality and human development.
Contents: Conceptual dimensions of poverty; deprivation and human development; absolute and relative poverty measures; notions of chronic poverty and socio-economic vulnerability with particular emphasis given to the role of health functioning and capability deprivation; Economic inequalities in India; Measurement of Human Development Index (HDI), Gender-related Development Index (GDI), Gender Empowerment Measure (GEM), Human Poverty Index (HPI)

Essential Reading:

1. Alkire, S. (2002) *'Dimensions of human development'*, World Development, vol 30, no 2, pp181–205
2. Anand, S. and Sen, A. (1997) *'Concepts of human development and poverty: A multidimensional perspective'*, Human Development Papers, UNDP, New York

Supplementary Reading:

1. Atkinson, A. B. and Bourguignon, F. (2001) *'Poverty and inclusion from a world perspective'*, in
2. J. Stiglitz and P.-A. Muet (eds) *Governance, Equity and Global Markets*, Oxford University Press, Oxford
3. Foster, J. E. (2006) *'Inequality Measurement'*, in D. Clark (ed.)
4. Edward Elgar, *The Elgar Companion to Development Studies*, Cheltenham

HS 543	**GLOBAL ISSUES IN DEVELOPMENT**	**4 Credit [3-1-0]**

Objective: This course will provide an introduction to the global issues in development confronting by both developed and developing countries. Core approach would be interdisciplinary and thematic, with special attention to cultural, economic, political, and social conflicts and patterns and their effect on development and inequality. **Contents:** Major political, economic, social, and environmental issues confronting the global community, Evaluation of demographic, economic, and ethno-national dimensions of development, interdisciplinary major with a focus on social justice, sustainable economic development, public health, global interconnection, and public service, Millennium Development Goals, Climate change and adaption policies, Demographic transition and Health policies.

Essential Readings:

1. Stiglitz, Joseph E. 2003. *Globalization and Its Discontents*. New York: Norton
2. Sachs, Jeffrey D. 2005. *The End of Poverty: Economic Possibilities of Our Time*. New York: Penguin Press
3. World Bank. 2003. *World Development Report 2003: Sustainable Development in a Dynamic World*. New York: Oxford University Press
4. World Bank and International Monetary Fund. 2003. *Global Monitoring Report 2003*. Washington, DC
5. Bhalla, Surjit. 2002. *Imagine There's No Country: Poverty, Inequality, and Growth in the Era of Globalization*. Washington, DC: Institute for International Economics.
6. Milanovic, Branko.2006. Global Inequality: What It Is and Why It Matters. Washington, DC: World Bank.

Supplementary Readings:

1. Collier, Paul, and Jan Dehn. 2001. Aid, Shocks, and Growth. Policy Research Paper 2688, World Bank, Washington, DC.
2. Rajan, Raghuram, and Arvind Subramanian. 2005. What Undermines Aid's Impact on Growth? Working Paper WP/05/126, International Monetary Fund, Washington, DC.
3. Meyer, Aubrey. 2000. Contraction and Convergence: The Global Solution to Climate Change. Totnes. United Kingdom: Green Books

HS 544	**ENVIRONMENT AND DEVELOPMENT**	**4 Credit [3-1-0]**

Objective: The course will thus teach methodological knowledge besides substantive knowledge about issues related to innovation and governance pertaining to sustainable environmental management and development. The course will also acquaint student with institutional theory and governance – how the plurality of interests is transformed into coordinated action and the compliance of actors is achieved. **Content:** Human Environment Interaction and Cultural Ecology: Human ecology, culture and ecosystem. Environmental degradation and poverty: Causes of resource degradation, Sustainable development. Climate Change and Human Adaptation, Environmental management and innovation strategies, Development: Environment and Sustainable Livelihood. Institutional theories in Environmental Management: Governance for sustainable development. Policy responses to environmental degradation: Displacement, Social movements, Industrialization, Ecotourism and Biodiversity Management.

Essential Readings:

1. Elinor Ostrom, 1997, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, New York.
2. Jhon Barry, 2000, *Environment and Social Theory*, Routledge, London.
3. Fikret Berkes, *Sacred Ecology* (second edition), 2008, Routledge, New York.
4. S.K Agarwal & P.S. Dubey, 2002, *Environmental Controversies*, APH Publishing Corporation, New Delhi.

Supplementary Readings:

1. Dr. I Sundar,2006, *Environment and Sustainable Development*, APH Publishing Corporation, New Delhi
2. Kartar Singh, 1994, *Managing Common Pool Resources: Principles and Case Studies*, Oxford, New Delhi

HS 545	INDIAN FINANCIAL SYSTEM	4 credits [3-1-0]

Objective: The basic objective of the course is to provide comprehensive introduction to the functioning of financial market in the emerging context of deregulation and globalization of markets. ; **Contents:** Introduction of financial System; Financial system and economy; Reforms in the financial system, Role of Indian financial system; Financial Markets and Instruments; The place of Financial markets in the Economy; Real assets and Financial assets, Money market, Capital market, Primary market, Secondary market, Government Securities market, Foreign exchange market, Debt market, and Derivative market.; Development of Financial Institution and Instrument.

Essential Readings:

1. Bhole, L.M. (2009), *"Financial Institutions and Markets: Structure, Growth and Innovation"*, Tata McGraw Hill Publishing Company Limited, New Delhi.
2. Pathak Bharati. V. (2006), *"India Financial System",* Pearson Education in South Asia Publishing Company, New Delhi.

Suggested Readings:

1. Avadhani, V.A (2000), *"Financial Economics: Theory and Practice"*, Himalaya Publishing House, Mumbai.
2. Chandra, P. (2005), *"Financial Management: Theory and Practice"*, Tata McGraw Hill Publishing Company Limited, New Delhi
3. Houthakar, H.S. and Williamson, P.J. (2000), *"The Economics of Financial Markets"*, Oxford University Press.
4. Hung, C. and Litzenberger (1998), *"Foundation of Financial Economics"*, North Holland.
5. Johnson, H.J. (1993), *"Financial Institutions and Markets"*, Tata McGraw Hill Publishing Company Limited, New York

HS 546	POPULATION DYNAMICS AND DEVELOPMENT	4 credits [3-1-0]

Objective: This course will help students to critically examine different analytical approaches of population studies and to explore interrelationships between population changes and socio-economic development ; **Contents:** Introduction to Population Studies, Sources of population data, Evaluation of quality of Demographic data; Differentials in age and sex composition; Measures of fertility, Mortality and Migration, Variations in rates and pattern of Fertility, Mortality, and Population growth, Level and trend of Urbanization, Economic interrelationship between Fertility, Mortality and Development; Socio-economic Implications of Population Ageing.

Essential Reading:

1. Agarwala S.N.: *India's Population Problem.*
2. Bose, A.: *India's Basic Demographic Statistics.*

Supplementary Reading:

1. Bogue, D.J.: *Principles of Demography.*
2. Bhende, Asha and Kanitkar T., (1993) *Principles of Population Studies*, Himalaya Publishing House, Bombay.

HS 548	DEMOGRAPHIC TRANSITION AND HEALTH POLICIES IN DEVELOPING WORLD	4 credits [3-1-0]

Objective: The aim of this course is to familiarise students with the main issues in health, population and society in developing and transitional societies. ; **Contents:** Overview of the world's current demographic situation at both global and regional level; Stages of demographic transition; Demographic transition theories and their relationships to theories of socio-economic development; Major threats to health, Mortality and burden of disease; Poverty and inequalities in health; Health consequences of HIV/AIDS epidemic in developing world; Child and maternal mortality; Health issues among ageing population; Achieving good health at low cost in developing countries; Health policies to reduce mortality and diseases.

Essential Reading:

1. Alan C. Swedlund, George J. Armelagos. 1990. *Disease in Populations in Transition: Anthropological and Epidemiological Perspectives*, Bergin & Garvey
2. David E. Bloom, David Canning, Jaypee Sevilla.2003. *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*, Rand

Supplementary Reading:

1. Nancy Birds all, Allen C. Kelley, Steven Sinding. 2001. *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World*, Oxford University Press, 2001
2. Richard Leete. 1999. *Dynamics of Values in Fertility Change*, Oxford University.

HS 570	ADVANCED LANGUAGE LABORATORY	4 credits [0-0-6]

Objective: The Digital Language Lab provides resources and facilities for language instruction and learning. It is an interactive, software-based, multimedia learning system that is used for imparting effective language learning skills, with the potential for learning independently at required pace and convenience. ; **Contents**: Spellings, Grammar and Sentence Structures (as individually needed); Conversation Practice and Role Playing Vocabulary Building and Vocabulary usage in specific contexts; Jargon/Register related to Economics and Business and its usage; Word exercises and Word games to enhance self-expression of the participants; Advanced Reading Skills: Increase ability to negotiate through texts of a complex or technical nature; Summarization /forming a gist. Aspects of Phonology: pronunciation practice; Group Discussion. Group & Individual Presentations – prepared and extempore; Interview Techniques; Written Communication – Formal letters, Report and Minutes writing; Business Communication games and activities; Group Project.

CS 171	COMPUTING LAB-I	2 credits (0-0-3)

Objective: The aim of the course is to equip students with basic skills needed to work with computers.

Contents: Read a line of text and count the number of characters, vowels, consonants and blank spaces in it; Implementation of matrix manipulations; Programs on recursive function; Interchanging values of two variables without a third variable using arithmetic operators and also using bit-wise operators; Programs on the use of functions; Programs on Sorting and Searching; Programs on files for creating, populating and manipulating a simple database; Implementation of linked list; Implementation of other data structures; Menu driven programs.

HS 572	STATISTICAL LABORATORY	2 Credits [0-0-3]

Objective: The aim of the course is to provide training in use of various statistical packages for research purposes.

Contents: Introduction to SPSS, Data entry, Data Management, Descriptive statistics, Inferential Statistics .

