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**4. Foundation course 2**

**Any one of the following courses: Paper 16 (Not for Physics students)**

**F2.1 Spectroscopic Applications**

**F2.2 Optics and Optical Instruments.**

**Subject Centric Core Course which can be taken in lieu of Foundation course 2.**

**S2.1 Nonlinear Geophysics**

**S2.2 Experimental Techniques in Physics**

**S2.3 Communication Electronics**

**S2.4 Electroacoustics**

## Semester I Paper 1 (Core 1) Mathematical Physics

### **Unit I**

Curvilinear co-ordinate Systems, Physical ideas about gradient, divergence and Curl, Fourier Series : Definition, Dirichlet's condition, Convergence, Fourier Integral and Fourier transform, Convolution theorem, Parseval's identity, Applications to the solution of differential equations,

### **Unit II**

Elementary ideas about tensors, Cartesian tensors, differential of Cartesian tensors, gradient, divergence and curl , Laplacian of Cartesian tensors. Non-Cartesian tensors. Tensor densities and capacities. Differentiation of Non-Cartesian tensors, Christoffel symbols. gradient, divergence and curl , Laplacian of Non-Cartesian tensors

Laplace transform of elementary functions – Inverse Laplace transforms – Methods of finding Inverse Laplace transforms – Heaviside expansion formula – Solutions of simple differential equations

### **Unit III**

Linear vector spaces - linear independent bases, Dimensionality, inner product, matrices, linear transformation, Matrices- Inverse, Orthogonal and Unitary matrices, Cayley Hamilton theorem, eigen vectors and eigen value problem, Diagonalization, Complete orthonormal sets of function.

### **Unit-IV**

Linear differential equations, Special Function- Laguerre, Hermite, Legendre polynomials, Special Bessel's function, Spherical harmonics, Generating Function and recursion relations, differential and integral form.

1. Matrices and Tensor in Physics: A.W.Joshi
2. Mathematical Physics: H.K.Dass
3. Vector analysis – Newell
4. Rajput B S, Mathematical Physics, PragatiPrakashan (Meerat) 1999

## Semester I Paper 2 (Core 2) Complex Analysis and Numerical Methods

### **Unit I**

Definition of Complex Numbers, Equality of Complex Number, Complex Algebra, Conjugate Complex Numbers, Geometrical representation of Complex Number, Geometrical representations of the sum, difference, product and quotient of Complex Number, Cauchy-Riemann Conditions, Analytic functions, Multiply connected regions, Cauchy Theorem, Cauchy Integration formula, Derivatives, problems (Rajput – 283 – 314).

### **Unit II**

Singularities- Poles, Branch Points, Calculus of Residues-Residues Theorem, Cauchy Principle value, Pole Expansion of Meromorphic Functions, Product expansion of entire Functions, problems (Rajput 326 – 384).

### **UNIT III**

Methods for determination of zeros and linear and non-linear single variable algebraic and transcendental equations, (Bisection method, false position method, iteration method, Newton-Raphson method, secant method), Finite differences. Newton's formulae (no proofs)

### **Unit IV**

Lagrange's interpolation, Divided differences. Numerical integration, trapezoid rule, Simpson's  $1/3^{\text{rd}}$  rule, Simpson's  $3/8^{\text{th}}$  rule, Linear least squares. Euler and RungeKutta methods for solving ordinary differential equations. (No proofs)

### References:

1. Rajput B S, Mathematical Physics, PragatiPrakashan (Meerat) 1999
2. Introductory Methods of Numerical Analysis: S S Sastry
3. Computer Oriented Numerical Methods: V Rajaraman
4. R. V. Churchill, Complex variables and Applications, 7th Edition McGraw Hill
5. Computer oriented Numerical Methods: R.S.Salaria
6. Mathematical Physics: H.K.Dass
7. Higher Engineering Mathematics : B. S. Grewal

## Semester I Paper 3 (Core 3) Electronics

### **Unit I**

Electronics Semiconductor discrete devices (characteristic curves and physics of p-n junction), Schottky, Tunnel and MOS diodes, Bipolar junction transistor, junction field effect transistor (JFET), Metal-oxide-Semiconductor Field effect transistor (MOSFET), unijunction transistor (UJT) and silicon controlled rectifier (SCR), Opto-electronic devices (Photo-diode, solar cell, LED, LCD and photo transistor), Diffusion of impurities in silicon, growth of oxide.

### **Unit II**

Applications of semiconductor devices in linear and digital circuits- Zener regulated power supply, Transistor (bipolar, MOSFET, JFET) as amplifier, coupling of amplifier stages (DC, RC and Transformer coupling), RC-coupled amplifier, dc and power amplifier Feedback in amplifiers and oscillators (phase shift, Hartley, Colpitts and crystal controlled) clipping and clamping circuits. Transistor as a switch OR, AND and NOT gates (TTL and CMOS gates).

### **Unit III**

Digital integrated circuits- NAND and NOR gates building block, X-OR gate, simple combinational Circuits -Half and full adder, Flip-Flops, Multivibrators (using transistor) and sweep generator (using transistors, UJT and SCR). shift registers, counters, A/D and D/A converters, semiconductor memories (ROM, RAM, and EPROM, basic architecture of 8 bit microprocessor (INTEL 8085). Linear integrated circuits- Operational amplifier and its applications-Inverting and noninverting amplifier, adder, integrator, differentiator, waveform generator, comparator and Schmitt trigger, Butterworth active filter, phase shifter,

### **Unit IV**

Communication Electronics-Basic principle of amplitude frequency and phase modulation. Simple circuits for amplitude modulation and demodulation, digital (PCM) modulation and demodulation. Fundamentals of optical communication, Microwave Oscillators (reflex, klystron, magnetron and Gunn diode), Cavity resonators. Standing wave detector.

### **Textbooks:**

1. A. Malvino and D. J. Bates: Electronic Principles (Mc Graw Hill Education, India)
2. Boylestad & Nashishkey, "Electronic devices & circuits", PHI
3. Millman, J. Halkias, "integrated electronics", Tata McGraw Hill
4. J. J. Cathey Schaum's Outlines "Electronic Devices & Circuits" Tata McGraw Hill.
5. J. D. Ryder, "Electronics Fundamentals and Applications", John Wiley-Eastern Publications.
6. A. P. Malvino, D.P. Leach, "Digital Principles and Applications", McGraw Hill Book Co., 4th Edition (1986).
7. Ramakant A. Gayakwad, "Op-amps and Linear Integrated Circuits" PHI
8. Anil Maini, Varsha Agrawal, "Electronic Devices and circuits" Wiley
9. George Kennedy, "Electronic Communication Systems", Tata McGraw Hill.
10. Dennis Roddy, John Coolen, "Electronic Communication Systems", Pearson.

## Semester I Paper 4 (Core 4) Electrodynamics I

### **Unit I**

**Electrostatics:** Coloumb's law, Electric field, Charge distribution, Dirac delta function, Field lines, Gauss's law and applications, Differential form of Gauss's law, Electric potential, Poisson and Laplace's equations, Electrostatic potential energy.

### **Unit II**

**Electrostatics:** Boundary value problems, Uniqueness theorems, Green's theorem, Method of images, Method of separation of variables (Cartesian Coordinates, Spherical and Cylindrical Coordinates), Multipole expansion.

### **Unit III**

**Magnetostatics:** Biot-Savart law, Ampere's law, Differential form of Ampere's law, Vector potential, Magnetic field of a localized current distribution, magnetic moment, Magnetostatics boundary conditions, Magnetic Shielding.

### **Unit IV**

**Time varying fields:** Faraday's law, Maxwell's displacement current, Maxwell's equations, Maxwell's equations in matter, Scalar and vector potentials, Gauge Transformation, Wave equations, Poynting's theorem, Conservation laws.

### **Text Books:**

1. Introduction to Electrodynamics, David J. Griffith, Prentice Hall of India Private Limited.
2. Classical Electrodynamics, John D. Jackson, Wiley Eastern Limited.
3. Classical Electrodynamics, Tung Tsang, World Scientific Publishing Private Limited.



## Semester I Practical 1 and 2

### **Practical 1 (core 1 and 2)**

1. To find the largest or smallest of a given set of numbers.
2. Bubble sort.
3. To generate and print first hundred prime numbers.
4. Matrix multiplication.
5. To generate and print an odd ordered magic square.
6. Other exercises involving conditions, loop and array
7. Lagrange Interpolation.
8. Method of successive approximation
9. Bisection Method
10. Newton-Raphson Method.
11. Gaussian Elimination
12. Linear Least Squares Fit.
13. Simpson's rule integration.
14. Computation of special functions

### **Practical 2 (Core 3 and 4)**

1. Design of a regulated power supply.
2. Characteristics and applications of silicon controlled rectifier.
3. Design of common emitter Power transistor amplifier.
4. Experiments on bias stability.
5. Negative feedback (Voltage series / shunt and current series / shunt).
6. Astable, Monostable and Bistablemultivibrator.
7. Experiment on FET and MOSFET characterization and application as an
8. amplifier.
9. Experiment on Uni-junction transistor and its application.
10. Digital – I: Basic, TTL, NAND and NOR.
11. Digital – II: Combinational logic.
12. Flip-Flops.
13. Study of modulation (FM, AM, etc.).
14. Operational Amplifier.
15. Differential Amplifier.
16. Microprocessor.
17. Verification of Biot-Savart law.
18. Verification of Faraday's Law

## **Semester II Paper 5 (Core 5) Quantum Mechanics I**

### **Unit- I**

Time dependent and time-independent Schrodinger equation, continuity equation, wave packet, admissible wave functions, stationary states.

