Joint M. Sc. - Ph. D.
Curriculum and Syllabi

M.Sc. – Ph.D. Course Structure:
School of Basic Sciences

Joint M.Sc. - Ph.D. Programme (Chemistry, Mathematics and Physics)

School of Basic Sciences

Admission Criteria:

Joint M.Sc. - Ph.D. Programme (Basic Sciences)

Joint M.Sc. - Ph.D.	Previous Degree	Essential Requisite
Chemistry	Bachelor's degree with Chemistry as a subject for three years/six semesters and Mathematics at (10+2) level.	At least 55%(50%) aggregate marks* for General/OBC (SC, ST and PD) category candidates in the qualifying degree#
Mathematics	Bachelor's degree with Mathematics / Statistics as a subject for at least two years/ four semesters.	At least 55%(50%) aggregate marks* for General/OBC (SC, ST and PD) category candidates in the qualifying degree#
Physics	Bachelor's degree with Physics as a subject for at least two years/four semesters and Mathematics for at least one year/two semesters.	At least 55%(50%) aggregate marks* for General/OBC (SC, ST and PD) category candidates in the qualifying degree#

* Taking into account all subjects, including languages and subsidiaries, all years combined

\# For candidates with letter grades/CGPA (instead of percentage of marks), the equivalence in percentage of marks will be decided by the institute.

Distribution of Credits (Mathematics):

Details	Sem. I	Sem. II	Sem. III	Sem. IV	Total Credits
Core Subjects	18	17	10	7	52
Elective Subjects	--	--	7/14	7/14	14
Lab. Subjects	2	2	2	--	6
Seminar	2	2	--	--	4
Research Review Paper	--	--	--	[4]	[4]
Project	--	--	10	16	26
Total Credits	**22**	**21**	**29**	**30**	**102**

[4] : Elective IV/Research Review Paper (4 credits are included in the Elective Subjects)

Distribution of Credits (Chemistry):

Details	Sem. I	Sem. II	Sem. III	Sem. IV	Total Credits
Core Subjects	14	19	3	--	36
Elective Subjects	--	--	9/15	6/15	15
Lab. Subjects	8	8	--	--	16
Seminar	2	--	2	--	4
Research Review Paper	--	--	--	[3]	[3]
Project	--	--	10	16	26
Total Credits	**24**	**27**	**24**	**22**	**97**

[3] : Elective IV/Research Review Paper (3 credits are included in the Elective Subjects)

Distribution of Credits (Physics):

Details	Sem. I	Sem. II	Sem. III	Sem. IV	Total Credits
Core Subjects	20	16	6	--	42
Elective Subjects	--	--	6/12	6/12	12
Lab. Subjects	6	6	--	--	12
Seminar	--	2	2	--	4
Research Review Paper	--	--	--	[3]	[3]
Project	--	--	10	16	26
Total Credits	**26**	**24**	**24**	**22**	**96**

[3] : Elective IV/Research Review Paper (3 credits are included in the Elective Subjects)

Selection: As per Institute norms

Opting for Ph.D. Programme: As per Institute norms

MATHEMATICS

Credit Structure

		Recommended	Actual
1	**Course Credits**		
	Total Credit Requirement:	**94-102**	**102**
	Theory	56-66	66
	Laboratories	6-10	6
	Seminars	4	4
	Thesis	26	26
2	**Theory subjects**		
	Total number of theory subjects (cores + electives)	16-20	20
	Number of core subjects (%)	60-80%	80%
	Number of elective subjects (%)	40-20%	20%
	Total credit of theory subjects	56-66	66
3	**Laboratory subjects**	6-10	6
4	**Seminars**	2+2	2+2
5	**Thesis (Part I and Part II)**	10+16	10 +16

Semester-wise course details

Semester	Course Name	L-T-P	Credits
I	Linear Algebra	3-0-0	3
	Real Analysis	3-1-0	4
	Discrete Mathematics	3-1-0	4
	Probability and Statistics	3-1-0	4
	Computer Programming and Data Structures	3-0-0	3
	Computer Programming Lab	0-0-3	2
	Seminar I	0-0-3	2
	Semester Total Credits		**22**
II	Algebra	3-1-0	4
	Complex Analysis	3-0-0	3
	Topology	3-1-0	4
	Ordinary Differential Equations	3-0-0	3
	Numerical Analysis	3-0-0	3
	Numerical Analysis Lab	0-0-3	2
	Seminar II	0-0-3	2
	Semester Total Credits		**21**
III	Functional Analysis	3-1-0	4
	Continuum Mechanics	3-0-0	3
	Optimization Techniques	3-0-0	3
	Optimization Techniques Lab	0-0-3	2
	Elective-I	3-0-0	3
	Elective-II	3-1-0	4
	Project Part I	0-0-15	10
	Semester Total Credits		**29**
IV	Measure Theory and Integration	3-1-0	4
	Partial Differential Equations	3-0-0	3
	Elective-III	3-0-0	3
	Elective-IV/ Research Review Paper	3-1-0	4
	Project Part II	0-0-24	16
	Semester Total Credits		**30**
	Total Credits		**102**

Sr. No.	Course Name	Nature of course	Course code	L-T-P (Credit)	Page
Compulsory Courses					
SEMESTER – I					
1	Linear Algebra	Core	MA4001	3-0-0(3)	
2	Real Analysis	Core	MA4002	3-1-0(4)	
3	Discrete Mathematics	Core	MA4003	3-1-0(4)	
4	Probability and Statistics	Core	MA4004	3-1-0 (4)	
5	Computer Programming and Data Structures	Core	MA4005	3-0-0(3)	
6	Computer Programming Lab	Core	MA4101	0-0-3(2)	
7	Seminar I	Core	MA4401	0-0-3 (2)	
	SEMESTER – II				
8	Algebra	Core	MA4006	3-1-0(4)	
9	Complex Analysis	Core	MA4007	3-0-0(3)	
10	Topology	Core	MA4008	3-1-0(4)	
11	Ordinary Differential Equations	Core	MA4009	3-0-0 (3)	
12	Numerical Analysis	Core	MA4010	3-0-0 (3)	
13	Numerical Analysis Lab	Core	MA4102	0-0-3 (2)	
14	Seminar II	Core	MA4402	0-0-3 (2)	
SEMESTER - III					
15	Functional Analysis	Core	MA5001	3-1-0 (4)	
16	Continuum Mechanics	Core	MA5002	3-0-0 (3)	
17	Optimization Techniques	Core	MA5003	3-0-0(3)	
18	Optimization Techniques Lab	Core	MA5101	0-0-3(2)	
19	Elective-I	Elective		3-0-0 (3)	
20	Elective-II	Elective		3-1-0 (4)	
21	Project Part-I		MA5501	0-0-15 (10)	
SEMESTER - IV					
22	Measure Theory and Integration	Core	MA5004	3-1-0(4)	
23	Partial Differential Equations	Core	MA5005	3-0-0(3)	
24	Elective-III	Elective		3-0-0 (3)	
25	Elective-IV/ Research Review Paper	Elective	/ MA6201	3-1-0 (4)	
26	Project Part-II		MA5502	0-0-24 (16)	

COURSE CURRICULUM

List of subjects to be floated under Electives I & III

List of subjects to be floated under Electives I & III					
i	Number Theory		MA5006	3-0-0(3)	
ii	Advanced Matrix Theory		MA5007	3-0-0(3)	
iii	Numerical Linear Algebra		MA5008	3-0-0(3)	
iv	Lie Groups and Lie Algebra		MA5009	3-0-0(3)	
v	Mathematical Logic		MA5010	3-0-0(3)	
vi	Algebraic Topology		MA5011	3-0-0(3)	
vii	Differential Geometry		MA5012	3-0-0(3)	
viii	Fluid Dynamics		MA5013	3-0-0(3)	
ix	Functions of Several Variables		MA5014	3-0-0(3)	
List of subjects to be floated under Electives II & IV					
x	Numerical Solution of Ordinary and Partial Differential Equations		MA6001	3-1-0(4)	
xi	Non-Negative Matrix Theory		MA6002	4-0-0(4)	
xii	Advanced Complex Analysis		MA6003	3-1-0(4)	
xiii	Fractals		MA6004	3-1-0(4)	
xiv	Computational Topology		MA6005	3-1-0(4)	
xv	Integral Equations and Variational Methods		MA6006	3-1-0(4)	
xvi	Soft Computing		MA6007	3-1-0(4)	
xvii	Neural Network		MA6008	3-1-0(4)	
xviii	Queuing Theory in Computer Science		MA6009	3-1-0(4)	
xix	Queueing, Inventory and Reliability		MA6010	3-1-0(4)	
xx	Time Series Analysis and Forecasting		MA6011	3-1-0(4)	
xxi	Mathematical Theory of Elasticity		MA6012	3-1-0(4)	
xxii	Theory of groups and its application to physical problems		MA4013	3-1-0(4)	
xxiii	Computational Fluid Dynamics		MA6014	3-1-0(4)	
xxiv	Algebraic Graph Theory		MA6015	3-1-0(4)	
xxv	Complex Dynamics		MA6016	3-1-0(4)	
xxvi	Ergodic Theory and Dynamical System		MA6017	3-1-0(4)	
xxvii	Abstract Harmonic Analysis		MA6018	3-1-0(4)	
xxviii	Fourier Analysis		MA6019	3-1-0(4)	
xxix	Nonlinear Functional Analysis		MA6020	3-1-0(4)	
xxx	Finite Element Methods		MA6021	3-1-0(4)	
xxxi	Advanced Techniques in Operation Research		MA6022	3-1-0(4)	
xxxii	Convex Analysis and Optimization		MA6023	3-1-0(4)	
xxxiii	Stochastic Processes Simulation		MA6024	3-1-0(4)	
xxxiv	Mathematical Theory of Control		MA6025	3-1-0(4)	

xxxv	Mathematical Biology		MA6027	3-1-0(4)	

List of Electives

Detail Syllabus

Semester-I
Total Credits = 22

1. Linear Algebra (MA4001):

3-0-0: 3 Credits **Prerequisite: Nil**

Vector spaces over fields, subspaces, bases and dimension; Systems of linear equations, matrices, rank, Gaussian elimination; Linear transformations, representation of linear transformations by matrices, rank-nullity theorem, duality and transpose; Determinants, Laplace expansions, cofactors, adjoint, Cramer's Rule; Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonalization, rational canonical form, Jordan canonical form; Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators; Rayleigh quotient, Min-Max Principle. Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness.

Texts:
1. S. Axler, Linear Algebra Done Right, 2nd edition, UTM, Springer, 1997.
2. M. Artin, Algebra, Prentice Hall of India,1994.

References:
1.M. Artin, Algebra, Prentice Hall of India,1994.
2.K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. Prentice-Hall of India, 1991.
3.S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag, NewYork, 1989.
4.H.E. Rose, Linear Algebra, Birkhauser, 2002.
5.G. Strang, Linear Algebra and its applications. 4^{th} edition

2. Real Analysis (MA4002):

3-1-0: 4 Credits **Prerequisite: Nil**

Real number system and set theory: Completeness property, Archimedian property, Denseness of rationals and irrationals, Countable and uncountable, Cardinality, Zorn's lemma, Axiom of choice. Metric spaces: Open sets, Closed sets, Continuous functions, Completeness, Cantor intersection theorem, Baire category theorem, Compactness, Totally boundedness, Finite intersection property. 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, Weierstrass approximation theorem.

Texts:
1. T. Apostol, Mathematical Analysis, 2nd ed., Narosa Publishers, 2002.
2. W. Rudin, Principles of Mathematical Analysis, 3rd ed., McGraw-Hill, 1983.

References:
1. E. Hewitt and K. Stomberg, Real and Abstract Analysis: A Modern Treatment of the Theory of Functions of a Real Variable, Springer, 1975.

2. K. Ross, Elementary Analysis: The Theory of Calculus, Springer Int. Edition, 2004.
3. H. L. Royden, Real Analysis, 3rd edition, Prentice Hall of India, 1995.
4. Terence Tao, Analysis-I and II, Second edition, Hindustan Book Agency, 2009.

3. Discrete Mathematics (MA4003):

3-1-0: 4 Credits
Prerequisite: Nil

Set theory: sets, relations, functions, countability; Logic: formulae, interpretations, methods of proof, soundness and completeness in propositional and predicate logic; Number theory: division algorithm, Euclid's algorithm, fundamental theorem of arithmetic, Chinese remainder theorem, special numbers like Catalan, Fibonacci, harmonic and Stirling; Combinatorics: permutations, combinations, pigeonhole principle, inclusion and exclusion principle, partitions, recurrence relations, generating functions; Graph Theory: paths, connectivity, subgraphs, isomorphism, trees, complete graphs, bipartite graphs, matchings, colourability, planarity, digraphs, Eulerian cycle and Hamiltonian cycle, adjacency and incidence matrices.

Texts:

1. K. H. Rosen, Discrete Mathematics & its Applications, 6th Ed., Tata McGraw-Hill, 2007.
2. V. K. Balakrishnan, Introductory Discrete Mathematics, Dover, 1996.

References:

1. C. L. Liu, Elements of Discrete Mathematics, 2nd Ed., Tata McGraw-Hill, 2000.
2. R. P. Grimaldi, Discrete and Combinatorial Mathematics, Pearson Education, 2002.
3. R. C. Penner, Discrete Mathematics: Proof Techniques and Mathematical Structures, World Scientific, 1999.
4. R. L. Graham, D. E. Knuth, and O. Patashnik, Concrete Mathematics, 2nd Ed., Addison-Wesley, 1994.
5. J. L. Hein, Discrete Structures, Logic, and Computability, 3rd Ed., Jones and Bartlett, 2010.
6. D. M. Burton: Elementary Number Theory. McGraw Hill, 2002.
7. N. Deo, Graph Theory, Prentice Hall of India, 1974.

4. Probability and Statistics (MA4004):

3-1-0: 4 Credits
Prerequisite: Nil

Probability:-Axiomatic definition, Properties. Conditional probability, Bayes rule and independence of events. Random variables, Distribution function, Probability mass and density functions, Expectation, Moments, Moment generating function, Chebyshev’s inequality. Special distributions: Bernoulli, Binomial, Geometric, Negative Binomial, Hypergeometric, Poisson, Uniform, Exponential, Gamma, Normal, Joint distributions, Marginal and conditional distributions, Moments, Independence of random variables, Covariance, Correlation, Functions of random variables, Weak law of large numbers, P. Levy’s central limit theorem (i.i.d. finite variance case), Normal and Poisson approximations to binomial.

Statistics:-Introduction: Population, Sample, Parameters. Point Estimation: Method of moments, MLE, Unbiasedness, Consistency, Comparing two estimators (Relative MSE). Confidence interval estimation for mean, difference of means, variance, proportions, Sample size problem, Test of Hypotheses:-N-P Lemma, Examples of MP and UMP tests, p-value, Likelihood ratio test, Tests for means, variance, Two sample problems, Test for proportions, Relation between confidence intervals and tests of hypotheses, Chi-square goodness of fit tests, Contingency tables, SPRT, Regression Problem:- Scatter diagram, Simple linear regression, Least squares estimation, Tests for slope and correlation, Prediction problem, Graphical residual analysis, Q-Q plot to test for normality of residuals, Multiple regression, Analysis of Variance: Completely randomized design and randomized block design, Quality Control: Shewhart control charts and Cusum charts.

Texts:

1. Geoffrey R. Grimmett, David R. Stirzaker, Probability and Random Processes, Oxford University Press, USA; 3 edition, 2001.
2. Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, Wiley, 2006.
3. Miller & Freund's Probability and Statistics for Engineers, 7th Edition, Pearson-Prentice Hall, 2005

References:

1. Sheldon M. Ross, A First Course in Probability, Prentice- Hall, Sixth Edition, 2001.
2. Harold J. Larson: Introduction to Probability Theory and Statistical Inference. Wiley 1982.
3. V. K. Rohatgi: An Introduction to Probability Theory and Mathematical Statistics. John Wiley & Sons 1976.
4. W. Feller, Introductopn to Probability Theory and its applications, Vol I, Wiley, 1968.
5. A. M. Gun, M. K. Gupta, and B. Das Gupta: Fundamentals of Statistics.
6. A. M. Gun, M. K. Gupta, and B. Dasgupta: Outline of Statistics.

5. Computer Programming and Data Structures (MA4005):

3-0-0: 3 Credits
Prerequisite: Nil

Introduction - the von Neumann architecture, machine language, assembly language, high level programming languages, compiler, interpreter, loader, linker, text editors, operating systems, flowchart; Basic features of programming (Using C) - data types, variables, operators, expressions, statements, control structures, functions; Advance programming features - arrays and pointers, recursion, records (structures), memory management, files, input/output, standard library functions, programming tools, testing and debugging; Fundamental operations on data - insert, delete, search, traverse and modify.

Fundamental data structures - arrays, stacks, queues, linked lists; Trees, Binary trees, Searching and sorting - linear search, binary search, insertion-sort, bubble-sort, selection-sort; Introduction to object oriented programming.

Texts:

1. E. Balagurusamy, Programming in ANSI C., Tata Mc graw Hill, 2004.
2. A. Kelly and I. Pohl, A Book on C, 4th Ed., Pearson Education, 1999.

References:

1. H. Schildt, C: The Complete Reference, 4th Ed., Tata Mc graw Hill, 2000.
2. B. Kernighan and D. Ritchie, The C Programming Language, 2nd Ed., Prentice Hall of India, 1988.
3. B. Gottfried and J. Chhabra, Programming With C, Tata Mc graw Hill, 2005.
4. Data Structures, Schum Series, Tata Mcgraw Hill, 1986.

6. Computer Programming and Data Structures Lab (MA4101):

0-0-3: 2 Credits
Prerequisite: Nil

Programming laboratory will be set in consonance with the material covered in lectures of the course "Computer Programming and Data Structures". This will include assignments in a programming language like C and C++ in GNU Linux environment.

Texts:

1. E. Balagurusamy, Programming in ANSI C., Tata Mc graw Hill, 2004.

2. Kelly and I. Pohl, A Book on C, 4th Ed., Pearson Education, 1999.

References:

1. H. Schildt, C: The Complete Reference, 4th Ed., Tata Mc graw Hill, 2000.
2. Kernighan and D. Ritchie, The C Programming Language, 2nd Ed., Prentice Hall of India, 1988.
3. Gottfried and J. Chhabra, Programming With C, Tata Mc graw Hill, 2005.
4. Data Structures, Schum Series, Tata Mcgraw Hill, 1986.

7. Seminar I (MA4401):

0-0-3: 2 Credits

Literature survey on assigned topic and presentation.

Semester II
Total Credits = 21

8. Algebra (MA4006):

3-1-0: 4 Credits **Prerequisite: Linear Algebra**

Groups: Binary operation and its properties, Definition of a group, Examples and basic properties, Subgroups, Cyclic groups, Dihedral Groups, Permutation groups, Cayley's theorems. Coset of a subgroup, Lagrange's theorem, Order of a group, Normal subgroups, Quotient group, Homomorphisms, Kernel Image of a homomorphism, Isomorphism theorems, Direct product of groups, Group action on a set, Semi-direct product, Sylow' theorems, Structure of finite abelian groups.

Rings: Definition, Examples and basic properties. Zero divisors, Integral domains, Fields. Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems, Ring of polynomials. Prime, Irreducible elements and their properties, UFD, PID and Euclidean domains. Prime ideal, Maximal ideals, Prime avoidance theorem, Chinese remainder theorem.

Fields: Field of fractions, Gauss lemma, Fields, field extension, Galois theory.

Texts:

1. W. J. Gilbert. and W. K. Nicholson, Modern Algebra with Applications, 2nd Edition, Wiley, 2004.
2. D. Dummit and R. Foote, Abstract Algebra, Wiley, 2004

References:

1. Artin, Algebra, Prentice-Hall of India.
2. Herstein, Topics in Algebra, Wiley, 2008
3. Herstein, Abstract Algebra, 3nd edition, Wiley, 1996.
4. Gallian, Contemporary Abstract Algebra, 4th edition, Narosa, 2009.
5. J. B. Fraleigh, A First Course in Abstract Algebra, Pearson, 2003.

9. Complex Analysis (MA4007):

3-0-0: 3 Credits **Prerequisite: Real Analysis**

Polar representation and roots of complex numbers; Spherical representation of extended complex plane; Elementary properties and examples of analytic functions: The exponential, Trigonometric functions, Mobius transformations, Cross ratio; Complex integration: Power series representation of analytic functions, Zeros of analytic functions, Cauchy theorem and integral formula, The index of a point with respect to a closed curve, the general form of Cauchy's theorem; Open Mapping Theorem; Classification of singularities: Residue theorem and applications; The Argument Principle; The Maximum modulus Principle; Schwarz's lemma; Phragmen-Lindelof theorem.

Texts:

1. J.B. Conway, Functions of One Complex Variable, 2nd ed., Narosa, New Delhi, 1978.
2. L. V. Ahlfors, Complex Analysis, 3rd edition, McGraw Hill, 1979.

References

3. T.W. Gamelin, Complex Analysis, Springer International Edition, 2001.
4. R.V. Churchill and J.W. Brown, Complex Variables and Applications, 5th edition, McGraw Hill, 1990.
5. W. Rudin, Real and complex analysis. McGraw-Hill Book Co., 1987.

10. Topology (MA4008):

3-1-0: 4 Credits **Prerequisite: Real Analysis**

Topological spaces, Basis and subbasis, The order topology, Subspace topology, Closed sets. Countability axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, homomorphisms. The product topology, box topology, Metric topology, Quotient topology. Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One point compactification. Separation axioms, Uryshon's lemma, Uryshon's metrization theorem, Tietz extension theorem. The Tychonoff theorem, Completely regular spaces, Stone -Czech compactification.

Texts:

1.J.R. Munkres, Topology, 2nd Ed., Pearson Education (India), 2001.
2. H. L. Royden, Real Analysis, 3rd edition, Prentice Hall of India, 1995.

References:

1. M. A. Armstrong, Basic Topology, Springer(India), 2004.
2. J.L. Kelley, General Topology, Van Nostrand, Princeton, 1955.
3. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York,1963.

11. Ordinary Differential Equations (MA4009):

3-0-0: 3 Credits **Prerequisite: Nil**

Ordinary differential equations- first order equations, Picard's theorem (existence and uniqueness of solution to first order ordinary differential equation). Second order differential equations- second order linear differential equations with constant coefficients. Systems of first order differential equations, equations with regular singular points, stability of linear systems. Introduction to power series and power series solutions. Special ordinary differential equations arising in physics and some special functions (e.g. Bessel's functions, Legendre polynomials, Gamma functions) and their orthogonality. Oscillations - Sturm Liouville theory.

Texts:

1. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall, 1995.
2. G. F. Simmons, Differential Equations, Tata McGraw Hill, 2009

References:

1. P.F. Hsieh and Y. Sibuya, Basic Theory of Ordinary Differential Equations, UTX, Springer, 1999.
2. S. L. Ross, Differential Equations, 3rd Edition, Wiley, 1984.
3. Apostol, Calculus, Volume II, Chapters 7,8. John Wiley & Sons {ASIA} Pvt Ltd 2002.
4. S.G. Deo, V. Lakshmikantham and V. Raghavendra , Textbook of Ordinary Differential Equations, Tata- McGraw-Hill Publishing Co. Ltd., New Delhi,1997.
5. H. Rama Mohana Rao, Ordinary differential equations, Edward Arnold, Wiley, 1981.
6. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1990.

12. Numerical Analysis (MA4010):

3-0-0: 3 Credits **Prerequisite: Nil**

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, Solution for Stiff equations BVP: Finite difference method.

Texts:

1. S. D. Conte and Carl de Boor, Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edition, McGraw Hill, 1980.

References:

2. M. T. Heath, Scientific Computing: An Introductory Survey, McGraw Hill, 2002.
3. K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edition, John Wiley, 1989.
4. C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis, 5th edition, Addison Wesley, 1994

13. Numerical Analysis Lab (MA4102):

0-0-3: 2 Credits **Prerequisite: Nil**

Programming laboratory will be set in consonance with the material covered in lectures of the course "Numerical Analysis". This will include assignments in MATLAB.

Texts:

1. S. D. Conte and Carl de Boor, Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edition, McGraw Hill, 1980.

References:

1. M. T. Heath, Scientific Computing: An Introductory Survey, McGraw Hill, 2002.
2. K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edition, John Wiley, 1989.
3. C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis, 5th edition, Addison Wesley, 1994

14. Seminar II (MA4402):

0-0-3: 2 Credits

Literature survey on assigned topic and presentation.

Semester III
Total Credits = 29

15. Functional Analysis (MA5001):

3-1-0: 4 Credits **Prerequisite: Linear Algebra**

Fundamentals of normed linear spaces: Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Bounded linear maps on a normed linear spaces: Examples, linear map on finite dimensional spaces, finite dimensional spaces are isomorphic, operator norm. Hahn-Banach theorems: Geometric and extension forms and their applications. Three main theorems on Banach spaces: Uniform boundedness principle, divergence of Fourier series, closed graph theorem, projection, open mapping theorem, comparable norms. Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, Banach Alaoglu theorem, adjoint of an operator. Hilbert spaces : Inner product spaces, orthonormal set, Gram-Schmidt ortho-normalization, Bessel's inequality, Orthonormal basis, Separable Hilbert spaces. Projection and Riesz representation theorem: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem. Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self adjoint operators, compact operators, eigen values, eigen vectors, Banach algebras. Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators.

Texts:

1. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley &Sons, New York, 1978.
2. J. B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990.

References:

3. B.V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996.
4. A. Taylor and D. Lay, Introduction to Functional Analysis, Wiley, New York,1980.
5. W. Rudin, Functional analysis, McGraw-Hill (1991).
6. C. Goffman and G. Pedrick, A First Course in Functional Analysis, Prentice-Hall, 1974.

16. Continuum Mechanics (MA5002):

3-0-0: 3 Credits **Prerequisite: Nil**

Bodies, Deformation, Strain, Characterization of rigid deformations, Small Deformations, Characterization of infinitesimal rigid displacements, Motions, Smoothness Lemma, Types of motions, Rate of Stretching, Characterization of rigid motions, Transport Theorems, Volume, Isochoric motions, Spin, Circulation, Vorticity; Conservation of mass, linear and angular momentum, Centre of mass; Force, Theorem of Virtual Work, Stress, Cauchy's Theorem for Existence of stress, Balance of momentum Theorem of Power Expended; Constitutive Equations Ideal fluids, Properties of ideal fluid motion, Steady, plane, irrotational flow of an Ideal fluid, Blasius-Kutta-Joukowski Theorem, Elastic fluids; Change in Observer and Invariance of material response under change in observer, Newtonian fluids, Finite elasticity, Derivation of the linear theory of elasticity.

Texts:

1. M. E. Gurtin, An Introduction to Continuum Mechanics, Academic Press, 1981.
2. J. M. Spencer, Continuum Mechanics, Longman, 1980.

References:

1. Y. C. Fung, A First Course in Continuum Mechanics, 3rd edition, Prentice Hall, 1994.
2. L. E. Malvern, Introduction to the Mechanics of a Continuous Medium, Prentice-Hall, Upper Saddle River, NJ, 1969.
3. P. Chadwick, Continuum Mechanics: Concise Theory and Problems, Halsted, 1976.
4. P. Boresi and K. P. Chong, Elasticity in Engineering Mechanics, 2nd edition, Wiley, 2000.
5. R. W. Ogden, Non-Linear Elastic Deformations, Dover, 1997.

17. Optimization Techniques (MAA(5003):

3-0-0: 3 Credits **Prerequisite: Nil**

Mathematical foundations and basic definitions: concepts from linear algebra, geometry, and multivariable calculus. Linear optimization: formulation and geometrical ideas of linear programming problems, simplex method, revised simplex method, duality, sensitivity analysis, transportation and assignment problems. Nonlinear optimization: basic theory, method of Lagrange multipliers, Karush-Kuhn-Tucker theory, convex optimization. Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.

Texts:

1. M. C. Joshi, Optimization: Theory and Practice, Alpha Science International, Ltd; 1 edition, 2004.
2. D. G. Luenberger, Linear and Nonlinear Programming, 2nd Ed., Kluwer, 2003.