SCHOOL OF MANAGEMENT

DETAILED SYLLABI OF COURSES

Sl. No.	Sub Code.	Subjects	L-T-P	Credits
1.	SM 501	Organizational Behavior and Structure	3-0-0	3
2.	SM 502	Human Resource Management	3-0-0	3
3.	SM 503	Managerial Economics	3-0-0	3
4.	SM 504	Production & Operations Management	3-0-0	3
5.	SM 505	Financial and Cost Accounting	3-0-0	3
6.	SM 506	Financial Management	3-0-0	3
7.	SM 507	Marketing Management	3-0-0	3
8.	SM 508	Quantitative Techniques and Operations Research	3-0-0	3
9.	SM 509	Research Methodology	3-0-0	3
10.	SM 510	Economic and Legal Environment	3-0-0	3
11.	SM 511	Management Information System	3-0-0	3
12.	SM 512	Technology and Innovation Management	3-0-0	3
13.	SM 513	Basic Computer Lab	0-0-3	2
14.	SM 514	Statistics Lab	0-0-3	2
15.	SM 515	OB Lab	0-0-3	2
16.	SM 516	HR Lab	0-0-3	2
17.	SM 517	Business Simulation Lab	0-0-3	2
18.	SM 518	Management Games Lab	0-0-3	2
19.	SM 519	Seminar and Technical Writing - I	0-0-3	2
20.	SM 520	Seminar and Technical Writing - II	0-0-3	2
21.	SM 601	Strategic Management	3-0-0	3
22.	SM 602	Business Ethics and Corporate Governance	3-0-0	3
23.	SM 603	Internship	3-0-0	3
24.	SM 604	Presentation and Comprehensive Viva-voce	0-0-0	3
25.	SM 605	OR Lab	0-0-3	2
26.	SM 606	Banking Operations Lab	0-0-3	2
27.	SM 607	Leadership Lab	0-0-3	2
28.	SM 608	Project Lab	0-0-3	2
29.	SM 609	Language Lab	0-0-3	2
30.	SM 610	Marketing Lab	0-0-3	2
31.	SM 611	Seminar and Technical Writing - III	0-0-3	2
32.	SM 612	Customer Relationship Management	3 0 0	3
33.	SM 612	Seminar and Technical Writing - IV	0-0-3	2
34.	SM 613	Consumer Behaviour and Marketing Research	3-0-0	3
35.	SM 614	Customer Relationship Management	3-0-0	3
36.	SM 615	Product and Brand Management	3-0-0	3
37.	SM 616	Retail Management	3-0-0	3
38.	SM 617	Sales and Distribution Management	3-0-0	3
39.	SM 618	Industrial and Services Marketing	3-0-0	3
40.	SM 619	Integrated Marketing Communication	3-0-0	3
41.	SM 620	International Marketing	3-0-0	3
42.	SM 621	Financial Institutions, Instruments and Markets	3-0-0	3
43.	SM 622	Financial Options, Futures and Swap	3-0-0	3
44.	SM 623	Commercial Banking	3-0-0	3

45.	SM 624	International finance	3-0-0	3
46.	SM 625	Financial Services	3-0-0	3
47.	SM 626	Mergers and Acquisitions	3-0-0	3
48.	SM 627	Security Analysis and Portfolio Management	3-0-0	3
49.	SM 628	Insurance and Risk Management	3-0-0	3
50.	SM 630	Project Planning and Appraisal	3-0-0	3
51.	SM 631	Employee Relations and Labour Legislations	3-0-0	3
52.	SM 632	Performance Management	3-0-0	3
53.	SM 633	Human Resource Planning	3-0-0	3
54.	SM 634	Organization Change and Development	3-0-0	3
55.	SM 635	Training and Development	3-0-0	3
56.	SM 636	Leadership for Corporate Excellence	3-0-0	3
57.	SM 637	Employee Compensation and Benefits Management	3-0-0	3
58.	SM 638	Strategic Human Resource Management	3-0-0	3
59.	SM 640	Knowledge Management	3-0-0	3
60.	SM 641	Materials Management	3-0-0	3
61.	SM 642	Reliability and Risk Management	3-0-0	3
62.	SM 643	Total Quality Management	3-0-0	3
63.	SM 644	Supply Network Management	3-0-0	3
64.	SM 645	Business Process Transformation	3-0-0	3
65.	SM 646	Operations Strategy	3-0-0	3
66.	SM 647	Project Planning, Scheduling and Monitoring	3-0-0	3
67.	SM 648	Decision Modeling and Simulation	3-0-0	3
68.	SM 651	Strategic Information System	3-0-0	3
69.	SM 652	Database Management System	3-0-0	3
70.	SM 653	E- Commerce	3-0-0	3
71.	SM 654	Software Project and Quality Management	3-0-0	3
72.	SM 655	Enterprise Resource Planning	3-0-0	3
73.	SM 656	IT Strategy	3-0-0	3
74.	SM 657	System Analysis and Design	3-0-0	3
75.	SM 658	Software Engineering	3-0-0	3

SM 501 ORGANIZATIONAL BEHAVIOUR AND STRUCTURE 3 Credits [3-0-0]

Course Contents:
Introduction to OB; Foundations of Individual Behaviour; Values, Attitudes and Job Satisfaction; Personality and Emotions; Perception and Individual Decision Making; Motivation; Foundations of Group Behaviour; Understanding Work Teams; Leadership; Group Dynamics; Stress Management; Conflict Management, Transactional Analysis; Cross-cultural Management; Organization Culture and Climate. Organization Structure: Forms, Line and Staff Conflict, Formal & Informal Organization, Centralization & Decentralization; Span of Management, Delegation of Authority, MBO.

Essential Readings:

1. S. P. Robbins and T. A. Judge, *Organizational Behaviour*, 13/e, Prentice-Hall of India Pvt. Ltd., 2008.
2. D. L. Nelson and *J. C. Quick, Organizational Behaviour*, 5/e, Thompson, 2008.

Suggested Readings:

1. UdaiPareek, *Understanding Organizational Behaviour*, 2/e, Oxford University Press, 2008.
2. T. S. Bateman and S. A. Snell, *Management*, 8/e, TMH, 2008.

SM 502 HUMAN RESOURCE MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Concept, Nature and scope of Human Resource Management; growth and development of Human Resource Management in India; Job analysis and job design; Recruitment and Selection; Tests and Interviews; Orientation; Promotion; Transfer; Separations; Outplacement; Human resource planning; Training & Development: Concept, Training Vs Development, Learning Principle, Training need assessment and types of training programmes; Performance Management; Potential Appraisal; Career and Succession Planning; Job Evaluation; Compensation and benefits; Employees welfare, safety and health; HR Audit; HRIS; Knowledge Management.

Essential Readings:
1. Gary Dessler, *Human Resource Management*, 11/e, Pearson Education, 2008.
2. Scott Snell and George Bohlander, *Human Resource Management*, 2007.

Suggested Readings:
1. H. J. Bernardin, *Human Resource Management: An Experiential Approach*, TMH, 2007.
2. VSP Rao, *Human Resource Management: Text and Cases*, 2/e, Excel Books.

SM 503 MANAGERIAL ECONOMICS 3 Credits [3-0-0]

Course Contents:
Concept and context; Demand Analysis and Supply Analysis; Quantitative Demand Analysis and Revenue Analysis; Cost and Production Function; Price and Output Determination by the firm and Industry under various market structures e.g., Perfect Competition, Monopoly; Monopolistic Competition; Oligopoly; Business Cycle; National Income Measurement; Theories of Income Determination; Saving-Investment Analysis.

Essential Readings:
1. Keat, Young and Banerjee, *Managerial Economics*, Pearson Education, New Delhi.
2. Shappiro, *Macro Economics*, TMH, New Delhi.

Suggested Readings:
1. D.W.Carlton&J.W.Perloff, *Modern Industrial Organisation*, Harper Collins.
2. Y. Maheswari, *Managerial Economics*, PHI, New Delhi

SM 504 PRODUCTION AND OPERATIONS MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Introduction; Production and operations function and its relations to other management functions of an organization; Work system design: process planning, methods study, line balancing, work measurement, work sampling and its applications; Operations Strategy & competitiveness; Process Analysis; Manufacturing Process selection and design; Service Process selection and design; Facility Location and Facility Layout; Strategic capacity management; Aggregate sales and operations planning; Materials flow control: raw materials and WIP inventory control, JIT, lead-time control; Quality assurance and control: statistical process control, process capability improvement, sampling inspection, TQM, QC, Kaizen; Maintenance planning and management: corrective, preventive and predictive maintenance, replacement analysis; Inventory control; Operation Scheduling; Project management; Supply chain strategy.

Essential Readings:
1. Chase, Jacobs, Aquilano, Agarwal, *Operations Management*, TMH, New Delhi.
2. Mahadevan, *Operations Management- Theory and Practice*, Pearson Education, New Delhi

Suggested Readings:
1. S. N. Chary, *Production and Operations Management*, TMH, New Delhi.

2. Scott T. Young, *Essentials of Operations Management*, Sage Publication.

SM 505	**FINANCIAL AND COST ACCOUNTING**	**3 Credits [3-0-0]**

Course Contents:
Functions and objectives of Accounting; Cyclical nature of business and Accounting cycle; Golden Rule; Transactions; Balance Sheet & Income Statements; Accounting Standards. Capital and Revenue transactions; Trial Balance; Company Accounts, Authorized Share Capital, Kinds of Share Capital; Issue of share capital, preference share capital and Debentures, Financial Reporting; GAAP; Annual reports; Cash flow reporting. Basic Cost Concepts, Prime Cost & Overheads: Allocation, apportionment and absorption of overheads; Preparation of Cost Sheet; Cost Accounting Records: Cost ledger accounts, Reconciliation; Methods of Costing, Process costing, Joint Products and By-Products, Transport Costing; Marginal Costing and decision making: Marginal Costing Vs Absorption Costing, Cost-Volume–Profit Analysis, Application of Marginal Costing and Short run decision analysis; Budgets and Budgetary Control, Zero Based Budgeting; Standard Costing.