Formalism of wave mechanics, expectation values, quantum mechanical operators for position and momentum in the coordinate representation, Construction of quantum mechanical operators for other dynamical variables from those of position and momentum, Ehrenfest's theorem, momentum eigen functions in the coordinate representation, box normalization and Dirac delta function.

Coordinate and momentum representations, Schrodinger equation in momentum representation,

### **Unit-II**

Brief revision of linear vector spaces, inner or scalar product, Schwarz inequality, state vectors, general formalism of operator mechanics vector, operator algebra, commutation relations, eigen values and eigen vectors, hermitian operators degeneracy, orthogonality eigenvectors of Hermitian operators, noncommutativity of two operators and uncertainty in the simultaneous measurements of the corresponding dynamical variables, the fundamental expansion postulate, representation of state vector, Dirac's bra-ket notations. Matrix representation of operators, change of basis, unitary transformations, quantum dynamics, Schrodinger, Heisenberg and interaction picture.

### **Unit-III**

Solution of Schrodinger equation for simple problems, 1-D Square well, step and barrier potentials, 1-D harmonic oscillator, zero point energy. harmonic oscillator problem by operator method.

Angular momentum operator, commutation relations, expression for  $L^2$  operator in spherical polar coordinates, Role of  $L^2$  operators in central force problem, eigen value problem for  $L^2$ , separation of Schrodinger equation in radial and angular parts, solution of radial equation for hydrogen atom, 3-d square well potential, parity of wave function, parity operator.

### **Unit-IV**

Generalized angular momentum, raising and lowering operators, matrices for  $J^2$ ,  $J_x$ ,  $J_y$ ,  $J_z$  operators, Pauli spin matrices, Addition of angular momenta, Clebich-Gordon Co-efficient, spin angular momentum, spin momentum functions.

#### **Text and Reference Books:**

1. Quantum mechanics: E. Merzbacher
2. Quantum mechanics: L.I.Schiff
3. Quantum mechanics: Mathews and Venkatesan
4. Quantum mechanics :Ghatak and Loknathan
5. Quantum mechanics: B.Craseman and J.D.Powell
6. Modern quantum mechanics: J.J.Sakurai
7. Quantum Theory D. Bohm, (Asia Publishing House)
8. Quantum Mechanics: 500 problems with Solutions: Aruldas (PHI)

## **Semester II Paper 6 (Core 6) Statistical Physics**

### **Unit I**

Fundamentals of classical statistical mechanics, microstate and macrostate, distribution function, Liouville's theorem, Gibbs Paradox, ensembles (micro-canonical, canonical and grand-canonical), partition function, free energy and connection with thermodynamic quantities, energy and density fluctuations

### **Unit II**

Fundamentals of quantum statistical mechanics, BE and FD Statistics, Symmetry of wave functions, Boltzmann limit of Bosons and Fermions, Ideal Bose system: Bose-Einstein condensation, Behaviour of ideal Bose gas below and above Bose temperature, Photons and liquid helium as bosons.

### **Unit III**

Ideal Fermi system: Weak and strong degeneracy, Fermi function, Fermi energy, Behaviour of ideal Fermi gas at absolute zero and below Fermi temperature, Fermionic condensation, Free electrons in metals as fermions, Electronic specific heat, Cluster expansion for classical gas, Virial equations of states.

### **Unit IV**

Phase transition: Phase transition of first and second order, Landau theory of phase transition, Ising model, Order parameter, Critical exponents, Scaling hypothesis, Random walk, Brownian motion, Langevin theory, Correlation function and fluctuation-dissipation theorem, Fokker-Planck equation. Weiss theory of ferromagnetism.

### **Text and Reference Books:**

1. Fundamentals of Statistical Physics: B. B. Laud
2. Statistical Mechanics: R. K. Pathria
3. Statistical Mechanics: S. K. Sinha
4. Statistical and Thermal Physics: F. Reif
5. Statistical Mechanics: K. Huang
6. Statistical Mechanics: Loknathan and Gambhir
7. Statistical mechanics: R. Kubo
8. Statistical Physics: Landau and Lifshitz

## **Semester II Paper 7 (Core 7) Classical Mechanics**

### **Unit-I**

Survey of elementary principles of mechanics of a particle, Dynamical systems, Phase space dynamics, stability analysis, constraints & their classifications, D'Alemberts Principle, Variational Principle, Lagrange's equation, Hamilton's Principle

### **Unit-II**

Conservation theorems and symmetry properties, Hamiltonian formalism, Hamiltons equations, Routh's procedure for cyclic coordinates, conservation laws  
Canonical transformations, Poisson brackets and Poisson theorems, Hamilton-Jacobi Theory

### **Unit-III**

Central force motion, reduction to one body problem, equations of motions and first integrals , classification of orbits for inverse square central forces. Two body collisions, Rutherford scattering in laboratory and centre-of-mass frames;

### **Unit-IV**

Rigid body dynamics, Euler's angles, Euler's theorem, moment of inertia tensor, eigen values and principal axis transformation, non-inertial frames and Pseudo forces, Periodic motion,: small oscillations, normal modes.

### **Text and Reference books:**

1. Classical Mechanics: H. Goldstein
2. Classical Mechanics: N.C.Rana and P.S.Joag
3. Classical Mechanics : J. C. Upadhyaya (Himalaya Publishing House)

## Semester II Paper 8 (Core 8) Electrodynamics II

### **Unit-I**

Scalar waves : Plane waves, spherical waves, phase and group velocities and wave packets  
Vector waves : Electromagnetic plane waves, harmonic plane waves, elliptic linear and circular polarization, Stokes parameters (iii) Reflection and refraction of plane waves, Fresnel polarization on reflection and refraction, (iv) Propagation in dielectric films.

### **Unit-II**

Symmetries of Maxwell equations : Lorentz transformations, Covariance of electrodynamics, Lorentz gauge condition, equation of continuity and Maxwell equations, electrodynamics field tensor and its transformation.

### **Unit-III**

Motion of a charge in EM fields : Lorentz force, motion in uniform, static, electric and magnetic fields and combined static EM fields.

Electric dipole, electric quadrupole and magnetic dipole radiation, Radiation by a moving charge :Lienard-Wiechert potentials of a point charge, Larmor's formula, Angular distribution of radiation. Fields and radiation of a localized oscillating source, Bremsstrahlung, Synchrotron radiation.

### **Unit-IV**

Wave guides : fields on the surface and within a hollow metallic conductor, TE, TM, TEM modes in a rectangular and cylindrical wave guide, Resonant Cavities, Dielectric waveguides.

### **Reference Books**

1. Introduction to Electrodynamics: David Griffiths (PHI)
2. Electrodynamics J. D. Jackson
3. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa)
4. Classical theory of fields, Landau & Lifshitz
5. Electrodynamics, W. Panofsky and M. Phillips
6. Principles of Optics, M. Born & E. Wolf Pergamon Press
7. Electromagnetism and Classical Theory, A. D. Barut, Dover

## Semester II Practical 3 and 4

### **Practical 3 (C5 and C6)**

1. Study of B-H Curve
2. Determination of  $e/m$  of electron by normal Zeeman effect using Feby Perot Etalon.
3. Determination of Lande's factor of DPPH using ESR spectrometer
4. Determination of  $e/m$  by Thomson method.
5. Determination of  $e/m$  by Busch's helical beam method.
6. Study of paramagnetic to ferromagnetic phase transition.
7. Study of Paramagnetic salt by Guoy's balance
8. Differential scanning Calorimetry
9. Determination of Plank's constant.
10. Determination of Stephan's constant.
11. Simulation of Ising model.
12. Location of critical point in Ising model using Binder cumulant.
13. Simulation of random walk.
14. Simulation of mean field model of para-ferro transition.
15. Numerical solution of particle in a box.
16. Simulation of Maxwell's velocity distribution.

### **Practical 4 (core 7 and 8)**

1. Study of Foucault pendulum
2. Study of Bifilar pendulum
3. Fibre optics
4. Study of waveguide
5. Thickness of thin wire with lasers
6. Measurement of wavelength of He-ne laser light using ruler.
7. To study Faraday effect using He-Ne laser.
8. Simulation of simple pendulum
9. Simulation of compound pendulum
10. Simulation of planetary motion.

## **Semester III Paper 9 (Core 9) Quantum Mechanics II**

### **Unit- I**

Time independent perturbation theory, First order perturbation theory applied to non-degenerate states, second order perturbation extension to degenerate state, Application of perturbation theory to the ground state energy, He atom (calculation given in Pauling and Wilson), Normal and anomalous Zeeman effect, First order Stark effect in the ground and first excited states of H atom and second order Stark effect of H atom, an-harmonic oscillator.

### **Unit II**

Time dependent perturbation theory, transition rate, Fermi Golden rule, constant perturbation harmonic in time, radiative transitions, absorption and induced emission, atomic radiation, dipole approximation, Einstein's atomic radiation, Einstein's A and B coefficients and their calculations.

Approximation methods: W. K. B. method and its application to barrier penetration.

Variational principle and its application to simple cases like ground state of He atom and deuteron in Yukawa potential.

### **Unit III**

System of identical particles, exchange and transposition operators, totally symmetric and antisymmetric wave function and their expressions for a system of non-interacting particles, statistics of systems of identical particles, Relation of statistics with spin, Ortho and para states of the helium atom and their perturbation by Coulomb repulsion.

Hamiltonian of a molecule, Born-Oppenheimer approximation, outline of Heitler-London theory of the hydrogen molecule.

Scattering theory, scattering cross-section in laboratory and centre of mass system, scattering by a central potential, Partial wave method, phase shifts and their importance, scattering by a square well potential and a perfectly rigid sphere, resonance scattering.