References:

1. S. S. Rao, Optimization: Theory and applications.
2. R. Fletcher, Practical Methods of Optimization, 2nd Ed., John Wiley, 1987.
3. M. S. Bazarra, J.J. Jarvis, and H.D. Sherali, Linear Programming and Network Flows, WSE, 2003.
4. U. Faigle, W. Kern, and G. Still, Algorithmic Principles of Mathematical Programming, Kluwe, 2002.
5. D.P. Bertsekas, Nonlinear Programming, 2nd Ed., Athena Scientific, 1999.
6. M. S. Bazarra, H.D. Sherali, and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley, WSE, 2004.
7. N. S. Kambo, Mathematical Programming Techniques, East West Press, 1997.
8. E.K.P. Chong and S.H. Zak, An Introduction to Optimization, 2nd Ed., Wiley, 2001 (WSE, 2004).

18. Optimization Techniques Lab (MA(5101)):

0-0-3: 2 Credits **Prerequisite: Nil**

Programming laboratory will be set in consonance with the material covered in lectures of the course "Optimization techniques". This will include assignments in MATLAB.

19. Elective I:

3-0-0: 3 Credits

One has to choose one course from the list of Electives I & III.

20. Elective II:

3-1-0: 4 Credits

One has to choose one course from the list of Electives II & IV.

21. Project Part I (MA5501):

0-0-15: 10 Credits

Project in one assigned topic under the guidance of one faculty.

Semester IV

Total Credits = 32

22. Measure Theory and Integration (MA5004):

3-1-0: 4 Credits **Prerequisite: Real Analysis**

Rings and Algebra, Monotone classes. Measures and outer measures. Measurable sets; Lebesgue Measure and its properties. Measurable functions and their properties, Convergence in measure. Integration: Sequence of integrable functions; Signed measures, Hahn and Jordan decomposition, Absolute continuity of measures, Radon-Nikodym theorem; Product measures, Fubini's theorem; Transformations and functions: The isomorphism theorem, L^p-spaces, Riesz-Fischer theorem; Riesz Representation theorem for L^2 spaces, Dual of L^p-spaces; Measure and Topology: Baire and Borel sets, Regularity of Baire and Borel measures, Construction of Borel measures, Positive and bounded linear functionals.

Texts:

1.H.L. Royden, Real Analysis, 3rd ed.,Macmillan, 1988.
2.G. De Barra, Measure Theory and Integration, New Age International, 1981.

References:

1. P.R. Halmos, Measure Theory, GraduateText in Mathematics, Springer-Verlag, 1979.
2. D. L. Cohn, Measure Theory, Springer, 1996.
3. Inder K. Rana, An Introduction to Measure and Integration (2nd ed.), Narosa Publishing House, New Delhi, 2004.

23. Partial Differential Equations (MA5005):

3-0-0: 3 Credits **Prerequisite: Ordinary Differential Equations**

Mathematical models leading to partial differential equations. First order quasi-linear equations. Nonlinear equations. Cauchy-Kowalewski's theorem (for first order). Classification of second order equations and method of characteristics. Riemann's method and applications. One dimensional wave equation and De'Alembert's method. Vibration of a membrane. Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions. BVPs for Laplace's and Poisson's equations. Maximum principle and applications. Green's functions and properties. Existence theorem by Perron's method. Heat equation, Maximum principle. Uniqueness of solutions via energy method. Uniqueness of solutions of IVPs for heat conduction equation. Green's function for heat equation. Finite difference method for the existence and computation of solution of heat conduction equation.

Texts:

1. I. N. Sneddon, Elements of Partial Differential Equations, McGraw Hill, 1957.
2. F. John, Partial Differential Equations, Springer Verlag, 1982.

References:

1. W. E. Willams, Partial Differential Equations, Oxford, 1980.
2. W.A. Strauss, Partial Differential Equations: An Introduction, John Wiley, 1992.
3. G. B. Folland, Introduction to partial differential equations. Princeton University Press,1995.
4. J. Rauch, Partial differential equations. Graduate Texts in Mathematics, 128. Springer-Verlag, 1991.

24. Elective III:

3-0-0: 3 Credits

One has to choose one course from the list of Electives I & III.

25. Elective IV/ Research Review Paper (MA6201):

3-1-0: 4 Credits

One has to choose one course from the list of Electives II & IV.

26. Project Part II (MA5502):

0-0-24: 16 Credits

Project Part I will be continued.

Detail syllabus of courses under Electives-I & III

(i) Number Theory (MA5006):

3-0-0: 3 Credits **Prerequisite: Nil**

Congruences: linear and polynomial congruences; prime numbers: counting primes, numbers of special forms, pseudo-primes and primality testing; factorization: factorization algorithms; arithmetic functions: multiplicative and additive functions, Euler's phi function, sum and number of divisors functions, the Mobius function and other important arithmetic functions, Dirichlet products; primitive roots and quadratic residues: primitive roots, index arithmetic, quadratic residues, modular square roots; Diophantine equations: linear Diophantine equations, Pythagorean triples, Fermat's last theorem, Tell's, Bachet's and Catalan's equations, sums of squares; Diophantine approximations: continued fractions, convergent, approximation theorems; quadratic fields: primes and unique factorization.

Texts:

1. Koshy, Elementary Number Theory with Applications, Academic Press.
2. D.M. Burton, Elementary Number Theory, 5th Ed. McGraw Hill.

References:

3. Kenneth H. Rosen, Elementary Number Theory (and it's applications), Fifth Edition, Pearson Addison- Wesley.
4. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to the Theory of Numbers, Wiley, 1991.
5. K. Chandrasekaran, An Introduction to Analytic Number Theory, Springer, 1968.
6. G.H. Hardy and E.M. Wright, An introduction to the Theory of Numbers, 5th Ed. Oxford University Press.

(ii) Advanced Matrix Theory (MA5007):

3-0-0: 3 Credits **Prerequisite: Linear Algebra**

Eigenvalues, eigenvectors and similarity, Unitary equivalence and normal matrices, Schur's theorem, Spectral theorems for normal and Hermitian matrices; Jordan canonical form, Application of Jordan canonical form, Minimal polynomial, Companion matrices, Functions of matrices; Variational characterizations of eigenvalues of Hermitian matrices, Rayleigh-Ritz theorem, Courant-Fischer theorem, Weyl theorem, Cauchy interlacing theorem, Inertia and congruence, Sylvester's law of inertia; Matrix norms, Location and perturbation of eigenvalues Gerschgorin disk theorem; Positive semidefiniteness, Singular value decomposition, Polar decomposition, Schur and Kronecker products; Positive and nonnegative matrices, Irreducible nonnegative matrices.

Texts:

1. R. A. Horn and C. R. Johnson, Matrix Analysis, CUP, 1985.

References:

2. P. Lancaster and M. Tismenetsky, The Theory of Matrices, second ed., Academic Press, 1985.
3. F. R. Gantmacher, The Theory of Matrices, Vol-I, Chelsea, 1959.

(iii) Numerical Linear Algebra (MA5008):

3-0-0: 3 Credits **Prerequisite: Linear Algebra**

Fundamentals. Linear systems, LU decompositions, Gaussian elimination with partial pivoting, Banded systems, Positive definite systems, Cholesky decomposition. Vector and matrix norms, Perturbation theory of linear systems, Condition numbers, Estimating condition numbers, IEEE floating point arithmetic, Analysis of round off errors. Gram-Schmidt orthonormal process, Orthogonal matrices, Householder transformation, Givens rotations, QR factorization, Roundoff error analysis of orthogonal matrices, Stability of QR factorization. Solution of linear least squares problems, Normal equations, Singular Value Decomposition(SVD), Polar decomposition, Moore-Penrose inverse, Rank deficient least squares problems, Sensitivity analysis of least-squares problems. Review of eigenvalues and canonical forms of matrices, Sensitivity of eigenvalues and eigenvectors, Reduction to Hessenberg and tridiagonal forms, Power and inverse power methods, Rayleigh quotient iteration, Explicit and implicit QR algorithms for symmetric and non-symmetric matrices, Implementation of implicit QR algorithm. Computing the SVD, Sensitivity analysis of singular values and singular vectors. Overview of iterative methods: Jacobi, Gauss-Seidel and successive over relaxation methods, Krylov subspace method, The Arnoldi and the Lanczos iterations.

Software Support: MATLAB.

Texts:

1. L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.
2. D. S. Watkins, Fundamentals of Matrix Computation, Wiley, 1991.

References:

3. G. H. Golub and C.F.Van Loan, Matrix Computation, John Hopkins U. Press, Baltimore, 1996.
4. G. W. Stewart, Introduction to Matrix Computations, Academic Press, 1973.
5. J.W. Demmel, Applied numerical linear algebra, SIAM, Philadelphia, 1997.

(iv). Lie Groups and Lie Algebra (MA5009):

3-0-0: 3 Credits **Prerequisite: Linear Algebra, Algebra I, Algebra II**

Linear Lie groups: the exponential map and the Lie algebra of linear Lie group, some calculus on a linear Lie group, invariant diff erential operators, finite dimensional representations of a linear Lie group and its Lie algebra. Examples of linear Lie group and their Lie algebras, e.g., Complex groups: GL(n, C), SL(n, C), SO(n, C), Groups of real39matrices in those complex groups: GL(n, R), SL(n, R), SO(n, R), Isometry groups of Hermitian forms SO(m, n),U(m, n), SU(m, n). Finite dimensional representations of su(2)and SU(2) and their connection. Exhaustion using the lie algebra su(2). Lie algebras in general, Nilpotent, solvable, semisimple Lie algebra, ideals, Killing form, Lies and Engels theorem. Universal enveloping algebra and Poincare-Birkho-Witt Theorem (without proof). Semisimple Lie algebra and structure theory: Definition of Linear reductive and linear semisimple groups. Examples of Linear connected semisimple/ reductive Lie groups along with their Lie algebras (look back at 2 above and find out which are reductive/ semisimple).Cartan involution and its diff erential at identity; Cartan decomposition g = k + p, examples of k and p for the groups discussed above. Definition of simple and semisimple Lie algebras and their relation, Cartans criterion for semisimplicity. Statements and examples of Global Cartan decomposition, Root space decomposition; Iwasawa decomposition; Bruhat decomposition.

Texts:

1. J.E. Humphreys: Introduction to Lie algebras and representation theory, GTM (9),Springer-Verlag (1972).
2. S.C. Bagchi, S. Madan, A. Sitaram and U.B. Tiwari: A first course on representation theory and linear Lie groups, University Press (2000).

References:

3. Serge Lang: SL(2, R). GTM (105), Springer (1998).
4. W. Knapp: Representation theory of semisimple groups. An overview based on examples, Princeton Mathematical Series (36), Princeton University Press (2001).
5. B.C. Hall, Lie Groups, Lie Algebras and Representations: An Elementary Introduction,Springer (Indian reprint 2004).

(v) Mathematical Logic (MA5010):

3-0-0: 3 Credits
Prerequisite: Nil

Syntax of First-Order Logic: First Order Languages, Terms and Formulas of a First Order language, First Order Theories. Semantics of First-Order Languages: Structures of First-Order Languages, Truth in a Structure, Model of a Theory. Propositional Logic: Tautologies and Theorems of propositional Logic, Tautology Theorem. Proof in First Order Logic, Metatheorems of a first order theory, e.g. , theorems on constants, equivalence theorem, deduction and variant theorems etc., Consistency and Completeness, Lindenbaum Theorem. Henkin Extension, Completeness theorem, Extensions by definition of first order theories, Interpretation theorem. Model Theory: Embeddings and Isomorphisms, L¨owenheim-Skolem Theorem, Compactness theorem, Categoricity, Complete Theories. Recursive functions, Arithmatization of first order theories, Decidable Theory, Representability, Godel's first Incompleteness theorem.

Texts:

1. J. R. Shoenfield, Mathematical logic. Addison-Wesley Publishing Co., 1967.2001.
2. S. M. Srivastava, A Course on Mathematical Logic, Universitext, Springer (2008).

References:

1. E. Mendelson: Introduction to Mathematical Logic. Chapman & Hall, 1997.

(vi) Algebraic Topology (MA5011):

3-0-0: 3 Credits **Prerequisite: Topology, Algebra**

Paths and homotopy, homotopy equivalence, contractibility, deformation retracts. Basic constructions: cones, mapping cones, mapping cylinders, suspension. Cell complexes, subcomplexes, CW pairs. Fundamental groups. Examples (including the fundamental group of the circle) and applications (including Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem and Borsuk-Ulam Theorem, both in dimension two). Van Kampen's Theorem, Covering spaces, lifting properties, deck transformations. universal coverings (existence theorem optional). Simplicial complexes, barycentric subdivision, stars and links, simplicial approximation. Simplicial Homology. Singular Homology. Mayer-Vietoris Sequences. Long exact sequence of pairs and triples. Homotopy invariance and excision (without proof). Degree. Cellular Homology. Applications of homology: Jordan-Brouwer separation theorem, Invariance of dimension, Hopf's Theorem for commutative division algebras with identity, Borsuk-Ulam Theorem, Lefschetz Fixed Point Theorem. Optional Topics: Outline of the theory of: cohomology groups, cup products, Kunneth formulas, Poincare duality.

Texts:

1. A. Hatcher, Algebraic Topology, Cambridge Univ. Press, Cambridge, 2002.
2. J.R. Munkres, Elements of Algebraic Topology, Addison Wesley, 1984.

References:

3. M.J. Greenberg and J. R. Harper, Algebraic Topology, Benjamin, 1981.
4. W. Fulton, Algebraic topology: A First Course, Springer-Verlag, 1995.
5. W. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, Berlin, 1991.
6. J.J. Rotman, An Introduction to Algebraic Topology, Springer (India), 2004.
7. H. Seifert and W. Threlfall, A Textbook of Topology, translated by M. A. Goldman, Academic Press, 1980.
8. J.W. Vick, Homology Theory, Springer-Verlag, 1994.

(vii) Differential Geometry (MA5012):

3-0-0: 3 Credits **Prerequisite: Functions of Several Variables**

Parametrized curves in R3, length of curves, integral formula for smooth curves, regular curves, parametrization by arc length. Osculating plane of a space curve, Frenet frame, Frnet formula, curvatures, invariance under isometry and reparametrization. Discussion of the cases for plane curves, rotation number of a closed curve, osculating circle, 'Umlaufsatz'.Smooth vector fields on an open subset of R3, gradient vector field of a smooth function, vector field along a smooth curve, integral curve of a vector field. Existence theorem of an integral curve of a vector field through a point,

maximal integral curve through a point. Level sets, examples of surfaces in R3. Tangent spaces at a point. Vector fields on surfaces. Existence theorem of integral curve of a smooth vector field on a surface through a point. Existence of a normal vector of a connected surface. Orientation, Gauss map. The notion of geodesic on a surface. The existence and uniqueness of geodesic on a surface through a given point and with a given velocity vector thereof. Covariant derivative of a smooth vector field. Parallel vector field along a curve.
Existence and uniqueness theorem of a parallel vector field along a curve with a given initial vector. The Weingarten map of a surface at a point, its self-adjointness property. Normal curvature of a surafce at a point in a given direction. Principal curvatures, first and second fundamental forms, Gauss curvature and mean curvature. Surface area and volume. Surfaces with boundary, local and global stokes theorem. Gauss-Bonnet theorem.

Texts:

1. B O'Neill, Elementary Differential Geometry, Academic Press (1997).
2. A. Pressley, Elementary Differential Geometry, Springer (Indian Reprint 2004).
3. J. A. Thorpe, Elementary topics in Differential Geometry, Springer (Indian reprint, 2004).

References:

1. Manfredo P. Do Carmo, Differential Geometry of Curves and Surfaces, Prentice Hall, 1976.
2. John McCleary, Geometry from a Differentiable Viewpoint, Cambridge University Press, 1994.
3. Michael Spivak, A Comprehensive Introduction to Differential Geometry, Publish or Perish, 1994.
4. Carl Friedrich Gauss, General Investigations of Curved Surfaces, Edited with an Introduction and Notes by Peter Pesic, Dover 2005.

<u>(viii) Fluid Dynamics (MA5013)</u>

3-0-0: 3 Credits **Prerequisite: Continuum Mechanics**

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

Texts:

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

References:

3. L. M. Milne Thomson, Theoretical Hydrodynamics, Macmillan and Co., 1960.
4. G. K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 1993.
5. A. R. Patterson, A First Course in Fluid Dynamics, Cambridge University Press, 1992.

<u>(ix) Functions of Several Variables (MA5014):</u>

3-0-0: 3 Credits **Prerequisite: Real Analysis**

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.

Texts:

1. W. Fleming, Functions of Several Variables, 2nd Ed., Springer-Verlag, 1977.
2. T. Apostol, Calculus (Vol 2), John Wiley

References:

1. V. Guillemin and A. Pollack, Differential Topology, Prentice-Hall Inc., Englewood Cliffe, New Jersey, 1974.
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.
5. R. Courant and F. John: Introduction to Calculus and Analysis.

Detail syllabus of courses under Electives II &IV

(x) Numerical Solution of Ordinary and Partial Differential Equations (MA6001):

3-1-0: 4 Credits **Prerequisite: Ordinary and Partial Differential Equations**

Errors: Round-off error, Truncation error, Absolute error, Relative error, Percentage error; Ordinary Differential equations (ODE): Solutions of Initial Value Problems by Taylor Series, Euler, Improved Euler, Modified Euler, Runge-Kutta methods for First and second order differential equations, Multistep methods (Milne and Adams Bashforth). Consistency, stability and convergence aspects of the methods of IVP. Boundary Value Problems: Shooting and finite difference methods. Partial Differential Equations (PDE): Classification of PDEs, Finite difference approximations to partial derivatives, Numerical solutions of Elliptic, Parabolic and Hyperbolic partial differential equations. Solutions of Laplace equation by Leibmann's iteration procedure, Poisson equation, Explicit, Crank-Nickolson, Du Fort Frankel methods for Parabolic PDE. Explicit formula for Hyperbolic PDE and Consistency, stability and convergence aspects of these methods.

Texts/References:

1. G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rd Edn., 1986.
2. Numerical methods for scientific and Engineering computation by M.K. Jain, S.R.K. Iyengar (Fifth Edition) (2007).

References:

1. L. Lapidus and G. F. Pinder, Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley, 1982.
2. Numerical Solutions of Differential Equations by M.K.Jain (2008).
3. Numerical solutions of partial Differential Equations (Finite difference methods) by Smith, 3rd edition (2004).

(xi) Non-Negative Matrix Theory(MA6002):

4-0-0: 4 Credits **Prerequisite: Linear Algebra**

Matrices which leave a cone invariant: Introduction, Cones, Convex cones, Polyhedral cones, Solids, Spectral properties of matrices which leave a cone invariant, Cone primitivity. Nonnegative Matrices: Nonnegative matrices , Inequalities and Generalities, Positive matrices, Nonnegative Irriducible Matrices, Perron's Theorem, Perron-Frobenius Theory, Nonsingular M-matrices. Reducible Matrices, Primitive Matrices, A Genenral Limit Theorem Stochastic and Doubly Stochastic Matrices: The Birkhoff-von Neumann Theorem, Fully indecomposable matrices, Konig's Theorem and rank. Semigroups of Nonnegative Matrices: Algebraic semigroups, Nonnegative idempotents, The semigroup N_n, The semigroup Doubly Stochastic Matrices D_n. Symmetric Nonnegative Matrices: Inverse eigenvalue problems, Nonnegative matrices with given sums, Some applications.

Texts:

1. Berman and Plemmons, Nonnegative Matrices in the Mathematical Sciences, SIAM, 1994.
2. Henryk Minc, Nonnegative matrices, Wiley-Interscience Pub., 1988.

References:

1. Bapat and Raghavan, Nonnegative Matrices and Applications, Cambridge University Press, 2009.
2. R. A. Horn and C. R. Johnson, Matrix Analysis, Cambridge University Press, 2nd Edition 2012.
3. E. Seneta, Non-negative Matrices and Markov Chains, Springer, 2nd edition, 2006.

(xii) Advanced Complex Analysis (MA6003):

3-1-0: 4 Credits **Prerequisite: Complex Analysis**

Series and product developments: Power series expansions, Partial fractions and factorizations; Entire functions: The Hadamard's theorem, Jensen's formula, The Riemann zeta function; Normal families: Equicontinuity, Normality and compactness, Arzela's theore; Analytic continuation and Riemann surfaces: Germs and sheaves, Analytic continuations along arcs, Homotopic curves, The monodromy theorem, Branch points, Algebraic functions; Picard's theorem: Lacunary values; The Reimann mapping theorem;The Dirichlet problem; Canonical mappings of multiply connected regions; Elliptic functions and Weierstrass Theory; Basic results on univalent functions; The range of analytic functions: Bloch's theorem, Schottky's theorem;

Texts:

1. L. Ahlfors: Complex Analysis, 2nd ed., McGraw-Hill,New York, 1966
2. Peter L Duren, Univalent Functions, Springer-Verlag

References:

1. J. B. Conway, Functions of One Complex variable-II, Springer-Verlag
2. Boundary Behaviour of Conformal Maps, ChristainPommerenke, Springer
3. Walter Rudin, Real and Complex Analysis, TataMcGraw-Hill, 2006

(xiii) Fractals (MA6004):

3-1-0: 4 Credits **Prerequisite: Real Analysis**

The philosophy and scope of fractal geometry, Scaling and self-similarity, Hausdorff measure and dimensions, Box-counting dimensions, Techniques for calculating dimensions, Local structure and projections of fractals, The Thermodynamic Formalism: Pressure and Gibb's measures, the dimension formula, Invariant measuresand the transfer operator, Entropy and the Variational principle; The ergodic theorem; The renewal theorem; Martingales and the convergence theorem, Bi-Lipschitz equivalence of fractals; Multifractal Analysis; Applications of fractals: Iterated function systems (IFS) and Recurrent IFS, Applications to image compression, Julia sets and the Mandelbrot set, Random fractals, Brownian motion and Random walks, Percolation, Fractal interpolation,

Texts:

1. K. Falconer, Fractal Geometry: Mathematical Foundations and Applications, John Wiley & Sons
2. K. Falconer, Techniques in Fractal Geometry, John Wiley & Sons, 1997

References:

1. B. Mandelbrot, Fractal Geometry of Nature, W.H. Freeman and Company.
2. M. F. Barnsley, Fractals Everywhere , 2nd edition, Academic Press, 1995.
3. Mattila , Geometry of Sets and Measures in Euclidean Spaces: Fractals and Rectifiability, Cambridge University Press, 1999
4. Peitgen, Jurgens and Saupe, Chaos and Fractals: New Frontiers

(xiv) Computational Topology (MA6005):

3-1-0: 4 Credits **Prerequisite: Nil**

Topological space, subspace, base, subbase, continuous function, connectedness, paths, homotopy, homotopy of paths and homotopy of maps, simplicial complex, polyhedral, graphs, homology theory, computation of beti numbers.

Texts:

1. James R., Munkres, Topology, 2nd Edition, Pearson Education.
2. J Dugundji – Topology, PHI.
3. J L Kelley –General Topology (Von Nostrand).

References:

1. G F Simmons – Introduction to Topology and Modern Analysis (McGraw Hill).
2. Steen & Seebach – Counterexamples in Topology (Holden Day).
3. S Willard –General Topology (Addison Wesley).

(xv) Integral Equations and Variational Methods (MA6006):

3-1-0: 4 Credits **Prerequisite: Differential Equations**

Integral Equations: Basic concepts, Volterra integral equations, relationship between linear differential equations and Volterra equations, resolvent kernel, method of successive approximations, convolution type equations, Volterra equations of first kind, Abels integral equation, Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, iterated kernels, integral equations with degenereted kernels, eigen values and eigen functions of a Fredholm alternative, construction of Green's function for BVP, singular integral equations.

Calculus of variations: Euler-Lagrange equations, degenerate euler equations, Natural boundary conditions, transversality conditions, simple applications of variational formulation of BVP, minimum of quadratic functional. Approximation methods-Galerkin's method, weighted-residual methods, Colloation methods.Variational methods for time dependent problems.

Texts:

1. A Jerri, Introduction to Integral Equations with Applications, Wiley.
2. L. Elsgoltz, Differential Equations and Variational Calculus, Rubinos 1860; 4 Tra edition, 1996.
3. F. G. Tricomi, Integral Equations, Dover Pub, 1985.

References:

4. H. T. Davis, Introduction to Nonlinear Differential and Integral Equations, Dove
5. Harry Hotchstadst, Integral Equations, John Wiley.
6. A S Gupta, Calculus of Variations.
7. C Fox, An Introduction to the Calculus of Variations, Dover.
8.

(xvi) Soft Computing (MA6007):

3-1-0: 4 Credits **Prerequisite: Nil**

Introduction to Soft Computing, Components of Soft Computing, Importance of Soft Computing, Fuzzy Set Theory - Definition, Different types of fuzzy set Membership Functions, Fuzzy Set theoretic operations, Fuzzy Rules and Fuzzy Reasoning, Fuzzy Inference Systems, GA, Simulated Annealing, Particle swarm optimization, Neural Networks- Supervised Learning, Unsupervised Learning, Hybrid Systems - Neuro Fuzzy Modeling, Fuzzy c-means, Applications in Image Processing, Neuro-fuzzy control, Data Mining.

Implementation of the problems using MATLAB.

Texts:

1. Neuro Fuzzy and Soft Computing – J.S.R.Jang, C.T.Sun and E. Mizutani , Amazon
2. An Introduction to Neural Networks - Haykin

References:

3. Fuzzy Sets and Fuzzy Logic - Klir and Yuan
4. Genetic Algorithms – Goldberg.
5. Particle Swarm Intelligence: J. Kennedy, R.C. Eberhart and Y. Shi, Morgan Kaufman Publisher
6. Particle swaram Optimization: Maurice Clerce, ISTE
7. Particle swarm Optimization: Andrea E. Olsson

(xvii) Neural Network (MA6008):

3-1-0: 4 Credits **Prerequisite: Nil**

Biological and Artificial Neuron, Perceptron model, Adaline model, Different types of Activation functions, Learning Techniques: Supervised and Unsupervised, Multilayered feed forward Networks, Back propagation algorithm and its improvements, Applications of Back propagation algorithm to statistical pattern recognition, classification and regression problems, Advantages of Neural Networks over statistical classification techniques, Performance Surfaces and Optimum Points, Steepest Descent ,Stable learning Rates, Minimizing Along a line ,Newton's method and conjugate method. Recurrent networks, Radial Basis Function Networks as an interpolation model, Time delay neural networks for forecasting problems, Probabilistic Neural Networks, Kohonen's self organizing map, Self organizing maps with quadratic functions and its applications medical imaging, Adaptive Resonance, Theory model, Applications of Art model for knowledge acquisition, Extensive sessions in MATLAB for solving statistical pattern recognition, classification, regression and prediction problems using different kinds of Neural Network models

Texts:

1. Neural Networks Design: Martin T. Hagan, Howard B. Demuth and Mark Beale, Cengage Learning India Pvt.Ltd
2. Neural Networks: Simon S. Haykin, Macmillan

References:

3. Neural Networks,Fuzzy logic and Genetic Algorithm: Rajasekaran and G.A. Vijayalaxmi Pai, Prentice Hall of India
4. Neural Networks: Algorithms, Applications, And Programming Techniques, Freeman,Pearson Education India.
5. Neural Networks: Stish Kumar, Tata Mc-GraHill Education

(xviii) Queueing Theory in Computer Science (MA6009):

3-1-0: 4 Credits **Prerequisite: Probability and Statistics**

Probability and random variable, discrete and continuous univariate and multivariate distributions, moments, law of large numbers and central limit theorem (without proof). Poisson process, birth and death process, infinite and finite queueing models M/M/1, M/M/C, M/G/1, M/M/1/N, M/E/1, E/M/1, M/G/1/N, GI/M/1, and more complex non-Markovianqueueing models, such as GI/G/1 queues, Multiserver Queues: M/M/c, M/G/c, GI/M/c modles, Erlan'sg loss system, Queues with finite populations: M/M/1/N/K, M/G/1/N/K etc. models and Engset formula, Concept bulk queues: $M^{[X]}/M/1$, $M/M^{[Y]}/1$, $M/M^{(a,b)}/1$, $M^{[X]}/G/1$, $GI^{[X]}/M/1$, $M/G^{(a,b)}/1$, $GI/M^{(a,b)}/1$ etc. queueing models. Priority queueing models, Vacation queueing models,Network of queues, finite processor sharing models, central server model of multiprogramming, performance evaluation of systems using queueing models. Concepts of bottleneck and system saturation point. Introduction to discrete time queues and its applications.

