Department of Physics
Cochin University of Science and Technology
Scheme of Examinations and Syllabus for M.Sc. Physics
(From 2014 admission onwards)

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Scheme

Semester – I

Course Code	Name	C/E	Marks Distribution			
			Internal	External	Total	Credit
phy 2101	Mathematical Physics -I	C	50	50	100	4
phy 2102	Classical Mechanics	C	50	50	100	4
phy 2103	Basic Solid State Physics	C	50	50	100	4
phy 2104	Basic Electronics	C	50	50	100	4
phy 2105	Experiments in General Physics	C	50	-	50	2
	Total	-	250	200	450	18

Semester – II

Course Code	Name	C/E	Marks Distribution			
			Internal	External	Total	Credit
phy 2201	Quantum Mechanics-I	C	50	50	100	4
phy 2202	Statistical Physics	C	50	50	100	4
phy 2203	Electrodynamics	C	50	50	100	4
phy 2204	Lasers and Atomic and Molecular Spectroscopy	C	50	50	100	4
phy 2205	Experiments in General Physics	C	50	-	50	2
	Total	-	250	200	450	18

Semester – III

Course Code	Name	C/E	Marks Distribution			
			Internal	External	Total	Credit
phy 2301	Quantum Mechanics-II	C	50	50	100	4

phy 2302	Nuclear and Particle Physics	C	50	50	100	4
phy 2303	Mathematical Physics - II	C	50	50	100	4
phy 2304	Advanced Practical (Lab. Course) - I	C	50	-	50	2
	Elective I	E	50	50	100	4
	Total	-	250	200	450	18

Semester – IV

Course Code	Name	C/E	Marks Distribution			
			Internal	External	Total	Credit
phy 2401	Project	C	100	-	100	4
	Elective II	E	50	50	100	4
	Elective III	E	50	50	100	4
	Elective IV	E	50	50	100	4
phy 2430	Advanced Practical - II	C	100	-	100	4
	Total	-	350	150	500	20

Elective Courses

Course No	Name	C/E	Marks Distribution			
			Internal	External	Total	Credit
05	Advanced Solid State Physics	E	50	50	100	4
06	Applied Electronics	E	50	50	100	4
07	Quantum Electronics	E	50	50	100	4
08	Indusrtial Physics - I	E	50	50	100	4
09	Indusrtial Physics - II	E	50	50	100	4
10	Gravitation Cosmology	E	50	50	100	4
11	Nonlinear Dynamics and Chaos	E	50	50	100	4
12	Solar Cells	E	50	50	100	4
13	Quantum Field Theory	E	50	50	100	4
14	Modern Optics	E	50	50	100	4
15	Thin Film Physics	E	50	50	100	4
16	Solid State Devices and Applications	E	50	50	100	4
17	Physics of Nanostructured Materials	E	50	50	100	4

18	Quantum Computation and Information	E	50	50	100	4
19	Advanced Magnetism and Magnetic Materials	E	50	50	100	4
20	Molecular Physics and Laser Spectroscopy	E	50	50	100	4
21	Synthesis and Characterization of Materials	E	50	50	100	4
22	Quantum Optics	E	50	50	100	4
23	Nonlinear Optics	E	50	50	100	4
24	Remote Sensing	E	50	50	100	4
25	Digital Signal Processing	E	50	50	100	4
26	Elementary Astronomy	E	50	50	100	4
27	Nondestructive Techniques and Applications	E	50	50	100	4
28	Measurement and Instrumentation	E	50	50	100	4
29	Astrophysics	E	50	50	100	4
2430	Advanced Practical (Lab Course) - II	E	100		100	4

- Elective courses will be offered either in semester III or in semester IV.
- The Course Code for the Elective courses will be assigned at the time the course is offered.
- Each Lab course consists of nine hours per week and duration of practical examination is:
  - phy 2105, phy 2205 and phy 2304 - 4 hours each
  - phy 2430 - 6 hours
- Project work has five hours per week. Project report will be evaluated by the supervising guide and project report should be submitted in advance for evaluation. Project evaluation consists of a Viva-Voce examination also.
- Elective courses of the revised syllabus can be offered to M.Sc. Students admitted in 2014.

Core Courses (Semester I) 2014

Phy 2101 Mathematical Physics - I

Module 1 Vector analysis: Vectors and scalars- Direction angles and direction cosines -Change of coordinate system- The linear vector space V_n - Vector differentiation - Space curves - Motion in a plane -Conservative vector field-The divergence of a vector - The operator ∇^2 , Laplacian- The curl of a vector Formulas involving ∇ - Orthogonal curvilinear coordinates Cylindrical coordinates-Spherical coordinates -Vector integration and integral theorems- Helmholtz's theorem

Module 2 Complex numbers Functions of a complex variable Mapping Branch lines and Riemann surfaces, Calculus of functions of a complex variable , Elementary functions of z, Complex integration, Series representations of analytic functions Integration by the method of residues, Evaluation of real definite integrals .

Module 3 Special functions: Gamma and beta functions - definitions and simple properties. Legendre's equation, The associated Legendre functions. Hermite's equation, Laguerre's equation, The associated Laguerre polynomials,Bessel's equation, Spherical Bessel functions, Sturm-Liouville systems , Linear integral equations, Some methods of solution, The Schmidt-Hilbert method of solution, Use of integral equations, Greens function

Module 4 Heaviside unit step function, one dimensional Dirac delta function, properties and representations, three dimensional Dirac delta function. Fourier series–general properties, applications and properties of Fourier series. Integral transforms, Fourier transforms– inversion theorem, Fourier transform of derivatives, convolution theorem. Elementary Laplace transforms, Laplace transform of derivatives, inverse Laplace transforms, solution of ordinary differential equations with constant coefficients

Reference Books:

1. Tai L.Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge University Press
2. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) Edition. .

Phy 2102 Classical Mechanics

Module 1 D'Alembert's principle and applications - Variational principle - Calculus of variations - Derivation of Lagrange's equations from Hamilton's principles. Conservation theorems and Symmetry properties. Energy function and conservation of energy. Central force problem - equivalent one dimensional problem - classification of orbits - the differential equation for orbits - Kepler problem.

Module 2 Small oscillations - formulation of the problem - eigenvalue equation - normal coordinates - linear triatomic molecules. Independent co-ordinates of a rigid body. orthogonal transformations - Euler angles . Rigid body equations of motion- Angular momentum and kinetic energy of motion about a point- Inertia tensor-Solving rigid body problems and Euler equations of motion- torque free motion of a rigid body- Symmetric top. Rate of change of a vector, Centrifugal and Coriolis forces.

Module 3 Hamilton's equations of motion - cyclic Coordinates and conservation theorems. Hamilton's equation from a variational principle. Equations of canonical transformation - examples. Poisson Brackets. Infinitesimal canonical transformation - generators - angular momentum Poisson Bracket relations.

Module 4 Hamilton-Jacobi equation - harmonic oscillator problem - Hamilton's characteristic function. Action and Angle variables-separable systems - Kepler problem. Nonlinear Equations and Chaos : Introduction, Singular points of trajectories, Nonlinear oscillations, Limit cycles,Chaos : Logistic map, Definitions, Fixed points, Period doubling, Universality.

Reference Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics(Third Edition)
2. S.T. Thronton and J.B.Marion, Classical Mechanics of Particles and Systems.
3. Michael Tabor , Chaos and Integrability in Nonlinear Dynamics.
4. V.B.Bhatia , Classical Mechanics

Phy 2103 Basic Solid State Physics

Module 1 Crystal symmetry - Symmetry elements in crystals - point groups - space groups - Bravais space lattices. Crystal defects - imperfections in crystals - production of defects. Crystal binding - different types of crystal bindings - cohesive energy - calculation of cohesive energy- calculation of lattice energy of ionic crystals - Madulang constant of ionic crystals. Reciprocal lattice - properties - geometrical construction - reciprocal lattices of simple cubic structure. Bravais lattices - Ewald construction - Bragg condition - concept of Brillouin zone - structure factor - atomic form factor - X ray diffraction technique - electron scattering - neutron scattering - Elements of Quasi Crystals.

Module 2 Vibrations of monatomic and diatomic lattices - normal modes and phonons - quantisation of lattice vibrations - phonon momentum - elastic scattering of neutrons by phonons. Einstein model of specific heat - density of modes - Debye model - anharmonic crystal interactions - thermal expansion - normal and Umklapp process - thermal conductivity. Macroscopic field - depolarization field - local electronic field - Clausius-Mossotti relation - sources of polarisability - dielectric relaxation and loss - ferroelectric crystals - Piezoelectricity.