### **Unit IV**

Relativistic wave equation, the Klein-Gordon equation and initial difficulties in interpreting its solutions, Dirac's relativistic equation, Dirac's matrices, explanation of the spin of the electron, equation for an electron in an electromagnetic field and explanation of the magnetic moment due to the electron spin, spin-orbit interaction, solution for hydrogen atom in Dirac's theory, negative energy states and their qualitative explanations.

### **Text and References Books:**

1. E. Merzbacher, Quantum Mechanics (Wiley and Sons-Toppon)
2. J. L. Powell and B. Crasemann, Quantum mechanics (B I Publications)
3. L. I. Schiff, Quantum Mechanics (McGraw-Hill)
4. Quantum Mechanics: Aruldhas
5. Pauling and Wilson, Introduction to Quantum Mechanics
6. A.K. Ghatak and Lokanathan, Quantum Mechanics (Macmillan, India)
7. Quantum Mechanics: 500 problems with Solutions: Aruldhas (PHI)

## Semester III Paper 10 (Core 10) Solid State Physics and Spectroscopy

**Unit I:** Order in Solids-Crystal classes and system, 2d and 3d lattices, Space groups, b  
Concept of point group, bonding of common crystal structure; reciprocal lattice,  
diffraction and structure factor, Miller and Bravais indices, Bonding, diffraction and  
structure factor in solids, short and long range order in liquids and solids, liquid crystals,  
quasicrystals and glasses

### **Unit II**

**Defects:** Vacancies, Point defects, line defects and stacking faults, Burgers vector and  
Burger circuit, presence of dislocation, dislocation motion, perfect and imperfect  
dislocations, slip planes and slip directions, dislocation reactions

**Dielectric Properties:** -Polarization mechanisms, Clausius-Mossotti equation, piezo,  
pyro and ferroelectricity

### **Unit III**

**Atomic Structure and Atomic Spectra :** Quantum states of an electron in an atom.  
Electron spin. Spectrum of helium and alkali atom. Some features of one-electron and two  
electron atoms, Relativistic corrections for energy levels of hydrogen atom, hyperfine  
structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Inner shell  
vacancy, X-rays and Auger transitions. chemical shift. Frank-Condon principle.

### **Unit IV**

**Molecular Structure and Molecular Spectra :**Types of molecules, Electronic,  
rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Morse  
potential energy curve, Molecules as vibrating rotator, Vibration spectrum of diatomic  
molecule, PQR branches. Elementary discussion of Raman, ESR and NMR spectroscopy,  
chemical shift

- Reference Books:
1. Physics of Atoms and Molecules: Bransden and Joachain.
  2. Introduction to Atomic Spectra: H.E. White.
  3. Solid State Physics, Charles Kittel, John Willey & Sons
  4. Molecular Spectra and Molecular Spectroscopy (Vol. 1), G. Herzberg
  5. Introduction to Atomic Spectra: HG Kuhn
  6. Fundamentals of molecular spectroscopy, C.B. Banwell
  7. Introduction to molecular Spectroscopy , G. M. Barrow
  8. Introduction to Solid State Physics: C. Kittel
  9. Materials Science and Engineering: V. Raghavan
  10. Solid State Physics: S. O. Pillai (New Age International 2006)
  11. Ferroelectricity Jona and Shirane



## Semester III Practical 5

### **Practical 5 (Core 9 and Core 10).**

1. Determination of ionization potential of lithium
2. X-ray diffraction by TELEXOMETER.
3. Study of emission spectra of iron (Iron arc).
4. Determination of Dissociation Energy of Iodine Molecule by photography of the absorption band of Iodine in the visible region.
5. Study of Stark effect
6. Study of Molecular Spectra
7. Determination of Rydberg's constant
8. Determination of Plank's constant
  9. Study of Crystals
  10. Study of line spectra

## Semester III Paper 11 (Core Elective E1.1) Materials Science I

### Unit- I

**Equilibrium and kinetics:** Stability and metastability, Basic thermodynamic functions, Statistical nature of entropy, Kinetics of thermally activated process.

**Phase diagrams:** The phase rule, free energy composition diagram, correlation between free energy and phase diagram, calculation of phase boundaries, thermodynamics of solutions, single component system (water), two component system containing two phases and three phases, Binary phase diagrams having intermediate phases, Binary phase diagrams with eutectic system. Lever principle, maximum, minimum, super lattice, miscibility gap, microstructure changes during cooling, application to zone refining.

### Unit – II

**Phase transformations:** Time scale for phase changes, peritectic reaction, eutectoid and eutectic transformations, order disorder transformation, transformation diagrams, dendritic structure in alloys, transformation on heating and cooling, grain size effect on rate of transformation at constant temperature and on continuous cooling, grain size effect on rate of transformation, nucleation kinetics, growth kinetics, interface kinetics leading to the crystal growth.

### Unit-III

**Diffusion in solids:** Fick's laws and their solutions, the Kirkendall effect, mechanism of diffusion, temperature dependence of diffusion coefficient, self diffusion, interstitial diffusion, the Snoek effect in diffusion, diffusion in ionic crystals, diffusion path other than the crystal lattice, thermal vibrations and activation energy, diffusion of carbon in iron.

**Solid State Ionics:** Definition, classification and characteristic properties of solid electrolytes. Complex impedance spectroscopy, Arrhenius theory of ionic conductivity. Chemical sensors: Nernst equation, potentiometer and amperometric sensors for various gases, electrochemical redox-reaction, advantages of electrochemical sensors.

### UNIT-IV

**Solid state energy devices:** Fundamental of Solar cells, Primary and secondary solid state cells, advantages of lithium batteries, ion intercalation compounds for secondary cell, open circuit voltage and short circuit current, intercalation compounds for secondary cell, open circuit voltage and short circuit current, Energy density, power density. Fuel cells –advantages and disadvantages, classification, efficiency- emf of fuel cells, hydrogen/oxygen fuel cell, criteria for the selection electrode and electrolyte, methanol fuel cell, solid oxide fuel cells, phosphoric acid fuel cells, molten carbonate fuel cell, proton exchange membrane fuel cell, biochemical fuel cell.

**Text and Reference books:**

1. Vanvella: Materials Science.
2. V. Raghvan: Materials Science.
3. D. Kingery: Introduction to ceramics.
4. R. E. Reedhil: Physical metallurgy.
5. Martin Start Sharger: Introductory materials.
6. Sinnot: Solid state for engineers.
7. Kelly and Groves: Crystal and defects.
8. Kittel: Solid state physics, Vth edition.
9. M. A. Azaroff: Elements of crystallography
9. Introduction to solid state theory: Modelung.
10. Fuel Cells – A. Mcdougall, Macmillan 1976 Ch 3,5,7,8 and 11.

## **Semester III Paper 11 (Core Elective E1.2) X-ray I**

### **Unit I**

Production of X-rays: Continuous and characteristic X-ray spectra. X-ray emission from thick and thin targets. Efficiency of X-ray production. Various types of demountable and sealed X-ray tubes.

Basics of high-tension circuits and vacuum systems used for the operation of X-ray tubes. Synchrotron radiation: Production and properties of radiation from storage rings, Insertion devices.

### **Unit II**

Absorption of X-rays: Physical process of X-ray absorption. Measurement of X-ray absorption coefficients. Units of dose and intensity. Radiography, Microradiography and their applications.

X-ray fluorescence: Fluorescence yield. Auger effect. X-ray fluorescence analysis and its applications. Techniques and applications of Photoelectron spectroscopy and Auger electron spectroscopy.

### **Unit III**

X-ray spectroscopy: Experimental techniques of wavelength and energy dispersive x-ray spectroscopy.

Bragg and double crystal spectrographs. Focusing spectrographs. Dispersion and resolving power of spectrographs, Photographic and other methods of detection, resolving power of detectors.

X-ray emission and absorption spectra. Energy level diagram. Dipole and forbidden lines, Satellite lines and their origin, Regular and irregular doublets. Relative intensities of X-ray lines.

### **Unit IV**

Chemical Effects in X-ray Spectra: Chemical effects in X-ray spectra. White line, Chemical Shifts of absorption edges, Fine structures (XANES and EXAFS) associated with the absorption edges and their applications.

Dispersion Theory: Dispersion theory applied to X-rays, Calculation of the dielectric constant, Significance of the complex dielectric constant, Refraction of X-rays, Methods for measurement of refractive index

### **Text and Reference Books:**

1. A. H. Compton and S. K. Allison: X-rays in Theory and Experiment
2. J. A. Nielsen and D. Mc. Morrow: elements of Modern X-ray Physics.
3. M. A. Blokhin: X-ray Spectroscopy.
4. E. P. Bertin: Principles and Practice of X-ray Spectrometric Analysis.
5. C. Bonnelle and C. Mande: Advances in X-ray Spectroscopy.
6. D. C. Koningsberger and R. Prins: X-ray Absorption Principles, Applications, Techniques of EXAFS, SEXAFS and XANES.
7. C. Kunz: Synchrotron Radiation.

## **Semester III Paper 11 (Core Elective E1.3) Nanoscience and Nanotechnology I**

### **Unit I:**

#### *Introduction to Nanoscience:*

Free electron theory (qualitative idea) and its features, Idea of band structure, Density of states for zero, one, two and three dimensional materials, Quantum confinement, Quantum wells, wires, dots, Factors affecting to particle size, Structure property relation, Size dependence properties. Determination of particle size, Increase in width of XRD peaks of nano-particles, Shift in photoluminescence peaks, Variation on Raman spectra of nano-materials.

### **Unit II:**

#### *Synthesis of Nanomaterials:*

Physical methods: High energy Ball Milling, Melt mixing, Physical vapour deposition, Ionised cluster beam deposition, Laser ablation, Laser pyrolysis, Sputter deposition, Electric arc deposition, Photolithography.