Texts/ References:

1. Donald Gross and Carl M. Harris, Fundamentals of Queueing Theory, Wiley-India, 1998.
2. Leonard Kleinrock, Queueing Systems. Volume 1 : Theory, Wiley-Interscience, 1975.
3. Leonard Kleinrock, Computer Applications, Volume 2, Queueing Systems, Wiley-Interscience. 1975.

(xix) Queueing, Inventory and Reliability (MA6010):

3-1-0: 4 Credits **Prerequisite: Probability and Statistics**

Markov chains, Poisson process, Birth-Death process, Simple Markovianqueueing models: M/M/1, M/M/1/N, M/M/C, transient behaviour of M/M/1 and M/M/1/N queue. Models with general arrival or service: M/G/1, GI/M/1. Concept bulk queues, Some Markovian and no-Markovianbulk arrival or bulk service queueing models: $M^{[X]}/M/1$, $M/M^{[Y]}/1$, $M/M^{(a,b)}/1$, $M^{[X]}/G/1$, $GI^{[X]}/M/1$, $M/G^{(a,b)}/1$, $GI/M^{(a,b)}/1$ etc. models.

Network of Markovian queues.General concept of discrete time queues, system reliability, Reliability of Systems of Independent Components, Markovian models in reliability theory, Life testing using the exponential and Weibull models.Expected System Lifetime, Bounds on the expected system lifetime, Systems with Repair

Elementary inventory models, Deterministic and Stochastic models, Inventory models with price breaks, Multi-item Economic-order-quantity (EOQ) model with storage limitation, Single- and multi-period probabilistic inventory models, Concept of just-in-time inventory.

Texts/ References:

1. Donald Gross and Carl M. Harris, Fundamentals of QueueingTheory ,Wiley-Interscience.
2. Sheldon M. Ross, Introduction to Probability Models, Academic Press , Tenth Edition, 2009.
3. Hamdy A. Taha, Operations Research: An Introduction, 9th edition, Pearson/Prentice Hall, 2010.

(xx) Time Series Analysis and Forecasting (MA6011):

3-1-0: 4 Credits **Prerequisite: Probability and Statistics**

Stochastic and deterministic mathematical models for forecasting of time series, Classical techniques in Time Series Analysis, Different Smoothing Techniques, General linear process, Autoregressive process AR(P), Moving average process Ma(q): Autocorrelation, Partial autocorrelation, and Spectrum, Linear stationary models for autoregressive moving average processes, Mixed autoregressive moving average processes, Autocovariances, Autoregressive Integrated Moving Average Processes (ARIMA).

Forecasting, Calculating and updating forecast, Forecast function and forecast weight, Examples of forecast functions and their updating, Identification in time domain, Model Identification , Estimation of Parameters, Model estimation, Non-linear estimation, Model diagnostic checks, Seasonal models, Transfer function models, Discrete transfer function model, continuous dynamic models, Identification, fitting and checking of transfer function models, Intervention analysis models and outlier detection, Estimation of Autoregressive moving average (ARMA) models, Use of time series techniques in Engineering fields.

Texts/ References:

1. George Box, Gwilym M. Jenkins and Gregory Reinsel, Time Series Analysis: Forecasting & Control, 3/E Pearson Education India, 1994.
2. Douglas C. Montgomery, Cheryl L. Jennings, Murat Kulahci, Introduction to Time Series Analysis and Forecasting, John Wiley & Sons, 2011.

(xxi) Mathematical theory of Elasticity (MA6012):

3-1-0: 4 Credits **Prerequisite: Nil**

Analysis of strain, deformation, affine deformation, infinitesimal affaine deformation, geometrical interpretation of the components of strain, principal directions, invariants, general infinitesimal deformation, Examples of strain, strain compatibility equations; Analysis of stress, body and surface forces, stress tensor, equations of equilibrium, stress quadric of Cauchy, examples of stress; The strain – energy function and its connection with hooks law, Saint Venant's principle. Boundary value problems in elasticity; Extension, bending and Torsion: statement of problem, extension of beams by longitudinal forces, Beam stretched by its own weight, Bending of beams by terminal couples of elliptic cylinder, Torsion of a circular shaft, Torsion of cylindrical bars, stress function, Torsion of elliptical cylinder; Two-dimensional elastostatic problems: plane deformation, plane stress, Generalized plane stress, plane elastostatic problems, Airy’s stress function, General solution of Biharmonic equation, formulas for stresses and displacements, the structure of the functions ø(z) and φ(Z); Vibration of elastics solids, wave propagation in infinite regions, Ryleigh and Love waves .

Texts:

1. I.S.SOKOLINIKOFF, Mathematical theory of Elasticity; Tata McGraw Hill, 1972.
2. Martin H. Sadd, Elasticity: Theory, Applications, and Numerics; Elsevier Butterworth Heinman, 2005.

(xxii) Theory of groups and its application to physical problems (MA6013):

3-1-0: 4 Credits **Prerequisite: Algebra**

Elements of Group theory, Operators in Hilbert Space, Representation theory – finite groups, Continuous groups, Group theory and Quantum mechanics, Crystallographic and Molecular Symmetries.

Texts:

1. C. J. Bradley and A. P. Cracknell, Mathematical Theory of Symmetry in Solids, OUP, 1972.
2. A. P. Cracknell, Applied Group Theory, Elsevier Science & Technology, 1968.

References:

3. N. Hammermesh, Group Theory and Its Application to Physical Problems, Courier Dover Publications, 1962.
4. S. Bhagavantam and T. Venkatarayudu, Theory of groups and its application to physical problems, Academic Press, 1969.
5. W Joshi, Elements Of Group Theory For Physicists, New Age International, 1997.

(xxiii) Computational Fluid Dynamics (MA6014):

3-1-0: 4 Credits **Prerequisite: Fluid Dynamics, Numerical methods**

Classification of Partial Differential Equations; Classification of system of first order PDE's; Classification of system of second order PDE's; Boundary conditions; consistency, stability and convergence of FDE; Lax's equivalence theorem. Finite difference approximations to partial derivatives for equally spaced grid points and unequally spaced grid points. Methods to solve Parabolic partial differential equations, Elliptic and Hyperbolic partial differential equations and stability analysis; Vorticity Stream function formulation of the Navier-Stokes equations, Finite difference methods for steady, viscous incompressible N-S equations: Flow in a lid driven cavity, Viscous flow past a circular cylinder, flow past a sphere. Line Gauss-Seidal, Point Gauss Seidal , SOR schemes, Finite difference applications in Heat conduction and convection; Discussion on first, second and higher order accurate methods. Higher order compact schemes to Navier Stokes equations.

Texts:

1. Computational Fluid Dynamics, Volume 1 by K. A. Hoffmann and S. T. Chiang .
2. Computational Fluid Flow and Heat transfer by K. Muralidhar and T. Sundararajan.(Narosa)

References:

1. Computational Methods for Fluid Dynamics by J. H. Ferziger and M. Peric (Springer)
2. Computational Fluid Dynamics by J. F. Wendt (Springer)
3. Computational Fluid Dynamics by T. J. Chung (Cambridge University Press).
4. Fundamentals of Computational Fluid Dynamics by T. K. Sengupta (Universities Press).

(xxiv) Algebraic Graph Theory (MA6015):

3-1-0: 4 Credits **Prerequisite: Linear Algebra, Elements of Graph Theory**

Fundamental Concepts: independent sets, matchings, spanning trees, Hamiltonian cycles, Eulerian orientations, cycle covers, etc.; Operations on Graphs and the Resulting Spectra: the polynomial of a graph, eigenvalues and eigenvectors, line graphs and total graphs. etc.; The Divisor of Graphs: The divisor and cover, symmetry properties, some generalizations; Spectral Characterizations: Eigenvalues of L-, Q-, and adjacency matrix, co-spectral graphs, graphs characterized by their spectra; Spectral

Techniques in Graph Theory and Combinatorics: Computing the structures suchas, independent sets, matchings, spanning trees, Hamiltonian cycles, Eulerian orientations, etc.
Additional Topics: Random Graphs, Ramsey Theory, Extremal Problems.

Texts:

1. R. B. Bapat, Graphs and Matrices, Springer, 1st Edition, 2011.
2. C. D. Godsil and G. Royale, Algebraic Graph Theory, Springer, 2001.

References:

1. N. Biggs, Algebraic Graph Theory, Cambridge University Press, 2nd Edition, 1994.
2. Reinhard Diestel, Graph Theory, Third Edition, Springer, 2005.
3. D. Cvetković, M. Doob, and H. Sachs, Spectra of Graphs: Theory and Application Wiley-VCH, 1998.

(xxv) Complex Dynamics (MA6016):

3-1-0: 4 Credits **Prerequisite: Complex Analysis**

Normal families, Montel's theorem; Iteration of polynomials and rational maps: The structure of the Fatou set, Sullivan classification of Fatou components, External rays, Properties of the Julia set; Polynomial like mappings; Parameter spaces of rational maps: Mandelbrot set, Holomorphic motion and stability; Renormalisation; Dynamics of transcendental entire and meromorphic functions: Singular points of inverse function, Baker domains and Wandering domains, Maps of bounded type, Escaping points, Omitted values and dynamics; Conformal measure on Julia sets, Dimension of Julia sets; Kleinian groups and Sullivan's dictionary.

Texts:

1. A. F. Beardon, Iteration of Rational Functions, Springer
2. L. Carleson and T.W. Gamelin, Complex Dynamics, Springer

References:

1. J. Milnor, Dynamics in one complex variable, Princeton University Press
2. S. Morosawa et al, Holomorphic Dynamics, Oxford University Press
3. DierkShleicher, Complex Dynamics-Families and Friends, AK Peters Ltd
4. P. J. Rippon and G. Stallard, Transcendental Dynamics and Complex Analysis, Cambridge University Press
5. Curtis T. McMullen, Complex Dynamics and Renormalization, Princeton University Press

(xxvi) Ergodic Theory and Dynamical Systems (MA6017):

3-1-0: 4 Credits **Prerequisite: Topology, Measure Theory**

Examples and Basic concepts: Dynamical system, orbits, Circle rotations, Shifts and sub-shifts, Hyperbolic toral automorphisms, The Horseshoe, The solenoid, Flows and differential equations, Chaos and Lyapunov exponents; Topological dynamics: Limit sets, Recurrence, Mixing, Transitivity, Entropy; Symbolic Dynamics: Subshifts, Sofic shifts, codes, Perron Frobenius Theorem, Data storage; Ergodic Theory: Ergodicity and mixing, Ergodic theorems (Von Neumann Ergodic Theorem, Birkhoff Ergodic Theorem), Invariant measures for continuous maps,; Unique ergodicity and Weyl's theorem, Discrete spectrum, Weak mixing, Internet search; Hyperbolic dynamics: Stable and unstable manifolds, Anosov diffeomorphisms, Axiom A and structural stability; Ergodicity of Anosov diffeomorphisms: Holder continuity of the stable and unstable distributions, Absolute continuity of stable and unstable foliations;

Texts:
1. M. Brin and G. Stuck, Introduction to Dynamical Systems, Cambridge University Press, 2002

References:
1. M. Pollicott and M. Yuri, Dynamical systems and Ergodic Theory, Cambridge University Press, 1998

(xxvii) Abstract Harmonic Analysis (MA6018)):

3-1-0: 4 Credits **Prerequisite: Topology, Algebra**

Topological groups, locally compact groups, Haar measure. Modular function, convolutions, homogenous spaces , unitary representations, Gelfand-Raikov theoremFunctions of positive type, GNS construction, Potrjagin dulaity, Bochner's theorem, Induced representations, Mackey's impritivity theorem.

Texts:
1. G. B. Folland: A course in Abstract Harmonic Analysis. Studies in Advanced mathematics, CRC press, 1995.
2. E. Hewitt and K. Ross: Abstract Harmonic Analysis , Vol 1, Springer 1979

References:
3. S. A. Gaal. Linear Analysis and Representation theory. Springer

(xxviii) Fourier Analysis (MA6019):

3-1-0: 4 Credits **Prerequisite: Real Analysis**

Basic Properties of Fourier Series: Uniqueness of Fourier Series, Convolutions, Cesaro and Abel Summability, Fejer's theorem, Poisson Kernel and Dirichlet problem in the unit disc. Mean square Convergence, Example of Continuous functions with divergent Fourier series. Distributions and Fourier Transforms: Calculus of Distributions, Schwartz class of rapidly decreasing functions, Fourier transforms of rapidly decreasing functions, Riemann Lebesgue lemma, Fourier Inversion Theorem, Fourier transforms of Gaussians. Tempered Distributions: Fourier transforms of tempered distributions, Convolutions, Applications to PDEs (Laplace, Heat and Wave Equations), Schrodinger-Equation and Uncertainty principle. Paley-Wienner Theorems, Poisson Summ-ation Formula: Radial Fourier transforms and Bessel's functions. Hermite functions.
Optional Topics: Applications to PDEs, Wavelets and X-ray tomography.Applications to Number Theory.

Texts:
1. R. Strichartz, A Guide to Distributions and Fourier Transforms, CRC Press.
2. E.M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
3. I. Richards and H. Youn, Theory of Distributions and Non-technical Approach, Cambridge University Press, Cambridge, 1990.

References:
1. Stein, E.M., Singular integrals and differentiability properties of functions, 1970.
2. Sadosky, C., Interpolation of operators and singular integrals, 1979.
3. Dym, H. and Mckean, H.P., Fourier series and integrals, 1972.
4. Katznelson, Harmonic Analysis.

(xxix) Nonlinear Functional Analysis (MA6020):

3-1-0: 4 Credits **Prerequisite: Functional Analysis**

Fixed point theory, Banach contraction mapping theorem, contractive type mappings, generalization of Banach contraction mapping theorem, fixed point theorem of other types. Nonlinear operators, monotone, strictly monotone and strongly monotone operators, their properties and applications. Variational inequalities and complementarity problem. Approximation theory, theory of best approximation and farthest points. Calculus of Banach Space, Frechet and Gateaux differentiability, strict convexity and uniform convexity of norms, semi inner product space.

Texts:

1. Eberhard Zeidler, Nonlinear Functional Analysis and its applications, Springer.
2. Antonio Ambrosetti, David Arcoya, An Introduction to Nonlinear Functional Analysis and Elleptic Problems, Birkhauser.

References:

3. Lokenath Debnath and P Mikusinski, Hilbert Spaces with Applications, Academic Press.
4. D Kinderleherer, G Stampacchia, An Introduction to Variational Inequalities and their Applications, Academic Press.
5. J. Tinsley Oden,LeszekDemkowicz, Applied Functional Analysis, CRC Press, 2nd Edition.

(xxx) Finite Element Method (MA6021):

3-1-0: 4 Credits **Prerequisite: Functional Analysis, Numerical Analysis**

Introduction and motivation, Weak formulation of BVP and Galerkin approximation, Piecewise polynomial spaces and finite element method, Computer implementation of FEM, Results from Sobolev spaces, Variational formulation of elliptic BVP, Lax-Milgram theorem, Estimation for general FE approximation, Construction of FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.

Texts:

1. Brenner, Susanne C., Scott, Ridgway, The Mathematical Theory of Finite Element Methods, Springer, 3rd ed., 2008.

References:

2. J N Reddy, Introduction to Finite Element Methods, MacGragHill.
3. Thomas J.R. Hughes, The Finite Element Method, Dover Publications.
4. O.C. Zienkiewicz, The Finite Element Method, Tata McGrawHill, NewDelhi.

(xxxi) Advanced Techniques in Operation Research (MA6022):

3-1-0: 4 Credits **Prerequisite: Optimization Techniques**

Non-Linear Programming Problems: One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non convex programming, steepest and Quasi-Newton method. Dynamic Programming: Characteristics of dynamic problems, deterministic dynamic programming and probabilistic dynamic programming, Network analysis, Shortest path problems, minimum spanning tree problem, maximum flow problem, minimum cost flow problem,

network simplex, interior point methods, stochastic programming, Nonlinear goal programming applications, Geometric Programming.
Multi-objective Optimization Problems: Linear and non linear programming problems, Weighting and Epsilon method, P-norm methods, Gradient Projection Method, STEM method, Convex Optimization.

Texts:

1. M. Ehrgott, Multi-criteria Optimization, Springer 2006
2. Y. Colletee, P. Siarry, Multiobjective Optimization, Springer.

References:

3. K.M, Miettien, Non-linear multi-objective optimization, Kluwers International Series, 2004
4. S.S. Rao, Engineering Optimization Theory and Practices, John Wiley and Sons, 2009
5. K. Deb, Multi-objective evolutionary optimization for product design and manufacturing, Springer, 2011.

(xxxii) Convex Analysis and Optimization (MA6023):

3-1-0: 4 Credits **Prerequisite: Optimization Techniques**

Conic programming: linear programming (LP), second-order cone programming (SOCP), semidefinite programming (SDP), linear matrix inequalities, conic duality, conic duality theorem, Applications of semidefinite programming: control and system theory, combinatorial and nonconvex optimization, machine learning, Smooth convex optimization: gradient descent, optimal first-order methods (Nesterov's method and its variants), complexity analysis, Nonsmooth convex optimization: conjugate functions, smooth approximations of nonsmooth functions by conjugation, prox-functions, Nesterov's method for composite functions, Proximal minimization and mirror-descent algorithms (MDA),Augmented Lagrangian methods and alternating direction method of multipliers (ADMM),Example problems in statistics, signal and image processing, control theory.

Texts:

1. Convex Optimization by S. Boyd and L. Vandenberghe, Cambridge University Press.
2. Nonlinear Programming by D. Bertsekas, Athena Scientific.

References:

3. Lectures on Modern Convex Optimization: Analysis, Algorithms, and Engineering Applications by A. Ben-Tal and A. Nemirovski, MPS-SIAM Series on Optimization.
4. Introductory Lectures on Convex Optimization: A Basic Course by Y. Nesterov, Kluwer Academic Publisher.
5. Convex Analysis and Optimization by D. Bertsekas, A. Nedic, and A. Ozdaglar Convex Analysis, Athena Scientific.

(xxxiii) Stochastic Process Simulation (MA6024):

3-1-0: 4 Credits **Prerequisite: Probability and Statistics**

Definition and classification of stochastic processes, Poisson process, Flow of events, telegraph signal, Birth and death processes, application in queues, Random walk, Markov chains: classification of states, hitting times and absorption probabilities, Analysis of finite transient discrete Markov chain,finite and infinite ergodic chains, Continuous-time Markov chains, The Kolmogorov differential equations and transition probabilities, Martingales, Stopping times, Martingales to analyze random walks, application to GI/G/1 queues and ruin problems in risk theory.

Renewal processes, key renewal theorem, renewal reward process, Regenerative processes, stationary point processes, Branching process,Condititional limit laws of branching process, Continuous time Markov branching process, General branching process, Elements of continuous time and continuous state space processes: Brownian motion, Diffusion processes, variations of Brownian motions and drift, backward and forward diffusion equations, applications of Kolmogorov's equations for obtaining limiting distributions of semi-Markov processes, queues

Texts/ References:

1. Sheldon M. Ross, Stochastic processes, 2nd edition, Wiley-India 1996.
2. J. Medhi, Stochastic processes, 2nd edition, New Age International, 1982.
3. Samuel Karlin and Howard M. Taylo, A First Course in Stochastic Processes, Second Edition, Academic Press, 1975.

(xxxiv) Mathematical Theory of Control (MA6025):

3-1-0: 4 Credits **Prerequisite: Nil**

Solutions of uncontrolled systems, spectral form, exponential matrix, repeated roots, solutions of controlled systems, time varying systems, discrete time varying systems, relation between state space and classical forms; Controllability, observability, controllability and polynomials, linear feedback, state observer realization of constant systems; Algebraic criteria for linear systems, Nyqist criteria Liapunov theory, applications to linear systems, construction of liapunov functions, input-output stability, optimal control.

Texts:

1. R Bellman, Introduction to mathematical Theory of Control Processes, Academic Press,1967.

References:

2. S Barnett, Introduction to Mathematical Control Theory, Clarendon Press, 1975.

(xxxv) Mathematical Biology (MA6026):

3-1-0: 4 Credits **Prerequisite: Nil**

Single Species Population Dynamics: Linear and Nonlinear First Order Discrete Time Models, Differential Equation Models, Evolutionary Aspects, Continuous Models and Discrete Models. Population Dynamics of Interacting Species: Host-parasitoid Interactions, The Lotka-Volterra Prey-predator Equations, Modelling the Predator Functional Response, Ecosystems Modelling, Interacting Metapopulations. Infection Diseases: The Simple Epidemic and SIS Diseases, SIR Epidemics, SIR Endemics, Eradication and Control, Age-structured Population, Basic Model for Macroparasitic Diseases.

Biological motion: Macroscopic Theory of Motion; A Continuum Approach, Directed Motion, or Taxis, Steady State Equations and Transit Times. Molecular and cellular biology: Biochemical kinetics, Metabolic Pathways, Neural Modelling. Tumour modeling, Pharmaco kinetics.

Texts:

1. Maicholas F Britton, Essential Mathematical Biology, Springer, 2005.

References:

1. S I Rubinow, Introduction to Mathematical Biology, Dover, 2002.
2. J.D. Murray, Mathematical Biology I. An Introduction, Third edition 2002, Springer.

3. J N Kapur, Mathematical Models in Biology and Medicine, Affliated East -West Private Ltd., New Delhi, 2000.
4. David L Hull ,The Philosophy of Biological Science, Prentice- Hall,1974.
5. Stephen Black, The Nature of Living Things, An Essay on Theoretical Biology, William Heinmann Medical Books Ltd, 1969.

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CHEMISTRY

Credit Structure

		Recommended	Actual
1	**Course Credits**		
	Total Credit Requirement:	**94-102**	**97**
	Theory	50-60	51
	Laboratories	12-18	16
	Seminars	4	4
	Thesis	26	26
2	**Theory subjects**		
	Total number of theory subjects (cores + electives)	14-16	14.5
	Number of core subjects (%)	60-80%	65%
	Number of elective subjects (%)	20-40%	35%
	Total credit of theory subjects	50-60	51
3	**Laboratory subjects**	12-18	16
4	**Seminars**	4	4
5	**Thesis (Part I and Part II)**	10+16	10 +16

Semester-wise course details

Semester	Course Name	L-T-P	Credits
I	Introduction to Quantum Chemistry	3-1-0	4
	Inorganic Chemistry–Structure, Principle and Reactivity	3-1-0	4
	Concept of Organic Synthesis	3-1-0	4
	Mathematics for Chemists	2-0-0	2
	Organic Chemistry Laboratory	0-0-6	4
	Inorganic Chemistry Laboratory	0-0-6	4
	Seminar-I	0-0-3	2
	Semester Total		**24**
II	Thermodynamics and Chemical Equilibrium	3-1-0	4
	Principles of Organometallic and Bio-inorganic Chemistry	3-1-0	4
	Advanced Organic Chemistry	3-1-0	4
	Group Theory and Spectroscopy	3-1-0	4
	Computational Methods and Applications	3-0-0	3
	Physical Chemistry Laboratory	0-0-6	4
	Advanced Instrumentation Laboratory	0-0-6	4
	Semester Total		**27**
III	Analytical Chemistry	3-0-0	3
	Elective I	3-0-0	3
	Elective II	3-0-0	3
	Elective III	3-0-0	3
	Seminar-I	0-0-3	2
	Project I	0-0-15	10
	Semester Total		**24**
IV	Elective IV	3-0-0	3
	Elective V/Research Review Paper	3-0-0	3
	Project II	0-0-24	16
	Semester Total		**22**
	Grand Total		**97**

COURSE CURRICULUM

Sl. No.	Course Name	Nature of course	Course code	L-T-P (Credit)	Page
	SEMESTER – I				
1	Introduction to Quantum Chemistry	Core	CY4001	3-1-0(4)	
2	Inorganic Chemistry- Structure, Principle and Reactivity	Core	CY4002	3-1-0(4)	
3	Concept of Organic Synthesis	Core	CY4003	3-1-0(4)	
4	Mathematics for Chemists	Core	CY4004	2-0-0 (2)	
5	Organic Chemistry Laboratory	Core	CY4101	0-0-6(4)	
6	Inorganic Chemistry Laboratory	Core	CY4102	0-0-6(4)	
7	Seminar I	Core	CY4401	0-0-6(4)	
	SEMESTER – II				
8	Thermodynamics and Chemical Equilibrium	Core	CY4005	3-1-0(4)	
9	Principles of Organometallic and Bioinorganic Chemistry	Core	CY4006	3-1-0(4)	
10	Advanced Organic Chemistry	Core	CY4007	3-1-0(4)	
11	Group Theory and Spectroscopy	Core	CY4008	3-1-0(4)	
12	Computational Methods and Applications	Core	CY4009	3-0-0 (3)	
13	Physical Chemistry Laboratory	Core	CY4103	0-0-6(4)	
14	Advanced Instrumentation Laboratory	Core	CY4104	0-0-6 (4)	
	SEMESTER – III				
15	Analytical Chemistry	Core	CY5001	0-0-3 (3)	
16	Seminar II	Core	CY5401	0-0-3 (2)	
17	Elective I	Elective		3-0-0 (3)	
18	Elective II	Elective		3-0-0 (3)	
19	Elective III	Elective		3-0-0 (3)	
20	Project I		CY5501	0-0-15 (10)	
	SEMESTER – IV				
21	Elective IV	Elective		3-0-0 (3)	
22	Elective V/Research Review Paper	Elective	/CY6201	3-0-0 (3)	
23	Project II		CY5502	0-0-24 (16)	

LIST OF ELECTIVES

List of subjects to be floated under Electives I-V					
i	Biochemistry		CY6001	3-0-0(3)	
ii	Solid State Chemistry		CY6002	3-0-0(3)	
iii	Chemical Kinetics and Surface Chemistry		CY6003	3-0-0(3)	
iv	Advanced Polymer Chemistry		CY6004	3-0-0(3)	
v	Metal Complexes in Catalysis		CY6005	3-0-0(3)	
vi	Physical Methods in Inorganic Chemistry		CY6006	3-0-0(3)	
vii	Advanced Inorganic Chemistry : Reactions, Kinetics and Mechanism		CY6007	3-0-0(3)	
viii	Advanced Main Group Chemistry		CY6008	3-0-0(3)	
ix	Inorganic Photochemistry		CY6009	3-0-0(3)	
x	Chemistry of Materials		CY6010	3-0-0(3)	
xi	Advanced Bio-inorganic Chemistry		CY6011	3-0-0(3)	
xii	Organic Reagents and Reactions		CY6012	3-0-0(3)	
xiii	Methods in Organic Synthesis		CY6013	3-0-0(3)	
xiv	Photochemistry and Pericyclic Reactions		CY6014	3-0-0(3)	
xv	Statistical Mechanics for Chemists		CY6015	3-0-0(3)	
xvi	Chemical Biology of Receptors		CY6016	3-0-0(3)	
xvii	Application of Fluorescence Spectroscopy in Chemistry and Biology		CY6017	3-0-0(3)	
xviii	Theory of Conductance and Diffusion		CY6018	3-0-0(3)	
xix	Structure and Function of Biomolecules		CY6019	3-0-0(3)	
xx	Receptor Pharmacology and Drug Discovery		CY6020	3-0-0(3)	
xxi	Biophysical Chemistry		CY6021	3-0-0(3)	

xxii	Chemical Bonding and Reactivity		CY6022	3-0-0(3)	
xxiii	Advanced Quantum Chemistry		CY6023	3-0-0(3)	
xxiv	Advanced Magnetic Materials		CY6024	3-0-0(3)	
xxv	Design and Application of Nanomaterials		CY6025	3-0-0(3)	
xxvi	Electroanalysis and Sensors		CY6026	3-0-0(3)	
xxvii	Catalyst Design and Function		CY6027	3-0-0(3)	
xxviii	Organic Spectroscopy		CY6028	3-0-0(3)	
xxix	Chemistry of Natural Products		CY6029	3-0-0(3)	
xxx	Chemistry of Pharmaceutics		CY6030	3-0-0(3)	
xxxi	Advanced Heterocyclic Chemistry		CY6031	3-0-0(3)	
xxxii	Organometallic strategies in Organic Synthesis		CY6032	3-0-0(3)	
xxxiii	Special Topics in Polymer & Composites		CY6033	3-0-0(3)	
xxxiv	Advanced Chemistry of Carbohydrates, Nucleosides and Nucleotides		CY6034	3-0-0(3)	
xxxv	Advanced Topics in Organic Chemistry		CY6035	3-0-0(3)	
xxxvi	Chemo and Bio Informatics		CY6036	3-0-0(3)	
xxxvii	Molecular recognition and Supramolecular Chemistry		CY6037	3-0-0(3)	

Semester-I

Total credits=24

(1) <u>Introduction to Quantum Chemistry (CY4001):</u>

3-1-0: 4 Credits **Prerequisite: Nil**

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 hybridization.