Essential Readings:
1. Narayanswamy, *Financial Accounting - A Managerial Perspective*, PHI, New Delhi
2. Charles T Homgen, G Foster and S M Datar, *Cost Accounting a Managerial Emphasis*, 10th Ed, PHI

Suggested Readings:
1. Ramachandran&Kakani, *Accounting for Management*, TMH, New Delhi
2. Banerjee, *Cost Accounting: Theory and Practice*, PHI, New Delhi

SM 506	**FINANCIAL MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Introduction, Scope, Objectives & Nature of Financial Management; Role of finance manager; Sources of finance: Equity Capital, Debentures, Preference Capital and Term Loan; Cost of Capital: Time Value of Money, Concept of Risk & return; Cost of Capital & Value of firm: Measurement of specific cost of capital, Weighted Average Cost of Capital ,Valuation of stock & bonds; Financing Decision: Capital Structure theories, EBIT-EPS relationship, Determinants of Capital Structure; Leverages: Operating, Financial & Combined Leverages; Investment Decisions: Capital budgeting methods, NPV, IRR, Capital budgeting under risk & uncertainty, Capital rationing; Dividend Decisions: Forms of Dividends, Theories of dividend Polices, Determinants of Dividends Decisions, Implication of Bonus Issue, Right Issue, Stock Split and Buy back of shares; Working capital Management: Concept, Operating cycle, Estimation of working Capital requirement, Cash Management, Receivable Management, Inventory Management.

Essential Readings:
1. Van Horne, Bhaduri, *Fundamentals of Financial Management*, Pearson Education, New Delhi.
2. I.M. Pandey, *Financial Management*, Vikash Publications, New Delhi.

Suggested Readings:
1. Keown, *Financial Management: Principles and Applications*, Pearson Education, New Delhi.
2. P. C. Chandra, *Financial Management*, TMH, New Delhi.

SM 507	**MARKETING MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Introduction to marketing; challenges of modern marketing; Customer value and satisfaction; Market-oriented strategic planning; Marketing Information System; Scanning the marketing environment; Buyer Behaviour; Models of Consumer Behaviour; Market segmentation; Marketing

Mix; Demand Assessment and Forecasting; and targeting; differentiation and positioning. Developing new market offerings and global market offerings; developing the product and branding strategy; services marketing; pricing policy, marketing channels & physical distribution and communication strategies; sales management; rural marketing; Internet marketing; marketing strategy implementation and control.

Essential Readings:

1. Kotler& Armstrong, *Principles of Marketing*, Pearson Education/PHI, New Delhi.
2. Philip Kotler, Keller, Koshy&Jha, *Marketing Management,* Pearson Education, New Delhi.

Suggested Readings:

1. Grewal and Levy, Marketing, TMH, New Delhi.
2. Ramaswamy&Namkumari, A Text Book of Marketing Management, Macmillan.

SM 508	**QUANTITATIVE TECHNIQUES AND OPERATIONS RESEARCH**	**3 Credits [3-0-0]**

Course Contents:

Business Statistics: Measures of Central tendency and Dispersion; Variance and Covariance; Correlation & Regression Analysis; Testing of Hypotheses: t- test, z- test, chi-square test, ANOVA. Introduction to Operations Research and Decision Theory, Structure of decision strategies, decision making under competitive situation. Introduction and use of linear programming; Graphical Method; Simplex method: Minimization and Maximization Cases. Transportation Problems: Introduction and use; North-West Corner Rule; Stepping-Stone Method; Vogel Approximation Method (VAM). Assignment Problems: Introduction and use; Hungarian Method; Balanced and Unbalanced Problems; Maximization Case. Queuing Theory: Introduction to Waiting-line Model; uses of Queuing Model; Queuing Models of different category. Game Theory: Introduction and Use; Problems solving using Dominance Theory; Problems of Mixed Strategy, PERT; CPM; Simulation, Stochastic Programming.

Essential Readings:

1. Hamdy A Taha, *Operations Research*, PHI, 7th Edition.
2. Levin and Rubin, *Statistics for Management*, PHI, New Delhi

Suggested Readings:

1. Chase, Richard B.; Aquilano, Nicholas J and Jacobs, F. Robert (9th Edition); *Operations Management For Competitive Advantage*, by Tata McGraw-Hill.
2. Anderson David R, *Quantitative Methods for Business*, 10th Ed., Cengage.

SM 509	**RESEARCH METHODOLOGY**	**3 Credits [3-0-0]**

Course Contents:

Research Methodology: Meaning, Objectives, Types, and Approaches; Identification of Research Problem; Research Design: Exploratory, Descriptive, Experimental, Observational Studies & Survey; Literature Review; Hypotheses; Sampling; Data Sources; Data Collection Tools; Reliability and Validity; Introduction to Qualitative Research Methods; Interpretation and Report Writing.

Essential Readings:

1. D. R. Cooper and P. S. Schindler, *Business Research Methods*, 9/e, TMH, 2009.
2. C. R. Kothari, *Research Methodology, 2/e*, New Age International (P) Ltd. Publishers, 2006.

Suggested Readings:

1. Alan Bryman, *Social Research Methods*, 3/e, Oxford University Press, 2009.
2. S. N. Murthy and U. Bhojanna, *Business Research Methods*, 3/e, Excel Books.

SM 510 ECONOMIC AND LEGAL ENVIRONMENT 3 Credits [3-0-0]

Course Contents:
Environment of Business, Socio Cultural and Politico Legal Environment, Changing role of government and socio economic scenario. Structure and Dimension of the Economy, Structure of the Industry, Public Sector, Small & Medium Sector, Emerging Economic Scenario, National Planning Process, Evolution of Industrial Policy, Regulatory and Promotional Framework, Foreign Trade, Balance of Payments, Export and Import Policy, Foreign Direct Investment, External Debt, Industrial Policy, Economic Reforms, Inclusive Growth. Introduction to Business Law; Law of Contract; Sale of Goods Act; Companies Act; Patents law and Enforcement; Trade Mark Law and Enforcement; Corporate Taxation, Banking Law & Practice; Negotiable Instruments Act; Transfer of Property Act; Limitation Act, Industrial Regulation and Development Act, Securities Act.

Essential Readings:
1. Baumel W J.,A S Blinder and W. M. Scarth (1985), *Economics: Principles and Policy*, Academic Process Canada, Toronto.
2. ND Kapoor, *Business Law*, Sultan Chand

Suggested Readings:
1. Swamy, D.S. (1994), *The Political Economy of Industrialization*, Sage Publications, New Delhi, Introduction, Chapter-1, and Conclusion.
2. Tulsian, *Business Law*, TMH, New Delhi

SM 511 MANAGEMENT INFORMATION SYSTEM 3 Credits [3-0-0]

Course Contents:
Management and Systems Advance in Management: The process of MIS Development MIS Organisation, Information Dynamics, Planning Design and Implementation of MIS, IS Strategic Planning MIS Design, Gross Design Concepts, Detail Design Concepts, MIS Implementation Acquiring Information Systems, Contemporary Approaches System Life Cycle: Information, Flow Entity Relationship Modeling, Data Modeling, Detailed Process Analysis, Data Flow Diagrams, Decision Making with MIS System: Concepts for MIS Data Information and Communication, Problem Solving and Decision Making IS Security, Control System Success and Failure, The Future Trends in MIS: The Emerging IT Trends Electronic Data Interchange, Objected Oriented Approach, Networking (Information System Highway), Extended Enterprise Systems, Managing International Information Systems

Essential Readings:
1. Davis & Olson, *Management Information Systems*, TMH, New Delhi.
2. O'Brein&Marakas, *Management Information Systems*, TMH, New Delhi

Suggested Readings:
1. Laudon and Laudon, *Management Information Systems Managing the Digital Firm*, Pearson Education/PHI.
2. JiawehanMichelineKamber, *Data Mining Concepts and Techniques*, Morgan Kauffman.

SM 512 TECHNOLOGY AND INNOVATION MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Evolution of Technology; Effects of New Technology; Technology Innovation: Technology development; Technology transfer; Technology Assessment; Organizational and Social Implications of Technology; Human Aspects in Technology Management; Introduction; Types and Pattern of Innovation; Innovation within the Life Cycle of a Technology; Choosing Innovation Projects; Collaborating Strategies; Protecting Innovation; Innovation Strategies ; Organizing for Innovation: Organization Structure and Culture, Managing the Innovation Process, Social Networks and

Informality in the Innovation Process; New Product Development Teams, Crafting a development strategy; Organization as a laboratory for learning.

Essential Readings:

1. R. Boutellier, O. Gassmann and M. Zedtwitz, *Managing Global Innovation - Uncovering the Secrets of Future Competitiveness*, Springer, 1999.
2. Melissa Schilling, *Strategic Management of Technological Innovation*, TMH, 2008.

Suggested Readings:

1. M. Iansiti, *Technology Integration making critical choices in a dynamic world*, Harvard Business School Press, Boston, 1998.
2. Steve Conway and Fred Steward, *Managing and Shaping Innovation*, Oxford University Press, 2009.

SM 601	**STRATEGIC MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
An overview of company strategy; Understanding a Company: Vision, Mission, Objectives, Goals, Strategies, and Tactics, Concept and process of strategic Management, Strategic Business Unit (SBU). Environmental Scanning, SWOT analysis, Internal and External environmental analysis. Competition Analysis: Porter's Five Force Theory, Competitive Advantage, Value chain analysis. Classification of Strategies (long term vs. short term, generic, grand strategies); Strategic Planning for Competitive Advantage: Business Strategy, Corporate Strategy, Diversification, Mergers, Acquisitions, Strategic Alliances, Joint ventures, Divestment, BCG, GE Matrices; Evaluation of Strategic Alternatives and Strategy Implementation.