Chemical methods: Chemical vapour deposition, Synthesis of metal & semiconductor nanoparticles by colloidal route, Langmuir-Blodgett method, Microemulsions, Sol-gel method, Combustion method, Wet chemical method

### **Unit III:**

#### *Nanomaterials Characterizations:*

X-ray diffraction, UV-VIS spectroscopy, Photoluminescence spectroscopy, Raman spectroscopy, Transmission Electron Microscopy, Scanning Electron Microscopy, Scanning Tunnelling Electron Microscopy, Atomic Force Microscopy, Vibration Sample Magnetometer, Spintronics

### **Unit IV:**

#### *Special Nanomaterials and Properties:*

Carbon nanotubes, Porous silicon, Aerogels, Core shell structures. Self assembled nanomaterials. Metal and semiconductor nanoclusters

Mechanical, Thermal, Electrical, Optical, Magnetic, Structural properties of nanomaterials

### **Text and Reference books:**

1. Nanotechnology: Principles &Practicals. Sulbha K. Kulkarni ,Capital Publishing Co.New Delhi.
2. Nanostructures & Nanomaterials Synthesis, Properties & Applications. Guozhong Cao, Imperials College Press London.
- 3.Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein &R.C.Commorata.Institute of Physics Publishing, Bristol & Philadelphia.
4. Introduction to Nanotechnology. C.P. Poole Jr. and F. J.Owens, Wiley Student ed.
5. Nano: The Essentials. T.Pradeep , McGraw Hill Education.
6. Handbook of Nanostructures: Materials and Nanotechnology. H. S. Nalwa Vol 1- 5, Academic Press, Bostan.
7. Hand Book of Nanotechnology, Bhushan
8. Nanoscience and Technology: Novel Structure and Phenomena. Ping and Sheng

## Semester III Paper 11 (Core Elective E1.4) Atomic and Molecular Physics I

### **Unit I**

Quantum states of an electron in an atom, Electron spin, spectrum of hydrogen, Helium and alkali atoms, Relativistic corrections for energy levels of hydrogen; Basic principles of interaction of spin and applied magnetic field.

Concepts of NMR spectroscopy concepts of spin-spin and spin-lattice relaxation, chemical shift; spin-spin coupling between two and more nuclei; chemical analysis using NMR.

Mossbauer effect-Recoil less emission of gamma rays, chemical shift, magnetic hyperfine interaction,

### **Unit II**

electron spin resonance, experimental setup, hyperfine structure and isotopic shift, width of spectral lines, LS & JJ coupling, Zeeman, Paschen Back & Stark effect. Spontaneous and Stimulated emission, Einstein A & B Coefficients; LASERS, optical pumping, population inversion, rate equation, modes of resonators and coherence length, Role of resonant cavity, three and four level systems, Ammonia MASER, ruby, He-Ne, CO<sub>2</sub>, dye and diode lasers, Lasers applications

### **Unit III**

Rotational, vibrational and Raman spectra of diatomic molecules, Quantum theory, Molecular polarizability, Intensity alteration in Raman spectra of diatomic molecules, Experimental setup for Raman spectroscopy in the structure determination of simple molecules. polyatomic molecules, symmetric top asymmetric top molecules. Hund's rule.

### **Unit IV**

Electronic spectra of diatomic molecules, Born Oppenheimer approximation, Vibrational Coarse structure of electronic bands, intensity of electronic bands, Franck Condon principle, and selection rules, dissociation and pre dissociation, dissociation energy, rotational fine structure of electronic bands. General treatment of molecular orbitals, Hund's coupling cases.

### **Text Book and References:**

1. Molecular Spectroscopy: - Jeane L. McHale.
2. Mossbauer spectroscopy -M. R. Bhide.
3. NMR and Chemistry - J. W. Akitt.
4. Structural Methods in inorganic chemistry, E.A V.Ebsworth, D. W. H.Rankin, S.Crdoek.
5. Introduction to Atomic Spectra - H. E. White.
6. Fundamental of Molecular Spectroscopy - C. B. Banwell.
7. Spectroscopy Vol. I, II and III, Walker and Straghen.
8. Introduction to Molecular Spectroscopy - G. M. Barrow.
9. Spectra of diatomic molecules - Herzberg.
10. Molecular spectroscopy - Jeanne L. McHale.
11. Molecular spectroscopy - J. M. Brown.
12. Spectra of Atoms and Molecules - P. F. Bemath.
13. Modern Spectroscopy - J. M. Holkas.
14. Laser spectroscopy and instrumentation- Demtroder

## Semester III Paper 11 (Core Elective E1.5) Applied Electronics I

### **Unit – I**

Operational Amplifiers, Block diagram of a typical operational amplifier, analysis, open loop configuration, inverting and non-inverting amplifiers, operational amplifier with negative feedback, voltage series feedback, effect of feedback on close loop gain, input resistance output resistance bandwidth and output offset voltage, voltage follower. Practical operational amplifier, input offset voltage, input bias current, input offset current, total output offset voltage, CMRR, frequency response, dc and ac amplifier, summing, scaling and averaging amplifier, instrumentation amplifier, integrator and differentiator. Application of Op-Amp as fixed and variable voltage regulator. Oscillators principles- Barkhausen criterion for oscillations, The phase shift oscillator, Weinbridge oscillator, LC tunable oscillator, multi-vibrators, mono-stable and astable, comparators, square wave and triangular wave generators

### **UNIT II**

Communication electronics: Amplitude modulation , generation of AM waves, demodulation of AM waves, DSBSC modulation, generation of DSBSC waves, coherent detection DSBSC wave, SSB modulation, generation and detection of SSB waves, Vestigial sideband modulation, frequency division multiplexing (FDM).

Microwave communication: Advantage and disadvantage of microwave transmission, loss in free space propagation of microwaves, atmospheric effect on propagation, Fresnel zone problem, ground reflection, fading sources, detector components, antennas used in microwave communication systems

### **Unit – III**

Microprocessor: Introduction to microcomputers, Memory. Input-output devices, interfacing devices. 8085 CPU, architecture, bus timing, de-multiplexing, the address bus, generating control signals, instruction set, addressing modes, illustrative programmes, assembly language programmes, looping, counting and indexing, counters and timing delay, stack and sub routings. read only memory (ROM) and applications. Random access memory (RAM) and applications,

Digital to analogue converters. Ladder and weighted register types, analog to digital converters, successive approximations and dual slope converters, application of DAC and ADC,

### **Unit – IV**

Microwave devices: Klystrons, magnetrons, and travelling wave tubes, velocity modulation, basic principle of two cavity klystrons and reflex klystrons, principle of operation of magnetrons, Helix travelling wave tubes, wave modes, transferred electron devices, gunn effect, principle of operation, modes of operation, read diode, IMPATT diode, TRAPATT diode..

### **Text and Reference Books:**

1. Electronic devices and circuit theory: Robert Boylested and L. Nashdsky (PHI, New Delhi).
2. OP-Amps and linear integrated circuits: Ramakanth A. Gayakwad (PHI 2nd Edn).
3. Digital principles and Applications: A. P. Malvino and D. P. Leach (Tata Ma-Graw Hill).
4. Microprocessor architecture, programming and Application with 8085/8086, Ramesh S. Gaonkar (Wiley-Estern).
5. Microelectronics: Jacob Millman (Mc-Graw Hill International).

6. Optoelectronics: Theory and Practices: Edited by Alien Chappal (Mc Graw Hill).
7. Microwaves: K. L. Gupta (Wiley Ester New Delhi).
8. Advanced electronics communication systems: Wayne Tomasi (Phi Edn).
9. Fundamentals of microprocessors and Micro-computers: B. Ram. (Dhanpat Rao and Sons.).



## Semester III Paper 11 (Core Elective E1.6) Methods of Theoretical Physics I

Mathematical and Computational Methods:

### **Unit 1**

Definition of groups, subgroups and conjugate classes - Symmetry elements, Transformation, Matrix representation - Point groups - representation of a group - Reducible and irreducible representations - Orthogonality theorem - character of a representation - character Table  $C_{2v}$  and  $C_{3v}$  - Application to Infrared and Raman active vibrations of  $XY_3$  type molecules - Projection operators applied to an equilateral triangle - Rotation group and angular momenta.

### **Unit 2**

Elements of C Programming Language: Algorithms and flowchart; Structure of a high level language program; Features of C language; constants and variables; expressions; Input and output statements; conditional statements and loop statements; arrays; functions; character strings; structures; pointer data type; list and trees.

### **Unit 3**

Partial Differential equations in Physics, Discretization of equation, matrix method relaxation method, groundwater dynamics, initial value problems, temperature field of nuclear waste rod (Peng)

### **Unit 4**

Generation of uniformly distributed random integers, Statistical tests of randomness, Monte-Carlo evaluation of integrals and error analysis, Non-uniform probability distributions, Importance sampling, Rejection method, Metropolis algorithm, Brownian Motion and Ising model in 2 dimensions.