Module 3 Diamagnetism - paramagnetism - origin of magnetic dipoles - Larmor precession - quantum theory of paramagnetism - Curie law. Introduction to superconductivity- electromagnetic properties- Meissner effect- Types of super conductors -thermal properties - microwave and infrared properties- isotope effect- Josephson effect - Elements of super fluidity - BCS theory. (elementary ideas only)

Module 4 Fermi-Dirac distribution - quantum theory of free electron gas - density of states - Fermi energy -electrical conductivity - thermal conductivity - Wiedemann-Franz law - paramagnetism of conduction electrons in metals - electronic specific heat - Hall effect. Bloch theorem - energy bands - Kronig-Penny model - Different models (elementary ideas only). The nearly free electron model - tight-binding model- motion of electrons in one dimension - concept of effective mass and holes - distinction between metals, insulators and semiconductors.

Reference Books:

1. A. J. Dekker, Solid State Physics
2. C. Kittel, Introduction to Solid State Physics
3. A. R. A. Levy, Introduction to solids
4. L. V. Azaroff, Introduction to X ray Crystallography
5. J. S. Blackemore, Solid State Physics

Phy 2104 Basic Electronics

Module 1 Combinational systems - Synthesis of Boolean functions, Boolean algebra, Universal gate - NAND, Integrated NAND circuit, Arithmetic circuits, Adder, Subtractor, BCD Addition, 2's complementary technique, Sequential systems - Flip flops-RS, JK, JK-MS, D-FF, Register, Buffer register, serial and parallel registers, Tristate switches, Tristated buffer registers, Bus organisation in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion,-Accuracy and resolution - ADC/DAC chips, Flash Converters

Module 2 Ideal amplifier - operational amplifier - the basic operational amplifier, differential amplifier and its transfer characteristics, frequency response of operational amplifiers, adder, subtractor, Op-amp as differentiators, integrators, applications of differentiators and integrators, Solution of differential equations – general ideas about analog computation and simulation – other applications of Op-amps, filters, comparators, sample and hold circuits, waveform generators.

Module 3 Microprocessor architecture – memory – input/output – 8085 MPU – Instructions and timings – instruction classification – instruction format – instruction timing and operation status – Programming the 8085 – data transfer instructions – arithmetic operations – logic operations – branch operations – examples of assembly language programs.

Module 4 Amplitude Modulation – Double and Single sideband techniques – Frequency modulation and Demodulation techniques – Bandwidth requirements – Pulse communication – Pulse width, Pulse position and Pulse code modulation – Digital communication – error detection and correction – frequency and time division multiplexing.

Reference Books:

1. John Ryder, Electronic Fundamentals and Applications (5^{th} Edition), Prentice Hall, New Delhi, (1983)
2. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983)
3. Robert G. Irvine, Operational Amplifier – Characteristics and Applications, 2^{nd} Edition, Prentice Hall, New Jersey (1987)
4. Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited, New Delhi (1992)
5. John Wakerly, Digital Design: Principles and Practices (4^{th} Ed.), Prentice Hall (2005)
6. D. C. Green, Digital Electronics (5^{th} Ed.), Pearson Education Ltd., (2005)
7. Roddy and Coolen, Electronic Communications, Prentice Hall 4^{th} Ed (1995)
8. B. P. Lathi, Modern Digital and Analog Communication Systems 3^{rd} Ed, Oxford University press (1998)

Semester II

Phy 2201 Quantum Mechanics - I

Module 1 de Broglie's hypothesis of matter Waves, Experimental confirmation of de Broglie's hypothesis, Wave packets, Linear vector space, the Hilbert space, Wave Functions, Hermitian adjoint operators, Projection operators , Commutator algebra , Uncertainty relation , Inverse and unitary operators, Eigenvalues and eigenvectors of an operator, Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in continuous bases, Position representation, Momentum representation, Connecting the position and momentum representations, Matrix and wave mechanics.

Module 2 Postulates of Quantum Mechanics, State of a System , Probability Density , The Superposition Principle, Observables and Operators, Measurement in quantum mechanics, Expectation values, Complete sets of commuting operators, Measurement and the uncertainty relations, Time evolution of the system's state, Time evolution operator, Stationary states, Time-independent potentials , Schrödinger equation and wave packets, Conservation of probability, Time evolution of expectation values, Symmetries and conservation laws, Infinitesimal unitary transformations, Finite unitary transformations, Poisson's brackets and commutators, Ehrenfest theorem.

Module 3 Many-particle systems, Interchange symmetry , Systems of distinguishable noninteracting particle, Systems of identical particles, Exchange degeneracy, Symmetrization postulate, Constructing symmetric and antisymmetric functions, Systems of identical noninteracting particles, Pauli's exclusion principle

Module 4 Infinite square well potential, Symmetric potential well, Finite square well potential, Scattering and bound state solutions, Harmonic oscillator, Schrödinger equation in presence of central Potential, Hydrogen Atom. Scattering Cross Section, Connecting the Angles in the Lab and CM frames, Scattering Amplitude of Spinless Particles, Scattering Amplitude and Differential Cross Section, Scattering Amplitude, The Born Approximation, Validity of the Born Approximation, Partial Wave Analysis, Scattering of Identical Particles .

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications (Second edition)
2. David Griffiths, Introduction to Quantum Mechanics (Second edition)

Reference Books:

1. V.K. Thankappan, Quantum Mechanics
2. J.J.Sakurai, Modern Quantum Mechanics
3. Mathews and Venkatesan, Quantum Mechanics

Phy 2202 Statistical Physics

Module 1 Statistical basis of thermodynamics: macro states and micro states - connection between statistics and thermodynamics - Classical ideal gas - entropy of mixing and Gibbs paradox. Phase space of a classical system, Liouville's theorem, microcanonical ensemble, Quantum states and phase space, The canonical ensemble, Equilibrium between a system and a heat reservoir, A system in the canonical ensemble, Physical significance of various statistical quantities in canonical ensemble, Partition function, ideal gas in canonical ensemble theory, Equipartition theorem, system of harmonic oscillators in canonical ensemble theory, Statistics of para magnetism.

Module 2 Energy fluctuations in canonical ensemble. Grand canonical ensembles, Equilibrium between a system and a particle reservoir, system in grand canonical ensemble, Physical significance of various statistical quantities in grand canonical ensemble, Grand partition function, Ideal gas in grand canonical ensembles, Density and energy fluctuations in grand canonical ensembles.

Module 3 Quantum statistics: Density matrix in quantum mechanical ensemble theory. Ideal gas in quantum mechanical, micro canonical and other ensembles. Statistics of occupation number. Gaseous systems composed of molecules of internal motion, mono atomic and diatomic molecules. Thermodynamic behavior of ideal Bose gas -Bose-Einstein condensation- thermodynamics of black body radiation- Specific heats of solids . Thermodynamic behavior of an ideal Fermi gas - Magnetic behaviors of an ideal Fermi gas. Electron gas in metals.

Module 4 General remarks on problem of condensation, Condensation of van der Waals gas. Lattice gas, Ising model in zeroth approximation, One dimensional Ising model .Brownian motion-Einstein Smoluchowski theory of Brownian motion. Langevin equation for Brownian motion.

Text Books:

1. R. K. Pathria, Statistical Mechanics
2. K. Huang, Statistical Mechanics

Reference Books:

1. Landau and Lifshitz , Statistical Physics

Phy 2203 Electrodynamics

(Units followed is the rationalized MKSA Units)

Module 1 Boundary value problems, Formal solution with Green's functions, electrostatic potential energy. Method of images- Point charge near a grounded conducting sphere-Point charge near a charged insulated conducting sphere - conducting sphere in an uniform electric field. Laplace equation in spherical polar coordinates- Boundary value problem with azimuthal symmetry.

Multiple expansion Electrostatic multipole moments - energy of a charge distribution in an external field, electrostatics of macroscopic media - electric polarization and displacement, dielectric constant, boundary condition at the dielectric interface.Magneto statics: Biot-Sawart Law and its differential statement, Ampere's law. Vector potential.

Module 2 Faraday's Law of electromagnetic induction - energy in a magnetic field - displacement current - Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge, Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.

Module 3 Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Simple radiating systems: Green's function for wave equation, fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields, centre-fed linear antenna.

Module 4 Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields. Magnetism as a relativistic phenomenon, Transformation of the field, Electromagnetic field tensor.

References:

1. J. D. Jackson, Electrodynamics
2. David J Griffiths, Introduction to Electrodynamics

Phy 2204 Lasers and Atomic and Molecular Spectroscopy

Module 1 Quantum states of electrons in atoms - Pauli's exclusion principle, calculation of spin-orbit interaction energy in one electron systems, fine structure of spectral lines in hydrogen and alkali atoms. Equivalent and non-equivalent electrons, two electron systems, interaction energy in lS and jj couplings, spectra of helium and alkaline earth elements. Normal and anomalous Zeeman effects, Stark effect, Paschen-Back effect (all in one electron system only). Hyperfine structure of spectral lines - calculation in one electron systems. Line broadening mechanisms - line shape functions for Doppler and natural broadening (TB.1)

Module 2 Types of molecules, rotational spectra of diatomic molecules as rigid rotor, intensity of rotational lines, The effect of isotopic substitution, energy levels and spectrum of non rigid rotor, techniques and instrumentation for microwave spectroscopy. (Banwell et al.) The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions - the Franck-Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation. (TB.2)

Module 3 Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra - linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy - simple examples, fundamentals of SERS.

Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, , NMR: NMR of hydrogen nuclei - chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR - ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption. (TB. 2)

Module 4 Spontaneous emission-stimulated emission,. Einstein's coefficients. The laser idea-population inversion-lasing action-characteristics of laser-pumping mechanisms , three level laser - four level laser - rate equation - pumping threshold laser spiking .Specific laser systems - laser system involving low density medium - He-Ne laser -Argon ion laser - CO_2 laser - excimer laser. Laser systems involving high density medium - ruby laser - dye laser - ND:YAG laser - semiconductor diode lasers. (TB 3)

Text Books

1. H. E. White, Introduction to Atomic Spectra
2. C. N. Banwell and Elaine M. Mc Cash, Fundamentals of Molecular Spectroscopy
3. K. Thayagarajan and A.K Ghatak, Lasers Theory and Applications, Macmillan (Tata Mc-Graw Hill 1995)

Reference Books

1. B.P. Straughan and S.Walker , Spectroscopy Vol.I, II and III.

2. G. M. Barrow, Introduction to Molecular Spectroscopy
3. G. Aruldhas, Molecular structure and Spectroscopy (Prentice Hall of India 2001)
4. G. Herzberg, Spectra of diatomic molecules
5. H. Haken and H.C. Wolf, The Physics of Atoms and Quanta (Springer Verlag – 1994)
6. William T Silfvast, Laser fundamentals, Cambridge University press
7. Milonni and Eberly, Laasers
8. A.K.Gahtak and K. Thayagarajan Optical Electronics (Cambridge University press)

Semester III

Phy 2301 Quantum Mechanics-II

Module 1 Orbital angular momentum, Matrix representation of angular momentum, Spin angular momentum and Pauli spin matrices, Eigenfunctions of orbital angular momentum, Eigenfunctions and eigenvalues L_z and L^2. Properties of the spherical harmonics, Addition of two angular momenta, Clebsch – Gordan coefficients, Calculation of the Clebsch – Gordan coefficients.

Module 2 Time-independent perturbation theory , Non degenerate perturbation theory , Degenerate perturbation theory, Fine structure and the anomalous zeeman effect, Variational method, WKB method, Bound states for potential wells with no rigid walls, Bound states for potential wells with one rigid wall, Bound states for potential wells with two rigid walls, Tunneling through a potential barrier .

Module 3 Pictures of quantum mechanics, Time-dependent perturbation theory, Transition probability, Constant perturbation, Harmonic perturbation , Adiabatic and sudden approximations , Interaction of atoms with radiation , Transition rates for absorption and emission of radiation, Transition rates within the dipole approximation, Electric dipole selection rules, Spontaneous emission.

Module 4 Klein Gorden equation, Dirac equation, Dirac matrices, Gama matrices, Derivation of Pauli's equation from Dirac equation, Spin orbit coupling, Solution of free Dirac equation, Lorentz invariance of Dirac equation, Bilinear covariants, Weyl's Equation for neutrino, Wave equation of the photon, Charge conjugation.

Text Books:

1. Nourdine Zettili , Quantum Mechanics Concepts and Applications (Second edition)
2. V.K. Thankappan, Quantum Mechanics (For module 4)
3. David Griffiths, Introduction to Quantum Mechanics

Reference Books:

1. J. J. Sakurai, Modern Quantum Mechanics
2. Mathews and Venkatesan, Quantum Mechanics

Phy 2302 Nuclear and Particle Physics

Module 1 Nuclear properties: Nuclear radius – shape – spin – parity – Magnetic and electric moments – Nuclear binding energy.

Nuclear two body problem – The deuteron – simple theory- spin dependence – tensor force – nucleon-nucleon scattering – partial wave analysis of n-p scattering – determination of phase shift – singlet and triplet potential – effective range theory – low energy p-p scattering – Meson theory of nuclear forces.

Module 2 Nuclear models – semi empirical mass formula – stability of nucleus – shell model – spin orbit potential – magnetic and electric moments – valance nucleons – collective structure.

Nuclear reactions – conservation laws – energetic – compound nuclear reactions – direct reaction – resonant reaction – nuclear fission – energy in fission – controlled fission reactions – fission reactors.

Module 3 Nuclear decays: barrier penetration and alpha decay – beta decay – simple theory of beta decay – Kurie plot-parity violation in beta decay –gamma decay – multipole moments and selection rules –

Detection of nuclear radiation: Interaction of radiation with matters – gas-filled counters - scintillation detectors – semiconductor detectors – energy measurement.

Module 4 Meson Physics – properties of pi-mesons – decay modes – meson resonance – strange meson and baryons – CP violation in K decay.

Particle interaction and families – symmetries and conservation laws - quark model – coloured quarks and gluons – reactions and decays in the quark model – c, b and t quarks –quark dynamics

Text Books:

1. Harald A Enge, Introduction to Nuclear Physics
2. Kenneth S Krane, Introductory Nuclear Physics

Reference Books:

1. R. R. Roy and B. P. Nigam, Nuclear Physics Theory and Experiment
2. J. M. Blatt and V. P. Weisskopf, Theoretical Nuclear Physics
3. David Griffiths, Introduction to Elementary Particles

Phy 2303 Mathematical Physics II

Module 1 Numerical methods : Interpolation -Finding roots of equations- Graphical methods -Method of linear interpolation -Newton's method. Numerical integration- The rectangular rule - The trapezoidal rule - Simpson's rule. Numerical solutions of differential equations- Euler's method- The three-term Taylor series method. The Runge-Kutta method- Equations of higher order. System of equations Least-squares. Fundamental probability theorems- Random variables and probability distributions. Expectation and variance- Special probability distributions- The binomial distribution - The Poisson distribution- The Gaussian distribution - Continuous distributions - The Maxwell-Boltzmann distribution.

Module 2 Second order differential equations- The Euler linear equation- Solutions in power series- Simultaneous equations . The gamma and beta functions. Partial differential equations, Solutions of Laplace's equation, Solutions of the wave equation Solution of Poisson's equation, Green's function, Laplace transform solutions.

Module 3 Defnition of a group- Cyclic groups -Group multiplication table - Isomorphic groups - Group of permutations and Cayley's theorem - Subgroups and cosets - Conjugate classes and invariant subgroups - Group representations -The symmetry group D_2 and D_3 - One-dimensional unitary group U(1) Orthogonal groups SO(2) and SO(3) -The SU(n) groups. Homogeneous Lorentz group.

Module 4 Contravariant and covariant tensors - transformation rules - direct product, contraction, quotient rule. Metric tensor - lowering and raising of indices - covariant derivatives - Christoffel symbols. Riemann curvature tensor - Einstein tensor. Physical basis of general relativity - Mach's principle - principle of equivalence, Einstein's Equation - Schawrzschild solutions (Qualitative ideas)

Reference Books:

1. Tai L.Chow, Mathematical Methods for Physicists
2. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) Edition.
3. Micael Berry- Principles of Cosmology and Gravitation.

Elective Courses (2014)

05 Advanced Solid State Physics

Module 1 Optical absorption: Free carrier absorption-optical transition between bands-direct and indirect-excitons- photoconductivity - general concepts - model of an ideal photoconductor - traps - space charge effects - crystal counters - experimental techniques - Transit time. Luminescence in crystal - excitation and emission - decay mechanism - Thallium activated alkali halides - model of luminescence in sulphide phosphors - electroluminescence.

Module 2 Density of states- classification of solid into metals, semimetals, semiconductors and insulators- Calculation of number of carries in intrinsic semiconductor - Fermi level - carrier concentration in impurity semiconductors -electronic degeneracy in semiconductors. Equation of motion of electrons in a band - Effective mass and concept of holes- Boltzmann Transport equation. contact potential - metal-semiconductor contact - Schottky boundary layer - injecting contacts - surface states.

Module 3 Quantum wells and low dimensional systems: Electron confinement in -infinitely deep square well and square well of finite depth-confinement in two and one dimensional well-ideas of quantum well structures, quantum dots and quantum wires-methods of preparation of nanomaterials: top down and bottom up approaches: wet chemical, self assembled vapour, phase condensation.

Module 4 Growth of single crystals - general ideas. Thin film preparation techniques - thermal and electron gun evaporation - dc and rf sputtering - amorphous solids : preparation techniques - applications. Classification of liquid crystals - applications of liquid crystals - ceramic processing techniques - electrical and mechanical properties - composite materials.