Essential Readings:

1. Robert Pitts, *Strategic Management: Building and Sustaining Competitive Advantage*, Cengage Learning.
2. Pearce, *Strategic Management: Formulation*, Implementation and Control, TMH.

Suggested Readings:

1. AzharKazmi, *Strategic Management and Business Policy*, TMH.
2. Hitt, Ireland and Hoskisson, *The Management of Strategy: Concepts and Cases,*Cengage Learning.

SM 602	**BUSINESS ETHICS AND CORPORATE GOVERNANCE**	**3 Credits [3-0-0]**

Course Contents:
Introduction to Business Ethics: Need, Importance, Nature, Scope, Objectives of Business Ethics, Factors influencing Business Ethics, Characteristics of Business Ethics, Ethical decision making. Corporate Governance: Issues, Need and Importance, benefits of good governance to companies and to the society. Corporate Governance Mechanism: Anglo-American Model, German Model, Japanese Model and Indian Model. Managerial Obligations to Society, Investors, Employees, Customers.Role of Board of Directors, Auditors, SEBI and Government. Growth of Corporate Governance in India; Corporate Governance Ethics; How ethics can make corporate governance more meaningful; Corporate social responsibility of business.

Essential Readings:

1. C. Fernando, *Corporate Governance: Principles, Policies and Practices*, Pearson Education.
2. Velasquez, *Business Ethics: Concepts and Cases*, Pearson/PHI.

Suggested Readings:

1. Hartman, *Perspectives in Business Ethics*, TMH.
2. Solomons, *Corporate Governance and Accountability*, John Wiley.

SM 612 CUSTOMER RELATIONSHIP MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Introduction to CRM; CRM in marketing, CRM and Customer Service; Sales force automation; Analytical CRM; Planning for CRM; CRM tools; Managing CRM project; CRM in E- business; Product and service delivery on the web, communication using the web infrastructure, data collection and analysis, personalized exchange of information with customers and new models of managing customer relationships both internal and external.

Essential Readings:

1. Zikmund, *Customer Relationship Management*, John Wiley & Sons.
2. JilliDychi, *The CRM Handbook*, Pearson Education.

Suggested Readings:

1. Bee, Frances and Roland, *Customer Care*, Universities Press.
2. Jagdish Seth, AtulParvatiyar, G Shainesh, *Customer Relationship Management: Emerging Concepts, Tools and Applications*, TMH.

SM 613 CONSUMER BEHAVIOUR AND MARKETING RESEARCH 3 Credits [3-0-0]

Course Contents:
Consumer Decision Making: four views of consumer decision making- Economic man, Cognitive man, Emotional man, Passive man; Consumer Decision process, Factors influencing consumer decision making process, Comprehensive models of consumer decision making: Nicosia Model, Howard-Sheth model, Engel-Kollat-Blackwell model. Individual determinants of behavior: Personality, perception, Attitudes, learning and motivation. Social and ethical perspective of Consumer behavior: Family influences; Social, Cultural and Developmental Influences; Consumer response to marketing-Innovation and the product Life Cycle; Consumer Behaviour and Strategy- Issues; Organizational Buying Behaviour. ; Marketing Research: The marketing research process- defining research objectives, research designs, major qualitative research techniques – Depth interview, focus group, projective techniques, specialized techniques; Sampling; Field work; Questionnaire Design; Data Analysis: Test of significance using sampling statistics, chi-square and ANOVA, correlation and regression, factor analysis for data reduction cluster, analysis for market segmentation, conjoint analysis for product design, multidimensional scaling for brand positioning. Use of data processing packages such as SPSS; Research presentation and research process evaluation.

Essential Readings:

1. Schiffman and Kanuk, *Consumer Behavior*, Pearson Education.
2. Green &Tull, *Research for Marketing Decisions*, TMH.

Suggested Readings:

1. Lauden&Bitta, *Consumer Behaviour*, TMH.
2. N. K. Malhotra, *Marketing Research: An Applied Orientation*, PHI.

SM 614 CUSTOMER RELATIONSHIP MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Introduction to CRM; CRM in marketing, CRM and Customer Service; Sales force automation; Analytical CRM; Planning for CRM; CRM tools; Managing CRM project; CRM in E- business; Product and service delivery on the web, communication using the web infrastructure, data collection and analysis, personalized exchange of information with customers and new models of managing customer relationships both internal and external.

Essential Readings:

1. Zikmund, *Customer Relationship Management*, John Wiley & Sons.

2. JilliDychi, *The CRM Handbook*, Pearson Education.

Suggested Readings:

1. Bee, Frances and Roland, *Customer Care*, Universities Press.
2. Jagdish Seth, AtulParvatiyar, G Shainesh, *Customer Relationship Management: Emerging Concepts, Tools and Applications*, TMH.

SM 615	PRODUCT AND BRAND MANAGEMENT	3 Credits [3-0-0]

Course Contents:
Product management- Introduction; Product strategy; Analysis of product line and Product mix decisions; Product life cycle; New Product development process and strategies; Product line extension; Product testing: Pre-test Marketing and Test Marketing, Launching strategies for new product. Product positioning/ repositioning strategies; Brand Management: Branding process and strategies; Building brand identity; Brand extensions and their equities; Brand portfolio management; Brand leverage; Brand image; Brand personality; Brand loyalty; Brand valuation techniques; Co-branding; Building strong brands in Indian and international contexts; Importance of Branding in terms of product success.

Essential Readings:

1. Keller Kevin, *Strategic Brand Management*, PHI
2. Lehman Donald, Russell, *Product Management*, TMH.

Suggested Readings:

1. Y L R Moorthi, *Brand Management: The Indian Context*, Vikas Publication.
2. Jean Noel Kapferer, *Strategic Brand Management*, Free press.

SM 616	RETAIL MANAGEMENT	3 Credits [3-0-0]

Course Contents:
Introduction to retailing; Retailing in India; Retail formats & theories; Phases of growth of retail markets; Retail Strategy; Understanding Retail Consumers; Retail institutions; Store Design & Layout; Retail Merchandising; Buying and Merchandising; Retail Pricing & Merchandise; Retail Operations; Measuring Retail Performance; Retail Management Information System; Retail Marketing & Communication; Service quality in Retail Sector; Design and Visual merchandising, Managing retail operations; Importance of Supply Chain Management; E-retailing.

Essential Readings:

1. Lamba A J, *The Art of Retailing*, TMH.
2. Berman & Evans, *Retail Management: A Strategic Approach*, Pearson Education/PHI

Suggested Readings:

1. Diamond, Jay and Gerald, *Retailing*, Prentice Hall.
2. Morgenstein, Melvin and Harriat Strong, *Modern Retailing*, Prentice-Hall.

SM 617	SALES AND DISTRIBUTION MANAGEMENT	3 Credits [3-0-0]

Course Contents:
Sales Management: The role of selling and sales management; Sales process; Characteristics of sales people; Sales force design; Territory management; Selection and Recruitment of sales force; Compensation and Motivation of sales force. Distribution Management: Distribution channel and their structure, Functions and Relationships, Channel Planning and Designing Channel Systems, Logistics of Distribution Channel, Evaluation and Control, Channel Conflicts.

Essential Readings:

1. Richard R. Still, Edward W. Cundiff, Norman A. P. Govoni, *Sales Management: Decisions, Strategies and Cases*, PHI.
2. K.K. Havaldar& V.M. Kavale, *Sales & Distribution Management*, TMH.

Suggested Readings:

1. S.L. Gupta, *Sales & Distribution Management*, Excel Books.
2. T. Panda and K. Sahadev, *Sales & Distribution Management*, Oxford Publication.

SM 618	INDUSTRIAL AND SERVICES MARKETING	3 Credits [3-0-0]

Course Contents:
Industrial Marketing-an overview, Concepts & systems; Dynamics of industrial buying & buyer behaviour; Industrial Marketing strategy Formulation; Product planning & New product development; Logistic & channel strategy; IM through communication planning; Pricing policies and strategies; IM environment. ; Service marketing: Origin, growth and classification of services; Emergence of Service Economy; Nature of Services; Goods and Services Marketing; Service Vision and Service Strategy; Service delivery process, pricing, promotion, positioning; Service blueprint; Customer satisfaction and service quality; Operating strategy; Hospital services, Financial services, Information Technology Services, Health care services, Services marketing in future, Marketing Challenges in service business.

Essential Readings:

1. Reeder, et al; *Industrial Marketing: Analysis*, Planning and Control, PHI.
2. Hoffman, *Services marketing: Concept, Strategies and Cases*, Cengage/Thomson.

Suggested Readings:

1. Fredrick E Webster Jr, *Industrial Marketing, Concepts and Cases*, John Wiley.
2. Zeithaml and Bitner, *Services Marketing*, McGraw Hill.

SM 619	INTEGRATED MARKETING COMMUNICATION	3 Credits [3-0-0]

Course Contents:
Situational analysis; Role of advertising in marketing mix; Positioning decisions Advertising opportunities for different product situations; Kinds of advertising; Setting of advertising objectives & planning; Formulation of strategies & budgets; Media Planning development; Media buying and research; Copy designing & testing; Evaluating advertising campaigns; Advertising research techniques; The social and economic effects of advertising; Advertising agencies; Public relations as an element of marketing mix; Various PR tools; Choosing PR message and vehicles; Ethical issues in advertising.

Essential Readings:

1. P.R.Smith and Jonathon Taylor, *Marketing Communication- An Integrated Approach,*Kogan Page.
2. Mohan Manendra, *Advertising Management- Concepts and Cases*, TMH.