### **References**

1. A Guide to Monte Carlo Simulations in Statistical Physics - D.P. Landau and K. Binder, (Cambridge University Press (2000))
2. Mathematical methods for physicists- G.B. Arfkenand ,H.T.Weber
3. A.W. Joshi, 1997, Elements of group Theory for Physicists, 4th Edition, New Age International, New Delhi.
4. F.A. Cotton, Chemical Application of Group Theory 3rd Edition, John Wiley and Sons, New York.
5. Let us C : Y Kanetkar
6. A First Course in Computational Physics - P.L. DeVries (Wiley).
7. Computer Applications in Physics - S.Chandra (Narosa)
8. Computational Physics - R.C. Verma, P.K. Ahluwalia and K.C. Sharma ( New Age )
9. Computational physics by S.F. Koonin (Addition – Wesley , NY) 1986
10. An introduction to computer simulationmethod PART – I (Addition – Wesley , NY) , 1998 by Gould and J. Tebochaik
11. An introduction to compulation physics by Tao Pang.(Cambridge Univ-Press, 1997)
12. A physicist's guide to Mathemetica by P.T. Tam (Academic Press, II Edition)

## Semester III Paper 11 (Core Elective E1.7) Nonlinear Dynamics I

### **Unit I**

Flows on a line, fixed points and their stability, Population growth, Linear Stability Analysis, Existence and Uniqueness, Impossibility of Oscillations, Potentials, Bifurcations, Saddlenode, Transcritical, Pitchfork, Examples, Imperfect Bifurcation. (Chapter 2 and 3 of Ref. 1)

### **Unit II**

Flows on a circle, Uniform and Nonuniform Oscillator, Over damped Pendulum, Superconducting Josephson Junction, Fireflies, Examples of Linear System, Classification of Linear System. (Chapter 4 and 5 of Ref. 1)

### **Unit III**

Phase portraits, Existence and Uniqueness, Fixed points and their Linearization, Conservative Systems, Reversible Systems, Index theory, Limit Cycles, Ruling out Closed Cycles, Poincare-Benedixon theorem, Lienard Systems, Relaxation Oscillations, Weakly Nonlinear Oscillators. (Chapter 6 and 7 Ref. 1)

### **Unit IV**

Bifurcations in detail, Saddle-node, transcritical, pitchfork, Hopf, Global Bifurcations, Hysteresis in Driven pendulum, Coupled Oscillators and Quasiperiodicity (Chapter 8 of Ref. 1)

### **Reference books:**

1. S. W. Strogatz : Nonlinear Dynamics with Applications to Physics, Biology, Chemistry and Engineering. (Perseus)
2. Edward Ott : Chaos in Dynamical Systems (Cambridge University Press)

## Semester III Practical 6 and 7 for elective papers

### **Practical 6 (elective)**

#### **Materials Science**

1. Crystal structure determination by powder diffraction.
2. Study of microstructures of metal alloys.
3. Dislocation in alkali halide crystals.
4. Crystal growth from slow cooling of the melt.
5. Thermal analysis of binary alloy.
6. Differential thermal analysis of BaTiO<sub>3</sub>-PbTiO<sub>3</sub> solid solution.
7. To study electrochemical method of corrosion control.
8. Dielectric behaviour of LiNbO<sub>3</sub> and BaTiO<sub>3</sub> in crystals and ceramics.
9. Electrical conductivity of ionic solids.
10. To test hardness of a material by Brinell hardness tester.
11. Photo elasticity study.
12. Multiple beam interferometric study of surfaces.
13. Thermal conductivity of bad conductor. 14. Thermal expansion coefficient of metals.
15. Study of transport property in solid electrolytes.
16. Verification Nernst law/Oxygen sensor.
17. Determination of Thermoelectricity Power.

#### **X-Rays**

1. Study of Crystal Models.
2. X-ray Diffraction Photograph of a Metal Foil by transmission (Hull Method).
3. X-ray Diffraction Photograph of a Metal Foil by Back Reflection.
4. Powder Photograph by Debye Scherrer Method, Computer Analysis.
5. Laue Photograph and Gnomonic Projection.
6. Rotation oscillation Photograph.
7. Diffraction of X-rays by Liquids.
8. Bragg's Spectrometer: Uhler and Cooksey's method. 55
9. Bent Crystal (Cauchois) Transmission Type Spectrograph: Study of K and L Absorption Edges.
10. Bent Crystal (Cauchois) Transmission Type Spectrograph: Study of K and L emission Spectra.
11. Measurement of Intensities of Emission Lines, Computer Analysis.
12. Study of Satellite Lines. 13. Analysis of XANES Spectrum, Computer Analysis.
14. Analysis of EXAFS Spectrum, Computer Analysis.
15. Determination of Planck's constant by X-rays.
16. X-ray Fluorescence Spectrum Analysis.
17. Absorption Coefficient for X-rays by G. M. / Scintillation Counter.
18. Characteristics of G. M. tube.
19. Compton Effect.
20. Operation of a Demountable X-ray Tube.

#### **Nanoscience and Nanotechnology**

1. Synthesis of metal oxide nanoparticles by wet chemical method.
2. Deposition of thin films by spray pyrolysis technique.
3. Synthesis of inorganic nanomaterials by combustion method.

4. Synthesis of nanomaterials by sol-gel method.
5. Synthesis of conducting polymer nanofibres by chemical oxidation method.
6. Study of optical absorption of nanoparticles.
7. Determination of particle size of nanomaterials from x-ray diffraction.
8. Study of photoluminescence of well known luminescent nanoparticles.
9. Deposition of thin films by spin coating method.
10. Thermoluminescence study of nanomaterials.
11. Deposition of thin films by dip coating technique.
12. Study of particle size effect on luminescence.
13. Electrical characterization of nanostructured materials.
14. Synthesis of metal oxide nanoparticles by hydro-thermal method.
15. Deposition of thin film in vacuum.
16. Electrical resistivity of nanomaterials using four probe method
17. Photoluminescence study of prepared red/blue/green luminescent nanomaterials.
18. Characterization of nanomaterials using SEM/TEM.
19. Computer modelling methods for studying materials on a wide variety of length and time scales.

### **Atomic and Molecular Physics**

1. Study of line spectra on photographed plates/films and calculation of plate factor.
2. Verification of Hartman's dispersion formula.
3. Study of sharp and diffuse series of potassium atom and calculation of spin orbit interaction constant.
4. Determination of metallic element in a given inorganic salt.
5. To record the spectrum of CN violet bands and to perform vibrational analysis.
6. To record the visible bands of ALO and to perform vibrational analysis.
7. To photograph and analyse the reddish glow discharge in air under moderate pressure.
8. To photograph the analyse the whitish glow discharge in air under reduced pressure.
9. To perform vibrational analysis of a band system of N<sub>2</sub>.
10. To perform vibrational analysis of band system of C<sub>2</sub>
11. To photograph and analyse the line spectrum of Calcium atom.
12. To record/analyse the fluorescence spectrum of a sample.
13. To record/analyse the Raman spectrum of a sample.
14. Study of Hyperfine structure of the green line of mercury.
15. To photograph the (O, O) band of CuH and to perform rotational analysis.
16. Flashing & quenching in Neon Gas.
17. E/m of electron.
18. Experiments on Prism/Grating Spectrometer.
19. Wavelength of laser light.
20. Faraday effect with laser.
21. Michelson interferometer.
22. Analysis of ESR Spectra of transition metals.
23. Analysis of H-atom spectra in minerals.
24. Measurements of dielectric constant of polymer sheet at low frequency.
25. E.S.R. of DPPH.
26. To measure the dielectric constant and polarisation of unknown liquid.
27. To measure the dielectric constant of unknown wood at microwave frequency
28. To measure the ultrasonic velocity in unknown liquid.

29. He-Ne Layer
30. To study polarisation of sodium light
31. To study polarisation of light using Babinet compensator

### **Methods of Theoretical Physics**

1. Solving Laplace's equation
2. Bench problem (Pang)
3. The relaxation scheme for one dimension
4. Ground water dynamics
5. The time-dependent temperature field
6. Ising Model
7. 2-d Percolation
8. Classical Scattering

Ref: T. Pang

### **Nonlinear Dynamics**

1. Bifurcation Diagram of logistic map.
2. Feigenbaum constant for period-doubling systems.
3. Study of Hopf Bifurcations.
4. Finding Lyapunov exponent.
5. Fractal dimension of strange attractor.
6. Simulation of Lorenz attractor
7. Simulation of Rossler attractor
8. Multifractal spectrum of strange attractor.
9. Study of quantum chaos

## Semester III Paper 12 (Foundation course F1.1) Fundamentals of Spectroscopy

### Unit I

**Atomic Spectra:** The hydrogen atom and the three quantum numbers  $n$ ,  $l$  and  $m_l$ . – electron spin - Vector atom model - electron spin - Stern-Gerlach experiment spectroscopic terms. Spin-orbit interaction, fine structure in sodium atom, selection rules. Lande  $g$ -factor, normal and anomalous Zeeman effects, Paschen-Back effect, Stark effect in one electron system. L S and j j coupling schemes (vector diagram) – examples

### Unit II

**Molecular Spectra: Microwave Spectra:** Rotational spectra of rigid diatomic molecules - effect of isotopic substitution. Non-rigid rotor – rotational spectra of polyatomic molecules

**IR Spectra:** Vibrating diatomic molecule as anharmonic oscillator, diatomic vibrating rotor – break down of Born-Oppenheimer approximation - vibrations of polyatomic molecules - overtone and combination frequencies - analysis by IR technique - Fourier transform IR spectroscopy.

### Unit III

**Raman Spectroscopy:** Pure rotational Raman spectra - linear and symmetric top molecules - vibrational Raman spectra – Raman activity of vibrations - structure determination from Raman and IR spectroscopy.

### Unit IV

**Electronic Spectroscopy:** Electronic spectra of diatomic molecules - progressions and sequences - intensity of spectral lines. Franck – Condon principle - dissociation energy Rotational fine structure of electronic-vibrational transition - Fortrat parabola – Pre dissociation energy-fluorescence and phosphorescence.