Reference Books:

1. C. Kittel, Introduction to Solid State Physics
2. A. J. Dekker, Solid State Physics
3. R. H. Bube, Electronic Properties of Crystalline Solids
4. G. Busch and H. Schade, Lectures on Solid State Physics
5. A. Haug, Theoretical Solid State Physics
6. T. H. Lynton, Superconductivity
7. T. V. Ramakrishnan and C. N. R. Rao, Superconductivity Today
8. N. W. Aschroft and N. D. Mermin, Solid State Physics

06 Applied Electronics

Module 1 The 8086 microprocessor-Architecture - Memory segmentation - Addressing modes - Instruction set of 8086 - Introduction to assembly language programing - Interfacing memory and I/O Devices - General ideas on advanced processors - 80286, 80386, 80486 and Pentium families. (Programme examples)

Module 2 The 8051 microcontroller - 8051 Architecture - Registers in 8051 - Pin description - I/O ports - Memory Organization - Counters and Timers - Serial data Input and Output - Interrupts.

Module 3 Programing of 8051-Addressing modes - Instruction set of 8051 - Data Transfer operations - Logic operations - Arithmetic operations - Jump and Call instructions - Interrupts - Assembly language program examples.

Module 4 PIC Microcontrollers - Overview and features - PIC 16C6X/7X architecture - Memory organization - Addressing modes - Instructions - I/O ports - Interrupts - Timers- Analog to Digital Converter - PIC 16F8XX Flash microcontrollers - Registers - Memory organization - Interrupts - I/O ports and Timers

Reference Books:

1. Microcomputer systems: The 8086/8088 Family - Liu and Gibson, Prentice Hall India
2. The 8088 and 8086 Microprocessors - W. A. Triebl and A. Sing, Pearson Education.
3. Advanced Microprocessors and Peripherals - Burchandi and Ray , McGraw Hill Education (India)
4. The 8051 Microcontroller - Kenneth J Ayala, Penram International Publishing India.
5. Microcontrollers, Theory and Applications - Ajay V. Deshmukh, Tata McGraw - Hill Publishing Co. India.

07 Quantum Electronics

Module 1 Solution of two level system – Rabi flip-flop – saturation behaviour of homogeneously and inhomogeneously broadened systems.

Variation of Laser power around threshold – optimum output coupling – Laser spiking – semiclassical Laser theory of Lamb polarization of cavity medium – first order theory.

Module 2 Density matrix and equation of motion, quantization of electromagnetic field – Basic ideas of Fock states, density modes, coherent states –minimum uncertainity states, squeezed states, Detection of squeezed states, Interaction of any atomic system with quantized radiation field –Atom field Hamiltonian Jayness Cummings Model , dressed states, transition rates – spontaneous emission – phase operator.

Module 3 Optical resonators – modes of rectangular and open planar resonators, Properties of laser modes, spatial dependence, frequency dependence, mode competition, spectral hole burning, spatial hole burning –

Q factor – pole selection – stability of a general spherical resonator. Q-switching – basic ideas – methods of Q-switching Rotating mirrors, elctro-optic shutter, Pockels cell, Kerr cell, acoustooptic shutter, saturable absorber, – mode locking – theory of mode locking – Methods of mode locking. Active shutters acoustooptic switches, passive shutters, Kerr lens mode locking, Properties of laser beams – spatial and temporal coherence monochromaticity brightness – directionality.

Module 4 Three level laser-four level laser-rate equations-, basic ideas and Excitation mechanism, applications of He- Cd laser, Nitrogen laser, Excimer laser, free electron laser, , X-ray laser, lasers, Laser pumped cw and pulsed dye laser, Titanium sapphire laser, Ultrafast lasers, Liquid energy levels and their radiation Properties- energy levels of dye molecules, energy levels in semiconductor laser materials, Hetrojunction semiconductor materials, basic ideas of quantum wells.

Text Books

1. K. Thyagarajan and A. K. Ghatak, Lasers -Theory and Applications (Mcmillan India Ltd.)
2. Peter M Milonni and Joseph H. Eberly, Lasers (John Wiley and Sons), 1988
3. B. B. Laud, Lasers and Nonlinear Optics
4. Orszag- Quantum optics(Springer)
5. W.T. Silfvast, Laser Fundamentals (Cambridge University Press)

References Books

1. A. Yariv, Optical Electronics (Saunders College Publishing)
2. O. Swelto, Principles of Lasers
3. A.K.Gahtak and K. Thayagarajan Optical Electronics (Cambridge University press)

08 Industrial Physics-I

Module 1 Crystalline and amorphous semiconductors – general introduction – band structure of crystalline and amorphous semiconductors (qualitative). Carrier transport phenomena – mobility lifetime. Optical properties of solids – Optical constants – fundamental absorption in semiconductors – direct and indirect transitions. Photoconductivity. Radiative transitions – Photoluminescence – methods of excitation – efficiency.

Module 2 Device Physics, p-n junction – depletion region and depletion capacitance (abrupt junction) – current – voltage characterization – heterojunction – depletion layer photo-diodes – avalanche photodiode. Solar cell basic characteristics – spectral response recombination current and series resistance, semi-conductor lasers – transition process – population inversion – gain junction lasers – threshold current density.

Module 3 Important elemental and compound semiconductors - Ge, Si, Se, Te, II-VI, III-V, IV-VI and amorphous Si. Single crystal growth techniques – float zone – Czochralski – hydrothermal growth – growth of Si – growth of GaAs – Production of Si and GaAs. Wafers – growth of quartz. Thin film deposition techniques – thermal and electron gun evaporation – DC and RF sputtering. Epitaxial film deposition techniques – CVD. VPE, LPE and MBE – general ideas.

Module 4 Production of diffused p-n junction – transistor. Planar epitaxial technology – Photolithography – production of integrated circuits – Production of LED – Production of laser diodes, both homo and hetero junctions.

Reference Books:

1. R.A. Smith , Semiconductors
2. R.J. Elliot and A.P. Gibson, An Introduction to Solid State Physics Physics and its applications
3. S.M. Sze, Physics of Semiconductor Devices
4. H.E. Talley and D.G. Daugherty, Physical Principles of Semiconductor
5. B.R. Pamplin, Crystal growth
6. W. Bardsley, D.T.O. Hurle and J.B. Mulin, Crystal growth: A tutorial approach
7. L. Maissel and R. Glang, Handbook of Thin film Technology
8. Fairchild Corportion, Semiconductor and Integrated Circuits Fabrication Techniques
9. Hartman, Crystal Growth
10. Hannay, Treatise on Solid State Chemistry -
11. Johnson, Optics and Optical Instruments
12. E.W. Williams and R.Hall, Luminescence and the Light Emitting Diodes (Pergamon Press)

09 Industrial Physics -II

Module 1 Time-delay action – RC time constant. Direct coupling of transistors – Darlington circuit – Differential Amplifier. Uni-junction transistor. Silicon controlled rectifiers – SCR in simple AC circuits – phase control of the SCR – firing by UJT – Phase control by pedestal and ramp-turn off of SCR; Jone's circuit. Triac circuits – zero voltage switching circuit.

Module 2 Regulators of voltage and motor speed – Voltage compensator – DC voltage regulated DC power supplies. Inverters – multivibrator inverter – two SCR inverter.

Closed loop systems, Servomechanisms – basic parts of a serve – Comple serve diagram – loop gain – PID controllers.

Module 3 Switching and counting circuits – flip-flops – shift register – serial to parallel converter. MOS gates – complementary MOS – digital -to analog converter – analog-to digital converter – Sample and hold. Information conversion – parallel to serial converter – multiplexer - addressing – BCD and octal binary codes – numeric displays – Microprocessor and its operation (elementary ideas).

Industrial heating systems – electron beam heating – microwave heating – Induction heating.

Measurement of light, PMT – photodiode - IR detectors; Temperature – Thermocouple amplifiers - optical pyrometer; strain – strain gauges: electrochemical transducers – pH.

Module 4 Production of Vacuum-rotary pumps – diffusion pumps – ion-getter pumps – design of high vacuum units – Ultra high vacuum units. Measurement of pressure - Pirani gauge – Penning gauge – hot cathode Ionization gauges – UHV gauges.

Reference Books:

1. G.M. Chute and R.D. Chute, Electronics in Industry
2. R.W. Henry, Electronic Systems and Instrumentation
3. R.W. Perbwitt and S.W. Fards, Instrumentation: Transducers Experimentation and Application
4. S. Dushman and J.M. Lafferty, Scientific Foundation of Vacuum Technology
5. Llyod P. Hunter, Hand Book of Semiconductor Electronics
6. Malvino, Digital Computer Electronics

10 Gravitation and Cosmology

Module 1 - Tensor analyses: Tensors - Contravarien and covarient tensors, direct product, contraction, inner product, quotient rule, tensor densitites, dual tensors. Metric tensor, Parallel transport. Christoffel symbol, Covarient derivative, Riemanian geometry, Riemann curavture tensor, Ricci tensor, Equation of geodeis.

Module 2 - GTR Drawback's newtonian theory of gravity, Mach's principle, principle of equivalence, consequences of principle of equivalence (bending of light, redshift, time dialation). Gravity as curvature of spac-time, Einstein equation, reduction to Newtonian form.