Suggested Readings:

1. Kazmi and Batra, *Advertising and Sales Promotion*, Excel Books.
2. Russel and Lane, Klepnner's, *Advertising Procedure*, Pearson Education.

SM 620	INTERNATIONAL MARKETING	3 Credits [3-0-0]

Course Contents:
Introduction to International Marketing: International Marketing Environment, Preparing for International Marketing Strategies. International Marketing Mix: International Research and

Segmentation, Developing Global Products and Pricing, International Promotion and Advertising, International Distribution Systems. The Indian Export Scenario: The Export Import Scene in India, Import-Export Policy, Export Documentation, Export Procedure, International Technology Transfer and Counter Trade, The Trade Mark Regime. International Marketing Planning: Managing Systems for International Marketing, Reflection and Evaluation of the Endeavours.

Essential Readings:

1. Roger Bennett, Jim Blythe, *International Marketing: Strategy Planning, Marketing Entry and Implementation*, Kogan Page.
2. Hans Muhlbacher, HelmuthLeihs and Lee Dahringer, *International Marketing: A Global Perspective*, Thomson Learning.

Suggested Readings:

1. Philip R Cateora, John L Graham and PrashantSalwan, *International Marketing*, TMH.
2. Michael R. Czinkota, IikkaA.Ronkainen, *International Marketing*, Thomson.

SM 621	**FINANCIAL INSTITUTIONS, INSTRUMENTS AND MARKETS**	**3 Credits [3-0-0]**

Corse Contents:

Introduction to Financial System, Classification of Financial Markets, Capital Market (Primary Market & Secondary Market), Money Market, Commodity Market. Financial Markets- Indian & Global financial Markets; Financial Institutions: Money Market Institutions, Capital Market Institutions, Financial Service Institutions, Stock Exchanges: Organizations and Functions, SEBI Regulations, Securities Appellate Tribunal, Investor services, Ombudsmanship, Financial Services Institutions, Commodity Exchanges, NSDL, STC, Forward Markets Commission, Credit Rating Institutions; Financial Instruments: Money market instruments, Capital Market Instruments, Commodity market Instruments, Forex market Instruments, Mutual Funds: Types; Operations; SEBI Guidelines regarding launching Mutual funds schemes; Computation of NAV; Performance measurement of MF's; Marketing of MF products; Indian Financial Institutions: Commercial banks:- Roles, Functions, Public sector, Private Sector, Foreign Banks, Development Banks:- IFCI, IDBI, SFCs, NABARD, RRBs, SIDBI, Insurance Regulatory Development Authority (IRDA), Non-banking Financial Institutions (NBFCs), Insurance Companies: Public & Private.

Essential Readings:

1. Nasser Arshadi, Gordon V Karels, *Modern Financial Intermediaries*, PHI.
2. Guruswamy, *Financial Markets & Institutions*, Thomson.

Suggested Readings:

1. M. Y. Khan, *Indian Financial System*, TMH.
2. L. M. Bhole, *Financial Institutions, Markets and Service*, TMH.

SM 622	**FINANCIAL OPTIONS, FUTURES AND SWAP**	**3 Credits [3-0-0]**

Course Contents:

Financial Derivative: Features, Types of Derivatives; Basic Financial Derivatives; History of Derivatives Market; Use of Derivatives; Critiques of Derivatives. Traders in Derivative Markets; Calculus for derivative products; Factors contributing to the growth of Derivatives; Financial Derivatives Market in India. Introduction to Forwards, Futures, Swap, Options, and other exotic derivatives; Pricing forward contracts; The carry cost model; Pricing option contracts; Black-Scholes Model; Binomial pricing models; Risk – Neutral valuation, Volatility estimation techniques; ARCH family of models; Currency Option; Future Option; Measuring option price sensitivity; Value at risk concept and it's application; Hedging; Basic Hedging with derivative products.

Essential Readings:

1. John C Hull, Option, *Futures and Other Derivatives*, PHI.

2. Sudaresan, *Fixed Income Markets and their Derivatives*, Cengage.

Suggested Readings:

1. Robert W. Kolb, *Understanding Futures Market*, PHI.
2. Marshall &Bansal, *Financial Engineering: A complete guide to Financial Innovation*, PHI.

SM 623 COMMERCIAL BANKING 3 Credits [3-0-0]

Course Contents:
Introduction to Banking; Overview of Banking; Evolution of commercial banking, Challenges; Banker-Customer Relationships; Characteristics of Negotiable Instruments; Cheque and its characteristics; Customers' Deposit Accounts; Risk profile of financial systems; Evolving international financial markets- recent changes and their effects; Banking instruments, investment planning and capital adequacy norms; Cash management, business risk and profitability planning; Branch banking, international banking and country risk assessment; Development Banking, Banking Sector Reforms, ALM, Introduction to International Banking, Banking Technology.

Essential Readings:

1. Reed,Cotter,Gill and Smith, *Commercial Banking*, Prentice Hall.
2. B. S. Khubchandani, *Practice and Law of Banking*, Macmillan

Suggested Readings:

1. McDonald, *Management of Banking*, Cengage/Thomson.
2. Guruswamy, *Banking Theory Law and Practice*, TMH

SM 624 INTERNATIONAL FINANCE 3 Credits [3-0-0]

Course Contents:
International Financial Management- An Overview; International Flow of Funds- The Balance of payments; International Financial System & The Market for Foreign Exchanges; International Monetary Systems; Evolvement of Floating Rate Regime; Foreign Exchange Market in India; Determination of Exchange Rates- PPP & IRP; International Parity Conditions; Exchange Rate Forecasting; Managing Foreign Exchange Risk; Currency derivatives: Forwards, Swaps & Interest Parity; Currency & Interest rate futures; Currency options; Interest Rate Risk Management; International Investment & Financing; Financing the Global Firms; Foreign Investment Decisions; International Trade Finance; International financial markets & instruments.

Essential Readings:

1. Eitman, Stonehill, Mofett, *Multinational Business Finance*, Pearson Education.
2. P.G Apte, *International Financial Management*, TMH.

Suggested Readings:

1. M. D Levi, *International Finance*, TMH.
2. Giancarlo Gandolfo, *International finance and open-economy macroeconomics*, Springer

SM 625 FINANCIAL SERVICES 3 Credits [3-0-0]

Course Contents:
Financial system; Financial Markets- Meaning, Classification; Capital Market; Capital Market intermediaries; Primary & Secondary Market; Stock Exchange; Functions of Stock Exchange; SEBI Guidelines, Investor protection. Call Money Market; Commercial Papers; Treasury Bills; Certificate of Deposits; Commercial Bills; Gilt-edged Securities; Warrants and Convertibles; ADRs and GDRs; Derivatives- Options and futures. Merchant Banking; Role of Lead managers, Registrars, Underwriters, Brokers and Bankers; Capital issue management; Pre and Post Issue Management; Role of NBFCs; Leasing; Lease Evaluation and Accounting; Hire purchase concept and Financial Evaluation; Factoring and Bill Discounting; Venture Capital; Credit Rating.

Essential Readings:
1. Clifford E Kirsch, *The Financial Services Revolution*, McGraw Hill
2. M.Y. Khan, *Financial Services*, TMH

Suggested Readings:
1. Nalini P Tripathy, *Financial Instruments and Services*, PHI
2. Meir Kohn, *Financial Institutions and Markets*, Oxford

SM 626 MERGERS AND ACQUISITIONS 3 Credits [3-0-0]

Course Contents:
Various Forms of Business Alliances; Strategic Choice of Type of Business Alliance; Who should go for Merger and Acquisition and Take-over; Defining and Selecting Target; Pricing of Mergers (Pricing the Competitive Bid for Take-over); Negotiation/Approach for Merger, Acquisition and Take-over; Contracting; Implementation of Merger and Acquisition; Managing Post-Merger Issues; Legalities Involved in Merger, Acquisition and Take-over; Ethical Issues of Merger and Take-over; Accounting for Mergers; Financing the Mergers and Take-overs; Corporate Restructuring; Divestment and Abandonment.

Essential Readings:
1. Kevin K Boeh, Paul W. Beamish, *Mergers and Acquisitions*, Sage.
2. SudiSundersanam, *Value Creation from Mergers and acquisitions*, Pearson Education.

Suggested Readings:
1. Food Western, Kunag S Chung, Susan E Hung, Mergers, *Restructuring and Corporate Control,* PHI.
2. AswathDamodaran, *Corporate Finance- Theory and Practice*, John Willey.

SM 627 SECURITY ANALYSIS AND PORTFOLIO MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Concept of investment, objective and constraints; Developments of security markets in India: Primary market, Secondary market, Stock market Index & calculation methodology; Concept & Measuring of Risk and Return; Reduction of risk through diversification; Investment decision based on “alpha” & “beta”; Bond valuation, Valuation of equity shares (Dividend discount model, PE approach & DCF Model); Equity investment styles; Technical Analysis and Oscillators; Efficient market hypothesis; Method of Fundamental Analysis; Tools of Technical Analysis; Portfolio Analysis; CAPM; APT; Portfolio concepts; Markowilz’s Mean-Variance analysis; Portfolio Construction and Optimization; Portfolio performance evaluation; Portfolio revision.

Essential Readings:
1. Fischer and Jordon, *Security Analysis & Portfolio Management*, PHI.
2. Sharpe, *Alexander and Bailey, Fundamentals of Investment*, PHI.

Suggested Readings:
1. Jones, *Investments: Analysis and Management*, John Wiley.
2. Reilly, *Investment Analysis & Portfolio Management*, Cengage.