### Reference Books:

1. Introduction of Atomic Spectra, H.E. White, McGraw Hill
2. Spectroscopy (Vol. 2 & 3), B.P. Straughan & S. Walker, Sciencepaperbacks 1976
3. Raman Spectroscopy, D.A. Long, McGraw Hill international, 1977
4. Introduction to Molecular Spectroscopy, G.M. Barrow, McGraw Hill
5. Molecular Spectra and Molecular Structure, Vol. 1, 2 & 3. G.Herzberg, Van Nostard, London.
6. Elements of Spectroscopy, Gupta, Kumar & Sharma, PragathiPrakshan
7. The Infra Red Spectra of Complex Molecules, L.J. Bellamy, Chapman & Hall. Vol. 1 & 2
8. Laser Spectroscopy techniques and applications, E.R. Menzel, CRC Press, India

## Semester III Paper 12 (Foundation course F1.2) Fundamentals of Nanoscience and Nanotechnology

### **Unit-I Basics of Nanoscience**

Introduction to quantum physics, electron as waves, wave mechanics, Schrödinger equation and particle in a box, Heisenberg's uncertainty principle, exclusion principle, Free electron theory (qualitative idea) and its features, Idea of band structure, Density of states for zero, one, two and three dimensional materials, Quantum confinement, Quantum wells, wires, dots, Factors affecting to particle size  
The p-n-junction and bipolar transistor, Metal semiconductor and metal insulator, semiconductor junction, field effect transistor.

### **Unit-II Properties of Nanomaterials**

Mechanical, Thermal, Electrical, Optical, Magnetic and Structural.

Carbon nanostructures- Fabrication, structure, electrical properties and mechanical properties.

### **Unit-III Synthesis of Nonmaterial's**

Physical methods: Bottom up-Ball Milling, Melt mixing, Physical vapour deposition, Ionised cluster beam deposition, Laser pyrolysis, Sputter deposition, Electric arc deposition, Gas evaporation.

Chemical methods: Hydrothermal combustion, bath deposition with capping techniques and top down, Chemical vapour deposition, Synthesis of metal & semiconductor nanoparticles by colloidal route, Microemulsions, Sol-gel method, Combustion method, Wet chemical method

### **Unit-IV Bionanotechnology**

Biological building blocks, nanostructure, protein nanoparticles, DNA double nanowire. Bionanostructures- Micelles, vesicles, multilayer films, biological interactions, bilayers, bioelectronics and biosensors.

### **Text and Reference Books:**

1. Nanotechnology: Principles & Practicals. Sulbha K. Kulkarni, Capital Publishing Co. New Delhi.
2. Carbon nanotechnology..recent developments in Chemistry, Physics, materials science and device applications, -Elsevier Science
3. Nanostructures & Nanomaterials Synthesis, Properties & Applications. Guozhong Cao, Imperial College Press London
4. Physics, Chemistry and Application of Nanostructures, world scientific co.
5. Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein & R.C. Commorata. Institute of Physics Publishing, Bristol & Philadelphia.
6. Introduction to Nanotechnology. C.P. Poole Jr. and F. J. Owens, Wiley Student Edition.
7. Nano: The Essentials. T. Pradeep, McGraw Hill Education.
8. Handbook of Nanostructures: Materials and Nanotechnology. H. S. Nalwa Vol 1-5, Academic Press, Boston.
9. Nanoscience and Technology: Novel Structure and Phenomena. Ping and Sheng
10. Hand Book of Nanotechnology, Bhushan

## **Semester III (Subject Centric Core Course S1.1) Solid Earth Geophysics**

### **UNIT-I**

A brief history of the development of Earth Sciences and of Geophysics in particular, An overview of Geophysical methods and their essential features, Problems of inversion and non-uniqueness in Geophysics, Origin & evolution of Earth, A review of the Earth's major surface features, its structure and composition, A brief review of the knowledge of the solar system and history of the earth-moon system

### **UNIT-II**

Chemical composition of Earth, Rheological behaviour of crust and upper mantle, Geochronology:

Radiometric dating and their advantages, meaning of radiometric ages, Major features of the Earth's gravitational field and relationship with tectonic processes in the crust and upper mantle, concept of isostasy, hypotheses of isostasy.

### **UNIT-III**

Origin of geomagnetic field, polar wandering, secular variations and westward drift, reversals of geomagnetic field, geomagnetic storms, sea-floor spreading, Paleomagnetism and its uses, Thermal history of the Earth, sources of heat generation and temperature distribution inside the earth, convection in the mantle.

### **UNIT-IV**

Earthquake seismology, Global seismicity and tectonics, Earth's internal structure derived from seismology, Earthquake mechanism and Anderson's theory of faulting, Continental drift and plate tectonics: its historical perspective and essential features, present day plate motions, Triple junctions, oceanic ridges, Benioff zones, trenches and island arcs, Mountain building, origin of Himalaya.

### **References:**

- (1) The Solid Earth by C.M.R. Fowler
- (2) Understanding the Earth by I.G. Guass, P.S. Smith and R.G.L. Wilson
- (3) The dynamic Earth by P.J. Wyllie
- (4) Introduction to Geophysics by B.F. Howell
- (5) Physics and Geology by J.J. Jacobs, R.D. Russel and J.T. Klilson
- (6) Fundamental of Geodynamics by A.E. Schieddeggar
- (7) Fundamentals of Geophysics by W. Lowrie



## **Semester III (Subject Centric Core Course S1.2) Nanoscience and Nanotechnology**

### **Unit I: Introduction to Nanoscience**

Introduction to quantum physics, electron as waves, wave mechanics, Schrödinger equation and particle in a box, Free electron theory (qualitative idea) and its features, Idea of band structure, Density of states for zero, one, two and three dimensional materials, Quantum confinement, Quantum wells, wires, dots, Factors affecting to particle size, Size dependence properties. Determination of particle size, Increase in width of XRD peaks of nano-particles, Shift in photoluminescence peaks, Variation on Raman spectra of nanomaterials.

### **Unit II: Nanomaterials Synthesis**

**Physical methods:** High energy ball milling, Physical vapour deposition, Ionised cluster beam deposition, Laser ablation, Laser pyrolysis, Sputter deposition, Electric arc deposition, Photolithography.

**Chemical methods:** Chemical vapour deposition, Synthesis of metal & semiconductor nanoparticles by colloidal route, Langmuir-Blodgett method, Microemulsions, Sol-gel method, Chemical bath deposition, Wet chemical method.

### **Unit III: Nanomaterials Characterizations**

X-ray diffraction, UV-VIS spectroscopy, Photoluminescence spectroscopy, Raman spectroscopy, Transmission Electron Microscopy, Scanning Electron Microscopy, Scanning Tunnelling Microscopy, Atomic Force Microscopy, Vibration Sample Magnetometer.

### **Unit IV: Special Nanomaterials and Properties:**

**Special Nanomaterials:** Carbon nanotubes, Porous silicon, Aerogels, Core shell structures. Self assembled nanomaterials.

**Properties of nanomaterials:** Mechanical, Thermal, Electrical, Optical, Magnetic, Structural.

### **Text and Reference books:**

- a. Nanotechnology: Principles & Practicals. Sulbha K. Kulkarni ,Capital Publishing Co.New Delhi.
- b. Nanostructures & Nanomaterials Synthesis, Properties & Applications. Guozhong Cao, Imperials College Press London.
- c. Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein & R.C.Commorata. Institute of Physics Publishing, Bristol & Philadelphia.
- d. Introduction to Nanotechnology. C.P. Poole Jr. and F. J.Owens, Wiley Student Edition.
- e. Nano: The Essentials. T.Pradeep , McGraw Hill Education.
- f. Handbook of Nanostructures: Materials and Nanotechnology. H. S. Nalwa Vol 1-5, Academic Press, Bostan..
- g. Nanoscience and Technology: Novel Structure and Phenomena. Ping and Sheng
- h. Hand Book of Nanotechnology, Bhushan

(This course cannot be offered to students opting for elective Nanoscience and Nanotechnology E1.3 and E2.3)

### **Semester III (Subject Centric Core Course S1.3) Quantum Computing**

#### **Unit 1** Introducing quantum mechanics:

Quantum kinematics, quantum dynamics, quantum measurements. Single qubit, multiqubits, gates. Density operators, pure and mixed states, quantum operations, environmental effect, decoherence. Quantum no-cloning, quantum teleportation.

#### **Unit 2** Introduction to quantum algorithms.

Deutsch-Jozsa algorithm, Grover's quantum search algorithm, Simon's algorithm. Shor's quantum factorization algorithm.

#### **Unit 3 Quantum Cryptography:**

Cryptography, classical cryptography, introduction to quantum cryptography. BB84, B92 protocols. Introduction to security proofs for these protocols.

#### **Unit 4 Quantum Entanglement:**

Quantum correlations, Bell's inequalities, EPR paradox.

Theory of quantum entanglement. Entanglement of pure bipartite states.

Entanglement of mixed states. Peres partial transpose criterion. NPT and PPT states, bound entanglement, entanglement witnesses

#### **Textbook**

Nielsen, Michael A., and Isaac L. Chuang. *Quantum Computation and Quantum Information*. Cambridge, UK: Cambridge University Press, September 2000. ISBN: 9780521635035.

N. David Mermin "Quantum Computer Science: An introduction" Cambridge University Press (2007).

## **Semester III (Subject Centric Core Course S1.4) Digital Electronics and Microprocessor**

### **Unit-I:**

Logic gates: Characteristics of TTL, ECL, CMOS circuits with reference to fan in / out noise, speed, power dissipation with suitable examples. Simplifying logic circuits: Algebraic method SOP (minterm) and POS (maxterm) forms. Karnaugh mapping Fundamental products, pairs, groups, octets, Don'ts care conditions.

Complementary Karnaugh map. Diagonal adjacencies. NAND-NAND and NOT-NOR networks. Applications of K maps to half adder, full adder. Arithmetic circuits: Number representation. Binary point, negative numbers, sign and magnitude. 1s and 2s complement adder, parallel binary adder, BCD addition, parallel BCD adder, binary multiplication and division

### **Unit – II**

Multiplexers, demultiplexers : IC 74150 multiplexer and IC 74154 demultiplexer.