Texts/ References:
1. Ira N. Levine, Quantum Chemistry, Prentice Hall, 5^{th} ed., 1999.
2. A. K. Chandra, Introductory Quantum Chemistry, Tata McGraw-Hill Education, 1994.
3. George C. Schatz and Mark A. Ratner, Quantum Mechanics in Chemistry, Dover Publications, 2002.
4. Linus Pauling and E. Bright Wilson Jr., Introduction to Quantum Mechanics with Applications to Chemistry, Dover Publications, 1985.
5. Donald A. McQuarrie, Quantum Chemistry, University Science Books; 2^{nd} ed., 2007.

(2) <u>Inorganic Chemistry- Structure, Principle and Reactivity (CY4002):</u>

3-1-0: 4 Credits **Prerequisite: Nil**

Symmetry, Point groups with examples (Cnv, Dnh, Dnv, Oh, Td etc), Character tables, Terms symbols and RS coupling, CFT: principles and applications, Orgel energy diagram, Tanabe-Sugano diagram, Ligand field theory, Molecular orbital theory (for Heterodiatomics, Metallocenes etc). Magnetic and spectral properties of coordination compounds. Inorganic reaction mechanism-substitution, Electron transfer reactions (Inner sphere and Outer sphere mechanisms, Marcus-Hush Theory of electron Transfer), Thermodynamic stability and kinetic lability, Trans effect.

Texts/ References:
1. B. N. Figgis, J. E. Huheey, P. W. Atkins, Inorganic Chemistry.
2. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3^{rd}ed., Wiley-Eastern Company, New Delhi 1990
3. James E. House, Inorganic Chemistry (Elsevier)

(3) <u>Concept of Organic Synthesis (CY4003):</u>

3-1-0: 4 credits **Prerequisite: Nil**

Sterochemistry:Introduction, optical isomerism and chirality, resolution, conformational analysis, stereoelectronic effect, and stereochemical aspects; Reactive Intermediates: Carbenes, Nitrenes, Radicals, Carbo-cations, ylides, benzyne; Substitution and Elimination reactions; Acid and base concept of organic compounds; Ideal synthesis; fundamentals of retro-synthesis; Functional group transformations, umpolung and protecting groups; Reaction mechanisms: Definition of reaction mechanism, transition state theory, Substituent effects, linear free energy relationships, Hammett equation and related modifications. Basic mechanistic concepts like kinetic vs thermodynamic control, Hammond postulate, Curtin-Hammett principle, isotope effects; Oxidation and Reduction reactions, Chemistry of cyclic and acyclic compounds; Aromaticity and Aromatic electrophilic substitution: Basic definition of aromaticity, Huckels rule, intermediates and orientation, electrophiles, reactivity and selectivity, kinetic isotopic effects; Nitration, halogenation, sulfonation, Friedel-Crafts reaction, protonation; Nucleophilic aromatic substitution.

Texts/ References:

1. P. S. Kalsi, Stereochemistry, conformation and Mechanism, New Age International Pvt Ltd.; 7th ed. 2009.
2. E. L. Eliel and S. H. Wilen, Stereochemistry of Organic Compounds, John Wiley & Sons, New York, 1994.
3. Clayden, Greeves, Warren & Wothers, Organic Chemistry, Oxford University Press, 2001.
4. J. March. Advanced Organic Chemistry: Reactions, Mechanisms and Structure Wiley-India, 4th edition, 2005.
5. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, PartA and Part B, Springer; 5th edition, 2007.
6. M. B. Smith, Organic Synthesis, McGraw-Hill Science, 2001.
7. Stanley H. Pine, Organic Chemistry, McGraw-Hill.

(4) Mathematics for Chemists (CY4004):

2-0-0: 2 Credits **Prerequisite: Nil**

Function, Limits, Differential Calculus, Integral Calculus, Differential equations, Power series, Complex numbers, Determinants and Matrices, Error analysis, Scalars, Vectors, Curl, Divergence, Gradients, Polynomials: Legendre and Hermite

Texts/ References:

1. Patrick Geoffrey Francis Chapman and Hall, Mathematics for Chemists, 1984.
2. Mary L Boas, Mathematical Methods in the Physical Sciences, 2nd Edition, Wiley, 1983.
3. Graham Doggett and Brian T. Sutcliffe, Mathematics for Chemistry, Longman Scientific and Technical, 1995.
4. David M Hirst, Mathematics for Chemists, Chemical Publishing Company, 1979.

(5) Organic Chemistry Laboratory (CY4101):

0-0-6: 4 credits **Prerequisite: Nil**

Preparations of various organic compounds employing different reactions such as Diels-Alder reaction between furan and maleic acid, Thiamine hydrochloride catalyzed benzoin condensation, Pechmann consensation for coumarin synthesis, Electrophilic aromatic substitution reaction, Radical Coupling reaction, Three component coupling reaction etc will be carried out and followed by characterization using UV, IR and NMR technique with a view to give the student sufficient training in synthetic organic chemistry.

Texts/ References:

1. A. I. Vogel. Practical Organic Chemistry (3rd ed.), Longman Group Ltd. (1973).
2. R. K. Bansal. Laboratory Manual of Organic Chemistry (3rd ed.), Wiley-Eastern (1994)
3. V. K. Ahluwalia and R. Aggarwal, Comprehensive practical organic chemistry, University press. 2000.

4. A. K. Nad, B. Mahapatra and A. Ghoshal, An advanced course in practical chemistry, New Central Book Agency (P) Ltd.

(6) <u>Inorganic Chemistry Laboratory (CY4102):</u>

0-0-6: 4 Credits **Prerequisite: Nil**

Semi-micro Analysis of transition metal and rare earth metal ions in a mixture by using Spot technique. Preparation and (Spectroscopic Characterization) of: Layered Vanadyl Phosphate Dihydrate (Powder XRD, TGA); Tris(acetylacetonator)managanese(III) (Mag. Susceptibility at room temperature by Evans method, EPR); Tris(ethylenediamine)cobalt(III) ion & Optical Resolution (UV, specific rotation) Chlorotribenzyltin(IV) (^{1}H NMR); Halocobaloxime: a B12 model compound (IR, ^{1}H NMR) Estimation of phosphoric acid in soft drinks; Column Chromatographic separation of Chlorophyll from Plant (UV); Gravimetric estimation of metal ion from its ore, Characterization of Fullerenes (Using ^{13}C NMR, and CV).

Texts/ References:

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson, 2006.
2. Vogel's Text book of Quantitative Chemical Analysis
3. A. J. Elias, General Chemistry Experiment
4. G. S. Girolami, T. B. Rauchefuss, R. J. Angelici, Synthesis & Techniques in Inorganic Chemistry

(7) <u>Seminar I (CY4401):</u>

0-0-3: 2 Credits

Presentation on an assigned topic.

Semester-II

Total credits=27

(8) <u>Thermodynamics and Chemical Equilibrium (CY4005):</u>

3-1-0: 4 Credits **Prerequisite: Nil**

Equilibrium Thermodynamics: Review of the laws of thermodynamics, Free energy and chemical equilibria, van't Hoff's isotherm and isochore, Gibbs-Helmholtz equation, Ellihgham diagram-method of free energy determination; Non ideal systems, Thermodynamics of solutions, Debye-Huckel theory for activity coefficient of electrolytic solutions; determination of activity and activity coefficients; ionic strength. 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, theories of chemical reaction rates.

Texts/ References:

1. G. M. Barrow, Physical Chemistry, TATA MCGRAW-HILL, 2007.
2. T. Engel, P.Reid, Physical Chemistry, Pearson, 2006.
3. K. L. Kapoor, Text Book of Physical Chemistry, MACMILLAN, 2006.
4. A. W. Atkins, Physical Chemistry, W. H. Freeman and Company, 1997.

(9) <u>Principles of Organometallic and Bioinorganic Chemistry (CY4006)</u>:

3-1-0: 4 credits **Prerequisite: Nil**

Organometallic chemistry: Bonding models in sigma and pi-complexes. 18-electron formalism and isolobal principle. Basic concepts guiding the synthesis and stability of Li, Mg, B, Si organometallic compounds. Wades/Mingos/Jemmis rule. Basic concepts guiding the synthesis and stability of transition metal alkyls, carbonyls, alkenes, alkynes, arenes, allyls, carbenes, and metallocenes. Basic organometallic reactions: oxidative-addition, reductive elimination, transmetallation, insertion, nucleophilic attach on coordinated ligand. Typical examples of fluxional organometallics. Metal-metal bonding and meta clusters. Bioinorganic Chemistry: The biochemistry of Fe, Cu, Co and Cu. Hemoglobin, Hemocyanin, Ferredoxin, Cytochromes, Carbonic anhydrase, Vitamin B12. Dioxygen binding, Electron transfer, Alkylation reactions.

Texts/ References:

1. J. E. Huheey, Inorganic Chemistry
2. R. H. Crabtree, The Organometallic Chemistry of The Transition Metals
3. James P. Collman, Richard G. Finke, Jack R. Norton, Principles & Applications of Organo-transition Metal Chemistry
4. Lippard, and Bartini, Bioinorganic Chemistry
5. Jan Reedijk; Bioinorganic Catalysis (Publisher: Marcel Dekker)

(10) <u>Advanced Organic Chemistry (CY4007):</u>

3-1-0: 4 Credits **Prerequisite: Nil**

Modern methods of synthesis and reactions of Carbonyl compounds, addition of N, O, and S nuclophiles, Reduction using hydride reagents, chemo and stereoselctivity, formation of enols and enamines, kinetic and thermodynamic enolates, lithium and boron enolates in aldol and Michael reactions, stereoselective aldol condensations, alkylation and acylation of enolates, condensation reactions, Claisen, Dieckman, Knoevenegal, Stobbe and Darzen glycidic ester, acyloin, emphasis on synthetic utility of these reactions, Rearrangement reactions involving electron deficient carbon, nitrogen, oxygen centers and the synthetic utility of these rearrangements. Coupling reactions: Heck, Suzuki, Negishi, Stille, Sonogashira coupling Heterocyclic chemistry: Chemistry of furan, pyrrole, pyridine, indole, quioline, isoquinoline, azoles, pyrimidine and purine: Chemistry of mono and disaccharides. Pericyclic reactions: Classification, electrocyclic, sigmatropic, cycloaddition, chelotropic and ene reactions, Woodward-Hoffmann rules, frontier orbital and orbital symmetry correlation approaches, examples highlighting pericyclic reactions in organic synthesis, stereochemical aspects. Natural Product synthesis: concept of retro synthetic analysis with applications.

Texts/ References:

1. Clayden, Greeves, Warren & Wothers, Organic Chemistry, Oxford University Press, 2001.
2. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, PartA and Part B, Springer; 5th edition, 2007.
3. R. O. C. Norman and J. M. Coxon, Principles of Organic Synthesis 3rd edition, Nelson Thornes, 2005.
4. J. A. Joule and K. Mills, Heterocyclic Chemistry, Wiley-blackwell; 4th Ed, 2000.
5. S. Warren, Organic Synthesis: The Disconnection Approach, Wiley Student Ed. 2007
6. R. B. Woodward and R. Hoffmann, The Conservation of Orbital Symmetry, Academic Press, New York, 1971.

(11) <u>Group Theory and Spectroscopy (CY4008)</u>:

3-1-0: 4 Credits **Prerequisite: Nil**

The concept of groups, symmetry operations and symmetry elements in molecules, matrix representations of symmetry operations, point groups, relations between orders of a finite group and its subgroup irreducible representations and character tables. Orthogonality theorem and its importance. Application of group theory to atomic orbitals in ligand fields, molecular orbitals, hybridization, classification of normal vibrational modes, selection rules in electronic, vibrational, rotational and Raman spectroscopy, Woodward-Hoffman rules.

Texts/ References:

1. F. Albert Cotton, Chemical Applications of Group Theory, John Wiley & Sons, 2008.
2. S. C. Rakshit, Symmetry Theory: Principles, Molecules and Atoms: Problems and Solutions For Chemists (Sarat Book House).
3. Robert L. Carter, Molecular Symmetry and Group Theory, J. Wiley, 1998.
4. David M. Bishop, Group Theory and Chemistry, Dover Publications; Una Rev ed. 1993.
5. Alan Vincent, Molecular symmetry and group theory: a programmed introduction to chemical applications, Wiley, 1977.

(12) <u>Computational Methods and Applications (CY4009)</u>:

2-1-0: 3 Credits **Prerequisite: Nil**

Numerical solutions for simple Hamiltonian and Lagrangian equations, classical molecular dynamics, various integration schemes, periodic boundary conditions, long range interactions, classical Monte Carlo method, Metropolis algorithm, applications to nano and biological systems

Numerical solutions of Schrodinger equation, electronic structure methods, application to simple molecules, clusters and solids

Texts/references:

1. M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Clarendon Press (Oxford).
2. S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).

(13) <u>Physical Chemistry Laboratory (CY4103):</u>

0-0-6: 4 credits **Prerequisite: Nil**

Expt. 1. Determination of isoelectric point of gelatin.

Expt. 2. Determination of CMC of a surface active agent (SDS) conductometrically.

Expt. 3. Determination of rate constants of alkaline hydrolysis of ethyl acetate at different temperatures and estimation of activation parameters.

Expt. 4. To determine the amount of acetic acid adsorbed at its different concentrations by charcoal and hence verify the Freundlich adsorption isotherm.

Expt. 5. Determination of dimerisation constant of benzoic acid in benzene solution.

Expt. 6. Determination of coordination number of Cu^{2+} ion by partition method.

Expt. 7. Determination of partition coefficient of iodine between water and CCl_4/equilibrium constant of tri-iodide formation.

Expt. 8. Verification of Beer-Lambert's law and determination of concentration of a solution.

Expt. 9. Determination of indicator constant by spectrophotometric method.

Expt. 10. To determine the ionization constant of a weak electrolyte.

Expt. 11. To determine the λ^{O} and K_a of a weak electrolyte by Debye Huckel Onsager equation.
Expt. 12. To determine the order of alkaline hydrolysis of crystal violet by spectrometric method.
Expt. 13. Determination of the catalytic co-efficient of an acid for mutarotation of glucose.
Expt. 14. Determination of rate constant of sucrose by polarimeter.
Expt. 15. Determination of solubility and solubility product of silver chloride by E.M.F. measurement of a concentration cell.
Expt. 16. Determination of activity solubility product of silver chloride by E.M.F. measurement.
Expt. 17. Potentiometric titration of a solution of chloride ion with a solution of silver nitrate.
Expt. 18. Determination of stern-Volmer constant of a Iodine quenching reaction by fluorimetric method.
Expt. 19. Estimation of protein concentration by Bradford's method.
Expt. 20. Estimation of concentration of reducing sugar by DNS method.
Expt. 21. DNA and protein gel electrophoresis.

Texts/ References:

1. S. Maity and N. Ghosh, Physical Chemistry Practical, New Central Book Agency (P) Ltd.
2. A. K. Nad, B. Mahapatra and A. Ghoshal, An advanced course in practical chemistry, New Central Book Agency (P) Ltd.

(14) Advanced Instrumentation Laboratory (CY4104):

0-0-6: 4 Credits **Prerequisite: Nil**

Hands on and demonstration experiments and interpretative spectroscopy for UV-Vis, IR, NMR, EPR spectroscopy, Mass Spectrometry, Atomic Absorption Spectroscopy, XRD, Fluorescence, TG, DTA/DSC, Auger, XPS, SEM/TEM and HPLC.

Texts/ References:

1. Skoog and Leary, Principles of Instrumental Analysis.
2. Skoog, West, and Holler, Analytical Chemistry an Introduction
3. Bailey, Clark, Ferris, Krause, and Strong; Chemistry of the Environment, second edition (San Diego: Academic Press, 2002)

Semester III
Total Credits = 24

(15) <u>Analytical Chemistry (CY 5001):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

Introductory Topics: Development of Analytical Chemistry, Analytical Terms, Precision and Accuracy, Figures of Merit. Measurement Fundamentals: Signal-to-Noise Ratio, Origin of Instrument Noise, Quantifying Measurements and Extracting Information. Atomic Absorption Spectroscopy, Emission Spectroscopy, Electrochemical Techniques, XRD, NMR, Fluorescence. Chromatographic Techniques: HPLC, GC. Thermal techniques: TG, DTA/DSC.

Texts/ References:

1. Skoog and Leary, Principles of Instrumental Analysis.
2. Skoog, West, and Holler, Analytical Chemistry an Introduction.
3. Bailey, Clark, Ferris, Krause, and Strong; Chemistry of the Environment, second edition (San Diego: Academic Press, 2002)

(16) <u>Seminar II (CY 5401):</u>

0-0-3: 2 Credits

Literature survey on assigned topic and presentation.

(17) Elective-I:
3-0-0: 3 Credits

(18)Elective-II:
3-0-0: 3 Credits

(19) Elective-III:
3-0-0: 3 Credits

(20) <u>Project-I (CY5501):</u>

0-0-12: 8 Credits

Semester IV
Total Credits = 22

(21) Elective-IV/

3-0-0: 3 Credits

(22) Elective-V/Research Review Paper (/CY6201):

3-0-0: 3 Credits

(23) <u>Project –II (CY5502):</u>

0-0-18: 12 Credits

For course detail belongs to Electives I-V are given below:

(i) <u>Biochemistry (CY6001):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

Composition, structure and function of biomolecules: Amino acids, Carbohydrates, Lipids, Proteins and Nucleic acids.
Stabilizing interactions: Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction, etc.
Principles of biophysical chemistry: pH, buffer, reaction kinetics, thermodynamics, colligative properties.
Metabolism and bioenergetics: Generation and utilization of ATP. glycolysis, TCA cycle,
pentose phosphate pathway, oxidative phosphorylation, gluconeogenesis, glycogen and fatty acid metabolism.
Principles of catalysis: enzymes and enzyme kinetics and inhibition, enzyme regulation, mechanism of enzyme catalysis, isozymes. Vitamins and coenzymes.
Fundamental processes: DNA replication, repair and recombination; Transcription, RNA processing and splicing, translation.
Immune system: Immune system. Active and passive immunity. Complement system. Antibody structure, function and diversity. T, B and macrophages. T and B cell activation. Major histocompatibilty complex. T cell receptor.

Text/References:

1. Lehninger Principles of Biochemistry, Nelson and Cox
2. Biochemistry by Berg, Tymoczko and Stryer
3. Biochemistry by Voet and Voet
4. Molecular Cell Biology by Lodish et al
5 Gene IX by Benjamin Lewin
6 Molecular Biology of Cell by Alberts et al

(ii) <u>Solid State Chemistry (CY6002):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

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. Method of characterization-Powder X-ray diffraction, electron and Neutron diffraction, Thermal analysis, microscopic and spectroscopic techniques as tools for material characterization. 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 and its application.

Texts/ References:

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.
3. A. F. Wells, Structural Inorganic Chemistry, Oxford University Press, USA; 5th ed., 1984.

(iii) Chemical Kiinetics and Surface Chemistry (CY6003):

3-0-0: 3 Credits **Prerequisite: Nil**

Chemical Kinetics: Theories of reaction rates, kinetics and thermodynamic control of reactions. Reactions in solutions, Effect of pressure, dielectric constant and ionic strength; kinetic of enzyme catalysed reactions, fast reactions; Theories of unimolecular reactions and catalysis. Types of inhibitors and their influence in kinetics. Surface Chemistry: Colloidal state of matter. Properties of lyophillic and lyophobic colloidal solutions. Thermodynamics of electrified interface, stability of colloidal solutions: Theory of Verwey and Overbeek, colloidal electrolytes., polyelectrolytes. Donnan membrane equilibria. Determination of molecular weight of macromolecules. Micelles, reverse micelles. Surface energetics and adsorption from liquids. Emulsion, detergent, gels and foams.

Texts/ References:

1. M. R. Wright, An Introduction to Chemical Kinetics, John Wiley & Sons, 2005.
2. K. J. Laidler, Chemical Kinetics, Harper and Row, 3rd Edition, 1990.
3. Richard I. Masel, Chemical Kinetics & Catalysis, Wiley-Interscience; 1st ed, 2001.
4. G. A. Somorjai Introduction to Surface Chemistry and Catalysis, Wiley-Interscience, 1994
5. E. M. McCash, Surface Chemistry, Oxford University Press, USA; 2001.

(iv) Advanced Polymer Chemistry (CY6004):

3-0-0: 3 Credits **Prerequisite: Nil**

Introductory concepts, definition, common system chemistry and classification of polymers, synthetic and natural polymers, types of polymerization, natural and synthetic rubbers, fibers. 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. Various polymerization techniques, Thermodynamics aspect of Polymerization, Stereo Chemistry and mechanism of 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

Texts/ References:

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 ed, 2005.
3. F. W Billmeyer, Text book of Polymer Science, Johns Wiley and sons Publication, 3rd ed., 1984.
4. I. M. Cambell, Introduction to synthetic polymer, Oxford university press, 2nd ed., 2000.

(v) Metal Complexes in Catalysis (CY6005):

3-0-0: 3 Credits **Prerequisite: Nil**

Catalytic Reactions and the 16/18 VE Rule. Review of basic concepts of ligand dissociation, substitution, and elimination reactions. Transition metal assisted valence isomerizations; Isomerization of unsaturated molecules; Arylation/vinylation of olefins; Alkene and Alkyne metathesis; Oligomerization and Polymerization; Olefin oxidation; Hydrogenation of alkenes; Fischer-Tropsch reactions; The water- gas shift reactions; Carbonylation Reactions;
Hydroformylation; Hydrocyanation; Activation of C-H bonds in alkanes; Hydrosilylation and Hydroboration Reactions; Oxygen transfer reactions.

Texts/ References:

1. Sumit Bhaduri, Homogeneous Catalysis.
2. F. A. Cotton and G.Wilkinson, Advanced Inorganic Chemistry, 6th ed., Wiley-Eastern Company, New Delhi.

(vi) Physical Methods in Inorganic Chemistry (CY6006)

3-0-0: 3 Credits **Prerequisite: Nil**

Infrared and Raman Spectroscopy: Review of basics, applications of IR and Raman in inorganic systems – metal coordinated sulphate, dioxygen, carboxylate, aminoacids, perchlorates, nitrites, nitrates, thiocyanate and isocyanate. Mass Spectrometry: Principles and presentation of spectra – molecular fragmentation – ion reactions – Inorganic applications. NMR Spectroscopy: Review of basics, applications of multinuclear nmr in inorganic compounds – Examples from ^{1}H, ^{11}B, ^{13}C, ^{19}F, ^{31}P, ^{51}V, ^{77}Se, ^{95}Mo, ^{119}Sn, ^{199}Pt. Study of fluxional behavior of molecules – an elementary treatment of second order spectra – examples – NMR of paramagnetic molecules – Lanthanide shift reagents Magnetic properties: Magnetic moments and their applications to the elucidation of the structures of inorganic compounds – temperature independent paramagnetism. Magnetic properties of lanthanides and actinides. Spin crossover in coordination compounds. EPR spectroscopy: Theory of EPR spectroscopy - Spin densities and McConnell relationship –Applications of ESR to some simple systems such as CH3, p-benzosemiquinone, Xe^{+2} -Factors affecting the magnitude of g and A in metal species - Zero field splitting and Kramers degeneracy – Spectra of VO(II), Mn(II), Fe(II), Co(II), Ni(II) and Cu(II) complexes – Applications of EPR to a few biological molecules containing Cu(II) and Fe(III) ions. Mossbauer Spectroscopy: Isomer shifts – Magnetic interactions – Mossbauer emission spectroscopy –applications to iron and tin compounds.

Texts/ References:

1. R. S. Drago, Physical Methods in Inorganic Chemistry, 3rd ed., Wiley Eastern Company.
1. 2. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd ed., Wiley-Eastern Company, New Delhi 1990.
2. Lewis and Wilkins, Modern Coordination Chemistry.
3. E. A.V. Ebsworth, Structural Methods in Inorganic Chemistry, 3rd ed., ELBS, Great Britain, 1987.

(vii) Advanced Inorganic Chemistry: Reactions, Kinetics and Mechanism(CY6007):

3-0-0: 3 Credits **Prerequisite: Nil**

Substitution in O_h and Square Planner complexes, thermodynamics and kinetics, stability of complexes, lability, trans-effect, conjugate base mechanism, mechanism of redox reactions, racemization, electron transfer transfer reaction: inner sphere and outer sphere mechanism, Marcus theory. Inorganic photochemistry: photosubstitution and photo redox reactions of Cr, Co, and Ru compounds, Adamson's rules. Lanthanides and actinides spectral and magnetic properties, NMR shift reagents.

Texts/ References:

1. J. E. Huheey, Inorganic Chemistry
2. Shriver & Atkins: Inorganic Chemistry
3. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 6^{th} ed., Wiley-Eastern Company, New Delhi 1990.
4. James E. House, Inorganic Chemistry (Elsevier)

(viii) Advanced Main Group Chemistry (CY6008):

3-0-0: 3 Credits **Prerequisite: Nil**

Structure and Bonding in main group compounds including Hypervalency and Multiple Bond. Recent advances in the coordination, redox, organometallic and cluster chemistry of main group elements. Elements to cover:– Group 1 (Li, Na), Group 2 (Mg), Group 13 (B, Al, In), Group 14 (Si, Sn, Pb), Group 15 (P, As, Sb, Bi), Group 16 (Se, Te). Recent examples of organic synthesis via main group elements with a focus on C-C bond formation and design of asymmetric ligands. Bioinorganic chemistry of main group elements.

Texts/ References:

1. F.A. Cotton and G.Wilkinson, Advanced Inorganic Chemistry, 3rd ed., Wiley-Eastern Company, New Delhi 1990.
2. J. E. Huheey: Inorganic Chemistry
3. Shriver & Atkins: Inorganic Chemistry
4. James E. House, Inorganic Chemistry (Elsevier)

(ix) Inorganic Photochemistry (CY6009):

3-0-0: 3 Credits **Prerequisite: Nil**

Introduction to inorganic photochemistry. Photochemical laws and photochemical kinetics. Photophysical processes. The electronic absorption spectra of inorganic compounds. Characteristics of the electronically excited states of inorganic compounds. Photoelectochemistry of excicted state redox reactions. Photosensitization. Photochemical reactions; substitution, decomposition and fragmentation, rearrangement, and redox reactions. Selective inorganic photochemistry using laser beams. Inorganic photochemistry in biological processes and their model studies.

Texts/ References:

1. G. L. Geoffrey and M. S. Wrighton, Organometallic Photochemistry, Academic Press, 1979.
2. K. K. Rohatagi-Mukherjee, Fundamentals of Photochemistry, Wiley Eastern, 1978.
3. M. S. Wrighton, Inorganic and Organometallic Photochemistry, ACS Pub., 1978.
4. V. Balzani and V. Carasiti, Photochemistry of Co-ordination compounds, Academic Press, 1970.

(x) <u>Chemistry of Materials (CY6010):</u>

3-0-0: 3 Credits **Prerequisites: Nil**

Introduction to Materials: Overview, theory, definitions, history, societal and industrial implication of materials. Classifications of Materials: Metals, semiconductors, insulators, superconductors, macromolecules, zeolites. Advanced materials such as supramolecular assembiles, polymers composites, nanomaterials (i.e. metal, metal oxide, and core-shell structured nanocomposites). Structural features, physical & chemical properties. Preparation: Supramolecular Assemblies: Organic and metal-organic assemblies with voids and channels, thin-films of monolayers and self-assembled layers, structural transformations. Metal nanoparticles: wet chemistry, mechanical, form in place, gas phase. Size control synthesis: metal precursor, solvent, reducing agent, stabilizer, etc. Characterization: Techniques such as, UV-Vis, XRD, TEM, SEM, XPS, AFM, elecectrochemical, etc. Properties: Electrical, optical, mechanical, magnetic; catalytic, chemical and electrochemical. Selective examples of synthesis: Metal nanoparticles, metal oxide nanoparticles, carbon nano-tubes and graphenes. Functionalization of metals nanoparticles: With organic ligands, polymers and biomolecules for selective applications. Applications of advanced materials: catalysis, Fuel Cells, Display devices, Hybrid materials for nano-bio systems, bioelectronic devices, biorecognition events and sensors.

Presentation by the student on assigned topic.