Module 3 - Astrophyical Applications of Eintein's equation. Schwarzchil solution : derivation, schwarzchild singularity, Gravitational redshift, particle orbits - precession of the perihelion of planet Mercurry, Light ray orbits - the deflection and time delay of light. Linearised gravitational waves.

Module 4 - Cosmology Cosmologic Principle, Hubble's law, FRW model of the universe:- FRW metric, cosmological redshift, open, clossed and falt universes, matter dominated and radiation dominated universes, Particle horizon and event horizon, primordial nucleosynthesis, CMBR, Flaws of the FRW model. Jean's mass in the expanding universe, evolution of the Jean's mass. Dark matter, recent acceleartion of the universe, Dark energy. (only introcuctory ideas.)

References:

1. S. Weinberg, Gravitaion and Cosmology, Wiley.
2. Schutz, Bernard. A First Course in General Relativity. New York, NY: Cambridge University Press, 1985. ISBN: 9780521277037.
3. J. B. Hartle, Gravity, Pearson Education.
4. J V Narlikar, Introction to cosmology
5. Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler , Gravitation,(1973)

11 Nonlinear Dynamics and Chaos

Module 1 Linear and nonlinear forces- Working definition of nonlinearity.

Linear oscillators- free, damped and forced oscillators- Nonlinear oscillations and resonance.

Dynamical systems as systems of first order ordinary differential equations. Equilibrium points and their classification (two-dimension). Limit cycles. Attractors. Dissipative and conservative systems.

Module 2 Simple bifurcations in dissipative systems. Discrete dynamical systems. Logistic map. Equilibrium points and stability. Periodic orbits. Period-doubling bifurcations. Onset of chaos. Lyapunov exponents. Bifurcation diagram. Strange attractors in Henon map. Quasiperiodic and intermittency route to chaos. Period-doubling bifurcations and chaos in Duffing oscillator and Lorenz equations.

Module 3 Canonical perturbation theory- Problem of small devisors. Statement and discussuion of KAM theorem.

Surface of section. Henon-Heiles Hamiltonian(numerical results). Area-preserving maps. Poincare-Birkhoff theorem. Homoclinic points.

Module 4 Lyapunov exponents-numerical computation-one-dimensional maps and continuous time systems. Power spectrum. Autocorrelations.

Fractal sets-examples. Fractal dimension-box counting. Correlation dimension. Criteria for chaotic motion.

Text Books:

1. M.Lakshmanan and S.Rajasekar, Nonlinear Dynamics (Springer, 2003)
2. M.Tabor, Chaos and Integrability in Nonlinear dynamics (John Wiley, 1989)

Reference Books:

1. J.Alligood, T.Sauer and J.Yorke, Chaos- an introduction to nonlinear dynamics (Springer, 1997)
2. R.C.Hilborn, Chaos and Nonlinear Dynamics (Oxford University Press, 1994)
3. H.G.Schuster, Deterministic Chaos (Verlag, Weinheim,1988)

12 Solar Cells

Module 1 Physical source of energy - sun light-The solar constant-Solar intensity at earth's surface- Direct and diffuse radiation- Apparent motion of sun-solar insolation data.

Energy band structure-Determination of Fermi level-Variation with temperature and doping-Electrons and holes-Energy density of allowed states-Densities of electrons and holes-Electrical conductivity-Variation in carrier mobility

Module 2 Interaction of light with semiconductors-Optical absorption-Direct and indirect-Opti cal Constants-Photoconductivity-Steady and transient-Effects of traps-Recombination through traps-Recombination at surfaces-Minority carrier generation and recombination.

Contact problems-Metal semiconductor contacts-Schotky barrier-Semiconductor - semiconductor contacts-p n junctions-Electrostatics of p n junction-Junction capacitance-Carrier injection-Diffusive flow in quasi neutral regions-Dark characteristics-Minority carrier currents-

Module 3 Illuminated characteristics-Solar cell out put parameters-Effect of finite cell dimensions-Efficiency measurements- Efficiency limits-Short circuit current-Open circuit voltage-Effect of temperature-Efficiency losses-Short circuit current and open circuit voltage loses-Fill factor losses.

Module 4 Optimum band gap and optical absorption for solar cell applications-Space and terrestrial applications-Materials for solar cells-crystalline silicon cells-Prospects and limitations-Thin film solar cells-CdS based cells-CdS/Cu_2S-CdS/CdTe- CdS/$CuInSe_2$-Amorphous silicon cells.

References:

1. S. P. Sukhatma, Solar Energy
2. G. Busch and Schade, Lectures on Solid State Physics
3. B. O. Seraphin, Solar Energy Conversion
4. S. R. Das and K. L. Chopra, Thin Film Solar Cells
5. Harold J. Hovel, Semiconductors and Semimetals Vol. II
6. Martin A. Green, Solar Cells
7. Tom Markvart and Luis Castner, Hand book of Solar Cells

13 Quantum Field Theory

Module 1 Classical field theory, Euler Lagrange equations, Hamilton formalism, conservation laws. Canonical quantization of neutral and charged scalar filed, symmetry transformations.

(Sect. 2.1-2.2, 2.4, 4.1-4.3 of Ref. 1)

Module 2 Scalar fields: The invariant commutation relations, scalar Feynman propagator. Dirac fields-- canonical quantization of Dirac fields-Feynman propagator.

(Sect. 4.4-4.5, 5.1-5.4 of Ref. 1)

Module 3 Canonical quantization of Maxwell's field-Maxwell's equations-Lorentz and Coulomb gauges-Lagrangian density.

Canonical quantization in Lorentz and Coulomb gauges-Coulomb interaction and transverse delta functions.

(Sect. 6.1--6.2, 7.1--7.5, 7.7 of Ref. 1)

Module 4 Interacting fields, interaction picture, time evolution operator, scattering matrix, Wick's theorem(no proof), Feynman rules(no rigorous treatment) -Moller and Compton scattering.

(Sect. 8.1-8.7 of Ref. 1)

Spontaneous symmetry breaking, scalar theory, Goldston theorem(no proof), spontaneous breaking of gauge symmetries.

(Sect. 8.1-8.3 of Ref. 2)

Reference Books:

1. Greiner W and Reinhardt J, Field Quantization
2. Ryder L H, Quantum Field Theory
3. Itzykson C and Zuber J B, Quantum Field Theory
4. Bjorken J D and Drell S D, Relativistic Quantum Fields I & II

14 Modern Optics

Module 1 Matrix representation in optics-ABCD matrix-translation reflection and refraction matrices-matrices for thin and thick lenses-Polarisation-Nature of polarized light-polarisers-Jones Vectors of linearly, elliptically and circularly polarized light-Jones matrices for optical components.

Polarisation by reflection-Optical activity-Induced optical effects-optical modulators

Module 2 Coherence-Spatial and temporal coherence-Visibility-Mutual coherence function-Degree of coherence

Condition for interference-Wave front splitting-Amplitude splitting-Multiple beam interference - Fabri Perot interferometer-Etalon-Applications-Thin film optics-Theory of multi layer films-High and anti-reflection coatings

Module 3 Diffraction-Kirchhoff's theorem-Fresnel-Kirchhoff Formula-Fraunhofer diffraction patterns for single, double slits and circular aperture-Fresnel diffraction pattern-Zone plate

Fourier Optics-Fourier transform-Applications of Fourier transform to Diffraction-Aperture function-Spatial filtering-Apodization

Holography-Recording and reconstruction of wave fronts.

Module 4 Non-linear optics-principle-nonlinear wave equation- Born approximation-second order non-linear optics-second harmonic generation-phase matching-frequency conversion-electro optic effect-three wave mixing.

Third order non-linear optics-third harmonics generation- optical Kerr-effect- parametric oscillator –self focusing –soliton (elementary ideas).

References:

1. G.R.Fowles, Introduction to modern optics
2. Ghatak and Thyagarajan, Optical electronics
3. Ajoy Ghatak, Optics
4. Hechst, Optics
5. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics

15 Thin Film Physics

Module 1 Vacuum Technology: High vacuum production – Mechanical pumps – Diffusion pumps Cryogenic pumps – Cryosorption pumps - Getter pumps – ion pumps.

Vacuum gauges – McLeod gauge – Thermal conductivity gauges - Cold cathode and hot cathode ionisation gauges.

Module 2 Film Preparations: Vacuum evaporation - Evaporation theory - Rate of evaporation - Hertz-Kundsen equation - Free evaporation and effusion - Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron bean gun - flash evaporation - sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Triode sputtering - Magnetron sputtering - Ion beam sputtering - CVD - PLD.

Film thickness measurements - Optical methods - FECO - Fizeau?s technique - Ellipsometry - Vamfo. Other techniques - Electrical - Mechanical - Micro-balance - Quarts crystal monitor.

Module 3 Nucleation Theories: Condensation process - Theories of Nucleation – Capillarity theory – Atomistic theory – Comparison – stages of film growth – Incorporation of defects during growth.