SM 628 INSURANCE AND RISK MANAGEMENT 3 Credits [3-0-0]

Course Contents:
An overview of risk and risk management: Introduction to risk and uncertainty, rationale and objectives of risk management; Risk assessment: Risk identification and measurement, pooling arrangements and diversification of risks. Insurance business and operations: Introduction to insurance, Agency Law, Principles of general underwriting and claims management, Product

management, Actuarial functions, Pricing strategies, Place and distribution strategies; Commercial Insurance Contracts: Life Insurance, Marine Insurance, Fire Insurance, Motor Insurance and Miscellaneous insurance contract; Hedging risk with derivative contracts, Relevant Case Studies in Indian context.

Essential Readings:

1. George E. Rejda, *Principles of Risk Management and Insurance*, Pearson Education.
2. Vaughan and Vallghan, *Fundamental of Risk and Insurance,* John Willey & Sons.

Suggested Readings:

1. Trieschmann, *Risk Management and Insurance*, Cengage/Thomson
2. Mishra and Mishra, *Insurance Principles & Practice,* Sultan Chand.

SM 630	**PROJECT PLANNING AND APPRAISAL**	**3 Credits [3-0-0]**

Course Contents:
Capital Investment Decisions, Project Analysis, Introduction to Capital Budgeting, Strategy and Resource Allocation, Project Screening, Technical Analysis, Product Mix, Alternatives and Implementation, Financial Estimates and Appraisals, Feasibility, Working Capital Requirements, Project Cash Flows, Risk Analysis.

Essential Readings:

1. Prasanna Chandra, *Projects Planning, Analysis, Selection, Implementation and Review*, TMH.
2. Y Khan & P K Jain, *Financial Management: Texts Problems and Cases*, TMH.

Suggested Readings:

1. Andrew Fight, *Introduction to Project Finance*, Butterworth, Elseiver.
2. Stefano Gatti, *Project Financing: Theory and Practice,*Elseiver.

SM 631	**EMPLOYEE RELATIONS AND LABOUR LEGISLATIONS**	**3 Credits [3-0-0]**

Course Contents:
Approaches to Industrial relations: Unitary, Pluralistic, and Radical approaches; Trade Unionism: Concept, Function and Structure, union registration and recognition, Trade Unionism in India. Industrial Disputes: Concept, Causes and types, procedure for settlement of disputes in India, Grievance Management. Collective Bargaining: Nature, scope and functions, Stages & Bargaining Process. Participative Management: Concept, Scope and Objectives, Workers' participation in Indian Industries, Employee Empowerment and Involvement; Industrial Discipline: Code of conduct, Code of discipline, Disciplinary action, Employee Counseling. Factories Act, 1948; Mines Act 1952; Contract Labour (Regulation and Abolition) Act, 1970; Trade Union Act, 1926; Industrial Employment (Standing Orders) Act, 1946; Industrial Disputes Act, 1947.

Essential Readings:

1. C. S. VenkatRatnam, Industrial Relations, Oxford University Press, 2006.
2. P. R. N. Sinha; IndubalaSinha and S. P. Shekhar, Industrial Relations, Trade Unions, and Labour Legislation, Pearson Education, 2004.

Suggested Readings:

1. Mamoria; Mamoria and Gankar, *Dynamics of Industrial Relations*, Himalaya Publishing House, 2007.
2. P. L. Malik, *Handbook of Labour and Industrial Law*, 12/e, Eastern Book Company, 2009.

SM 632 PERFORMANCE MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Performance Management: Nature, Scope, Importance, Benefits, Process; Performance Planning; Performance Management; Performance appraisal: Methods and Approaches of performance appraisal, Obstacles in appraisal, Designing appraisal for better results, Performance appraisal interview. Potential Appraisal; Performance monitoring; PM Strategy: Career based, Team based, Culture based, Measurement based, Competency based and Reward based. Competency Mapping; 360 feedback; Assessment centers; Performance review; Coaching and counseling and Performance Management in some selected industries.

Essential Readings:
1. T. V. Rao, *Performance Management and Appraisal Systems*, Response Books, 2009.
2. S. R. Kandula, *Performance Management: Strategies, Interventions and Drivers*, PHI, 2006.

Suggested Readings:
1. R. L. Cardy, *Performance Management*, PHI.
2. Armstrong and Baron, *Performance Management*, Jaico Publishing House.

SM 633 HUMAN RESOURCE PLANNING 3 Credits [3-0-0]

Course Contents:
Job Analysis; HR Planning: Concept, Importance, Objectives, Types of HR plan, Dimensions of Human Resource Planning; Approaches-Social Demand Approach, Rate of Return Approach and Manpower Requirement Approach. HRIS and HRP; Human Resource Reporting, Computerized HRIS. Methods of demand forecasting and supply forecasting at micro level; Managing surplus and shortage; Evaluating HRP effectiveness. Career planning: Concept, Objective; Career planning vs. Human resource planning; Career planning vs. Succession planning, Process of career planning and career development, Human Resources Evaluation: Human Resources Audit and Human Resource Accounting, Succession planning.

Essential Readings:
1. Monica Belcourt and Kenneth J. McBey, *Strategic Human Resource Planning*, 2/e, Thomson, 2004.
2. Dipak Kumar Bhattacharyya, *Human Resource Planning*, 2/e, Excel Books, 2006.

Suggested Readings:
1. Gordon Mcbeath, *The Handbook of Human Resource Planning: Practical Manpower Analysis Techniques for HR Professionals*, Atlanta.
2. William J. Rothwell and H. C. Kazanas, *Planning and Managing Human Resources*, Jaico Publishing House.

SM 634 ORGANIZATION CHANGE AND DEVELOPMENT 3 Credits [3-0-0]

Course Contents:
Organizational Change: Concept, Forces demand organizational change - External and Internal, Recognizing the need for change, Problem diagnosis, Identifying alternate change techniques, Resistance to change, The process of organizational change. Managing change and Transformation: Planning, Creating the support system, managing the transition, organizational Restructuring, reorganizing work activities, strategies, process oriented strategies, competitor and customer oriented strategies. Team work; Effective Change Leader; Change Management Competencies and its development. Organization Development: OD process, OD Interventions, Action Research Orientation, Evaluating OD Effectiveness.

Essential Readings:

1. Cummings and Worley, *Theory of Organization Development and Change*, Cengage Learning, 2005.
2. Jones, *Organizational theory, design and change*, Pearson Education

Suggested Readings:

1. Nilakant and Ramnarayan, *Managing Organizational Change*, Response Books.
2. Kavita Singh, *Organization Change and Development,* Excel Books.

SM 635	**TRAINING AND DEVELOPMENT**	**3 Credits [3-0-0]**

Course Contents:
Introduction: Socializing, Orienting & Developing Employees, Teaching & Training, Training & Learning, Transfer of learning, Trainers & Training Style; Strategizing training; Training Need Analysis; Methods & Techniques of delivering training; Training Delivery; Training Interventions and Learning Experiences; Management Development: Designing Programme, Process and Techniques; Business Games; Case Study & Role Plays; Use of Films & Tales; Training Evaluation & Follow up; Impact Analysis & Return on Investment; Special Issues in Training and Employee Development.

Essential Readings:

1. Raymond A. Noe, *Employee Training and Development*, 4/e, TMH, 2008.
2. Lynton and Pareek, *Training for Organizational Transformation (Part -1 & 2)*, Sage Publication.

Suggested Readings:

1. Irwin L. Goldstein and J. Kevin Ford, *Training in Organizations*, Thomson Learning, 2007.
2. A.Mayo, *Creating a Training and Development Strategy*, Universities Press.

SM 636	**LEADERSHIP FOR CORPORATE EXCELLENCE**	**3 Credits [3-0-0]**

Course Contents:
Introduction and overview; Nature and importance of leadership; traits, motives and characteristics of leaders; charismatic and transformational leadership; leadership behaviours, attitudes and styles; contingency and situational leadership; leadership ethics and social responsibility; power, politics and leadership; influence tactics of leaders; motivation and coaching skills; creativity, innovation, and leadership; communication and conflict resolution skills; developing leadership diversity; leadership development, succession and followership; creating vision and strategic direction; shaping cultures and values. Group dynamics: cohesion and development, structure, influence, performance, decision making. Designing and leading a learning organization; leading change.

Essential Readings:

1. Richard L. Daft, *Leadership*, Cengage Learning, 2005.
2. Robert J. Allio, *Leadership: Myths and Realities*, TMH, 2008.

Suggested Readings:

1. D. R. Forsyth*, Group Dynamics*, Thomson, 2007.
2. G. Vijayaragavan, *High Performance Leadership,* HPH, 2007.

SM 637	**EMPLOYEE COMPENSATION AND BENEFITS MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Conceptual Framework of Compensation Management; Theories of wages; Job Evaluation; Wage and Salary Administration; Wage Differentials; Wage Structure; Wage Fixation; Employee compensation; Incentive Payment and types of incentive plans. Compensation practices of

multinational and global organizations. Incentive based pay systems, Executive compensation Practices of MNCs. Legal Aspect: Minimum Wages Act, 1948, Payment of Wages Act, 1936, Payment of Bonus Act, 1965, Equal Remuneration Act, 1976, Workmen's Compensation Act, 1923, Employees' State Insurance Act, 1948, Employees' Provident Funds and (Miscellaneous Provisions) Act, 1952, Payment of Gratuity Act 1972, Maternity Benefit Act, 1961.

Essential Readings:

1. G. T. Milkovich and J. M. Newman, *Compensation*, 8/e, TMH, 2007.
2. Joseph J. Martocchio, *Strategic Compensation*, Pearson Education, 2007.

Suggested Readings:

1. Henderson, *Compensation Management in knowledge based world*, Pearson Education.
2. P. L. Malik, *Handbook of Labour and Industrial Law,* 12/e, Eastern Book Company, 2009.