Texts/ References:

1. A. R. West, Solid State Chemistry and its applications.
1. L. Smart and E. Moore, Solid State Chemistry – An Introduction.
2. V. Raghavan, Material Science and Engineering.
3. C C Koch, Nanostructured Materials: Processing, Properties and Potential Applications.
4. H. Singh Nalwa, Handbook of Nanostructured Materials and Nanotechnology.
5. L. Murr, Industrial Materials Science and Engineering.
6. W.G. Moffatt, Structure and Properties of Materials.

(xi) <u>Advanced Bio-inorganic Chemistry (CY6011)</u>:

3-0-0: 3 Credits **Prerequisite: Nil**

Overview of bioinorganic chemistry. Properties of biological molecules. Physical methods in bioinorganic chemistry. Choice,uptake and assembly of metal containing units in biology. Transition metal storage, transport and biomineralization. Electron-transfer proteins: Blue copper proteins, long distance electron transfer. Atom and group transfer chemistry in Fe and Mo:Cytochrome P450, methane monooxygenase, catechol and other dioxygenase, molybdenum oxotransferases. The frontiers of bioinorganic chemistry. Metal/Nucleic-acid interactions. Metals in medicine.

Texts/ References:

1. Lippard & Bartini, Bioinorganic Chemistry
1. Jan Reedijk, Bioinorganic Catalysis (Publisher: Marcel Dekker)
2. Wolfgang Kaim, Brigitte Schwederski, Bioinorganic Chemistry: Inorganic elements in the chemistry of life

(xii) <u>Organic Reagents and Reactions (CY6012):</u>

3-0-0: 3 Credits instrument **Prerequisite: Nil**

General introduction; Modern oxidizing and reducing reagents with applications; organotransition metal reagents: Organosilicon, organotin, organoborane, organocopper, organopalladium and functionalized Grignard reagents; oragnocatalysts; metal carbonyl reagents; Lewis Acids, Tebbe reagent, Corey-Nicolaou reagent, Peterson's synthesis, baker's yeast, lipase, Mosher's reagent in organic synthesis. Name reactions including coupling reactions, rearrangement reactions in organic synthesis and functional group transformations.

Texts/ References:

1. W. Carruthers, Modern methods of Organic Synthesis, Cambridge University Press, 4th ed. 2004.
2. F. A. Carey, R. Sundberg, Advanced Organic Chemistry, Part B, 5th ed., Plenum Press, 2007.
3. R. O. C. Norman and J. M. Coxon Principles of Organic Synthesis 3rd ed., Nelson Thornes, 2005.
4. R. O. C. Norman and J. M. Coxon, Principles of Organic Synthesis 3rd ed., Nelson Thornes, 2005.

(xiii) Methods in Organic Synthesis (CY6013):

3-0-0: 3 Credits **Prerequisite: Nil**

A review of various synthetic methods in organic chemistry: Formation of C-C, C=C, C□C bonds and various rings (namely 3, 4, 5, 6, 7 and 8-membered ring); disconnection approach, chemoselective synthesis, Selected syntheses of natural and unnatural products having these ring systems. A concise introduction to various aspects of asymmetric synthesis followed by detailed discussion on resolution, chiral auxiliaries, chiral ligands, chiral catalysts, and organocatalysts with specific examples. A brief discussion on biosynthesis and biomimetic synthesis with selected examples from monoterpenes, sesquiterpenes, diterpenes, steroids, and alkaloids. Introduction of domino and tandem reaction concepts with a detailed discussion, Protecting groups: protection of hydroxyl, carboxyl, carbonyl, amino groups. Protection of carbon-carbon multiple bonds. Illustration of protection and deprotection in synthesis.

Texts/ References:

1. S. Warren, Organic Synthesis: The Disconnection Approach, Wiley Student Ed. 2007
2. M. B. Smith and J. March, March's Advanced Organic Chemistry, 5th edition, Wiley, 2001.
3. F. A. Carey, R. Sundberg, Advanced Organic Chemistry, Part B, 5th edition, Plenum Press, 2007.
4. B. M. Trost and I. Fleming, Comprehensive Organic Synthesis, Pergamon Press, 1992.
5. R. O. C. Norman and J. M. Coxon Principles of Organic Synthesis 3rd edition, Nelson Thornes, 2005.

(xiv) Photochemistry and Pericyclic Reactions (CY6014):

3-0-0: 3 Credits **Prerequisite: Nil**

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, Jabolnski 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.

Texts/ References:

1. R. B. Woodward and R. Hoffmann, The Conservation of Orbital Symmetry, Academic Press, New York, 1971.

2. M. Smith, Organic Synthesis, Mc Graw Hill, 2nd ed. 2004.
3. T. L. Gilchrist and R. C. Storr, Organic Reactions and Orbital Symmetry, Cambridge University Press, 1972.
4. Fleming, Frontier Orbitals and Organic Chemical Reactions, Wiley, 1976.

(xv) Statistical Mechanics for Chemists (CY6015):

3-0-0: 3 Credits **Prerequisite: Nil**

Introduction to statistical thermodynamics - postulates, microcanonical, canonical and grand canonical ensembles, partition function and thermodynamics, fluctuation, statistical mechanics of independent particles - degeneracy of energy levels and equilibrium distribution function in Maxwell-Bolzmann, Fermi-Dirac and Bose-Einstein statistics.
Statistical mechanics of mono-,diatomic and polyatomic ideal gas -contribution of rotation, vibration and translation to partition function, electronic contribution to the specific heat of diatomic gases. Solids - vibrational contribution to the specific heat of solids, Einstein-Born-Debye model.
Classical statistical mechanics - phase space, Liouville's theorem. Intermolecular interaction. Application to - imperfect gases, liquid structure, chemical equilibrium and phase equilibrium.
Electrochemical systems - effect of non-polar and charged solutes on the structure of water; formation of charge double layer near a charged electrode. Introduction to macromolecular solutions.
Transport properties in gases and condensed phases - kinetic theory of gases, diffusion in solution, transport in electrolyte solutions - Debye-Huckel Theory; Beyond the Debye-Huckel approximation - Debye-Huckel-Bronsted theory, Debye-Huckel-Onsager theory.
Dynamics of chemical reactions in solution - transition state theory using partition functions, non-Arrhennius kinetics resulting from solvent effects.

Texts/ References:

1. Donald A. McQuarrie, Statistical Mechanics, University Science Books, 2000.
2. David Chandler, Introduction to Modern Statistical Mechanics, Oxford University Press, 1987.
3. B. Widom, Statistical Mechanics- A concise Introduction for Chemists, Cambridge University Press, 2002.
4. Terrell L. Hill, Statistical mechanics: principles and selected applications, Courier Dover Publications, 1987.
5. J. –P. Hansen, I. R. McDonald, Theory of simple liquids, Academic Press, London, 1986.

(xvi) Chemical Biology of Receptors (CY6016):

3-0-0: 3 Credits **Prerequisite: Nil**

Origin of life, tree of life, Building blocks of life, Genome and Proteome, Introduction to the cells, Visualizing cells, Chemistry and organization of cells, Cell membrane, Membrane structure, Membrane proteins, G-protein Coupled Receptors (GPCRs): Occurrence and importance, Receptors in human genome, Classification of GPCRs, Structure of GPCRs, Receptor activation mechanism, Desensitization and recycling, Receptor interacting proteins: G-proteins, beta-arrestins, Signal transduction, Secondary messengers: adenyl cyclases, Phospolipases, Rho proteins, Effect on enzymes, ion channels, and transporters. Brief introduction: GPCRs in human body and role in human physiology, Case studies on GPCRs: Rhodopsin and Visual cascades.

Text/References:

1. Molecular Biology of the Cell, Alberts B, et al. 4th or 5th Ed. Publisher: Garland Science.
2. Lehninger Principles of Biochemistry. Nelson D, and Cox M. 4th or 5th Ed. Publisher:W.H. Freeman
3. G Protein-Coupled Receptors: Structure, Signaling, and Physiology, Sandra Siehler (Editor), Graeme Milligan (Editor)

(xvii) Application of Fluorescence Spectroscopy in Chemistry and Biology (CY6017):

3-0-0: 3 Credits **Prerequisite: Nil**

Introduction to fluorescence , fluorescence lifetime and quantum yields, fluorescence anisotropy & polarization and their application in chemistry & Biology, fluorescence quenching and their application, energy transfer, protein fluorescence, fluorescence lifetime of proteins, dynamics of protein revealed by fluorescence methods, molecular probes and surface hydrophobicity, protein unfolding

Texts/ References:

1. J. R. Lakowicz., Fluorescence spectroscopy,
2. C. N. Banwell and E. M. McCash, Molecular spectroscopy, Tata McGraw-Hill, 7th reprint, 1999.

(xviii) Theory of Conductance and Diffusion (CY6018):

3-0-0: 3 Credits **Prerequisite: Nil**

Theory of electrolytic conductance - Debye-Huckel theory of strong electrolytes - Debye-Huckel-Onsager equation - validity of DHO equation - deviation of DHO, migration of ions, transport number in simple electrolytes and mixtures - abnormal transport number. Activity coefficients of electrolytes - ionic strength, Debye-Huckel limiting law, modifications of DHLL, qualitative test of DHLL, verification of DHLL, ion association, fraction of association, association constant, equilibria in electrolytes - dissociation constant, activity coefficient and solubility measurements. Applications of conductance measurements.

Diffusion: Fick's Law of steady state diffusion, diffusion coefficient, relation between diffusion and mobility. Galvanic cells: Cells with and without transference, liquid junction potential and its determination, Donnan membrane equilibrium, Applications of EMF measurements, solubility and solubility product, pH and its measurement, Temperature coefficient of EMF and determination of ΔG, ΔH and ΔS.

Texts/ References:

1. J. O'M. Bockeris, A. K. N. Reddy and M. G-Aldeco, Modern Electrochemistry 2A: Fundamentals of electrodics, Kluwer academic, 2001;
2. A. J. Bard and L.R. Faulkner, Electrochemical methods: Fundamentals and Applications, Wiley, 2000.
3. S. Glasstone, Introduction to Electrochemistry, Affiliated East West Press.

(xix) Structure and Function of Biomolecules(CY6019):

3-0-0: 3 credits **Prerequisite: Nil**

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.

Texts/ References:

1. D. L. Nelson and M. M. Cox, Lehlinger Principles of Biochemistry, W. H. Freeman publisher, 4th ed, 2004.
2. K. Lindhorst, Essentials of Carbohydrate Chemistry and Biochemistry (Wiley-VCH), 2nd Revised Edition, 2003.
3. U. Satyanarayan , Biochemistry, New Central Book Agency, 3rd ed.,2006.
4. L. Stryer, J. Berg, J. L. Tymoczko , Biochemistry, W. H. Freeman Publisher, 6th Ed., 2006.

(xx) Receptor Pharmacology and Drug Discovery (CY6020):

3-0-0: 3 Credits **Prerequisite: Nil**

Basic concepts in molecular pharmacology: Receptor-ligand interaction, Enzymes, agonists, partial agonist, inverse agonists, neutral antagonists and antagonist; potency, intrinsic activity and efficacy, Druggable proteome, Drugs targeting GPCRs, G-protein coupled receptor (GPCR) and biochemical classification of its ligands, Conformational dynamics of GPCRs, Orthosteric and allosteric binding sites, Receptor dimerization, Receptor characterizations: measurement of ligand binding and signaling, Dose response: IC50, LD50, GPCR signaling in endocrine, paracrine, autocrine and synaptic transmissions, GPCRs in homeostasis and diseases, Peptide / protein binding GPCRs, inhibition of signaling and opportunity for drug discovery

Text/References:

1. G Protein-Coupled Receptors: Structure, Signaling, and Physiology, Sandra Siehler (Editor), Graeme Milligan (Editor)
2. G-protein-coupled Receptors: Molecular Pharmacology, Georges Vauquelin (Author) and Bengt von Mentzer (Author)
3. GPCR Molecular Pharmacology and Drug Targeting: Shifting Paradigms and New Directions, Annette Gilchrist (Editor)

(xxi) Biophysical Chemistry (CY6021):

3-0-0: 3 Credits **Prerequisite: Nil**

Structures of biological macromolecules (proteins and polynucleic acids); Molecular Mechanics-simulating macromolecular structure; Spectroscopic methods to study structure of proteins and DNA; structural transitions in polypeptides, proteins and polynucleic acids. Interactions between macromolecules; Thermodynamics of protein folding/stability by fluorescence and circular dichroism techniques. Macromolecule-small molecule binding by biophysical methods.

Texts/ References:

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.
3. C. R. Cantor and P. R. Schimmel, Biophysical Chemistry Part-III, Freeman and Co. 1980.

(xxii) Chemical Bonding and Reactivity (CY6022):

3-0-0: 3 credits **Prerequisite: Nil**

Valence bond theory; molecular orbital theory; Huckel theory; aromaticity; potential energy surfaces; Hammond postulate, Woodward-Hoffmann rule; crystal and ligand field theories; symmetry and symmetry adapted linear combinations; global reactivity descriptors: electronegativity, hardness, polarizability, electrophilicity index; local reactivity descriptors: local softness, Fukui functions and frontier orbital theory, molecular electrostatic potential and associated electronic structure principles.

Texts/ References:

1. R G Parr and W Yang, Density functional theory of atoms and molecules.
2. R G Pearson, Chemical hardness: Applications from Molecules to Solids.

(xxiii) Advanced Quantum Chemistry (CY6023):

3-1-0: 4 Credits **Prerequisite: Nil**

Approximate methods of quantum chemistry: variational principle; LCAO approximation; Huckel Theory; Time-independent perturbation theory. Many electron atoms: Orbital approximation, Slater determinant; Hartree-Fock selfconsistent field theory; Slater type orbitals. Angular momentum of many-particle systems. Spin orbital interaction; LS and JJ coupling. Spectroscopic term symbols for atoms. Molecules and Chemical bonding: Born-Oppenheimer approximation, MO and VB theories illustrated with H2-molecule; Spectroscopic term symbols for diatomics; Directed valence & hybridization in simple polyatomic molecules. Elementary treatments of scattering and density functional theories

Texts/ References:

1. P.W. Atkins, Methods of Molecular Quantum Mechanics.
2. I. N. Levine, Quantum Mechanics
3. R.G. Parr and W.Yang, Density functional theory of atoms and molecules
4. A. Szabo and N.S. Ostlund, Modern Quantum Chemistry.

(xxiv) Advanced Magnetic Materials (CY6024):

3-0-0: 3 Credits **Prerequisite: Nil**

Magnetism: Fundamentals and Theory, Magnetic fields, Magnetization and magnetic moments, magnetic measurements. Single molecule magnet and their properties

Magnetic materials: Classifications of Magnetic Materials, Magnetic properties, Hysteresis and related properties, Parametric characterization of hysteresis, Cause of hysteresis, Micromagnetism, Magnetic order and critical phenomena, Theories of paramagnetism and diamagnetism, Novel Techniques for Characterizing and Preparing Samples , Novel Materials, Spintronics and Magnetoelectonics.

Magnetics-technological applications: Soft magnetic materials, Hard magnetic materials, Magnetic recording, Magnetic evaluation of materials.

Texts/ References:

1. Helmut Kronmüller (Editor), Stuart Parkin (Editor); Handbook of Magnetism and Advanced Magnetic Materials, 5 Volume Set
2. David Jiles; Introduction to Magnetism and Magnetic Materials (2^{nd} Edn. Taylor and Francis).

(xxv) Design and Application of Nanomaterials (CY6025):

3-0-0: 3 Credits **Prerequisite: Nil**

Introduction: Inorganic Materials Chemistry and Nanochemistry; Basics Nanomaterials Synthesis Methods: Bottom-up vs. Top-down Methods; Nanoclusters and Nanowires; Metal, Metal Oxide, semiconductor nanoparticles, quantum confinement, fluorescent properties, and Carbon Nanotubes. Inorganic Materials synthesis by Templating and Self-Assembly; 2-D Nanopatterns and Self-assembled Monolayers on Inorganic Substrates; Mesostructured and Mesoporous Materials; Inorganic-Organic and Inorganic-Polymer Nanocomposite Materials; Opals and Photonic Materials; Layer by layer self-assembly and core-shell Inorganic Nanomaterials; Biomimetics: Bioinspired Synthesis of Inorganic Nanobiomaterials; Catalysis and Photocatalysis (Environmental remediation); Solar Cells and Nanoelectronics/ Nanophotonics Applications Studying and working with matter on an ultra-small scale. Delivery of anti-cancer drugs. New ethical, health and safety or social issues.

Texts/ References:

1. Andre Arsenault and Geoffrey A. Ozin, Nanochemistry: A Chemical Approach to Nanomaterials, RSC, 2005.
2. Kenneth J. Klabunde, Nanoscale Materials in Chemistry, Wiley Interscience, 2001.
3. M. Vollmer and U. Kreibig, Optical Properties of Metal Clusters (Springer) 1993.

(xxvi) Electroanalysis and Sensors (CY6026):

3-0-0: 3 Credits **Prerequisite: Nil**

Basics of electroanalytical chemistry- modified electrodes and their application. Fundamentals of electrochemical sensosr. Electroanalytical chemistry in neuroscience. Electrochemistry of redox proteins. Design of third generation electrochemical sensors. Electrochemical DNA sensors. Electrochemical Impedance spectroscopy and their application. Electrochemical immunoassay: redox and enzyme labeled immunoassay. Electrochemiluminescence and immunoassay; Electrochemical quartz crystal microbalance and its applications. Design of in vivo sensor and measurement of biological molecules like glucose, insulin and cholesterol. Electrochemical sensor for food analysis.

Texts/ References:

1. F. Scholz, Electroanalytical methods, Springer, 2002.
3. P. Monk, Fundamentals of electroanalytical chemistry, Wiley, 2001.
4. A. P .F. Turner I. Karube, I. G. Wilson, Biosensors- Fundamentals and applications. Oxford University Press, New York, 1987.

(xxvii) Catalyst Design and Function (CY6027):

3-0-0: 3 Credits **Prerequisite: Nil**

Concepts in Catalyst: Design, Homogeneous Catalyst, Heterogeneous Catalyst, Metal Based Catalyst, Organo-Catalyst, Bio-Catalyst, Solid-Acid/Base Catalyst, Dual-Function Catalyst; Engineering a Catalyst; Preparative Protocol, Characterization Techniques; Catalyst Function: Selected Examples of Industrially Important Catalytic Processes, Oxidation, Reduction, Coupling, Hydrogenation, Hydroformylation, Hydrocarbon Activation, Asymmetric Catalysis; Catalyst Poisoning, Transition State Model, Surface Phenomenon

Texts/ References:

1. Sumit Bhaduri, Homogeneous Catalysis.
2. F. A. Cotton and G.Wilkinson, Advanced Inorganic Chemistry, 6th ed., Wiley-Eastern Company, New Delhi.

(xxviii) <u>Organic Spectroscopy(CY6028):</u>

3-0-0: 3 credits **Prerequisite: Nil**

Infrared Spectroscopy: Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols, amines; Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acid anydrides, lactones, lactams, conjugated carbonyl compounds); Effects of H-bonding and solvent effect on vibrational frequency, extension to various organic molecules for structural assignment. UV Spectroscopy: UV-Visible, Basic concepts and factors affecting the position of UV bands, Characteristic absorption of Organic compounds, Application of UV spectroscopy. Mass Spectroscopy: Mass spectral fragmentation of organic compounds, common functionalgroups; molecular peak, McLafferty rearrangements, examples of mass spectral fragmentation of organic compounds with respect to their structure determination. Nuclear Magnetic Resonance Spectroscopy: Approximate chemical shift values of various chemically non-equivalent protons and correlation to protons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic); Protons bonded to other nuclei (alcohols, phenols, enols, carboxylic acids, amines, amides, SH); Chemical exchange, effect of deuteration; complex spin-spin interaction; nuclear magnetic double resonance, Fourier transform technique and nuclear Overhauser effect (NOE). Chemical shift (aliphatic, olefinic, alkynes, aromatic, hetero-aromatic, carbonyl carbon); Coupling constants, two-dimensional NMR spectroscopy, NOESY, DEPT and INEPT terminologies. Applications of IR, NMR and Mass spectroscopy for structure elucidation of organic compounds.

Texts/ References:

1. R. M. Silverstein, C. G. Bassler and T. C. Morril, Spectrophotometric Identification of Organic Compounds, 5th ed.,Wiley, 1991.
1. D. H. Williams and I. Fleming, Spectroscopic Methods in Organic Chemistry, 3rd edition, McGraw Hill, 1980.
2. W. Kemp, Organic Spectroscopy, ELBS, 1979.

(xxix) <u>Chemistry of Natural Products (CY6029):</u>

3-0-0: 3 credits **Prerequisite: Nil**

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.

Texts/ References:

1. L. Finar, Organic Chemistry, Vol .2, 5th ed., ELBS, 1975.

2. R. D. Guthrie and J. Honeyman, An Introduction to the Chemistry of Carbohydratres, 3rd ed, Clarendon Press, 1968.
3. K. C. Nicolaou, Classics in Total Synthesis of Natural Products, Vol. I & II.
4. S. V. Bhat, Chemistry of Natural Products 2005.
5. P. M. Dewwick, Medicinal Natural products 2002.

(xxx) <u>Chemistry of Pharmaceutics (CY6030)</u>:

3-0-0: 3 credits **Prerequisite: Nil**

Structure and activity: Relationship between chemical structure and biological activity (SAR). Receptor Site Theory. Approaches to drug design. Antibiotics and antibacterials: (i) Introduction (ii) Antibiotic β-Lactam type - Penicillins, Cephalosporins (iii) Antitubercular – Streptomycin (iv) Broad spectrum antibiotics – Tetracyclines (v) Anticancer - Dactinomycin (Actinomycin D) (vi) Antifungal – polyenes (vii) Antibacterial – Ciprofloxacin, Norfloxacin (viii) Antiviral – Acyclovir; Antimalarials : Chemotherapy of malaria. SAR. Chloroquine, Chloroguanide and Mefloquine; Non-steroidal Anti-inflammatory Drugs: Diclofenac Sodium, Ibuprofen and Netopam; Antihistaminic and antiasthmatic agents : Terfenadine, Cinnarizine, Salbutamol and Beclomethasone dipropionate.

Texts/ References:

1. Burger. Medicinal Chemistry and Drug Discovery, Vol-1, Ed. M. E. Wolff, John Wiley (1994).
2. Goodman & Gilman. Pharmacological Basis of Therapeutics, McGraw-HilI (2005).
3. S. S. Pandeya & J. R. Dimmock. Introduction to Drug Design, New Age International. (2000).
4. D. Lednicer. Strategies for Organic Drug Synthesis and Design, John Wiley (1998).
5. Graham & Patrick. Introduction to Medicinal Chemistry (3rd ed.), OUP (2005).

(xxxi) <u>Advanced Heterocyclic Chemistry (CY6031):</u>

3-0-0: 3 credits **Prerequisite: Nil**

General introduction to heterocyclics and their importance. Nomenclature of ring systems. Synthesis and reactions: indoles, azines, purines, pteridines, azoles, benzopyrimidines, compounds with oxygen and sulfur hetero atoms and small-ring heterocycles. Role of heterocyclic compounds in biological systems.

Texts/ References:

1. J. A. Joule and K. Mills, Heterocyclic Chemistry, Wiley-blackwell; 4th ed, 2000.
2. T. L. Gilchrist, Heterocyclic Chemistry, Pearson Education, 3rd Ed. 2007.
3. J. A. Joule and G. F. Smith, Heterocyclic Chemistry, ELBS, 1978.

(xxxii) <u>Organometallic Strategies in Organic Synthesis (CY6032)</u>:

3-0-0: 3 credits **Prerequisite: Nil**

Introductory concepts of transition metal organometallics and their reaction patterns including selectivity and atom economy. C-C, C-O, C-N, C-S, C-P bond formation by stoichiometric and catalytic organometallic strategies. Activation of alkene, alkyne, diene, allyl, carbene, propargyl, arene, heteroarene, amine, alcohol, thiol, and P-X, P-O, P-N functionalities . Lanthanides in organic reactions.

Texts/ References:

1. J. Tsuji, Transition metal reagents and catalysts- Innovation in organic synthesis, 2000, John Wiley & Sons Ltd., Germany.
2. M. Beller and C. Bolm, Transition metals for organic synthesis- Building blocks and fine chemicals Vol. 1 and 2, 1998, Wiley-VCH, Germany.
3. R. O. C. Norman and J. M. Coxon Principles of Organic Synthesis 3rd edition, Nelson Thornes, 2005.

(xxxiii) Special Topics in Polymer and Composites (CY6033):

3-0-0: 3 credits **Prerequisite: Nil**

Introduction and applications of polymers, molecular weight distributions, various experimental methods (GPC/SEC, solution viscosity, VPO, light scattering) to determine relative and absolute molecular weight distributions, chain growth and step growth mechanisms and kinetics, ionic polymerization, living polymerization, stereochemistry of polymers, free radical copolymerization (random, block, alternate and graft copolymers), kinetics and mechanisms of free radical copolymerization, polymerization conditions and polymer reactions, thermal, mechanical and solution properties of polymers, thermoplastics, thermosets and elastomers, conducting polymers, branched polymers (star, dendritic and hyperbranched polymers).

Texts/ References:

1. G. Odian, Principle of Polymerization 3rd edition, John Wiley, 1991
2. P. J. Flory, Principles of Polymer Chemisty, Cornell University Press, 1953
3 M. Chanda, Advanced polymer chemistry: a problem solving guide, Marcel Dekker, 2000
4. F. W. Billmeyer Jr., Textbook of Polymer Science 3rd edition, John Wiley, 1991

(xxxiv) Advanced Chemistry of Carbohydrates, Nucleosides and Nucleotides (CY6034):

3-0-0 : 3 credits **Prerequisite:Nil**

Carbohydrates: Structures; Reactions at the anomeric centre; Reactions at the non-anomeric centre; protection-deprotection; chemical synthesis of oligosaccharides; chiral pool; natural products; Nucleosides: Structures; Modification of carbohydrate moiety; Modification of heterocycle moiety; ring conformation; DNA and RNA; oligonucleotide synthesis; PNA, LNA and other unnatural oligonucleotides.

Texts/ References:

1. P. M. Collins and R. J. Ferrier, Monosaccharides, Wiley, 1995.
2. G. M. Blackburn, M. J. Gait, D. Loakes, D. Williams, Nucleic acids in chemistry and biology, Royal Society of Chemistry; 1st ed., 2006.
3. Z. A. Shabarova and A. A. Bogdanov, Advanced organic chemistry of nucleic acids, Wiley-VCH; 1 edition, 1994.

(xxxv) Advanced Topics in Organic Chemistry (CY6035):

3-0-0: 3 credits **Prerequisite: Nil**

Principles of asymmetric synthesis: Introduction, Topocity in molecules Homotopic, stereoheterotopic (enantiotopic and diastereotopic) groups and facessymmetry, substitution and addition criteria. Prochirality nomenclature: Pro-R, Pro-S, Re and Si. Selectivity in synthesis: Stereo specific reactions (substrate stereoselectivity). Stereo selective reactions (product stereoselectivity): Enantioselectivity and diastereoselectivity. Conditions for stereoselectivity: Symmetry and transition state criteria, kinetic and thermodynamic control. Methods for inducing enantio and diastereoselectivity. Methodology of asymmetric synthesis: Classification of asymmetric reactions into substrate controlled, chiral auxiliary controlled, chiral reagent controlled and chiral catalyst controlled.Total Synthesis of Biological Active Compounds.

Texts/ References:

1. Nasipuri, D., Stereochemistry of Organic Compounds, New Age Publications, 2nd Ed, 1994.
2. Eliel, E. et. al. Stereochemistry of Organic Compounds, Wiley-Interscience, 1994.
3. Carruthers, et. al. Modern Methods of Organic Synthesis, Cambridge University Press, 4th Ed. 2005.
4. Robert E. Gawley, R. E. Gawley, J. Aube, Principles of Asymmetric Synthesis Pergamon Title, Annotated Ed. 2004.