Optical properties - Reflection and transmission at an interface – Reflection and transmission by a single film – Optical constants - Refractive index measurement techniques – Reflectivity variation with thickness – Anti-reflection coatings – single and multiplayer – Reflection coatings.

Module 4 Electrical Properties: Sources of resistivity – sheet resistance – TCR – Influence of thickness on resistance – Theories of size effect – Theories of conduction in discontinuous films – Electronic conduction in thin insulating films. Metal insulator contact – High field effect.

Dielectric properties - Simple electrical theory – D.C. conduction mechanisms – High and low field conduction – Temperature dependence – space charge limited conduction – A.C. conduction mechanisms – Relaxation peaks.

Books:

1. Maissel and Glang, Hand Book of Thin Film Technology
2. K.L. Choppra, Thin Film Phenomena
3. Dupy and Kachard, Physics of Non-Metallic Thin Films -
4. S. Dushman and J.M. Lafferty, Scientific Foundations of Vacuum Technology

16 Solid State Devices and Applications

Module 1 Bulk semiconductor devices – Thermistor – Barratter – Hall effect devices – applications – Gunn effect devices – volt ampere characteristics – domain formation – modes of Gunn oscillator – Domain mode – inhibited domain mode – quenched domain mode – LSA mode – Gunn diode fabrication.

Junction devices – methods of pn-junction fabrication – pn-junction break down – Zener break down – Zener diode – Avalanche break down – temperature compensated reference diodes.

Module 2 IMPAT devices – IMPATT diode – small signal operation – TRAPATT devices – PIN diodes – physics of PIN diodes – dynamic characteristics – RF characteristics – switching considerations – power limitations – Typical applications.

Tunnel diode – principle of operation – characteristics applications. Backward diode – principle of operation – characteristics – application – Varactor diode – static and dynamic figure of merit.

Module 3 Thyristors – silicon controlled rectifier – characteristics – operation – application in power control circuit – Triac – characteristic – operation – typical application in power control circuit – diac.

Silicon controlled switches – characteristic – operation – forward blocking mode – reverse bias mode – forward conduction mode – applications.

Module 4 Opto electronic devices – photo detectors – photo conductors – photodiodes – avalanche photo diodes – radiation detectors – photo voltaic effect – solar cells – Electro luminescent devices – Electro luminescent displays – LED.

Semi conductor lasers – diode lasers – transition powers – population inversion – lasing conditions – device fabrication – tuneable diode lasers – use of diode lasers in optical communications.

Text Books:

1. F.F. Driscoll and R.F. Coughlin, Solid State Devices and Applications , (Prentice-Hall)
2. Mathur, Kulashrestha and Chandra , Electronic Devices Applications and Integrated Circuits(Umesh Publications, New Delhi).
3. Millman and Halkias, Integrated Electronics , (Mc Graw Hill)
4. Cooper, Solid State Devices and Applications

17 Physics of Nanostructured materials

Module 1 Introduction to Nanoscience and Technology(brief ideas). Review of metals, insulators and semiconductors. Concept of electrons, holes and excitons, low dimensional structure, quantum well, quantum wire and quantum dots and examples of quantum well, quantum wire and quantum dots. Fullerenes, carbon nanotubes, single walled carbon nanotubes and multi-walled carbon nanotubes, applications of CNTS. (Ref. 2,3,6,8,10,11.12)

Module 2 Size effects on the optical, electrical, magnetic and mechanical properties. Size effects on the optical properties of semiconductor nanostructures, weak excitonic confinement, strong excitonic confinement, semiconducting nanoparticles of ZnS, CdS, CdTe, size effects on the magnetic properties - super paramagnetism, spin glass, spin clusters. (Ref. 1,2,6,11)

Module 3 Synthesis and fabrication of nanostructured materials, bottom up approaches and top down methods, High Energy Ball Milling (HEBM), chemical methods, cold co-precipitation technique and sol gel synthesis of nanoparticles, molecular beam epitaxy (MBE), metal organic chemical vapour deposition(MOCVD), laser assisted MBE, template assisted deposition, electrode deposition, pulsed laser ablation(PLA), sputtering, DIP Pen lilthography, growth on patterned subtracts - nano-pattering, optical, X-ray, electron lithography, concept of clean rooms, nanolithography. (Ref. 2,6,7,9)

Module 4 Characterization of nanostructures, particle size determination (XRD), Debye-Scherrer formula, elimination of strain, size determination by mass spectrometry - scanning probe microscopy - atomic force microscope(AFM), magnetic force microscopy(MFM), electron microscopy, SEM, TEM and XPS. CMR and GMR materials, spintronics, photonic band gap materials, biomedical applications of nano- materials, MEMS, NEMS and some other applications of nanotechnology(general ideas).

Reference Books

1. S.V. Gaponenko, Optical properties of semiconducting nanocrystals, Cambridge University Press (1997)
2. A. K. Bandhyopadhyay, Nanomaterials, New Age International Publishers (2007)
3. B R Nag, Physics of quantum well devices, Kluwer Academic (2000)
4.) Bieter K. Schroder, Semiconductor material and device characterization, Wiley - Interscience publication (1993)
5. A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Publishing
6. Hari Singh Nalwla, Nanostructured materials and nanotechnology Vol. I, II, III, IV, V, VI, VII,VIII, IX (2002)
7. Douglas B. Chrisey and Graham K. Hubler, Pulsed Laser Deposition of Thin Films, John Wiley and Sons (1994)
8. K L Chopra and Inderjeet Kaur, Thin Film Device Applications, Plennum Press(1983)
9. P N Prasad, Nanophotonics, John Wiley & Sons(2004)
10. L Jack, P. Hawrylak, and A Wojs, Quantum dots, Springer - Verlag (1997)
11. J H Davis, Physics of low dimensional structures Cambridge (1998)
12. C . P. Poole Jr. and F J Owans, Introduction to nanotechnology, Wiley Interscience.

18 Quantum Computation and Information

Module 1 Introduction to classical computation. The Turing machine - the circuit model of computation - computational complexity (elementary ideas) - energy and information - reversible computation. Introduction to quantum mechanics - Linear vector space - Tensor products - Postulates of quantum mechanics - the EPR paradox and Bell's theorem. (relevant sections of Chapter 1 and 2 of Benenti et.al.)

Module 2 The qubit - single qubit gates - controlled gates - universal quantum gates - Deutsch and Deutsch - Josza algorithms - the quantum Fourier transform - period finding and Schor's algorithm - quantum search - first experimental implementations (relevant sections of Chapter 3 of Benenti et.al.)

Module 3 Classical cryptography-quantum no - cloning theorem - quantum cryptography - BB84 and E91 protocols - dense coding - quantum teleportation - experimental implementations. (relevant sections of Chapter 4 of Benenti et.al.)

Module 4 Classical information and Shannon entropy - data compression - density matrix in quantum mechanics - von Neumann etropy - quantum data compression - composite systems - Schmidt decomposition - entanglement concentration (relevant sections of Chapter 5 of Benenti et.al.)

Reference Books:

1. G. Benenti, G. Casati and G. Strini, Principles of quantum computation and information (World Scientific)
2. M. A. Nielson and I. L. Chuang, Quantum computation and quantum information (Cambridge University Press)

19 Advanced Magnetism and Magnetic Materials

Module 1 Review of Magnetism, Dia, Para, Ferro, Ferri and Antiferromagnetism- Ferrimagnetism in detail - Spinel Ferrites - Normal and inverse Spinels - Mixed Ferrites- Structure of Spinel Ferrites - Tailoring of electric and magnetic properties of Spinel Ferrites- Hexagonal ferrites and other ferrimagnetic substances.

Module 2 Magnetic Anisotropy, Anisotropy in cubic crystals, Anisotropy in hexagonal crystals, Physical origin of crystal anisotropy, Anisotropy measurements, Anisotropy constants- Polycrystalline materials - shape, size and magneto crystalline anisotropy. Magnetostriction and effect of stress, magnetostriction of single crystals, Magnetostriction of polycrystals, Physical origin of magnetostriction, Effect of stress on magnetostriction, Magneto resistance.

Module 3 Fine Particles and Thin films - Single domain versus multidomain behaviour, Coercivity of fine particles, Magnetization reversal by spin rotation, Reversal by wall motion, super paramagnetism, critical particle size, preparation and structure of thin films, Domain walls in thin films, Fine wires.

Module 4 Magnetic materials: Soft magnetic materials, eddy currents, Losses in electromagnets, Electrical steel, Special alloys, Soft ferrites, Hard magnetic materials, Operation of permanent magnets, Magnetic steel, Alnico, barium and strontium ferrites, Rare earth magnets, Application of magnetic materials, Recording audio/video, magneto-optical recording and spintronics

Reference Books:

1. Culity, Introduction to Magnetic materials, Addison Wesley (1972)
2. Chin Wen Chen, Magnetism and Metallurgy of Soft Magnetic Materials, North Holland Pub. Co. (1977)
3. J. Smith And Wijn, Ferrites, Philips Technical Laboratory, Eindhoven (1959)
4. M. F. Doug and De Mow, Ferromagnetic-Core Design and Application Handbook, Prentice Hall (1981)

20 Molecular Physics and Laser Spectroscopy

Module 1 Theory of chemical bonding in diatomic molecules Born-Oppenhemier approximation – Molecular orbital theory LCAO approximation. – H_2 molecule – Valence-Bond theory – H_2 molecule – Heitler and London treatment of H_2 molecule.