SM 638	**STRATEGIC HUMAN RESOURCE MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Overview of Business Environment & Strategic Management; Strategic management & HR linkages; Concept of Strategic HRM; Models of SHRM; SHRM & Organizational Success; Process of Strategic HRM; Formulating & Implementing HR Strategy; Strategy & OD; Strategic HR & Change Management; Strategy and Culture; Strategic HR & Recruitment; Strategic HR & Performance Management; Strategic HR & Employee Development; Strategic HR & Reward Management; Strategic HR & Employee Relations; Strategic Employee Retention, Restructuring and Strategic HR.

Essential Readings:

1. Mabey, Salaman and Storey, *Strategic Human Resource Management*, Sage Publication.
2. Dreher Dougherty, *Human Resource Strategy*, TMH, 2005.

Suggested Readings:

1. C. R. Greer, *Strategic Human Resource Management,* Pearson Education.
2. TanujaAgarwala, *Strategic Human Resource Management*, Oxford University Press, 2008.

SM 640	**KNOWLEDGE MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Knowledge Management: Introduction, Scope, Techniques, Principles, Types, Process; Drivers of KM; Knowledge at the environmental and organizational level; Building knowledge organization: Cultural and Strategic Imperitives; Technology and KM; HR and KM; Cross Functional Areas and KM; Team structures and KM; Organizational Dimension and KM; Learning Organizations; Enabling organizational transition into a knowledge enterprise; Role of human resources in creating knowledge organizations; Implementing KM at the enterprise level.

Essential Readings:

1. Donald Hislop, *Knowledge Management in Organizations: A Critical Introduction*, Oxford University Press, 2007.
2. Ganesh Natarajan and SandhyaShekhar, *Knowledge Management*, TMH.

Suggested Readings:

1. Sue Brelade and Chris Harman, *A Practical Guide to Knowledge Management*, Viva Books Pvt. Ltd., 2006.
2. B. Rathan Reddy, *Knowledge Management*, HPH, 2007.

SM 641 MATERIALS MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Introduction to materials management; Developing MPS; Materials requirement planning: MRP process, Bill of materials; Capacity management: Capacity planning, Capacity requirement planning (CRP), Capacity available, Capacity required, Scheduling orders; Production activity control: load leveling, theory of constraints and drum-buffer rope; Purchasing: Selecting suppliers, Impact of materials requirements planning on purchasing; Aggregate materials management; Supply and demand patterns; Order quantities: Economic order quantity (EOQ), Variations in EOQ, Quantity discounts; Order quantity under uncertain demand and uncertain lead time; Lot sizing rules: Fixed order quantity (FOQ), Lot-for-Lot (LFL), Fixed period requirement (FPR), Periodic order quantity (POQ), Least unit cost (LUC), Least total cost (LTC), Part period balancing, Wagner-Whitin algorithm; Analysis of lot-sizing heuristics: Groff method, Silver meal method, Wagner-Whitin method, Freeland-Colley method; Vendor rating and source location; Negotiations in purchasing; Stores function and inventory management.

Essential Readings:
1. J R Tony Arnold, Stephen N Chapman, Lloyd M Clive, *Introduction to Materials Management*, Prentice Hall.
2. Gupta and Chitale, *Materials Management: Text & Cases*, PHI.

Suggested Readings:
1. Lee and Dobler, *Materials and Purchasing Management*, Mc-Grawhill.
2. Menon K. S., *Purchasing and Inventory Control*, Wheeler.

SM 642 RELIABILITY AND RISK MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Reliability; Enhanced Reliability; Hazard analysis; Data sources; The human connection; The computer connection; Risk analysis; Estimation of risk; Risk assessment; Risk assessment and public policy; Failure to danger Human reliability: quantitative and qualitative assessment, Human factors in system design, Outcomes and consequences, Ionizing radiation, Harm and risk, Quantitative risk analysis: limitations and uses, Risk assessment and cognition: thinking about risk, Risk assessment in occupational health and safety, Risk management and communication: decision-making and risk, Safety management principles and practice.

Essential Readings:
1. Peter J Edwards and Paul A Bowen, *Risk Management in Project Organisations*, UNSW Press.
2. Sue Cox and Robin Tait, *Safety, Reliability and Risk Management: An Integrated Approach,* Elsevier Science

Suggested Readings:
1. Kit Sadgrove, *The Complete Guide to Business Risk Management*, Grover Publishing Limited.
2. Evgueni D Solojentsev, *Scenario Logic and Probabilistic Management of Risk in Business and Engineering*, Springer.

SM 643 TOTAL QUALITY MANAGEMENT 3 Credits [3-0-0]

Course Contents:
Introduction: Meaning & evolution of quality concepts, views of quality issues, cost of quality; TQM concepts and key elements; Scope of TQM; Japanese approach to TQM; Concept of Kaizen and Continuous Improvement; Quality Management System and ISO-9000; Tools and techniques for process improvement, Peoples Issues in TQM; Leadership Issues, Total Employee Involvement, 5S Concept; Quality Circles and its Relevance; TQM implementation and improvement initiatives;

Quality system standards; Total productive maintenance; Six sigma approach; Criteria for business performance excellence (MBNQA and EFQM).

Essential Readings:

1. James R. Evans and William M. Lindsay, The Management and Control of Quality, Thomson Learning.
2. Dale H. Besterfield, Carol Besterfield, Glen H. Besterfield and Marry Besterfield, Total Quality Management, PHI.

Suggested Readings:

1. Frank M, Gryna, Richard C. H. Chua, Joseph A. Defeo, *Juran's Quality Planning & Analysis for Enterprise Quality*, Tata McGraw Hill.
2. Gittow, H, Openheim A and Oppenheim R., *Quality Management*, McGraw Hill.

SM 644	**SUPPLY NETWORK MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Logistic management: functions and basic issues, Indian scenario; Areas of logistical decision making, Design of transportation network; Warehousing; Introduction to e-commerce; Performance measurement of Supply Chain Management. Supply Chain Management: Genesis, definitions and basic structure; Purchasing in SCM; Logistics in SCM; Manufacturing in SCM; Sales and Marketing in SCM; Planning demand and supply; Value chain concept; Relevant issues in supply chain; Strategy formulation; Product type- Supply chain matrix; Strategic sourcing and management of supply chain; Inventory in supply chain; Suppliers evaluation and development; Outsourcing strategy; Measuring performance in supply chain.

Essential Readings:

1. R.P.Mohanty and S.G.Desmukh, *Supply Chain Management Theories & Practice*, Biztantra
2. Janat Shah, *Supply Chain Management Text and Cases*, Pearson Education.

Suggested Readings:

1. D. K. Agarwal, *Text Book of Logistics and Supply Chain Management*, Macmillan.
2. Ballou, *Business Logistics/ Supply Chain Management*, Pearson Education.

SM 645	**BUSINESS PROCESS TRANSFORMATION**	**3 Credits [3-0-0]**

Course Contents:
Overview of Process Innovation, Process and Information, Overview of Process Change, Creating a Process Vision, Understanding and Improving Existing Process, Designing and Implementing the New Process and organization, Implementation of Innovative Business Processes, Process Innovation with Information Technology, Innovation Strategies for Typical Process Types, Customer Operations, Management Processes,

Essential Readings:

1. Thomas H Davenport, *Process Innovation Reengineering Work Through Information Technology*, Harvard Business School Press.
2. Grover Varun, M Lynne Markus, *Business Process Transformation*, M.E. Sharpe.

Suggested Readings:

1. Varun Grover, William J Ketingger, *Business Process Change, Reengineering Concepts, Methods and Technologies*, Idea group.
2. Michael Hammer & James Champy, *Reengineering the Corporation: A Manifesto for Business Revolution*, Harper Collins Business Essentials.

SM 646 OPERATIONS STRATEGY 3 Credits [3-0-0]

Course Contents:
Concept and principles of operation strategy; Introduction to decision categories and role of technology; Capacity and Facilities strategies; Supplier management; Logistics system and Supply chain; Organization and Human resources; Workforce Teams; Competing on cost, Competing on quality and Competing on time; Outsourcing strategies; Strategic services operations and Services supply chain.

Essential Readings:
1. Slack and Lewis, *Operations Strategy*, Prentice Hall.
2. Van Mieghen, *Operations Strategy: Principles and Practice*, Dynamic Idea.

Suggested Readings:
1. David A. Garvin, *Operations Strategy: Text and Cases*, Prentice Hall – Gale.
2. David Walters, *Operations Strategy*, Macmillan.

SM 647 PROJECT PLANNING, SCHEDULING AND MONITORING 3 Credits [3-0-0]

Course Contents:
Introduction to project Planning and Scheduling, Project Ideas: Generation Tools for identifying investment opportunities, Project Screening: Project Rating Index, Purpose of Planning, Concepts & Tools in Planning & Scheduling, Strategic planning, Operational Control planning, Steps in Project planning and Scheduling, CPM/PERT, planning process overview, Monitoring Environment,

Essential Reading:
1. Gregory T Haugan, *Project Planning & Scheduling*, Management Concepts.
2. P. Chandra, *Projects: Planning, Analysis, Selection, Financing, Implementation, and Review*, TMH

Suggested Reading:
1. Jack Gido, *An Introduction to project Planning*, Industrial Press.
2. Maylor, H., *Project Management*, Pitman Publications.

SM 648 DECISION MODELING AND SIMULATION 3 Credits [3-0-0]

Course Contents:
Integer programming and its application in managerial decision-making; Solution methodologies; Zero-one programming; Dynamic programming: Principle of optimality, Concepts of state and stage, Solution of discrete and continuous dynamic programming problems, Introduction to Markov process. Queuing Theory: Definitions & Classification, Birth & Death process, Single & Multiple server queues, Application of queuing analysis in decision making. Discrete-event Simulation: Generation of random numbers, Simulation of queuing, Inventory and Maintenance Systems, Validation of Simulation Models, Concept of Multi Criteria decision making. Stochastic Decision Making Models: Decision Tree, Introduction to Stochastic Programming Model.