(xxxvi) <u>Chemo and Bio Informatics (CY6036):</u>

3-0-0:3credits **Prerequisite: Nil**

Introduction to Bioinformatics: Definition and History of Bioinformatics, Internet and Bioinformatics, Introduction to Data Mining, Applications of Data Mining to Bioinformatics Problems and Applications of Bioinformatics; Bioinformatics Softwares: Clustal V, Clustal W 1.7, RasMol, Oligo, Molscript, Treeview, Alscript, Genetic Analysis Software, Phylip; Biocomputing: Introduction to String Matching Algorithms, Database Search Techniques, Sequence Comparison and Alignment Techniques, Use of Biochemical Scoring Matrices, Introduction to Graph Matching Algorithms, Automated Genome Comparison and its Implication, Automated Gene Prediction, Automated Identification of Bacterial Operons and Pathways; Introduction to Signaling Pathways and Pathway Regulation. Gene Arrays, Analysis of Gene Arrays; Systems Biology-an introduction; Markov chains and applications: Machine Learning Methods,Hidden Markov models,Applications of HMM in gene identification and Profiles HMMs, Neural Networks and Support Vector machines; Exploring current chemoinformatics resources for synthetic polymers, pigments, pesticides, herbicides, diagnostic markers, biodegradable materials, biomimetics; Primary, secondary and tertiary sources of chemical information; Database search methods: chemical indexing, proximity searching, 2D and 3D structure and substructure searching; Introduction to quantum methods, combinatorial chemistry (library design, synthesis and deconvolution), spectroscopic methods and analytical techniques. Analysis and use of chemical reaction information, chemical property information, spectroscopic information, analytical chemistry information, chemical safety information. Representing intermolecular forces: ab initio potentials, statistical potentials, forcefields, molecular mechanics. Monte Carlo methods, simulated annealing, molecular dynamics. High throughput synthesis of molecules and automated analysis of NMR spectra. Predicting reactivity of biologically important molecules, combining screening and structure - 'SAR by NMR', computer storage of chemical information, data formats, OLE, XML, web design and delivery.

Texts/ References:

1. J. M. Claverie, and C. Notredame , Bioinformatics for Dummies. Wiley Editor, 2003.
2. S. I. Letovsky, Bioinformatics. Kluwer Academic Publishers 1999.
3. P. Baldi and S. Brunak, Bioinformatics. the MIT Press 1998.
4. J. Setubal, and J. Meidanis, J. Introduction to Computational Molecular Biology. PWS Publishing Co., Boston 1996.
5. A. M. Lesk, Introduction to Bioinformatics. Oxford University Press, 2002.

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(xxxvii) Molecular recognition and Supramolecular Chemistry (CY6037):

3-0-0: 3 credits **Prerequisite: Nil**

From molecular to supramolecules, factors leading to strong binding, hydrogen bonding and stacking interactions, design, synthesis and binding studies of synthetic receptors, design, properties and applications of crown ethers, siderophores, cyclophanes, cyclodextrins, Catenanes and rotaxanes. Metal guided self-assemblies and applications, supramolecular reactivity and catalysis, supramolecular devices, transportation of anions and cations across transmembrane channels, Self-assembled monolayers, Crystal engineering of hydrogen bonded and metal-organic framework solids.

Texts/ References:

1. P. Beer, P. Gale and D. Smith, Supramolecular Chemistry, Oxford Chemistry Primers. 1999.
2. J. M. Lehn, Supramolecular Chemistry, VCH, New. York, 1973.

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PHYSICS

Credit Structure

		Recommended	Actual
1	**Course Credits**		
	Total Credit Requirement:	94-102	96
	Theory	50-60	54
	Laboratories	12-18	12
	Seminars	4	4
	Thesis	26	26
2	**Theory subjects**		
	Total number of theory subjects (cores + electives)	14-16	17
	Number of core subjects (%)	60-80%	77%
	Number of elective subjects (%)	20-40%	23%
	Total credit of theory subjects	50-60	54
3	**Laboratory subjects**	12-18	12
4	**Seminars**	4	4
5	**Thesis (Part I and Part II)**	10+16	10 +16

Semester-wise course details

Semester	Course Name	L-T-P	Credits
I	Classical Mechanics	3-0-0	3
	Mathematical Physics	3-0-0	3
	Quantum Mechanics I	3-1-0	4
	Electrodynamics I	3-0-0	3
	Electronics	3-0-0	3
	Introduction to Computational Methods	2-1-2	4
	Physics Laboratory I	0-0-9	6
	Semester Total	**-**	**26**
II	Quantum Mechanics II	3-0-0	3
	Statistical Mechanics	3-1-0	4
	Atomic & Molecular Physics	3-0-0	3
	Optics and Photonics	3-0-0	3
	Electrodynamics II	3-0-0	3
	Physics Laboratory II	0-0-9	6
	Seminar I	0-0-3	2
	Semester Total	**-**	**24**
III	Nuclear and Particle Physics	3-0-0	3
	Condensed Matter Physics	3-0-0	3
	Elective I	3-0-0	3
	Elective II	3-0-0	3
	Project I	0-0-15	10
	Seminar II	3-0-0	2
	Semester Total	**-**	**24**
IV	Project II	0-0-24	16
	Elective III	3-0-0	3
	Elective IV/Research Review Paper	3-0-0	3
	Semester Total	**-**	**22**
	Grand Total		**96**

COURSE CURRICULUM

S.N	Course Name	Nature of course	Course code	L-T-P (Credit)	Page
	SEMESTER – I				
1	Classical Mechanics	Core	PH4001	3-0-0(3)	
2	Mathematical Physics	Core	PH4002	3-0-0(3)	
3	Quantum Mechanics I	Core	PH4003	3-1-0(4)	
4	Electrodynamics I	Core	PH4004	3-0-0 (3)	
5	Electronics	Core	PH4005	3-0-0(3)	
6	Introduction to Computational Methods	Core	PH4006	2-1-2(4)	
7	Physics Laboratory I		PH4101	0-0-9(6)	
	SEMESTER – II				
8	Quantum Mechanics II	Core	PH4007	3-0-0(3)	
9	Statistical Mechanics	Core	PH4008	3-1-0(4)	
10	Atomic & Molecular Physics	Core	PH4009	3-0-0(3)	
11	Optics and Photonics	Core	PH4010	3-0-0(3)	
12	Electrodynamics II	Core	PH4011	3-0-0 (3)	
13	Physics Laboratory II	Core	PH4102	0-0-9(6)	
14	Seminar I	Core	PH4401	0-0-3 (2)	
	SEMESTER – III				
15	Nuclear and Particle Physics	Core	PH5012	3-0-0 (3)	
16	Condensed Matter Physics	Core	PH5013	3-0-0 (3)	
17	Elective I	Elective		3-0-0(3)	
18	Elective II	Elective		3-0-0(3)	
19	Project I		PH5501	0-0-15 (10)	
20	Seminar II	Core	PH5402	0-0-3(2)	
	SEMESTER – IV				
21	Project II	Core	PH5502	0-0-24 (16)	
22	Elective III	Elective		3-0-0 (3)	
23	Elective IV/Research Review Paper	Elective	/PH6201	3-0-0 (3)	

LIST OF ELECTIVES

List of subjects to be floated under Electives I-IV					
i	Physics and Technology of Lasers		PH6001	3-0-0(3)	
ii	Applied Photonics Technology		PH6002	3-0-0(3)	
iii	Non Equilibrium Phenomena in Physics		PH6003	3-0-0(3)	
iv	Advanced Statistical Physics		PH6004	3-0-0(3)	
v	Magnetism in Materials		PH6005	3-0-0(3)	
vi	General Relativity and Cosmology		PH6006	3-0-0(3)	
vii	Quantum Field Theory		PH6007	3-0-0(3)	
viii	Nanostructure and Quantum Devices		PH6008	3-0-0(3)	
ix	Particle Physics		PH6009	3-0-0(3)	
x	Methods in Experimental Nuclear and Particle Physics		PH6010	3-0-0(3)	
xi	SemiConductor Physics		PH6011	3-0-0(3)	
xii	Accelerator based physics of solids		PH6012	3-0-0(3)	
xiii	Radiation detection and measurement		PH6013	3-0-0(3)	
xiv	Biophysics		PH6014	3-0-0(3)	
xv	Computational Methods and Applications		CY4009	3-0-0(3)	

Semester-I
Total Credits = 26

(1) <u>Classical Mechanics (PH4001):</u>

3-0-0 : 3 Credits **Prerequisite: Nil**

Review of Newtonian mechanics, Lagrangian mechanics, generalized coordinates, constraints, principle of virtual work, Lagrange's equation, calculus of variations, central forces, collisions, scattering small oscillations, anharmonic oscillators. perturbation theory, forced oscillators. Hamilton's equations, phase space & phase trajectories, canonical transformations, Poisson brackets, Hamilton-Jacobi theory, rigid body dynamics, nonlinear dynamics. Special Relativity, Lorentz transformations, relativistic kinematics and mass-energy equivalence.

Texts:

1. H. Goldstein, C. P. Poole Jr., J. L. Safko, Classical Mechanics, 3rd edition, Addison-Wesley, 2001.
2. L. Landau and E. Lifshitz, Mechanics, 3rd edition, Butterworth-Heinemann, 1976.

References:

1. R. Resnick, Introduction to Special Relativity John Wiley (Asia), 1999.
2. F. Scheck, Mechanics, 3rd edition, Springer, 1999.
3. Philip Morse, Herman Feshbach, Methods of Theoretical Physics, Parts 1 and 2, 1st edition, Feshbach Publishing, 2005.

(2) <u>Mathematical Physics(PH4002):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

Vector Analysis: Gradient, divergence, and curl in curvilinear co-ordinate system; Tensor Analysis: Contraction, Direct Product, Quotient Rule, Pseudo-tensors, Dual tensors, General Tensors, Tensor Derivative Operators; Determinants and Matrices: Orthogonal, Hermitian and Unitary Matrices, Diagonalization of Matrices; Linear Algebra: Vector spaces, Inner products, Gram-Schmidt orthogonalization, Linear transformations, eigenvalues and eigenvectors, Hilbert space; Complex analysis: Cauchy-Riemann conditions, Cauchy's theorem, Taylor and Laurent series, Singularities, Calculus of residues, Conformal mapping; Differential Equations: Partial and First order equations, Series solution-Frobenius' method, Laplace equation, Separation of variables, Sturm-Liouville theory; Special Functions: Legendre, Bessel, Hermite and Laguerre functions; Integral Transforms: Fourier and Laplace transforms, applications; Probability: Random variables, binomial, Poisson and normal distributions, central limit theorem; Introductory Group theory: Lie groups, generators and representations.

Texts:

1. George B. Arfken, Hans J. Weber, Frank E. Harris, Mathematical Methods for Physicists: A Comprehensive Guide, 7th edition, 2012.

References:

1. T. Lawson, Linear Algebra, John Wiley & Sons, 1996.
2. R. V. Churchill and J.W. Brown, Complex Variables and Applications, 8th edition, McGraw-Hill, 2008.
3. Charlie Harper, Introduction to Mathematical Physics, Prentice-Hall of India Pvt. Ltd, 2008.
4. Mary L. Boas, Mathematical Methods in Physical Sciences, John Wiley & Sons, 2005.
5. H.W. Wyld, Mathematical Methods for Physics, 2nd edition, Westview Press, 1999.
6. Mathews and Walker, Mathematical Methods of Physics, 2nd edition, W.A. Benjamin, 1990.
7. P. Dennery and A. Krzywicki, Mathematics for Physicists, Dover Publications, 1996.

(3) <u>Quantum Mechanics I (PH4003):</u>

3-1-0 : 4 Credits **Prerequisite: Nil**

Introduction and Overview of quantum mechanics; Formalism: Linear vector space; State vectors and operators; Observables; Eigenvalues and eigenvectors;Dirac's notation; Hermitian adjoint operators. Position and Momentum Space:Different examples; Generalization for 3D cases. Eigenvalues and eigenvectors; Harmonic Oscillator: One dimensional; Raising and Lowering operators; Eigenstates; Coherent states; generalization to 3D; Isotropic oscillator; Angular Momentum: Angular momentum and rotation; General angular momentum; ; Orbital angular momentum; spherical harmonics; Spin angular momentum; Addition of angular momentum; Wigner-Eckart Theorem; Spherical Tensors; Central Potential:Hydrogen atom; Radial equation; Quantum Dynamics: Time evolution operator, Heisenberg picture; Interaction picture; Time Independent Perturbation Theory: Non-degenerate case; degenerate case. Time Dependent Perturbation Theory: Fermi Golden Rule; Adiabatic approximation; Sudden approximation. WKB Approximation: Bohr-Sommerfeld quantization Rule; Tunneling. Identical Particles: Pauli's exclusion principle; Two electron atoms; Quantum Statistics.

Texts:

1. David J. Griffiths, Introduction to Quantum Mechanics, 2nd edition, Pearson Education Inc., 2005.
2. J. J. Sakurai, Modern Quantum Mechanics, Addison Wesley, 1st edition, 1993.
3. F. S. Gasiorowicz, Quantum Physics, John Wiley (Asia), 2000.

References:

1. L. I. Schiff, Quantum Mechanics, McGraw-Hill, 3rd rev. edition, 1968.
2. E. Merzbacher, Quantum Mechanics, John Wiley (Asia), 1999.
3. P. W. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw Hill,1995.
4. F. Schwabl, Quantum Mechanics, Narosa, 1998.
5. B. H. Bransden and C. J. Joachain, Introduction to Quantum Mechanics, Longman, 1993.

(4) <u>Electrodynamics I (PH4004):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

Electrostatics, Solution of Laplace and Poisson equations in 2 & 3 dimensions (Uniqueness of solutions, Dirichlet, Neumann and mixed boundary conditions), method of images, Separation of variables and Green's function approach in Cartesian, Cylindrical and Spherical coordinate systems, Dirac delta function, multipole expansion; Dielectrics: Polarization, bound and free charges, susceptibility, boundary conditions, boundary value problems. Magnetostatics, vector potential, magnetic field, moments, force, torque and energy of localized current distributions, Kramers-Kronig relation, Magnetohydrodynamics: Alfen waves, Magnetic fields in Matter, Electromagnetic Induction, Maxwell’s equations for time varying fields, Gauge transformations, potential formulation: Scalar and Vector Potential, Coulomb and Lorentz Gauges, Conservation Laws; Maxwell's stress tensor; Electromagnetic wave Equation, Propagation of electromagnetic waves in conducting and non-conducting medium; Reflection and transmission; Wave guides. Radiation. Lienard-Wiechert potentials, Fields of a moving point charge.

Texts:

1. J. D. Jackson, Classical Electrodynamics, John Wiley (Asia), 1999.

References:

1. David J. Griffiths, Introduction to Electrodynamics, Addison-Wesley, 2012.
2. J. R. Reitz and F. J. Millford, Foundation of Electromagnetic Theory, Narosa, 1986.
3. Walter Greiner, Classical Electrodynamics, Springer, 1998.

4. Julian Schwinger, Classical Electrodynamics, Perseus Books, 1998.
   Hans C. Ohanian, Classical Electrodynamics, Firewall Media, 2009.
   Tung Tsang, Classical Electrodynamics, World Scientific, 1999.

(5) Electronics (PH4005):

3-0-0: 3 Credits **Prerequisite: Nil**

Semiconductors, BJT and FET, Transistor biasing, small signal transistor amplifiers, operational amplifier theory, frequency effects, feedback circuits, oscillators and timers, amplitude and frequency modulation and demodulation. Boolean algebra, logic gates, combinational and sequential logic, registers, counters and memory units, ADC & DAC, Data acquisition systems, Multiplexure, Demultiplexure, microprocessor system design and programming, data communications and interfacing.

Texts:

1. A. Mottershead, Electronic Devices and Circuits, Prentice Hall of India, 1993
2. J. Millman and C. C. Halkias, Integrated Electronics, Tata McGraw Hill, 1995

References:

1. R. Gaekwad, Op-Amps and Linear Integrated Circuits, Prentice Hall of India, 1995
2. A. P. Malvino and D. P. Leach, Digital Principles and Applications, Tata McGraw Hill, 1991
3. R. S. Gaonkar, Microprocessor Architecture: Programming and Applications with the 8085, 5th edition, CBS Publishers, 2011

(6) Introduction to Computational Methods (PH4006):

2-1-2: 4 Credits
Prerequisite: Nil
Introduction, Basic numerical analysis, Introduction to Unix, Introduction to C/C++ programming, Solutions to Nonlinear equations, Newton-Raphson method, Interpolation and Curve fitting, Numerical Solutions to ODE and PDE, Euler's and Runge-Kutta methods, Introduction to Latex, Random Numbers and Generators, Elementary treatment of Monte Carlo Method.

Texts:

1. K. E. Atkinson, Numerical Analysis, John Wiley (Asia), 2004.
2. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, Tata McGraw Hill, 2002.
3. W. H. Press, S. A. Teukolsky, W. T. Verlling and B. P. Flannery, Numerical Recipes in C++, Cambridge, 1998.

References:

1. D. W. Rogers, Computational Chemistry using PC, 3rd edition, John Wiley & Sons, 2003.

(7) Physics Laboratory I (PH4101):

0-0-9: 6 Credits
Prerequisite: Nil
General Physics: Measurement of magnetic susceptibility of a liquid or a solution by Quincke's method; Thermal conductivity (2 experiments)
Electronics: Monostable and astable multivibrator using Timer IC:555; Inverting and non-inverting amplifier; Integrator/differentiator; Phase Shift Oscillator; Seven-segment display (5 experiments)
Optics: Michelson Interferometer; Fabry-Perot Interferometer; Fiber-optic kit; Nd-Y Ag/He-Ne Laser; Faraday's rotation (5 experiments)

References:
1. Taylor, John R., An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books, 2nd edition, 1996
3. P. B. Zbar and A. P. Malvino, Basic Electronics: a text-lab manual, Tata McGraw Hill, 1983.
4. P. Leach, Experiments in Digital Principles, McGraw Hill, 1986
5. R. S. Gaonkar, Microprocessor Architecture: Programming and Applications with the 8085, 5th edition, CBS Publishers, 2011

Semester-II
Total Credits = 24

(8) Quantum Mechanics II (PH4007):

3-0-0: 3 Credits **Prerequisite: Quantum Mechanics I**

Path integral formulation of quantum mechanics and its application to elementary quantum systems. Aharanov-Bohm effect. Formal Scattering theory, interaction picture; S-matrix; Many-particle Green's functions, propagator for various particles; relativistic wave equations - Klein-Gordon equation, Dirac equation, Lamb shift, Majorana Fermions. Introductory treatment of classical fields, quantization, Lorenz transformations, Wick's theorem, Feynman rules and Feynman diagrams. Particle processes, Matrix elements and cross sections for – Moller scattering, Pair production and annihilation, Bhabha scattering and Compton scattering.

Texts:
1. S. Weinberg, Quantum Field Theory, Vols. I, II, III, Cambridge University Press: Cambridge, UK, 2005.
2. M.E. Peskin and D.V. Schroeder, Introduction to Quantum Field Theory, Addison-Wesley, 1995.

References:
1. Francis Halzen, Alan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics , John Wiley & Sons Singapore Pvt. Ltd. / Singapore, 1984.
2. James D. Bjorken, Sidney D. Drell, LSC Relativistic Quantum Mechanics (Pure & Applied Physics), McGraw-Hill Science/Engineering/Math; 1st edition, 1998.
3. James D. Bjorken, Sidney D. Drell, Relativistic Quantum Fields, Dover Books on Physics, 1998.

(9) Statistical Mechanics (PH4008):

3-1-0: 4 Credits
Prerequisite: Nil

Introduction and Overview of statistical mechanics; Ergodic hypothesis; Liouville theorem; Concepts of ensembles. Microcanonical Ensemble : Concepts of entropy; Some applications . Canonical (CE) and Grand-canonical Ensemble (GCE) : Probability distribution in CE and GCE; Thermodynamic quantities in CE and GCE; Energy dispersion in CE; Mean particle number and mean energy and the grand potential; Fluctuations in particle number; Some applications . Quantum Statistics : Ideal quantum gases; Photons and Phonons; Bose-Einstein Condensation. Interacting Systems : Model – Ising model (1D & 2D), XY model; Phase Transition; Mean field Theory; Scaling and Renormalization Group theory. Non-Equilibrium Statistical Mechanics: Fokker-Planck equation; Basics of Langevin Equation; Some applications; Master Equation, Growth and decay process.

Texts:
1. R. K. Pathria, Statistical Mechanics, Butterworth-Heinemann, 1996.
2. F. Reif, Statistical and Thermal Physics, McGraw-Hill, 1985.

3. K.Huang, Statistical Mechanics, John Wiley Asia, 2000.

References:

1. H. Risken & T Frank, The Fokker-Planck Equation: Methods of Solutions and applications, 3rd Edition, Springer, 1996.
2. R. Zwanzig, Non-equilibrium Statistical Mechanics, Oxford University Press, USA; 1st edition, 2001.
3. S. Dattagupta & S. Puri, Dissipative Phenomena in Condensed Matter Physics : Some Applications, Springer; 1st edition, 2004.
4. C.W. Gardiner, Handbook of Stochastic Methods: for Physics, Chemistry and Natural Sciences, 3rd Edition, Springer, 2004.
5. L. D. Landau and E. M. Lifshitz, Statistical Physics, Pergamon, 1980
6. W. Greiner, L Neise, and H. Stocker, Thermodynamics and Statistical Mechanics, Springer, 1994.

(10) Atomic and Molecular Physics (PH4009):

3-0-0: 3 Credits **Prerequisite: Quantum Mechanics I**

Spectra of alkali atoms, vector atom model, LS and jj couplings, normal and anomalous Zeeman effect, Stark effect. Symmetric and antisymmetric wave functions, Hartree-Fock method, Born-Oppenheimer approximation. Fine structure of spectral lines, Lambshift and QED corrections, nuclear spin and hyperfine structure, Spectral line broadening, Accelerator based atomic physics, Laser cooling and trapping of atoms, ion traps, Laser spectroscopy, X-ray spectroscopy, electron spectroscopy, Time-of-Flight spectroscopy, Raman Spectroscopy, ESR and NMR

Texts:

1. B. H. Bransden and C.J. Joachain, Physics of atoms and molecules, Longman Scientific & Technical, 2003.

References:

1. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, McGraw-Hill College, 1994.
2. Rodney Cotterill, Biophysics: An introduction, 1st edition, Wiley, 2002.
3. R.N.Roy, A Textbook of Biophysics, New Central Agency (P) Ltd., Calcutta, 2001.

(11) Optics and Photonics (PH4010):

3-0-0: 3 Credits **Prerequisite: Quantum Mechanics I**

Wave propagation in anisotropic media, 1-D and 3D dimensional wave equations, Superposition of waves, Fourier transform and spatial filtering, Coherence theory, Concept of spatial and temporal coherence, Diffraction theory, Interferometry and its applications, Optical fiber and waveguides, non linear optics, Holography, interaction of radiation with matter, line shape function, condition for amplification, optical resonators, Latest in optics and photonics.

Texts:

1. Saleh and Teich, Fundamentals of Photonics, 2nd edition, Wiley-Interscience, 2007.
2. E. Hecht, Optics, Addison-Wesley, 2008.
3. A. Ghatak, Optics,1st edition, McGraw-Hill, 2009.

References:

1. Amnon Yariv, Photonics, Wiley-Interscience, 2012.
2. Ghatak and Thayagrajan, Optical Electronics, Cambridge University Press, 1989.
3. A. Ghatak and K. Thayagrajan, An Introduction to Fiber Optics, Cambridge University Press, 1998.
4. R. Feynmann, Lectures on Physics, 1st edition, Basic Books, 2011.
5. A. E. Siegman, Lasers, 1st edition, University Science Books, 1986.
6. Orazio Svelto, Principles of Lasers, 6th edition, Springer Verlag, 2010.
7. K. Thyagarajan and Ghatak, Lasers, Theory and Applications, 2nd edition, Springer, 2011.

(12) Electrodynamics II (PH4011):

3-0-0: 3 Credits **Prerequisite: Electrodynamics I**

Special relativity, Minkowski space and four vectors, concept of four-velocity, four acceleration and higher rank tensors, relativistic formulation of electrodynamics, classical fields, Action formulation, symmetries, Noether's theorem, canonical quantization of the scalar, spin ½ fields, and Gauge bosons, relativistic particles in external electromagnetic fields, Gauge invariance, Gauge orbits and four-potential, Bianchi Identities and electromagnetic energy momentum tensor, solution of wave equation in covariant formulation, invariant Green's functions, Green function for wave equation: advanced and retarded. Radiating systems, fields and radiation from an accelerated charge, dispersion theory, scattering by free charges, Scalar diffraction (Kirchhoff theory), Elementary treatment of self-energy and radiative corrections, divergence and renormalization, Introductory quantum electrodynamics.

Texts:

1. J. D. Jackson, Classical Electrodynamics, John Wiley (Asia), 1999.
2. M. E. Peskin and D.V. Schroeder, Introduction to Quantum Field Theory, Addison-Wesley, 1995.

References:

1. L.D. Landau and E. M. Lifshitz, Electrodynamics of Continuous Media, Butterworth Heimemann, 1995.
2. J. R. Reitz and F. J. Millford, Foundation of Electromagnetic Theory, Narosa, 1986.
3. Julian Schwinger, Classical Electrodynamics, Perseus Books, 1998.
4. Stephen Parrott, Relativistic Electrodynamics and Differential Geometry, 1st editionSpringer, 1986.
5. N. M. J. Woodhouse, Special Relativity (Springer Undergraduate Mathematics Series), Springer, 2007.
6. T. M. Helliwell, Special Relativity, University Science Books, 2009.
7. S. Weinberg, Quantum Field Theory, Vols. I, II, III, Cambridge University Press: Cambridge, UK, 2005.

(13) Physics Laboratory II (PH4102):

0-0-9: 6 Credits
Prerequisite: Nil

Modern Physics: Planck's "quantum of action" and photoelectric effect; Diffraction at a slit and Heisenberg's uncertainty principle; Elementary charge and Millikan experiment; Geiger-Muller counter; Lande g-factor; Zeeman Effect (6 experiments)
Condensed Matter Physics: Hall effect in semiconductors; Deposition System; Photovoltaic cell; Band gap of Semiconductor (4 experiments)

References:

1. Taylor, John R., An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books, 2nd edition, 1996.
2. Tipler & Llewellyn, Modern Physics, 6th edition, University Science Books, 2012.
3. H. Sathyaseelan, Laboratory Manual In Applied Physics, New Age International Publishers, 2008.
4. A. C. Melissinos, Experiments in Modern Physics, Academic Press, 1996.
5. R. A. Dunlop, Experimental Physics, Oxford University Press, 1988.
6. P. V. Bork, H. Grote, D. Notz, M. Regler, Data Analysis Techniques in High Energy Physics Experiments, Cambridge University Press, 1993.

(14) <u>Seminar I (PH4401):</u>

0-0-3: 2 Credits

Semester-III
Total Credits = 24

(15) <u>Nuclear and Particle Physics (PH5012):</u>

3-0-0: 3 Credits **Prerequisite: Quantum Mechanics I, Electrodynamics I**

Nuclear properties: General properties: radius, mass, binding energy, nucleon separation energy, angular momentum, parity, electromagnetic moments, excited states; Nuclear models: liquid drop model, semi - empirical mass formula; Fermi gas model of nucleus, nuclear shell model; Nuclear reactions: energetics, conservation laws, isospin, classification of nuclear reactions, fusion and fission; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Radioactive decay: radioactive decay law, production and decay of radioactivity, radioactive dating. detection of nuclear radiation, alpha, beta and gamma decays; The Deuteron problem, Shell model and magic numbers, Collective models; Particle Phenomenology: elementary particles and interactions: fundamental interactions, classification of particles: leptons and quarks and gauge bosons; Quark model, quark dynamics, Standard model, Gell-Mann Okubo mass formula, Symmetries and conservation laws Parity violation in weak interaction, The V-A interaction, weak current, muon decay, pion decay, Cabbibo angle, CP violation in neutral Kaon decay, Kaon oscillations

Texts:

1. B.R.Martin, Nuclear and Particle Physics,1st edition, 2006.
2. K. S. Krane, Introductory Nuclear Physics, John Wiley, 1988.
3. D. Griffiths, Introduction to Elementary Particles, Wiley, 2008.

References:

1. Thomas Ferbel, Ashok Das, Introduction to Nuclear and Particle Physics, 1st edition, 1993.
2. Brian Martin, Nuclear and Particle Physics, An Introduction, 2nd edition, 2009.
3. Mittal V. K, Verma R. C, Gupta S. C, Introduction To Nuclear And Particle Physics, 2nd edition, 2011.
4. Richard Clinton Fernow, Introduction to Experimental Particle Physics, 1989.
5. B Martin and G P Shaw, Particle Physics, 3rd edition, 2008.
6. D. H. Perkins, Introduction to High Energy Physics, 4th edition, Cambridge, 2000.
7. F. Halzen and Alan D. Martin, Quarks and Leptons, Wiley India edition, 1984.
8. I. S. Hughes, Elementary Particles, Cambridge, 1991.
9. R. Roy and B. P. Nigam, Nuclear Physics: Theory and Experiment, New Age, 1967.