Tristate buffers, their use in bus organization. Key board encoders, BCD, octal, Hex and scanned matrix keyboard.

A/D and D/A converters: Weighted resistor and R-2R ladder D/A converters. A/D converter –parallel comparator and Application. ADC 0808, 08116/08117, DAC 0800, look up table, measurement of electrical and physical quantities.

### **Unit -III:**

Memories Allied Devices: Design consideration of Bipolar RAM, MOS memory and dynamic RAM, ROM, EXROM and CCD. Read/Write operation. Expanding memory size word size and word capacity. FIFO and LIFO. Study of 7489 RAM and 745370 RAM and other chip. Magnetic bubble memories. Floppy disks-track and sector organization, data format Winchester disk (hard disk).

### **Unit – IV:**

Microprocessor Architecture: Introduction to architecture, pin configuration etc. of 8086, The parts of up. CPU, memory requirements, numerical data, representation of characters, microprocessor instructions, program storage, instruction execution fetch and execute cycles, addressing modes including simple memory paging, direct scratch and pad addressing. The instruction set including memory reference, immediate conditional jump-shift, change control, stack and program counter, subroutines, flow charts, masking, simple programs.

I/O Systems: Program interrupts including multiple interrupt priorities. Interfacing memory mapping, memory mapped and I/P mapped I/O. Use of decoders, I/O posts. ic 8212, IC 8155 and IC8255 (with block diagram of internal circuits) Typical programs using these ICS.

### **Text and Reference Books**

1. Design of Digital Systems : P. C. Pitman (Galgotia Pub).
2. Digital Computer Electronics :A. P. Malvino (TMH).35
3. Digital Fundamentals: T. L. Floyd (Universal Book Stall).
4. Theory and Problems of Digital Principles : R. L. Tokheim (TMH).
5. Modern Digital Electronics : R. P. Jain (TMH).
6. Introduction to UP : A. K. Mathur (PHL).
7. Up and Small Digital Computer Systems for Scientist and Engineers L G. A. Korn, (McGraw Hill).
8. An Introduction to Micro-computer: Adam Osborne(Galgotia).
9. Introduction top 4 bit and 8 bit UP : Adam Osborne

(This course cannot be offered to students opting for elective Applied Electronics E1.5 and E2.5)

## **Semester IV Paper 13 (Core 11) Nuclear and Particle Physics**

### **UNIT 1 ;**

Basic nuclear properties; size, radii, shape, and charge distribution, spin, parity, mass, binding energy, semi-empirical mass formula, liquid drop model, nuclear stability, laws of radioactive decay. Nature of nuclear force, elements of deuteron problem, n-n scattering, charge independence and charge symmetry of nuclear forces. Electric and magnetic moments of nuclei. Evidence for nuclear shell structure, single particle shell model-its validity and limitations.

### **UNIT 2 :**

Elementary properties of alpha-, beta-, and gamma-, decay of nuclei, their classification, characteristics and selection rules. Elementary theories of alpha-, beta-, and gamma-, decay. Nuclear reactions- conservation laws, mechanism, and cross section. Nuclear reaction mechanism, compound nucleus, direct reactions. Fission and fusion reactions, nuclear energy, elements of nuclear power.

### **UNIT 3 :**

Interaction of charged particles and electromagnetic radiation with matter. Principles of nuclear radiation detectors: G-M counter, proportional counter, Na(Tl) scintillation detector, semiconductor detectors. Elementary principles of particle accelerators: linear accelerators, Van de Graaf, cyclotron, betatron, synchrocyclotron, ion beam accelerators.

### **UNIT 4 :**

Classification of elementary particles, strong, weak and electromagnetic interaction. Gellmann-Nishijima formula Properties of hadrons, baryons, mesons, leptons, and quarks- their quantum numbers, charge, mass, spin, parity, iso-spin, strangeness etc. Symmetry and conservation laws. Elements of quark model and standard model. Higgs boson.

### **Text-books recommended:**

- 1) Introductory Nuclear Physics, : Kenneth S Krane, Wiley, New York ,1988.
- 2) Nuclear and Particle Physics: Brian Martin.
- 3) Atomic and Nuclear Physics: S.N. Ghoshal.
- 4) Introduction to Particle Physics : D. Griffiths.
- 5) Introduction to Nuclear Physics: F. A. Enge, Addison Wesley (1975)
- 6) Introductory Nuclear Physics: Burcham

## **Semester IV Paper 14 (Core 12) Solid State Physics**

**Unit I: Band Theory:** Bloch theorem, the Kronig- Penney model, construction of Brillouin zones, extended and reduced zone schemes, effective mass of an electron, tight binding approximation. Fermi surface.

### **Magnetic Properties:**

Quantum theory of paramagnetism, magnetism of iron group and rare earth ions, exchange interactions. Pauli paramagnetic susceptibility

### **Unit II**

**Lattice Dynamics:** Energy of atomic motions, adiabatic principle, harmonic approximation, cyclic boundary condition. Lattice vibrations of linear monoatomic and diatomic chains. Dispersion relations, acoustic and optical phonons.

Theories of lattice specific heat, Dulong and Petit's law, Einstein and Debye models,  $T^3$  law, Born procedure, anharmonicity and thermal expansion.

**Unit III: Free Electron Theory:** Electrons moving in one and three dimensional potential wells, quantum state and degeneracy, density of states, electrical and thermal conductivity of metals, relaxation time and mean free path, the electrical resistivity of metals, thermionic emission. Seebeck effect, thermoelectric power.

**Semiconductors:** Free carrier concentration in semiconductors, Fermi level and carrier concentration in semiconductors, effect of temperature on mobility, electrical conductivity of semiconductors, Hall effect in conductors and semiconductors.

### **Unit IV**

Superconductivity, Type I and II super conductors, Meissner effect, isotope effect, London equation, coherence length, elements of B. C. S. theory, tunnelling DC and AC Josephson effect, Ginzberg-Landau Theory macroscopic quantum interference. Josephson junction. high temperature superconductor (elementary).

### **Text and Reference books:**

1. C. Kittel: Introduction to Solid State Physics (2nd and 4th Edition).
2. A. J. Dekker : Solid State Physics.
3. Kubo and Nagamiya : Solid State Physics.
4. Feynman Lectures: Vol. III.
5. Board and Huano : Dynamical Theory of Crystal Lattice.
6. N. W. Ashcroft and D. Mermin: Solid State Physics.

### **Semester IV Practical 7 for core papers**

Practicals based on core 11 and core 12

1. Measurement of resistivity of a semiconductor by four probe method at two different temperatures and determination of band gap energy.
2. Measurement of Hall coefficient of given semiconductor: identification of type of semiconductor and estimation of charge carrier concentration.
3. Determination of Hall life of 'In'.
4. Determination of range of Beta-rays from Ra and Cs.
5. G-M counter
6. Magnetoresistance by Hall effect
7. Determination of Dielectric constant
8. Random decay of nuclear disintegration using dice (or simulation)

In all 7 practicals, instructor can introduce new and relevant experiments which are not in the list.

## Semester IV Paper 15 (Core Elective E2.1) Materials Science II

### Unit –I

**Mechanical response of Materials :** Elasticity, model of elastic response, inelasticity, viscoelasticity, stress-strain curves, concept of various mechanical properties such as hardness, yield strength, toughness, ductility, yield toughness, ductility, brittleness, stiffness, young modulus, shear modulus, shear strength, Frenkel model, Peierls-Nabarro relation, Plastic deformation,

**Corrosion and degradation of materials** – electrochemical considerations – passivity forms of corrosion – corrosion inhibition.

**Spintronics and Photonics:** Spin glass, magnetic bubbles, domain walls, magnetic multilayers, manganites, GMR and CMR, DMS materials. Photonic band gap materials.

### Unit – II

**Concept of Synthesis:** Concept of equilibrium and nonequilibrium processing and their importance in materials science.

**Synthesis of materials:** Physical method – Bottom up: cluster beam evaporation, Ion beam deposition, Gas evaporation, Chemical method – Hydrothermal, combustion, bath deposition with capping techniques and top down: Ball milling. Solvated metal atom dispersion – thermal decomposition – reduction methods – colloidal and micellar approach.

### Unit-III

**Processing of materials:** Metallic and non metallic, Ceramics and other materials. Only basic elements of powder technologies, compaction, sintering calcination, vitrification reactions, with different example, phenomenon of particle coalescence, porosity. Quenching : concept, glass formation

#### **structural characterization:**

Diffraction techniques: interpretation of x-ray powder diffraction patterns, Identification & quantitative estimation of unknown samples by X-ray powder diffraction technique Electron and neutron diffraction.

### Unit –IV

Structural determination by fluorescent analysis. Theory and method of particle size analysis. Integral breadth method, Warren-Averbach's Fourier method, profile fitting method.

**Microscopic techniques** –TEM, SEM & STEM.AFM, EDX and XPS.

#### **Text and Reference Books:**

1. Basic Solid State Chemistry, 2nd Edition, Anthony R. West, John Wiley & Sons, 1996.
2. New Directions in Solid State Chemistry, C. N. R. Rao and J. Gopalkrishnan, Cambridge University Press, Cambridge, 1986.
3. Chemical approaches to the synthesis of inorganic materials, C. N. R. Rao Wiley Eastern Ltd.1994.

4. Materials Science and Engineering – An Introduction, W. D. Callister Jr. John Wiley & Sons, 1991.
5. Materials Science, J. C. Anderson, K. D. Leaver, R. D. Rawlings and J. M. Alexander, 4<sup>th</sup> Edition, Chapman & Hall (1994).
6. Nanostructured Materials and Nanotechnology, Hari Singh Nalwa, Academic Press (1998).