LCAO-MO treatment of general diatomic molecule – Valence-Bond treatment of diatomic molecules – Electronic states and Term symbols – Hund's coupling cases.

Module 2 M.O. theory of simple polyatomics and application to water molecule, Huckel M.O. theory and its application to ethylene, allyl and butadiene systems.

Microwave spectroscopy – Rotational spectrum of non-rigid diatomic molecules – Stark effect in rotational spectra. Nuclear Quadrupole hyperfine interaction due to single nuclear spin. Zaeman effect in rotational spectra. Description of microwave spectrometer.

Module 3 Electronic spectra of diatomic molecules – Rotational Structure of electronic bands – PQR branches – Bandhead formation and shading – Combination relations for evaluation of rotational constants.

Laser systems – three and four level schemes – solution of rate equations for three level systems – System description of semiconductor diode lasers – Ti-saphire lasers and Tunable Dye Lasers.

Module 4 Description of diode laser spectrometer – examples of diode laser spectra of diatomic molecules. Dunham representation of re-vibrational transitions. (basic ideas only)

CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwave frequency - optical double resonance spectroscopy and infrared optical double resonance spectroscopy

Reference Books:

1. R.K. Prasad, Quantum Chemistry
2. W. Gordy and E.L. Cook, Microwave Spectroscopy
3. G. Herzbera, Spectra of Diatomic Molecules
4. Qrazio Svelto, Principles of Lasers
5. Eizi Hirota, High Resolution Spectroscopy of Transient Molecules
6. A. Mooradian.T., Jaeger and P. Stockseth, Tunable Lasers and Applications
7. A.B. Budgor, L. Esterowitz and L.G. Deshazer, Tunable Solid State Lasers-II

21 Synthesis and Characterisation of Materials

Module 1 Crystal Growth Principles and Theory: Nucleation phenomenon – Homogenous and Heterogeneous nucleation Theories of crystal growth. Defects and Dislocations – Role of dislocations on the growth of crystals.

Experimental Techniques and methods. Melt and Flux Techniques Czochralski and Dridgmann Techniques – chemical vapour transport techniques, hydrothermal synthesis, growth by fused salt electrolysis.

Module 2 Polycrystalline Materials: Polycrystalline materials – Direct reactions – Chemical Precursion methods including spray pyrolysis – Low temperature precipitation and free energy criteria.

DC arc and laser fusion techniques Ceramic techniques – ceramic techniques for the preparation of some dielectric and magnetic materials.

Module 3 Characterisation Techniques: Techniques of characterization – chemical analysis, DTA, TGA and DSC techniques – Metallography techniques including etching.

X-ray Diffraction – Laue methods – Rotating crystal Method – Power Method – Applications of X-ray Diffraction – Examination of Polycrystalline materials.

Module 4 Neutron Diffraction: Neutron Diffraction – Nuclear scattering – Magnetic scattering – Inelestic Scattering – Applications of neutron diffraction for the determination of magnetic structure.

Surface analysis – Auguer Spectroscopy, AAS, XPS – Applications. Transmission and Electron Microscopy – Principles and applications LEED an d related techniques. Mossbauer spectroscopy – principle and applications – Magnetic Resonance – Applications.

Text Books:

1. Krishnan Lal, Synthesis, Crystal Growth and Characterisation - (Module 1,2)
2. T. Mudvey and Webster, Modern Physical Techniques in Materials Technology (Mod. 5,6,7,8)
3. F.C. Philips, Introduction to Crystallography
4. C.V. Asaroff, Elements of X-ray Crystallography
5. W.D. Kinger, H.K. Bower and V.R. Ulsimann, Introduction to Ceramics

Reference Books:

1. R. A. Waudise, Growth of Single Crystals
2. N.N. Greenwood and T.C. Gibb, Mossbauer Spectroscopy
3. Metals Handbook (9^{th} Ed.) Vol.10, Materials characterization

22 Quantum Optics

Module 1 Interaction between electromagnetic waves and matter – linear dipole oscillator method – radiative damping – coherence.

Nonlinear dipole oscillator method. Coupled mode equations cubic nonlinearity – nonlinear susceptibilities.

Module 2 Atom-field interaction for two level atoms – blackbody radiation – Rabi Flopping.

Introduction to laser theory – the laser self consistency equation – steady state amplitude and frequency – stability analysis – mode pulling.

Module 3 Doppler – broadened lasers – Two mode operation and the ring laser – mode locking – single mode semiconductor theory – evaluation of laser gain and index formulas – transverse vibrations and Gaussian beams.

Field quantization - single mode field quantization – multimode field quantization – single mode in thermal equilibrium. Coherent states – coherence of Quantum fields p ( ) representations.

Module 4 Interaction between atoms and quantized fields – Dressed states – Jaynes-Cummings model – collapse and revival.

Squeezed state of light – squeezing the coherent states – two side mode master equation – two mode squeezing – squeezed vacuum.

Books for Study:

1. P. Meystre and M. Sargent III, Elements of Quantum Optics (2^{nd} Ed.)

References:

1. W.H. Louisell, Quantum Statistical Properties of Radiation
2. M. Sargent III, M.O. Scully and W.E. Lamb, Laser Physics

23 Nonlinear Optics

Module 1 Review of the concepts of polarizability and dielectric tensor of a medium. Frequency dependence of the dielectric tensor – wave vector dependence of the dielectric tensor – electromagnetic waves in an isotropic dielectrics.

Nonlinear dielectric response of matter – frequency variation of the nonlinear susceptibilities – wave vector dependence of the nonlinear susceptibilities.

Module 2 Second harmonic generation – perturbation theory – phase matching evolution of SHW under phase matching conditions.

Four wave mixing spectroscopy – optical phase conjugation – nonlinear materials.

Module 3 Scattering of light – Raman scattering – Quantum theory of Raman scattering – Brillouin scattering.

Interaction of atoms with nearly resonant fields – wave function under near resonant conditions. Bloch equations – self induced transparency.

Module 4 Fibre optics – normal modes of optical fibres – nonlinear Schrodinger equations – linear theory.

Basic concepts of solitons and non-linear periodic structures. Effect of fibre loss – effect of wave quide property of a fibre – conditions of generation of a solitons in optical fibres.

Text Books:

1. D.L. Mills, Nonlinear Optics

Reference Books:

1. F.Zernike and J.E. Midwinter, Applied Nonlinear Optics
2. G.C. Badwin, Nonlinear Optics
3. A. Hasegawa, Optical Solitons in Fibres

24 Remote Sensing

Module 1 Introduction to Remote Sensing: Electromagnetic Spectrum, Physics of Remote Sensing, Effects of Atmosphere, Atmospheric Windows: Scattering, Absorption etc.

Spectral Reflectance of Earth's Surface features in different wavelength regions of EM Spectrum. Spectral Response Patterns.

Module 2 Platforms for data Acquisition: Satellite and Aerials sensors for data acquisitions – Active/Passive; Photographic/Scanning.

Optomechanical/OCD Arrays, Thermal Scanners, Microwave Sensors, Microwave Radiometers.

SLAR, SAR Satellite and Airborne Sensors.

Principles and basic concepts of remote sensing in FIR part of spectrum.

Module 3 History of Space Imagery: Landsat, SPOT, IRS, Meterological and other satellites; sensors; geometry and radiometry; data products.

Principles and basic concepts of microwave sensing – SLAR, SAR, Geometric characteristics, spatial resolution, Radar Grammetry.

Module 4 Ground Data Collection for interpretation and analysis: Principles of Image Interpretation – Types of Imagery, their formation and characteristics, elements of interpretation, techniques of visual interpretation.

High spectral resolution, Laser and Microwave Remote Sensing GPS and the use in Remote Sensing, Applications of Remote Sensing (General idea).

Reference Books:

1. Flayd. F. Sabins, Remote Sensing Principles and Interpretation 3rd Edn. W.H. Freeman and Co., New York – 1996
2. T. J. M. Kennie, Remote Sensing in Civil Survey, University Press, London, l985

25 Digital Signal Processing

Module 1 Continuous time signals, Discrete time signals and systems. Linear shift invariant systems, Difference equations, frequency domain representation, Relation between continuous and discrete systems.

Module 2 Z transform, Relation between Z Transform and the Fourier Transform of a sequence. Inverse Z Transform – Properties and Theorems, Two dimensional Z Transforms.

Module 3 Discrete Fourier transform, properties of DFT convolution of sequences – Linear convolution of finite duration sequences – sectioned convolutions – The discrete Hilbert transform – Hilbert transform relations for real signals.