(16) <u>Condensed Matter Physics (PH5013):</u>

3-0-0: 3 Credits **Prerequisite: Quantum Mechanics I**

Structure of solids: Symmetry operations; Bravais lattices; Miller indices and reciprocal lattice; Bonding and packing in crystals; Structure determination (X-ray, electron & neutron diffraction); Defects in crystals; Lattice vibration and thermal properties:dispersion relation; attenuation; density of states; phonons and quantization; Brillouin zones; lattice heat capacity; Einstein and Debye models; thermal conductivity of metals and insulators; Electronic properties: Free electron theory of metals;

electrons in a periodic potential; Bloch equation; Kronig-Penny model; tight-binding model; band theory; metal, semiconductor and insulators; bandgap; intrinsic and extrinsic semiconductors; Hall effect; p-n junction; Dielectrics: Polarizability; Clausius-Mossotti formula, Peizo-, Pyro- and Ferro-electric crystals; ferroelectric domains; optical behavior of bound and free electrons; Kramer-Kronig relations; optical absorption; photoconductivity; Magnetism: Dia- and para-magnetism; Van-Vleck and Pauli paramagnetism; Exchange interaction; Ferro-, antiferro- and ferri-magnetism, spin wave, resonance absorption; Superconductivity: Meissner effect; Energy gap; London equations; coherence length; type I & type II superconductors; BCS theory; Josephson effect

Texts:

1. C. Kittel, Introduction to Solid State Physics, John Wiley, 1996.

References:

1. H. P. Myers, Introduction to Solid State Physics, Viva books, 1998.
2. A. J. Dekker, Solid State Physics, Macmillan, 1986.
3. N. W. Ashcroft and N. D. Mermin, Solid State Physics, HBC Publ., 1976.

(17) Elective-I:
3-0-0: 3 Credits

(18) Elective-II:
3-0-0: 3 Credits

(19) Project-I (PH5501):
0-0-15: 10 Credits

Project in the assigned topic(s)

(20) Seminar II (PH5402):
0-0-3: 2 Credits

Semester-IV
Total Credits = 22

(21) Project-II (PH5502):
0-0-24: 16 Credits

Project in the assigned topic(s)

(22) Elective-III:
3-0-0: 3 Credits

(23) Elective-IV /Research Review Paper (/PH6201)::
3-0-0: 3 Credits

ELECTIVES I-IV COURSES

(i) Physics and Technology of Lasers (PH6001):

3-0-0: 3 Credits **Prerequisite: Nil**

Spontaneous and stimulated emission of radiation; Basic Physics and characteristic of laser, Rate equations, Pumping techniques, Practical example of lasers, Laser systems and its different applications in Science, industry, medicine, communication defense, printing etc., Recent advancement in laser and future

Texts:

1. A. E. Siegman, Lasers, 1st edition, University Science Books, 1986.
2. O. Svelto, Principles of Lasers, 6th edition, Springer, 2010.
3. K. Thyagarajan and Ghatak, Lasers, Theory and Applications, 2nd edition, Springer, 2011.

References:

1. A. Yariv, Photonics, 6th edition, Oxford University Press, USA, 2006.
2. D. J. Griffith, Introduction to Electrodynamics, 3rd edition, Addison Wesley, 1997.
3. A. Ghatak and K. Thayagrajan, Optical Electronics, Cambridge University Press, 1989.
4. Wolfgang Demtrder, Springer Verlag, Laser Spectroscopy 2nd edition, Springer, 1996.
5. Jiri Homola, Surface plasmon resonance based sensor, 1st edition, Springer, 2010.
6. A. Ghatak and K. Thayagrajan, An Introduction to Fiber Optics, Cambridge University Press, 1998.
7. R. Feynmann, Lectures on Physics, 1st edition, Basic Books, 2011.

(ii) Applied Photonics Technology (PH6002):

3-0-0: 3 Credits
Prerequisite: Nil

Review of basic optics, Polarization, Reflection and refraction of plane waves, Diffraction: diffraction by single slit and circular aperture, Gaussian beams, Fiber Optics; Fourier optics: Interference: two-beam and multiple beam interference, Fabry-Perot interferometer; Interaction of radiation with matter, light amplification; Laser rate equations, three level and four level systems; Optical Resonators, resonator stability; mode selection; Q switching and mode locking in lasers: Properties of laser radiation and some laser systems

Texts:

1. B. E. A. Saleh and M.C. Teich, Fundamentals of Photonics, 2nd edition, Wiley-Interscience, 2007.
2. E. Hecht, Optics, 4th edition, Addison-Wesley, 2001.

References:

1. A. Yariv, Photonics, 6th edition, Oxford University Press, USA, 2006.
2. A. Ghatak and K. Thayagrajan, Optical Electronics, Cambridge University Press, 1989.
3. A. Ghatak and K. Thayagrajan, An Introduction to Fiber Optics, Cambridge University Press, 1998.
4. R. Feynmann, Lectures on Physics, 1st edition, Basic Books, 2011.

(iii) Non Equilibrium Phenomena in Physics (PH6003):

3-0-0: 3 Credits
Prerequisite: Nil

Introduction: examples of non-equilibrium phenomena (i) glass transition;(ii) nucleation; (iii) phase separation; Experimental probes: dynamic scattering; inelastic neutron scattering; Theoretical tools: Two alternative theoretical approaches (a) Langevin equation - dissipation, non-linearity and noise; illustration with translational Brownian motion; (b) Fokker-Planck equation diffusion and drift; illustration with (i) translational Brownian motion, (ii) rotational Brownian motion; master equation - loss and gain of probabilities; concept of detailed balance; metastability and bi-stability: Kramers' theory of thermally activated barrier crossing , applications in (i) chemical reactions (ii) rock magnetism; Stochastic resonance : enhancing signals with the help of noise - applications of stochastic resonance in (a) nonlinear optics, (b) solid state devices, (c) neuro-science, (d) molecular motors and biological locomotion; Driven diffusive systems : Non-equilibrium steady-states in driven system, driven systems of interacting particles - applications to vehicular traffic; The phenomenon of Surface Growth: Roughening, Dynamic Scaling, Significance of correlations; Growth models; Random and Ballistic depositions.; Edward Wilkinson model.; Kardar-Parisi-Zhang model; Relaxation Phenomenon in nanomagnets: Relaxation of magnetic nanoparticles; superparamagnetism; spinglass phenomena; ageing; memory effects.

Texts:

1. N.G. Van Kampen, Stochastic Processes in Physics and Chemistry, 2nd Edition , North-Holland, 1992.
2. H. Risken & T Frank, The Fokker-Planck Equation: Methods of Solutions and applications, 3rd Edition, Springer, 1996.
3. R. Zwanzig, Non-equilibrium Statistical Mechanics, 1st edition, Oxford University Press, USA, 2001.
4. D. S. Lemons, An Introduction to the Stochastic Processes in Physics, The Johns Hopkins University Press, 2002.

References:

1. S. Dattagupta & S. Puri, Dissipative Phenomena in Condensed Matter Physics: Some Applications, 1st edition, Springer, 2004.
2. C.W. Gardiner, Handbook of Stochastic Methods: for Physics, Chemistry and Natural Sciences, 3rd edition, Springer, 2004.
3. S. Dattagupta, A Paradigm Called Magnetism, World Scientific Publishing Company, 2008.

(iv) <u>Advanced Statistical Physics (PH6004):</u>

3-0-0: 3 Credits
Prerequisite: Nil

Phase transitions in various dimensions: Magnetic systems and liquid-gas transitions. Correlation Functions. Landau theory of phase transitions. Calculation of critical exponents; Examples : Examples of first order and continuous phase transitions. Mean field (van der Waals and Weiss molecular field) theories. Fluid- magnet analogy. Correlations. classical (Ornstein -Zernicke) theory; Statistical mechanical models: Ising, lattice gas, Heisenberg, XY and Potts models. Transfer matrix method. illustration using the one-dimensional lsing model. Duality in the two-dimensional Ising model. High and low temperature series expansions; Critical phenomena: long-range order, order parameter, scaling, universality, critical exponents. Peierls argument for phase transitions. Spontaneous breakdown of symmetry, Landau theory of phase transitions. Role of fluctuations, lower and upper critical dimensions. Ginzburg-Landau model. Higgs mechanism, examples. Mermin-wagner theorem. Topological (Berezinski-Kosterlitz- Thouless) phase transition; Introduction to Renormalization Group: Fixed points. Relevant and Irrelevant variables. Relation between Critical exponents from RG. Momentum space RG: Going from discrete to continuous picture. Partition function. Functional integration. Landau-Ginzburg model. Consistency with Landau model. Scaling in momentum space. Dimensional analysis. Scaling and Anomalous dimensions. Evaluation of Partition Function in the Gaussian model. RG treatment of the Gaussian model.

Texts:

1. Nigel Goldenfeld, Lectures on Phase Transition and Renormalization Group, Westview Press, 1992.
2. Mehran Kardar, Statistical Physics of Fields, 1st edition, Cambridge University Press, 2007.
3. R. K. Pathria & P. D. Beale, Statistical Mechanics, 3rd edition, Academic Press, 2011.

References:

1. H. E. Stanley, Introduction to Phase Transitions and Critical Phenomena, Clarendon Press, Oxford, 1971.
2. P. M. Chaikin & T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press; Reprint edition, 2000.

3. W. D. McComb, Renormalization Methods: A Guide for Beginners, 1st edition, Oxford University Press, USA, 2008.

(v) Magnetism in Materials (PH6005):

3-0-0: 3 Credits **Prerequisite: Quantum mechanics and Solid state physics**

Magnetism in atoms and ions, dia- and para-magentism, environment effects: crystal field, tetrahedral and octahedral sites, Jahn- Teller effect, Hund's rule and rare earth ions in solids. Collective magnetism: molecular field theory for ferro-, antiferro- and ferri-magnetism, circular and helical order, spin glass. Direct and indirect exchange interactions, Itinerant magnetism, magnons, domains and domain walls, magnetic hysteresis, pinning effects. Experimental techniques, Magneto resistance, giant magneto resistance, nuclear magnetic resonance, technological aspects of magnetic materials.

Texts:

1. S. Blundell, Magnetism in Condensed Matter, Oxford, 2001.
2. J. M. D. Coey, Magnetism and Magnetic Materials, Cambridge University Press, 2010.

References:

1. D. Craik, Magnetism: Principles and Applications, John Wiley, 1995.
2. Mathias Getzlaff, Fundamentals of Magnetism, Springer, 2008.
3. Robert C. O'Handley, Modern Magnetic Materials: Principles and Applications, Wiley-Interscience, 1999.

(vi) General Relativity and Cosmology (PH6006):

3-0-0: 3 Credits
Prerequisite: Nil

Introduction and Scope of General Relativity, Space-time and Relativity, Riemannian-geometry. energy-momentum tensor and Einstein's equations. Principles of General Relativity, Field Equations of General Relativity, Schwarzschild metric and Black Holes. Introduction to cosmology, The Friedmann-Lemaitre-Robertson-Walker cosmology.

Texts:

1. Ta-Pei Cheng, Relativity, Gravitation and Cosmology: A Basic Introduction, 2nd edition, Oxford University Press, USA,2010.
2. B. F. Schutz, A First Course in General Relativity, 2nd edition, Cambridge U. Press, 2009.
3. S. Weinberg, Gravitation and Cosmology, Wiley, 1972.

References:

1. T. Padmanabhan, Gravitation: Foundation and Frontiers, Cambridge University Press, Cambridge, 2010.
2. N. M. J. Woodhouse, General Relativity (Springer Undergraduate Mathematics Series), 3rd edition, Springer, 2006.
3. B. Schutz, Gravity from the Ground Up, Cambridge, 2003.
4. J. B. Hartle, Gravity - An Introduction to Einstein's General Relativity, Addison Wesley, 2003.
5. J. Foster and J.D. Nightingale, A Short Course in General Relativity, 2nd edition, Springer 1994, 1995.
6. R. M. Wald, General Relativity, The University of Chicago Press, 1984.
7. C. W. Misner, K.S. Thorne, J.A. Wheeler, Gravitation, Freeman, 1973.

(vii) <u>Quantum Field Theory (PH6007):</u>

3-0-0: 3 Credits
Prerequisite: Nil

Review of Classical Field Theory, Lorentz transformations, relativistic wave equations; Lagrangian formalism for fields; symmetry transformations and Nöther's theorem, Canonical quantization of the Scalar, Dirac and Maxwell fields. Wick's theorem. Feynman rules and Feynman diagrams, gauge invariance. Lowest order cross- sections and elementary treatment of self-energy and radiative corrections, divergence and renormalization.

Texts:
1. A. Zee, Quantum Field Theory in a Nutshell, 2nd edition, Princeton University Press, 2010.
2. Mark Srednicki, Quantum Field Theory, 1st edition, Cambridge University Press, 2007.
3. M. E. Peskin and D.V. Schroeder, Introduction to Quantum Field Theory, Addison-Wesley, 1995.

References:
1. Franz Mandl and Graham Shaw, Quantum Field Theory, 2nd edition, Wiley, 2010.
2. S. Weinberg, Quantum Field Theory, Vols. I, II, III, Cambridge University Press: Cambridge, UK, 2005.
3. Malte Henkel, Conformal Invariance and Critical Phenomena (Theoretical and Mathematical Physics), paperback edition, Springer, 2010.
4. P. M. Chaikin , T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press, 2000.
5. Ta-Pei Cheng and Ling-Fong Li, Gauge Theory of elementary particle physics, Oxford University Press, USA, 1988.
6. Francis Halzen and Alan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, 1984.
7. Pierre Ramond, Field Theory: A Modern Primer (Frontiers in Physics Series, Vol 74), 2nd edition, Westview Press, 2001.

(viii) <u>Nanostructure and Quantum Devices (PH6008):</u>

3-0-0: 3 Credits
Prerequisite: Nil

Semiconductor Heterostructure, Nano-CMOS devices, Low-dimensional semiconductor structures, Semiconductor superlattices and miniband, Optical properties of nanostructures, Resonant tunneling phenomena, Coulomb blockade and quantum transport. Metallic superlattices, self-assembling nanostructures, Nanofabrication, probing of nanostructures, Quantum devices: Single electron devices, Quantum cascade Lasers, Ultra-fast switching devices, high density memories, giant magneto resistance and Josephson devices, long wavelength IR detector, photonic integrated circuits.

Texts:
1. S. M. Sze, Physics of Semiconductor Devices, 3rd edition, Wiley Eastern Limited, 2006.
2. Jacques I. Pankove, Optical Process in Semiconductor, 2nd edition, Dover Publications, Inc., 2010.
3. K. P. Jain, Physics of Semiconductor Nanostructures, Narosa Publishing House, 1997.

References:
1. S. V. Gaponenko, Optical Properties of Semiconductor Nanocrystals, Cambridge University Press, 2005.
2. H. S. Nalwa, Handbook of Nanostructured Material and Nanotechnology, 1st edition, Academic Press, 1999.
3. K. Sattler, Cluster assembled Materials, TransTech Publication Limited, 1st edition, CRC Press, 1996.
4. Jackie Ying, Nanostructure Material, 1st edition, Academic Press, 2001.

5. C. C. Koch, Nanostructure Material, processing, properties and application, 2nd edition, William Andrew Publishing, 2006.
6. J. H. Davies, The Physics of Low dimensional Semiconductor, Cambridge University Press, 1997.

(ix) Particle Physics (PHS6009):

3-0-0: 3 Credits
Prerequisite: Nil

Elementary particles, Fundamental forces, relativistic kinematics, Symmetries and conservation laws; Bound states, Scattering processes of spin-1/2 particles (Feynman's rules as thumb rule QFT course), propagators; QED; weak interactions, parity violation, Gauge symmetries, spontaneous symmetry breaking, Electroweak interaction, Glashow-Salam-Weinberg model, Higgs mechanism; Introduction to QCD, structure of hadrons (form factors, structure functions), parton model, Deep inelastic scattering; Physics beyond the standard model: LHC, extra dimensions, and other current topics

Texts:
1. D. Griffiths, Introduction to Elementary Particles, Wiley, 2008.
2. B Martin and G P Shaw, Particle Physics, 3rd edition, Wiley, 2008.

References:
6. The Review of Particle Physics, J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)
7. A. Zee, Quantum Field Theory in a nut shell, 2nd edition, Princeton University Press, 2010.
8. D. H. Perkins, Introduction to High Energy Physics, 4th edition, Cambridge, 2000.
9. T. P. Cheng and L.F. Li, Gauge Theory of elementary particle physics, Oxford, 1988.
10. E. Leader and E. Predazzi, An Introduction to Gauge Theories and Modern Particle Physics, Cambridge, 1996.
11. F. Halzen and Alan D. Martin, Quarks and Leptons, Wiley India edition, 1984.
12. The particle data group: http://pdg.lbl.gov/

(x) Methods in Experimental Nuclear and Particle Physics (PH6010):

3-0-0: 3 Credits
Prerequisite: Nil

Passage of radiation through matter : Interaction of heavy charged particles, neutrons, gamma rays and relativistic particles. ionization loss characterized by the Bethe-Bloch equation, loss via bremsstrahlung, and the Cherenkov effect; Radiation Detection : Detection mechanism, characteristics of detectors. Detectors in Nuclear Physics : gas detectors, scintillation counters; Solid state detectors. Detectors in Particle Physics : Drift Chambers, spark chambers, bubble chambers; Accelerators : Van de Graff, LINAC, Cyclotrons, Synchrotons, Colliders; Pulse Processing : Timing and Energy measurements, data acquisition and analysis; Present Detectors: Techniques used in present LHC (Large Hadron Collider) detectors, such as CMS, ATLAS

Texts:
1. Glenn F. Knoll, Radiation Detection and Measurements, 4th edition, John Wiley and Sons, 2010.
2. W. R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer Verlag, 1994.

References:
1. R. Cahn and G. Goldhaber, Experimental Foundations of Particle Physics, Cambridge U. Press, 2009.
2. C. Leroy and P. Rancoita, Principles of Radiation Interaction in Matter and Detection, World Scientific Publ. Co., 2009.
3. C. Grupen and B. Shwartz, Particle Detectors, 2nd edition, Cambridge U. Press, 2008.
4. W. Blum, W. Riegler and L. Rolandi, Particle Detection with Drift Chambers, 2nd edition, Springer, 2010.

5. D. Green, The Physics of Particle Detectors, Cambridge U. Press, 2000.
6. R. Fruhwirth, et al., Data Analysis Techniques for High-Energy Physics, Cambridge U. Press, 2000.
7. T. Ferbel, Experimental Techniques in High-Energy Nuclear and Particle Physics, ed., World Scientific Publ. Co., 1999.
8. M. S. Livingston and J.P. Blewet, Particle Accelerators, McGraw Hill, 1990.

(xi) <u>Semi Conductor Physics (PH6011):</u>

3-0-0: 3 Credits **Prerequisite: Nil**

Electron and hole statistics in semiconductors, semiconductor band structure, doping in semiconductors, transport properties, semiconductor heterostructures, charge carrier recombination, diffusion of electrons and holes, equation of continuity, carrier injection, p-n junction, current-voltage characteristic, Physical model of p-n junction, junction capacitance and width, breakdown phenomena, metal-semiconductor junction, rectification at metal-semiconductor junction, schottky-diffusion theory, photoconductivity, bipolar transistor (principle and characteristics),principle of operation of FET, photovoltaic effect.

Texts:

4. S. M. Sze, Physics of Semiconductor Devices, 3rd edition, Wiley Eastern Limited, 2006.

References:

1. Jacques I. Pankove, Optical Process in Semiconductor, 2nd edition, Dover Publications, Inc., 2010.
2. J. H. Davies, Physics of Low dimensional Semiconductor, Cambridge University Press, 1997.

(xii) <u>Accelerator Based Physics of Solids (PH6012):</u>

3-0-0: 3 Credits
Prerequisite: Nil

Need of accelerated particles in physics study; production of ion beams (ion sources and accelerators); Interaction of radiation with matter; Materials engineering using heavy ions – ion implantation; ion beam assisted deposition (IBAD); ion beam mixing (IBM), Materials analysis using heavy ions – Rutherford backscattering spectroscopy (RBS), Elastic recoil detection analysis (ERDA); ion induced nuclear reaction; Nuclear reaction analysis (NRA); nuclear solid state physics – Microscopic magnetism using perturbed angular distributions (PAD).

Texts:

1. D. R. Clarke, S. Suresh and I.M Ward, Ion-solid interactions: fundamentals and applications, Cambridge Solid State Science Series, Cambridge University Press, 2003.

References:

1. Patrick Richard, Methods of Experimental Physics: Atomic Physics, Accelerators (Vol. 17, Academic Press).
2. D. J. Griffiths, Quantum Mechanics, 2nd edition, Pearson Prentice Hall, 2004.
3. Michael Anthony Nastasi, James W. Mayer, James Karsten Hirvonen, Ion-solid interactions: fundamentals and applications, Cambridge University Press, 2004.
4. A. Mozumder and Y. Hatano, Charged particle and photon interactions with matter: Chemical, physicochemical, and biological consequences with applications, 1st edition, CRC Press, 2003.

(xiii) Radiation Detection and Measurements (PH6013):

3-0-0: 3 Credits
Prerequisite: Nil

Sources of Nuclear Radiations (Radioactive Sources and Particle Accelerators); Interaction of Ionizing Radiations (Heavy Ions, Gamma Radiations, Neutrons, etc.) with Matter; Radiation Dosimetry; Statistics for Nuclear Physics Experiments (Characterization of Data, Probability Distribution Functions, Propagation of Errors, Weighted Mean Method, Optimization of Counting Experiments, Curve Fitting, Least Squares Method, Chi-Square Distribution); Ionization Detectors (General Operating Principles); Gas-Filled Ionization Detectors (Parallel Plate and Cylindrical Ionization Chambers, Parallel Plate Avalanche Counter, Cylindrical Proportional Counter, Multiwire Proportional Counter, Drift Chamber, Streamer Chambers, Bubble Chamber); Liquid Ionization Detectors; Semiconductor Detectors; Scintillation Spectrometers; Cherenkov Radiation Detectors; Radiation Calorimeters; Modern Mass Spectrometers as Heavy Ion Reaction Analyzer

Texts:
1. Glenn F. Knoll, Radiation Detection and Measurements, John Wiley and Sons, 4th edition, 2010.

References:
1. H. F. Beyer and V. P. Shevelko, Introduction to the physics of highly charged ion, IoP.

(xiv) Biophysics (PH6014):

3-0-0: 3 Credits
Prerequisite: Nil

Atomic description of biomolecules: DNA, RNA, and proteins; forces and energetic in living systems: cells; Quantitative measurement techniques to investigate biological problems: NMR, Raman spectroscopy, ultrafast spectroscopy, magnetic resonance imaging, optical microscopy; Statistical physics in biology: energy and entropy in complex biomolecules, molecular machines; Molecular modeling of biological problems: Brownian motion and diffusion, protein folding, enzyme reaction; Biomechanics: statics and human anatomy, mechanics of motion

Texts:
1. P. Nelson, Biological Physics: Energy, Information, Life, Freeman, 2008.
2. Ken Dill and Sarina Bromberg, Molecular Driving Forces: Statistical thermodynamics in Biology, Chemistry, Physics and Nanoscience, 2nd edition, 2010.

References:

1. H. Lodish et al., Molecular Cell Biology, 7th edition, Freeman, 2012.
5. B. Alberts et. al., Molecular Biology of the Cell, 5th edition, Garland Science, 2007.

(xv) Computational Methods and Applications (CY4009):

2-1-0: 3 Credits **Prerequisite: Nil**

Numerical solutions for simple Hamiltonian and Lagrangian equations, classical molecular dynamics, various integration schemes, periodic boundary conditions, long range interactions, classical Monte Carlo method, Metropolis algorithm, applications to nano and biological systems

Numerical solutions of Schrodinger equation, electronic structure methods, application to simple molecules, clusters and solids

Texts/references:

1. M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Clarendon Press (Oxford).
2. S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).

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M.Sc. - Ph.D. Course Structure for Earth Sciences
School of Earth, Ocean and Climate Sciences

School of Earth, Ocean and Climate Sciences
Joint M.Sc. – Ph. D. Earth Science Programme

Admission Criteria:

M.Sc. Earth Science

Previous Degree			Prerequisite
B.Sc.	Geology (Honours/Major)	**JAM Score**	Bachelor's degree with Geology as a subject for three years/six semesters, and any two subjects among Mathematics, Physics, Chemistry. The candidate should have passed Mathematics at (10+2) level.

Compliance Report:

Item	**Committee Recommendation Credits**	**School's Proposal Credits**
Theory	50-60 Core - 60-80% Elective - 40-80%	55 Core: 78% Elective: 22%
Labs.	12-18	17
Seminars	4	4
Thesis **Part-I** **Part – II**	10 16	10 16
Field work	4	4
Field Training	2	2
Total	100 -108	108

Selection: Through JAM.

Opting for Ph. D. Programme: As per Institute norms.

Semester I						
Sl. No.	**Subject Name**	**Loading**				
		L	**T**	**P**	**C**
1	Dynamic Earth System	3	0	0	3
2	Igneous and Metamorphic Petrogenesis	4	0	0	4
3	Structural Geology	3	0	0	3
4	Advanced Mineralogy & Crystallography	3	0	0	3
5	Computational Geosciences	2	1	0	3
6	Structure Geology Laboratory	0	0	3	2
7	Petrology Laboratory	0	0	4	3
8	Advanced Mineralogy & Crystallography Laboratory	0	0	3	2
9	Computational Geosciences Laboratory	0	0	3	2
	Total				**25**

Semester II					
Sl. No.	**Subject Name**	**Loading**			
		L	**T**	**P**	**C**
1	Geophysical Techniques	3	0	0	3
2	Geomorphic processes and Sedimentary Rocks	3	0	0	3
3	Applied Hydrogeology	3	0	0	3
4	Engineering Geology and Rock Mechanics	3	0	0	3
5	Remote Sensing and GIS	3	0	0	3
6	Applied Paleontology & Stratigraphy	3	0	0	3
7	Remote Sensing and GIS Lab.	0	0	3	2
8	Applied Paleontology Lab.	0	0	3	2
9	Sedimentary Petrology Lab	0	0	3	2
10	Field Work - I (Two Weeks)	0	0	0	2
	Total				**26**

Semester III					
Sl. No.	**Subject Name**	**Loading**			
		L	**T**	**P**	**C**
1	Ore Geology	3	0	0	3
2	Coal and Petroleum Geology	3	0	0	3
3	Elective – I	3	0	0	3
4	Elective – II	3	0	0	3
5	Ore Geology Laboratory	0	0	3	2
6	Seminar I	0	0	0	2
7	Field Training (3/4 Weeks)	0	0	0	2
8	Project Work (I)	0	0	0	10
	Total				**28**

Semester IV					
Sl. No.	**Subject Name**	**Loading**			
		L	**T**	**P**	**C**
1	Reservoir Characterization	3	0	0	3
2	Elective – III	3	0	0	3
3	Elective – IV	3	0	0	3
4	Seminar II	0	0	0	2
5	Field work - II	0	0	0	2
6	Project work (II)	0	0	0	16
	Total				**29**

Electives					
Sl. No.	**Subject Name**	**Loading**			
Elective - I & II		**L**	**T**	**P**	**C**
1	Environmental Earth Sciences	3	0	0	3
2	Physics & Chemistry of Atmosphere and Ocean	3	0	0	3
3	Glacial Geoscience	3	0	0	3
4	Isotope Geology	3	0	0	3
5	Modeling and Simulation in Earth Sciences	3	0	0	3
Elective – III & IV					
1	Organic Geochemistry	3	0	0	3
2	Aqueous Geochemistry	3	0	0	3
3	Geothermal Energy	3	0	0	3
4	Mineral Resource Economics	3	0	0	3
5	Analytical Methods in Geosciences	3	0	0	3
6	Heat and Mass Transfer in Earth System	3	0	0	3

Joint M. Sc. - Ph. D. Programme in Earth Science

Subject Details

Semester I

<table>
<tr><td>Sl. No.</td><td>Subject Code: ESA5010</td><td>Subject Name: Understanding Earth System</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td>1.</td><td colspan="3">Earth as a planet; size, shape and mass of Earth. Relative and absolute age-dating of Earth. Earthquakes and seismic waves; Earth’s internal structure; Earth’s magnetic and gravity fields; palaeomagnetism. Continental and oceanic crust; Continental drift; Ocean floor spreading; Plate Tectonics. Structure of Atmosphere and related phenomena, Origin and Evolution of ocean basins, Ocean Circulation, Global Warming; causes and effects Composition of the earth; characteristics and elemental abundance in different layers. Geological processes operating on the surface of earth.