Essential Readings:
1. Stephen G. Powell and Kenneth R. Baker, *The Art of Modeling with Spreadsheets*, John Wiley & Sons.
2. David R. Anderson, Dennis J. Sweeney and Thomas A. Williams, *Introduction toManagement Science*, Thomson Learning.

Suggested Readings:
1. Render, *Quantitative Analysis for Management*, PHI.
2. Anderson, Sweeney and Williams, *Quantitative Methods for Business*, Thomson Learning.

SM 651 STRATEGIC INFORMATION SYSTEM 3 Credits [3-0-0]

Course Contents:
Introduction and Overview: From Human Decision making to DSS, DSS Architecture, Decision Modeling and Analysis, Decision Support Developments, Executive Information Systems, Data Warehousing, Access, Analysis, Mining and Visualization; Group Decision Support Systems: Goals of Group Decision Support Systems, Group versus Individual Activities, Types of Group DSS, Negotiation Support Systems; Intelligent Decision Support Systems: Knowledge-based Decision Support Systems, Knowledge Acquisition and Validation, Knowledge Representation, Inference Techniques; Decision Making Under Uncertainty: Understanding Risk in Making Decisions, Managerial Risk Taking and Organizational Decision Making, Modeling Uncertainty; Advanced Techniques: Neural Network Fundamentals, Neural Network Architecture, Simple Neural Network Applications, Genetic Algorithm, Fuzzy Logic, Fuzzy Sets in Decision Making, Intelligent Software Agents and Creativity; System Integration and Future of DSS.

Essential Readings:
1. Turban and Aronson, *Decision Support Systems and Intelligent Systems*, Pearson Education.
2. George M. Marakas, *Decision Support Systems*: In the 21st Century, PHI.

Suggested Readings:
1. V S Janakiraman, K Sarukesi, *Decision Support Systems*, PHI.
2. B Ravindranath, *Decision Support Systems and Data Warehouses*, New Age.

SM 652 DATABASE MANAGEMENT SYSTEM 3 Credits [3-0-0]

Course Contents:
Concepts of DBMS and RDBMS: Mathematical Definition of a relation, Candidate Key and Primary Key of a Relation, Foreign Key; Relational Operators, Insertion, Deletion, Update operations of a relation, Attribute, domain and their Implementation; Data Models: Object based logical models, Record based Logical Model, Network model, Hierarchical Model; Data Abstraction: Physical Level, Logical Level, View level; Data Independence; Normalization: Introduction, 1NF, 2NF, 3NF, BCNF, SQL: Codd's Rules; PL/SQL: Procedure & Function; Trigger; Components of Form Designer using windows; controls and Properties; Building Sample Application; Report Designer: Building the project Reports; Database Administration with Oracle: Storage structure and Access method definition; Physical organization modification, Granting of authorization for data access, Integrity constraint specification, Role of DBA; Security mechanisms: Need for security, Physical and Logical security, Design Issues, Maintenance Issues, Operating system Issues and Availability, Accountability, Integrity; Back-up and recovery mechanisms: Logical Backups, Physical Backups, Online backups, rollback, standby database, Recovery manager, Parallel Recovery.

Essential Readings:
1. Kahate, *An Introduction to Database Management Systems*, Pearson Education.
2. R. Ramakrishna, *Database Management System*, TMH.

Suggested Readings:
1. Gerald, *Database Management System*, TMH.
2. Rob, *Database Systems: Design Implementation & Management*, Cengage/Thomson

SM 653 E-COMMERCE 3 Credits [3-0-0]

Course Contents:
Introduction to e-commerce – Traditional Commerce vis-à-vis e-commerce; Internet & WWW; Web portals; Economic forces & e-commerce; Value chains in e-commerce; Infrastructure for e-commerce; Web based tools for e-commerce: E-commerce tools and Software; The environment of e-commerce: Principals of e-commerce (B2B, B2C); Security Issues for e-commerce; Implementing

security for e-commerce; Electronic payment system; Electronic assisted strategies for Marketing and Sales promotion; Systems and Strategies for purchasing and support activities; Strategies for web auctions, Virtual Shopping; International, Legal, Ethical and Tax issues; Business plan for implementing e-commerce

Essential Readings:
1. Kenneth C. Laudon and Carol G. Traver, *Electronic Commerce*, Pearson Education.
2. P. Gary Schneider and James T. Perry, *Electronic Commerce*, Thomson Learning Press.

Suggested Readings:
1. David Whitely, *e-Commerce*, McGraw Hill.
2. Joseph, *E-commerce – An Indian Perspective*, PHI.

SM 654	**SOFTWARE PROJECT AND QUALITY MANAGEMENT**	**3 Credits [3-0-0]**

Course Contents:
Introduction: The software Engineering discipline-evolution and impact; emergence of software engineering; notable changes in software development practices. Software Life Cycle Models and Waterfall Model; Classical Waterfall Model; Other SDLC Models; Software Project Management; Project Estimation Techniques; COCOMO: A Heuristic Estimation Technique; Software Configuration Management; Software Design; Function-Oriented Software Design; Object-Oriented Software Design; Software Testing; Software Reliability and Quality Management; Computer Aided Software Engineering; Software Maintenance and Reuse.

Essential Readings:
1. Roger S Pressman, *Software Engineering: A Practitioner's Approach*, McGraw Hill International.
2. Rajib Mall, *Fundamentals of Software Engineering*, PHI.

Suggested Readings:
1. Jessica Keyes, *Software Engineering Handbook*, Boca Raton.
2. Kan Stephen H, *Metrics and Models in Software Engineering*, Pearson Education.

SM 655	**ENTERPRISE RESOURCE PLANNING**	**3 Credits [3-0-0]**

Course Contents:
Business Functions, Processes and Data Requirements; Development of ERP Systems; Marketing Information Systems and Sales Order Process; Production and Supply Chain Management; Management Information System; Accounting in ERP Systems; Human Resource Processes with ERP; Process Modeling, Process Improvement, and ERP Implementation.

Essential Readings:
1. Ptak, Carol A. and Eli Schargenheim, *ERP*, St. Lucie Press, NY.
2. F.R. Jacubs, *Why ERP? A Premier on SAP Implementation*, TMH.

Suggested Readings:
1. Monk, *Concept in Enterprise Resource Planning*, Cengage/Thomson.
2. Alexis Leon, *ERP*, TMH.

SM 656	**IT STRATEGY**	**3 Credits [3-0-0]**

Course Contents:
Introduction, Challenges with information as a resource, IT Decisions & Principles ; Information Intensity Matrix, Architecture, Infrastructure, Business Application Needs ; Investment and Prioritization, IS Strategy Formulation, Assessing Business Needs ; Top-Down Approaches, Bottom-

Up Approaches, Inside Out Approaches, IS Strategy Formulation Process, IT Governance, Linking Governance to Environments, IT Environments and link to governance structures, Mechanisms to implement governance ; Decision Making Structures, Alignment processes (SLAs, chargeback), COBIT/ITIL Frameworks

Essential Readings:

1. Peter Weill and Jeanne W. Ross*, IT Governance, How Top Performers Manage IT Decision Rights for superior results*; HBS Press, 2004.
2. Michael J Earl, *Management Strategies for Information Technology*, Prentice Hall.

Suggested Readings:

1. ParagKulkarni and PradeepChandle, *IT Strategy for Business*, Oxford Univeristy
2. A Brown, *Creating a Business Based IT Strategy*, Kluwer.

SM 657	**SYSTEM ANALYSIS AND DESIGN**	**3 Credits [3-0-0]**

Course Contents:
Introduction to Systems and System Analysis; Information System Components; Business Information Systems; Organizational Structure; Responsibilities of System Analyst; Steps in System Analysis; System Development Life Cycle (SDLC) Models: Waterfall Model, Spiral Model; Tools of System Analysis and Design: Flowcharts, Pseudo-codes; Data Flow Diagram (DFD); Entity-Relationship diagram; Systems planning; System Analysis; Systems Design; System Implementation; Systems Operation & Support.

Essential Readings:

1. Charles S Wasson, *System Analysis, Design and Development Concepts, Principles, and Practices*, Wiley-Interscience.
2. Gary B Shelly, Harry J Rosenblatt, *Systems Analysis and Design*, Cenegage.

Suggested Reading:

1. V. Rajaraman, *Analysis and Design of Information Systems*, PHI.
2. Cashman, Shelly and Rosenbelt, *System Analysis and Design*, Thomson Learning.

SM 658	**SOFTWARE ENGINEERING**	**3 Credits [3-0-0]**

Course Contents:
Software Life Cycle Models, Managing software projects, Project management concepts, Software process and Project metrics, Software Project Planning, Risk Analysis and Management, Project scheduling and tracking, Software Quality Assurance, Software Configuration Management. Conventional methods for software engineering, System Engineering, Requirements Analysis and Specifications, Analysis Modeling, Design Concepts and principles, Architectural design, User Interface Design, Component level Design, Software Testing Techniques, Software testing Strategies, Software Reliability, Technical metrics for software, CASE tools, Software Maintenance, Software Reusability. Object oriented software engineering: Object Oriented Concepts and principles, Object Oriented analysis, Object Oriented Design, and Object Oriented testing, Technical metrics for Object Oriented Systems.

Essential Readings:

1. R. S. Pressman, *Software Engineering A Practitioner's Approach*, McGraw Hill Publications, 2006.
2. R. Mall, *Fundamentals of Software Engineering*, Prentice Hall of India, 2nd Ed, 2006.

Suggested Readings:

1. I Sommerville*, Software Engineering*, Pearson Education, Asia, 2006.
2. P.Jalote, *An Integrated Approach to Software Engineering*, Narosa, 2006.

National Institute of Technology, Rourkela

Kantajhar, Rourkela-769008

Phone: 0661-2462031

Fax: 0661-2462022

email:ar-acad@nitrkl.ac.in

www.nitrkl.ac.in