Module 4 Digital filters signal flow graph representation of digital network – matrix representation – Design of infinite impulse response (IIR) filters elementary properties of IIR filters. FIR filters – characteristics of FIR with linear phase frequency response, positions of zeros of linear phase FIR, comparison of IIR and FIR filters. Some applications of DSP (general ideas).

References:

1. A.V. Oppenheim and R.W. Schafer, Discrete time signal processing Prentice-Hall of India, 1994.
2. Lawrence R. Rabinder and Bernard Gold, Theory and application of digital signal Processing, Prentice-Hall of India, New Delhi, 1993.
3. N. Ahmed and T.R. Natarajan, Discrete time signals and systems Reston Pub – Co 1983
4. Anil K. Jain, Fundamentals of Digital Image Processing , Prentice-Hall of India, New Delhi, 1995.
5. Lawrence R. Rabinder and Bernard Gold, Theory and Applications of Digital Signal Processing, Prentice-Hall of India.

26 Elementary Astronomy

Module 1 Celestial Sphere and Time : Constellations. The celestial sphere. Equatorial, ecliptic system of co-ordinates. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date. Stellar Distances and Magnitudes : Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index.

Module 2 Theories of formation of the Solar System, The Sun: Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.

Planets and their Satellites : Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Module 3 Stars : Basics of Star formation & Evolution. The HR diagram. Pre-main sequence contraction, main sequence stage and formation of super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Module 4 The Milky Way Galaxy & Galaxies beyond : Structure of the Milky Way Galaxy Galactic and globular clusters, Inter Stellar Matter, Position of our Sun and its motion around the galactic centre. Rotation of the Galaxy and its mass.

Extragalactic Systems : Hubble's classification of galaxies and clusters of galaxies. Galaxy interactions, Elements of Astrobiology.

Introduction to Cosmology : The expanding universe. Big Bang and Steady State models of the universe. Dark matter.

References :

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy.
2. W.M.Smart: Foundations of Astronomy..
3. Frank H. Shu: The Physical Universe-An Introduction to Astronomy.
4. K D Abhyankar: Astrophysics of the Solar System.
5. Baidyanath Basu: Introduction to Astrophysics.
6. Horneck and Rettberg: Complete Course in Astrobiology, Wiley (2009)
7. Jayant Narlikar: Structure of Universe.

27 Nondestructive Measurement Techniques and Applications

Module 1 Magnetism-Basic Definitions- Principle of MPT - Magnetizing Techniques -Magnetization using a magnet - Magnetization using an electromagnet - Contact current flow method. Eddy Current - Principles - Instrumentation for ECT -Techniques - High sensitivity techniques - Inspection of heat exchanger tubings by single frequency EC system - Multifrequency ECT - High frequency ECT - Pulsed ECT - 3D or phased array ECT - Inspection of ferromagnetic materials - Sensitivity - Applications - Limitations - Standards.

- (Practical Nondestructive Testing). Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi

Module 2 Radiography - Basic principle - Electromagnetic Radiation Sources -X-ray source - Production of X-rays - High energy X-ray source - Gamma ray sources - Properties of X- and gamma rays - Radiation Attenuation in the specimen - Effect of Radiation in film - Film ionization -Inherent unsharpness- Radiographic Imaging - Geometric factors - Radiographic film - Intensifying screens -Film density - Radiographic sensitivity - Penetrameter - Determining radiographic exposure -Inspection Techniques -Single wall single image technique - Double wall penetration technique .

Microwave methods-introduction, microwave radiation, microwave instrumentation, microwave measurements.

(Practical Nondestructive Testing). Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi

Module 3 Ultrasonic Testing - Basic properties of Sound Beam - Sound waves - Velocity of ultrasonic waves - Acoustic pressure - Behaviour of ultrasonic waves - Ultrasonic Transducers - Characteristics of ultrasonic beam - Attenuation - Inspection methods - Normal incident pulse-echo inspection - Normal incident through transmission testing - Angle beam pulse-echo testing -Criteria for probe selection - Flaw sensitivity - Beam divergence - Penetration and resolution - Techniques for Normal beam inspection - Fatigue cracks -Inclusions, slag, porosity, and large grain structure - Thickness measurement-corrosion detection - Intergranular cracks-hydrogen attack-Techniques for Angle beam inspection- Flow characterization techniques - Ultrasonic flaw detection equipment - Modes of display - A-scan - B-scan - C-scan - Immersion testing - Applications of ultrasonic testing -Advantages - Limitations - Standards.

(Practical Nondestructive Testing). Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi

Module 4 Visual Examination Basic Principle - The Eye - Defects which can be detected by unaided visual inspection-Optical Aids Used for Visual Inspection-Microscope Borescope - Endoscope - Flexible fibre-optic Borescope (Flexiscope) - Telescope

(Practical Nondestructive Testing). Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi

The concept of Holographic imaging - The inline hologram- The off axis hologram-Fourier hologram- Nondestructive application of holography- Holographic interferometry-Real time holographic interferometry-Double-Exposure holographic interferometry- Sandwitch holograms- Holographic interferometry in an industrial environment- Holographic strain analysis

P.Hariharan, Optical Holography-Principles techniques and applications. Cambridge Studies in Modern Optics

Raman effect (Qualitative only), Raman spectroscopy as nondestructive tool. Instrumentation. For Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.

Reference Books :

1. Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6 Boundary Row,London SE1 8HN
2. Practical Nondestructive Testing. Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi
3. Optical Electronics Ajoy Ghatak and K.Thygarajan,Cambridge University Press India Pvt.Ltd
4. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi

28 Measurement Techniques and Instrumentation

Module 1 Measurement and error - definitions - accuracy and precision - Results of measurements - sources of uncertainty in measurement error - systematic error - random error - Definition of uncertainty - Analysis of repeated measurements - Mathematical description of data distribution function - Derivation and properties of distribution functions - propagation error - Analysis of data.

Reference: Micheal Sayer, Abhai Mansingh -Measurement, Instrumentation and Experiment design in Physics and Engineering - Prentice Hall of India Pvt.ltd. New-Delhi (2000).

Module 2 Method of least squares - least square fit to straight line - chi - square test - linear least square fitting - non - linear least square fitting

Reference: Computational Methods in Physics and Engineering S.S.M. Wong. World Scientific Publishing Co, Singapore (1997)

Basic idea of lock-in detection and box-car integrator. Resources from the net.

Module 3 Instrumentation and system design - Signal measurement (qualitative) - signal to noise enhancement - signal processing (qualitative) - transducers - transducers characteristics - selection of an instrumentation transducer - Transducer as an electrical element - modelling external circuit component - circuit calculations - Potential divider - potential distribution along a single stage - Frequency response of an R-C circuit - decibel units - Instrument probs - power measurements - measurement methods - two terminal measurements - Four terminal measurement - sheet resistance measurement using 4 probe Van der Paw method.

Reference: Micheal Sayer, Abhai Mansingh -Measurement, Instrumentation and Experiment design in Physics and Engineering - Prentice Hall of India Pvt.ltd. New-Delhi (2000).

Module 4 Transducer properties - temperature measurements - Definition of temperature - temperature transducers - Resistance thermometer - thermister - thermocouples - thermocouple fabrication - comparison of temperature transducer characteristics - semiconductor temperature sensors - thermal radiation temperature measurements - Ratio Pyrometer - infrared Pyrometers - Low temperature thermometer - Semiconductor thermometer - magnetic thermometers - melting curve thermometer - optical measurements and electromagnetic spectrum - Thermal detector - Bollometer or thermopiles - photo conduction detector - photo emission detector - strain gauges - piezo electric transducers - application of piezo electric - linear variable differential transformer capacitive transducer.

Reference: Micheal Sayer, Abhai Mansingh -Measurement, Instrumentation and Experiment design in Physics and Engineering - Prentice Hall of India Pvt.ltd. New-Delhi (2000).

29 Astrophysics

Module 1 Magnitudes: Apparent and Absolute stellar magnitudes, distance modulus, Bolometric and radiometric magnitudes, Color-index, Color temperature, effective temperature, Brightness temperature,luminosities of stars. Equatorial, ecliptic and galactic system of coordinates. Apparent and Mean solar time and their relations. Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram.

Module 2 Fundamental Equations :
Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources.

Module 3 Stellar Models :
The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of mass luminosity law. Polytropic configurations. Homology transformations.

Module 4 Stellar Evolution :
Jean's criterion for gravitational contraction and its difficulties. Pre-main sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of isothermal core and subsequent development. Ages of galactic and globular clusters.

Reference Books :

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.
3. M.Schwarzschild:Stellar Evolution
4. S.Chandrasekhar:Stellar Structure
5. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanavan (CUP)
6. Menzel,Bhatnagar and Sen:Stellar Interiors.
7. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)
8. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.
9. R.Bowers and T.Deeming:Astrophysics (John and Barlett.Boston)