Books:
1. Earth as an Evolving Planetary System, (2010): Kent C. Condie, Academic Press; 2 edition, Second Edition.
2. Introduction to Earth and Planetary System Science: New View of Earth, Planets and Humans (2012): Naotatsu Shikazono, Springer; 2012 edition.
3. Planetary Surface Processes (2011): H. Jay Melosh, Cambridge University Press; 1 edition.</td></tr>
<tr><td>2.</td><td>Subject Code: ESA5011</td><td>Subject Name: Igneous and Metamorphic Petrogenesis</td><td>Credit: 4
L-T-P: 4-0-0</td></tr>
<tr><td></td><td colspan="3">Classification of rocks; Physical and Chemical properties; Factors affecting Composition and evolution of magma, Crystallization of magmas, Physico-chemical interpretation of igneous textures. Norms - CIPW, Niggli values. Continental Flood Basalt, Oceanic Island Basalts, Rift Magmatism, Plume Volcanism.
Classification of metamorphic rocks; Type of Metamorphism, Metamorphic facies, Detailed description of low pressure, medium to high pressures and very high pressure facies. Tectonics and Metamorphism, Ultra high temperature, ultra-high pressure and ocean-floor metamorphism. Chemical zoning and its relation to tectonism. Isograds and reaction isograds and concept of P-t-t paths.
Laws of thermodynamics; Gibb’s free energy, entropy; ΔG of metamorphic reactions (solid-solid and dehydration reactions); Clausius – Clapeyron equation; Geothermobarometry.

Books:
1. Igneous and Metamorphic Petrology (2002): Myron G. Best, Wiley-Blackwell; 2 edition.
2. Principles of Igneous and Metamorphic Petrology (2009): John D. Winter, Prentice Hall; 2 edition.
3. Principles of Igneous and Metamorphic Petrology (2009): Anthony Philpotts & Jay Ague, Cambridge University Press; 2nd edition.
4. Igneous Petrology (1987): Anthony Hall, Longman Sci. & Tech.
5. Equilibrium thermodynamics in Petrology: An Introduction (1978): Powell, R., Harper and Row Publ., London.</td></tr>
<tr><td>3.</td><td>Subject Code: ESA5012</td><td>Subject Name: Structural Geology</td><td>Credit: 3</td></tr>
</table>

			L-T-P: 3-0-0
	Dynamic and kinematic analyses of rocks in two dimensions, stress and strain. Cleavage, schistosity, boudins. Microdeformation, plastic and brittle deformation, Large scale tectonics. Folds – classification, mechanism of folding, Theory of progressive evolution of fold shapes in single competent layers, Layer parallel shortening, Dependence of fold shape on high and low viscosity contrast between different layers. Superimposed folding, type 1, 2 and 3 interference patterns. Study of various types of fractures. Fault classification based on orientation of stress and strain axes. Thrust systems. Strike slip fault systems. Shear zones. Books: 1. Structural Geology (2010): Haakon Fossen, Cambridge University Press; 1 edition. 2. Structural Geology of Rocks and Regions (2011): G. H. Davis, S. J. Reynolds, C. F. Kluth, Wiley; 3 edition. 3. Fundamentals of Rock Mechanics (2007): J. Jaeger, N. G. Cook & R. Zimmerman, Wiley-Blackwell; 4 edition.		
4.	Subject Code: ESA5013	Subject Name: Advanced Mineralogy & Crystallography	Credit: 3 L-T-P: 3-0-0
	X- ray powder diffraction: reciprocal lattice, Ewald's sphere, indexing and calculation of cell parameters; Elements of crystal field-, molecular orbital and band theories. UV- VIS- NIR and vibrational spectroscopic methods (IR and Raman) and pertinent mineralogical applications; Micro-beam analysis: SEM, TEM, EPMA and their geochemical applications; Thermal analytical methods: DTA, DSC, TG; calculation of enthalpy and heat capacity; mineralogical characterization of industrial raw materials; Electrical and magnetic properties: resistivity, Hall potential, thermoelectric power, magnetic moments, magnetic susceptibility and application to characterization of sulfide minerals. Books: 1. Introduction to Mineralogy (2011): William Nesse, Oxford University Press, 2 edition. 2. Mineralogy (2010): Dexter Perkins, Prentice Hall; 3 edition. 3. Manual of Mineral Science (2007): Cornelis Klein & Barbara Dutrow, Wiley; 23 edition.		
5.	Subject Code: ESA5014	Subject Name: Computational Geosciences	Credit: 3 L-T-P: 2-1-0
	Basic introduction to computer, Introduction to programming, Programming methodology. Concepts of structured programming. Design and implementation of programs for scientific computing purposes; Program layout, variables and data structures, functions, loops and conditional statements, input/output routines; examination and implementation of useful algorithms. Basic numerical techniques of data analysis in geological sciences. Matrix Algebra: solution of simultaneous equations. Application of Statistics in Geosciences: Multivariate Normal Distribution. Multivariate Sampling Distributions, ANOVA. Multivariate Linear Regression. Principal Components, factor analysis, Canonical Correlation, Discrimination and Classification, Cluster and Factor Analysis. Test of significance. Introduction to various graphics and drawing software. Numerical methods & Partial differential equation. Books: 1. Data Structures and Algorithms Made Easy: Data Structure and Algorithmic Puzzles (2011): Narasimha Karumanchi, CreateSpace Independent Publishing Platform; 2 edition.		

	2. Software Architecture, Data Structures, Algorithms, Programming and Testing Questions and Answers (2013): Suresh Basandra, Basandra Books. 3. How to Solve It by Computer (1982): G. Dromey,, Prentice-Hall, Inc., Upper Saddle River, NJ. 4. MATLAB® Recipes for Earth Sciences (2010): Martin Trauth, Springer; 3rd ed. 2010 edition. 5. Statistics and Data Analysis in Geology (2002): John C. Davis, Wiley; 3 edition.		
Semester II			
1.	Subject Code: ESS5015	Subject Name: Geophysical Techniques	Credit: 3 L-T-P: 3-0-0
	Fundamental concepts of Geophysics; Introduction to various geophysical tools applied in the Earth Sciences, Introduction to various types of Electrical, Magnetic, Gravitational and Seismic Survey and its utitlity; Introduction to logging methodology and various logging techniques. Books: 1. Introduction to Geophysical Prospecting (1998): Milton B. Dobrin andCarl H. Savit, 4th Edition, Mcgraw-Hill College; 4 Sub edition. 2. An Introduction to Geophysical Exploration (2002): Philip Kearey, Michael Brooks, Ian Hill, 3rd edition, Wiley-Blackwell; 3 edition. 3. Standard Methods of Geophysical Formation Evaluation (1997): James K. Hallenburg, CRC Press; 1 edition.		
2.	Subject Code: ESS5016	Subject Name: Geomorphic processes and Sedimentary Rocks	Credit: 3 L-T-P: 3-0-0
	Geomorphic principles and processes, Concept of cycle of erosion; fluvial, aeolian, coastal, karst and glacial landscapes, methods of analysis of landforms, slopes and drainage, morphometry, terrain classification, Fluvial geomorphology, Arid Zone geomorphology, Geomorphology in coastal zones, Sedimentary Facies and sedimentary environments, Walther's law of Facies and Application. Sedimentary cycles and cyclotherms, Textural and mineralogical maturity of clastic rocks. Ancient sedimentary environments; transport and structures; sequence stratigraphy. Calcretes, Bioturbation and ichnofacies. Books: 1. Process Geomorphology (2011): Dale F. Ritter, R. Craig Kochel, Jerry R. Miller, Waveland Pr Inc; 5 edition. 2. Geomorphology: The Mechanics and Chemistry of Landscapes (2010): Robert S. Anderson & Suzanne P. Anderson, Cambridge University Press; 1 edition. 3. Sedimentary Petrology (2001): Maurice Tucker, Wiley-Blackwell; 3 edition. 4. Sedimentary Environments: Processes, Facies and Stratigraphy (1996): Harold G. Reading, Wiley-Blackwell; 3 edition. 5. Sedimentary Geology (2003): D. R. Prothero & Fred Schwab, W. H. Freeman; Second Edition edition.		
3.	Subject Code: ESS5017	Subject Name: Applied Hydrogeology	Credit: 3 L-T-P: 3-0-0
	Hydrological cycle, groundwater occurrence, flow through porous media; Aquifers and aquifer characteristics, Aquifer test and parameter estimation, run-off and stream flow;		

<table>
<tr><td></td><td colspan="3">Groundwater contamination, sources and causes, Laboratory methods to estimate contaminant attenuation.
Saltwater intrusion in the coastal aquifer, changing water demand due to global warming and its effect on aquifer parameters, Artificial recharge, Watershed management and groundwater modeling.

Books:
1. Groundwater Hydrology (2004): D. K. Tood, Wiley; 3 edition.
2. Applied Groundwater Hydrology and Well hydraulics (2010): M. Kasenow & L. Bagby, Water Resources Pubns.; Third edition.
3. Aquifer Test Data: Evaluation and Analysis (2006): M. Kasenow, Water Resources Pubns.</td></tr>
<tr><td>4.</td><td>Subject Code: ESS5018</td><td>Subject Name: Engineering Geology and Rock Mechanics</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Engineering geological and hydrogeological explorations. Concepts of stress, strain, Mohr circle and failure theories. Engineering properties of rocks, and soils and their classifications. Weathering. Discontinuities in rock masses. Engineering behaviour of rock materials and rock masses. Rock slope stability, landslides and stability of structures, construction materials, dams and reservoirs, tunnels and excavations, foundations and structures in earthquake prone regions. Engineering geological aspects of weaker materials. Reinforcements of rock masses. Site investigations and important case studies.
Application of Rock Mechanics, Basic concepts of rock excavation, Open and underground excavations, in-situ stress measurement techniques, Engineering Properties of Rocks, Fluid migration through porous media and its effect on behavior of rock. Stress distribution in and around the openings. Rock mass rating.

Books:
1. Engineering Geology, Second Edition (2007): F G Bell, Butterworth-Heinemann; 2 edition.
2. Foundations of Engineering Geology (2009): Tony Waltham, CRC Press; 3 edition.
3. Engineering Geology: Principles and Practice (2010): David George Price, Michael de Freitas, Springer.
4. Fundamentals of Rock Mechanics (2007): J. Jaeger, N. G. Cook & R. Zimmerman, Wiley-Blackwell; 4 edition.</td></tr>
<tr><td>5.</td><td>Subject Code: ESS5019</td><td>Subject Name: Remote Sensing and GIS</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Fundamentals of remote sensing, Photogrammetry, digital image data formats, image rectification and restoration techniques, image histograms, density slicing, image enhancement techniques – contrast manipulation, spatial filtering and edge enhancement, multi-image manipulations, principal components analysis, multi-spectral image classification. Hyper spectral image analyses, Optical/Thermal/Microwave/Acoustic Remote Sensing.
Remote Sensing (RS) Applications in Terrestrial & Environmental Sciences, Ocean & Marine Sciences, Atmospheric Sciences & Climate Sciences.
Fundamentals of GIS, vector, raster and attribute data models, vector and raster data structure, spatial data input and editing, visualization and query of spatial data, spatial data transformations, spatial analysis, case studies of geological applications, current issues and trends in GIS. GPS and Navigation, Web-GIS, Spatial Data Infrastructures (SDI).

Books:
1. Remote Sensing: Principles and Interpretation (2007): F. S. Sabins, Waveland Pr Inc; 3 edition.</td></tr>
</table>

	2. GIS Fundamentals: A First Text on Geographic Information Systems (2012): Paul Bolstad, Eider Press; 4 edition. 3. Elements of Photogrammetry with Applications in GIS (2000): Paul. R. Wolf, Bon. A. Dewitt, McGraw-Hill Education (India) Pvt. Limited. 4. Introductory digital image processing: a remote sensing perspective (1986): John R. Jensen, Prentice Hall, New Jersey.		
6.	Subject Code: ESS5020	Subject Name: Applied Paleontology & Stratigraphy	Credit: 3 L-T-P: 3-0-0
	Nature of the fossil record, taphonomy; growth, allometry and heterochrony; species concepts and systematics – nomenclature, classification and phylogenetics; adaptation and functional morphologic analysis; evolutionary rates and trends; global diversity and extinction, mass extinctions. Applications of fossils in biostratigraphy, correlation and sequence stratigraphy, Recent advancements in application of paleontology and micropaleontology Definition of stratigraphy: Classification of bedding; Basis of stratification; Types and recognition of stratification; Stratification and rock sequence; Indian stratigraphy. Code of stratigraphic nomenclature. Processes of sedimentation, Stratigraphic classification and correlation. Processes controlling stratification- physical, chemical and biological. Books: 1. Principles of Paleontology (2006): Michael Foote, Arnold I. Miller, W. H. Freeman; 3 edition. 2. Introduction to Paleobiology and the Fossil Record (2009): Michael J. Benton, David A. T. Harper, Wiley-Blackwell; 1 edition. 3. Introduction to Marine Micropaleontology (1998): Bilal-Ul- Haq & Anne Boersoma, Elsevier Science. 4. The Geology of Stratigraphic Sequences (2010):Andew D. Miall, Springer; 2nd ed. 2010 edition. 5. Principles of Sequence Stratigraphy: Developments in Sedimentology (2006): Octavian Catuneanu, Elsevier Science; 1 edition.		
Semester III			
1.	Subject Code: ESA5021	Subject Name: Ore Geology	Credit: 3 L-T-P: 3-0-0
	Processes of formation of mineral deposits, Structural and stratigraphic controls on mineralization. Metallic and non-metallic ore deposits; hydrothermal solutions; water rock interations; distribution and exploration methods; ore textures and paragenesis; application of ore microscopy in mineral technology; study of phase diagrams related to ore assemblages and construction of stability diagrams; geothermometry and geobarometry of ore assemblages. Genesis of ore deposits; application of stable isotope in ore genesis. Books: 1. The Geology of Ore Deposits (2007): John M. Guilbert, Charles Frederick Park, Waveland Press, Inc. 2. Understanding Mineral Deposits (1999): Kula Misra, Springer; 2000 edition. 3. Introduction to Ore-Forming Processes (2005): Laurence Robb, Blackwell Science Ltd.; 1 edition.		
2.	Subject Code: ESA5022	Subject Name: Geology of Coal &	Credit: 3

		Hydrocarbons	L-T-P: 3-0-0
	Fundamental concepts of organic and inorganic theories of hydrocarbon. Sedimentary processes and accumulation of organic matter - occurrence and distribution of hydrocarbons in sedimentary basins of India - types of coal - mode of occurrence - physical and chemical characteristics of coal - geological and geographical distribution - coalfields in India. Theories of origin of petroleum; Transformation of organic matter into petroleum. Limiting conditions of petroleum occurrence. Definition and types of reservoir and source rocks. Reservoir traps and classification. Migration and accumulation of petroleum. Petroliferous basins of India. Books: 1. Coal Geology (2012): Larry Thomas, Wiley-Blackwell; 2 edition. 2. The Chemistry and Technology of Coal: Chemical Industries (2012): James G. Speight, CRC Press; 3 edition. 3. Elements of Petroleum Geology, (2013): Richard C. Selley, Academic Press; 3 edition.		

Semester IV:

1.	Subject Code: ESS5023	Subject Name: Reservoir Characterization	Credit: 3 L-T-P: 3-0-0
	Processes controlling stratification- physical, chemical and biological. Classification of bedding; Basis of stratification; Types and recognition of stratification; Stratification and rock sequence; Breaks in record; Sequence Stratigraphy for Reservoir Characterization, key concepts of sequence stratigraphy, transgressions and regressions. Sequence stratigraphic surfaces, types of stratal terminations. Basic Principles and Applications of Reservoir Characterization, Tools and Techniques for Oil and Gas Reservoirs Characterization, Geologic Controls on Reservoir Quality Reservoir characterization in different depositional environment (Fluvial, Eolian, Non-Deltaic, Deltaic and Deepwater). Books: 1. The Geology of Stratigraphic Sequences (2010):Andew D. Miall, Springer; 2nd ed. 2010 edition. 2. Stratigraphic reservoir characterization for petroleum geologists, geophysicists, and engineers (2007): Roger M. Slatt, Elsevier Science, Volume 10. 3. Principles of Sedimentology and Stratigraphy (2011): Sam Boggs Jr., Prentice Hall; 5 edition.		

Electives:

Elective - I & II			
Sl. No.	Subject Code: ESA5030	Subject Name: Environmental Earth Sciences	Credit: 3 L-T-P: 3-0-0
1.	Earth Systems and Resources, Geologic time scale, plate tectonics, earthquakes, volcanism, seasons, solar intensity and latitude, The Atmosphere, Global Water Resources and Use, Soil and Soil Dynamics, Ecosystem Structure, Energy Flow, Natural Ecosystem Change, Natural Biogeochemical Cycles, Land and Water Use, Energy Resources and Consumption, Global Change, Elemental cycle in Global systems.		

<table>
<tr><td></td><td colspan="3">Books:
1. Environmental Geology (2010): Carla Montgomery, McGraw-Hill Science/Engineering/Math; 9 edition.
2. Environmental Geology (2010): Edward A. Keller, Prentice Hall; 9 edition.
3. Environmental Science Earth as a Living Planet (2009): Daniel B. Botkin, Wiley; 8th edition.</td></tr>
<tr><td>2.</td><td>Subject Code: ESA6031</td><td>Subject Name: Physics and Chemistry of Atmosphere and Ocean</td><td>Credit:3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Structure of the atmosphere and its composition, Thermodynamics of dry and moist air, Formation of Cloud droplets and Precipitation, Radiation basics and budget, Observations and Modelling Physical Processes. Atmospheric Chemistry, Gaseous, Heterogeneous & Aqueous Phase Reactions, Air Pollution, Fog-haze formation, Aerosol-Cloud interaction and chemistry, Ozone depletion, Observations and Modelling of Chemical processes. Characteristics of Ocean Basins, Properties of Sea water, Mixed layer, Heat Budgets of the Ocean, Ekman Dynamics, Upwelling and down welling processes, Western Boundary Currents, Observations and Modelling. Chemical property and composition of Sea water, Marine Biogeochemical Cycles.

Books:
1. The Atmosphere and Ocean: A Physical Introduction (Advancing Weather and Climate Science) (2011): Neil C.; Wiley; 3 edition.
2. Thermal Physics of the Atmosphere (Advancing Weather and Climate Science) (2010): Maarten H. P. Ambaum; Wiley; 1 edition
3. Radiative Transfer in the Atmosphere and Ocean (2002): Gary E. Thomas, Knut Stamnes; Cambridge Atmospheric and Space Science Series.</td></tr>
<tr><td>3.</td><td>Subject Code: ESA5032</td><td>Subject Name: Glacial Geoscience</td><td>Credit:3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Quaternary Stratigraphy; Glacial Systems; Dynamics & Deformation, Erosion-Transportation; Subglacial, Superglacial & Proglacial Deposition; Ice-Margin Deposits; Meltwater & Lakes (Glaciolacustrine); Glacial Floods. Understanding Polar Geoscience and its role.

Books:
1. Glacial Geology: Ice Sheets and Landforms (2010): Matthew M. Bennett and Neil F. Glasser, Wiley; 2 edition.
2. The Physics of Glaciers (2010): Kurt M. Cuffey, W. S. B. Paterson, Academic Press; 4 edition.
3. Fundamentals of Glacier Dynamics, (2013): C.J. van der Veen, CRC Press; 2 edition.</td></tr>
<tr><td>4.</td><td>Subject Code: ESA5033</td><td>Subject Name: Isotope Geology</td><td>Credit:3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Elements of nuclear systematics, introduction to isotopes and their properties, fundamentals of radiogenic isotope geochronometers, isotope geology of Sr, Nd and Pb and their applications, thermochronology, introduction to stable isotopes, studies of O, H, S, and C isotopes and their applications, cosmogenic nuclides and their applications, extinct radionuclides, analytical techniques and mass spectrometers. Application of isotopes in climate change evaluation.

Books
1. Isotope Geology (2008): Claude J. Allègre, Cambridge University Press.
2. Isotopes: Principles and Applications (2004): Gunter Faure, Teresa M. Mensing, Wiley; 3 edition.</td></tr>
</table>

	3. Principles of Stable Isotope Geochemistry (2006): Zachary Sharp, Prentice Hall; 1 edition.		
5.	Subject Code: ESA5034	Subject Name: Modeling and Simulation in Earth Sciences	Credit: 3 L-T-P: 3-0-0
	Basic ideas on multitasking and massively parallel processing, different architectures, application of HPC in global and regional models, parallelism in models, domain decomposition method, 1D, 2D and 3D parallelization of GCMs, MPI, PVM, SHMEM, message passing libraries, high performance compilers, load balancing, interprocessor communication, network communication, graphical user interface, data formats, local and wide area networking, data flow and data mining. Books: 1. An Introduction to Parallel Programming (2011): Peter Pacheco, Morgan Kaufmann; 1 edition. 2. Introduction to High Performance Computing for Scientists and Engineers (2010): Georg Hager, Gerhard Wellein , (Chapman & Hall/CRC Computational Science), CRC Press, 1 edition. 3. High Performance Computing in the Geosciences (1995): F.X. le Dimet, Nato Science Series C, Springer; 1995 edition		
Elective - III & IV			
1.	Subject Code: ESS5040	Subject Name: Organic Geochemistry	Credit: 3 L-T-P: 3-0-0
	Origin of Organic matter in natural systems, Classification and separation of different organic matter fractions, Humic substances in soils, sediments and water and their extraction, interaction of naturally produced humic substances with the sediments. Methods of quantification of organic matter. Atmospheric organic geochemistry, Carbonaceous species in ambient aerosols, Water-soluble and Poly Aromatic Hydrocarbons (PAHs), Carbon stable isotope geochemistry, Use of Carbon isotopes (13C and 14C) for source identification and past climatic conditions, Organic matter degradation and preservation, Global Carbon cycle, Soil carbon and turn over rates. Biomarkers in petroleum industry, Organic tools in petroleum exploration. Books: 1. The Biomarker Guide: Volume 1 & 2, Biomarkers and Isotopes in the Environment and Human History (2007), K.E. Peters, C.C. Walters, J.M. Moldowan, Cambridge University Press; 2 edition. 2. An Introduction to Organic Geochemistry (2005): Stephen D. Killops, and Vanessa J. Killops, Wiley; 2 edition. 3. Carbonaceous Aerosol, Vol. 30 (2004): András Gelencsér, Atmospheric and Oceanographic Sciences Library.		
2.	Subject Code: ESS5041	Subject Name: Aqueous Geochemistry	Credit: 3 L-T-P: 3-0-0
	Equilibrium thermodynamics; activity coefficients of dissolved species. Metal ions in aqueous solutions. Carbonate chemistry and pH control, clay minerals and ion exchange; adsorption-desorption reactions, stability relationships and silicate equilibria; mineral stability diagrams, chemical weathering and water chemistry. Redox equilibria. Rates of geochemical reactions. Water pollution.		

<table>
<tr><td></td><td colspan="3">Books:
1. Geochemistry, Groundwater and Pollution, (2005): C.A.J. Appelo, D. Postma, Taylor & Francis; 2 edition.
2. Groundwater Geochemistry: A Practical Guide to Modeling of Natural and Contaminated Aquatic Systems (2008): Broder J. Merkel, Britta Planer-Friedrich , Darrell K. Nordstrom, Springer; 2nd ed. 2008 edition.
3. Principles and Applications of Aquatic Chemistry (1993): François M. M. Morel, J. G. Hering, Wiley-Interscience; 1 edition.</td></tr>
<tr><td>3.</td><td>Subject Code: ESS5042</td><td>Subject Name: Geothermal Energy</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Generation of heat in the earth, Heat transfer - conduction, convection, radiation, heat flow measurements, Availability of Geothermal Energy - size and distribution, structural influence on the heat flow distribution, role of groundwater circulation and changes in the state of groundwater. Geothermal Resource Assessment, Recovery of Geothermal Energy, Various Types of Systems to use Geothermal Energy, Hydrothermal solutions, Chemical nature of hydrothermal systems, Geothermameters: Chemical and Isotopic, Rock alteration related to water geochemistry. Utilization of geothermal energy. Economics and management of geothermal energy, Case Studies of Indian and Global Geothermal Systems.

Books:
1. Geothermal Energy Systems: Exploration, Development, and Utilization (2010): Ernst Huenges , Patrick Ledru, Wiley-VCH; 1 edition
2. Geothermal Energy: Renewable Energy and the Environment (2010): William E. Glassley, CRC Press; 1 edition
3. Low-Enthalpy Geothermal Resources for Power Generation (2008): D. Chandrasekharam, Jochen Bundschuh, Taylor & Francis.</td></tr>
<tr><td>4.</td><td>Subject Code: ESS5043</td><td>Subject Name: Mineral Resources & Economics</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Definition of explorative criteria and indicators. Methods of explorations, their classification and applications in different stages of exploration. Processes of formation of mineral deposits, Structural and stratigraphic controls on mineralization.
Formation, association and distribution of essential and strategic minerals of India.
Various aspects of National Mineral Policy: Conservation of minerals, export and imports, taxation and subsidies, pricing policy etc.

Books:
1. Economic Evaluations in Exploration (2010): Friedrich-Wilhelm Wellmer, Manfred Dalheimer & Markus Wagner, Springer; 2nd edition.
2. Mineral Economics: Development and Management of Natural Resources (1996): O. Rudawsky, Elsevier Science
3. Economic Evaluations in Exploration (2010): Friedrich-Wilhelm Wellmer, Manfred Dalheimer & Markus Wagner, Springer; Softcover reprint of hardcover 2nd edition.</td></tr>
<tr><td>5.</td><td>Subject Code: ESS5044</td><td>Subject Name: Analytical Methods in Geosciences</td><td>Credit: 3
L-T-P: 3-0-0</td></tr>
<tr><td></td><td colspan="3">Concepts in analytical chemistry; Classical and rapid methods of analyses; Atomic absorption spectrometry; Inductively coupled plasma-atomic absorption spectrometry; X-ray fluorescence analysis; Energy dispersive X-ray spectrometry; X-ray diffraction analysis; micro beam and surface analysis techniques; neutron activation analysis, mass-spectrometry.</td></tr>
</table>

	Books: 1. A Handbook of Silicate Rock Analysis (1987): Potts, P.J., Springer; 1 edition. 2. A Handbook of Inductively Coupled Plasma Spectrometry (1983): Thompson, M. and Walsh, J.N., Chapman and Hall. 3. Analytical Atomic Absorption Spectroscopy (1980): Van Loon, J.C., Academic Press. 4. Chemical Methods of Rock Analysis (1981): Jeffery, P.G. and Hutchinson, D., Butterworth-Heinemann; 3 edition.		
6.	Subject Code: ESS5045	Subject Name: Heat and Mass Transfer in Earth System	Credit: 3 L-T-P: 3-0-0
	Diffusive heat transfer; measurement of surface heat flow. Heat sources and sinks: radiogenic heating and release of latent heat during crystallisation of melts; shape of crustal isotherms. Transients; cooling of oceanic crust and mid-ocean ridges; contact metamorphism; intrusion of igneous bodies. Advective transfer; effect of uplift and erosion on the thermal structure of mountain belts. Natural and forced thermal convection of melt in the Earth's mantle and aqueous fluids in the Earth's crust. Mass transfer in Earth's interior; Applications of mass transfer to magma generation and transport; Case studies-ocean ridges, trenches, continental rift systems; mantle plumes. Books: 1. Fundamentals of Heat and Mass Transfer (2011): T. L. Bergman, A. S. Lavine, F. P. Incropera & David P. DeWitt, Wiley; 7 edition. 2. Heat and Mass Transfer: Fundamentals and Applications (2010):Y. Cengel & A. Ghajar, McGraw-Hill Science/Engineering/Math; 4 edition. 3. Mass Transport in Solids and Fluids (2000): David S. Wilkinson, Cambridge University Press.		