## Semester IV Paper 15 (Core Elective E2.2) X-ray II

### **Unit I**

Space lattice and unit cell of a crystal, Choice of a unit cell, Crystal systems, Bravais lattices, Crystal faces and internal arrangement, Miller indices, Law of rational indices, Indices of a direction. Point groups, Space groups.

Perspective projections: Gnomonic projection, Stereographic projection, Orthographic projection.

Reciprocal lattice concept: Graphical construction, Relation to interplanar spacing, Interpretation of Bragg's law.

### **Unit II**

Scattering of X-rays: Thomson scattering, Compton scattering, Wave mechanical treatment of scattering, Scattering by a pair of electrons, Theory of scattering by a helium atom, Scattering by many electrons, Experiments on scattering by monatomic and polyatomic gases, liquids and amorphous solids.

### **Unit III**

Physical Basis of X-ray Crystallography: Atomic and crystal structure factors, Structure factor calculations, The integrated intensity of reflection. Different factors affecting the intensity of diffraction lines in a powder pattern. Dynamical theory X-ray diffraction.

The Fourier Transform, electron density projections in crystals, Application to X-ray diffraction.

### **Unit IV**

Experimental Methods of Structure Analysis: Laue method, Debye-Scherrer method, rotation Oscillation method, Weissenberg camera, The sources of systematic errors and methods of attaining precision.

Principles of energy dispersive and time analysis diffractometry.

Methods of detecting and recording diffraction patterns.

Structures of metals and alloys. Phase transformations, Order-disorder phenomenon. Super lattice lines. Determination of grain size.

Other Diffraction Techniques: Electron and neutron diffraction techniques and their applications. Comparison with X-ray diffraction.

### **Text and Reference Books:**

1. A. H. Compton and S. K. Allison: X-rays in Theory and Experiment.
2. N. F.M. Henry, H. Lipson and W. A. Wooster: The interpretation of X-ray Diffraction Photographs.
3. K. Lonsdale: Crystals and X-rays.
4. B. D. Cullity: elements of X-ray Diffraction.
5. M. M. Woollfson: X-ray Crystallography.
6. M. J. Buerger: X-ray Crystallography.
7. Bacon: Neutron Physics.

## Semester IV Paper 15 (Core Elective E2.3) NanoScience and Nanotechnology II

### **Unit – I:**

#### *Nanophotonics:*

Fundamentals of photonics and photonic devices, Lasers, CFLs, LEDs, OLEDs, Wall paper lighting, Display devices, X-ray imaging nanophosphers, Photo therapy lamps and its applications, Nanomaterials for radiation, Dosimetry special for thermoluminescence. Optical stimulated luminescence, Luminescence solar concentration.

### **Unit – II:**

#### *Nanomagnetics:*

Basics of Ferromagnetism, effect of bulk nanostructuring of magnetic properties, dynamics of nanomagnets, nanopore containment, giant and colossal magnetoresistance, applications in data storage, ferrofluids, Superparamagnetism, effect of grain size, magneto-transport, Magneto-electronics, magneto-optics, spintronics.

### **Unit – III:**

#### *Nanoelectronics:*

Top down and bottom up approach, CMOS Scaling, Nanoscale MOSFETs, Limits to Scaling, System Integration, Interconnects;  
NanoDevices: Nanowire Field Effect Transistors, FINFETs, Vertical MOSFETs, Other Nanowire Applications, Tunneling Devices, Single Electron Transistors, Carbon nanotube transistors, Memory Devices,

### **Unit – IV:**

#### *Nanocomposites:*

Classification of nanocomposites, Metallic, ceramic and polymer nanocomposites, Tribology of polymeric nanocomposites, Nano ceramic for ultra high temperature MEMS, Optimizing nanofiller performance in polymers, Preparation techniques, Graphene/Fullerene/Carbon nanotube (CNT) polymer nanocomposites, One dimensional conducting polymer nanocomposites and their applications

### **Text and reference books:**

1. H.S.Nalwa; Hand book of Nanostructure materials and nanotechnology; (Vol.1-5), Acad. Press, Boston, 2000
2. C.P.Poole Jr., F.J.Owens; Introduction to Nanotechnology, John Wiley and sons, 2003
3. C. Furetta; Hand book of thermoluminescence; World Scientific Publ.
4. S.W.S. McKEEVER; Thermoluminescence in solids; Cambridge Univ. Press.
5. Alex Ryer; Light measurement hand book; Int. light Publ.
6. M.J.Weber; Inorganic Phosphors; The CRC Press.
7. T.J.Deming; Nanotechnology; Springer Verrlag, Berlin, 1999
8. W.D.Kalister Jr., Materials Science and Engineering, 6th Eds, WSE Wiley, 2003
9. Gusev; Nanocrystalline Materials
10. C. Delerue, M.Lannoo; Nanostructures theory and Modelling
11. Fausto, Fiorillo ; Measurement and Characterization of Magnetic materials
12. Bhushan; Hand Book of Nanotechnology
13. Janos H., Fendler; Nanoparticles and Nanostructured Films
14. T.Pradip; Nano: The Essentials

15. Liu; Hand Book of Advanced Magnetic Materials (4 Vol.)
16. Lakhtakia; Nanometer Structure
17. Banwong, Anurag Mittal; Nano CMOS Circuit and Physical Design
18. G.W.Hanson: Fundamental of Nanoelectronics
19. Edward L. Wolf (2nd Ed.), *Nanophysics & Nanotechnology: An Introduction to Modern Concepts in Nanoscience*, WILEY-VCH, 2006
20. S. Sakka; Sol-gel science and technology processing, characterization and applications; Kluwer Acad. Publ.
21. Gosser et al, "*Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices*"
22. Supriyo Datta, "*From Atom to Transistor*"
23. John H. Davies, *The Physics of Low Dimensional Semiconductors: An Introduction*", Cambridge University Press, 1998.
24. Hari Singh Nalwa, "*Encyclopedia of Nanotechnology*"
25. A. A. Balandin and K. L. Wang, "*Handbook of Semiconductor Nanostructures & Nanodevices*"
26. Cao Guozhong, "*Nanostructures & Nanomaterials - Synthesis, Properties & Applications*"

## Semester IV Paper 15 (Core Elective E2.4) Atomic and Molecular Physics II

### **Unit I**

Time dependence in quantum mechanics, Time dependent perturbation theory, rate expression for emission, perturbation theory, calculation of polarizability. Quantum mechanical expression for emission rate.

time correlation function and spectral Fourier transform pair, properties of time correlation functions and spectral time shape,

Fluctuation dissipation theorem rotational correlation function and pure rotational spectra, Re-orientational spectroscopy of liquids.

### **Unit II**

Saturation spectroscopy, Burning and detection of holes in Doppler broadened two level systems, Experimental methods of saturation spectroscopy in laser, Ramsey fringes,

Saturation techniques for condensed matter application,

Laser optical galvanics spectroscopy. Two photon absorption spectroscopy, Selection rules,

Expression for TPA cross section –photo acoustic spectroscopy, PAS in gaseous medium,

Rosenzweig and Greshow theory, Thermally thin, thick samples, Typical experimental set up, Application in Spectroscopy,

### **Unit III**

Stimulated Raman scattering, Quantum mechanical treatment, Raman Oscillation Parametric instabilities, Electromagnetic theory of SRS. Vibronic interaction, Herzberg Teller theory,

Fluorescence spectroscopy, Kasha's rule, Quantum yield, Non-radioactive transitions,

Jablonski diagram, Time resolved fluorescence and determination of excited state

lifetime. Light detectors, Single photon counting technique, Phase sensitive detectors.

### **Unit IV**

Matrix isolation spectroscopy, Fourier transforms spectroscopy, Laser cooling. Molecular symmetry and group theory, Matrix representation of symmetry elements of a point group,

Reducible and irreducible representations, and character tables specially for  $C_{2v}$  and  $C_3$  point group molecules, Normal coordinates normal modes, Application of group theory to

molecular vibrations.

### **Text Book and References:**

1. Molecular Quantum Mechanics: P. W. Atkins and R. S., Fridman.
2. Quantum electron – A. Yariv.
3. Introduction to non-linear laser spectroscopy – M. D. Levenson.
4. Photoacoustics and its applications, Rosenzweig.
5. J. M. Hollas, High resolution spectroscopy.
6. Cotton, Chemical Applications of Group Theory.
7. Herzberg, Molecular spectra and molecular structure II and III.
8. Demtroder, Laser spectroscopy and instrumentation.
9. King, Molecular spectroscopy.
10. Lakowicz, Principles of fluorescence spectroscopy.
11. Molecular Quantum Mechanics: P. W. Atkins and R. S., Fridman.

## Semester IV Paper 15 (Core Elective E2.5) Applied Electronics II

### **Unit – I:**

An Overview of Electronic Communication system ; block diagram of an digital electronic Communication system, Pulse modulation systems, sampling theorem, lowpass and band-pass signals,PAM channel bandwidth for a PAM signal, Natural sampling, flat top sampling, signal recovery throughholding, quantization of signals, quantization, differential PCM delta modulation, adoptive delta modulation CVSD. Digital modulation techniques: BPSK, DPSK, QPSK, PSK, QASK, BFSK, FSK, MSK. Mathematical representation of noise, sources of noise, frequency domain representation of noise, Noise in Pulse Code and Delta modulation system, PCM transmission, calculation of quantization of noise, out put signal power effect of thermal noise, outr signal to noise ratio in PCM, DM, quantization noise in DM, out put signal power, DM oput-put, signal to quantization noise ratio, effect of thermal noise in delta modulation, output signal to noise ratio in DM.

### **Unit – II**

Computer communication systems: Types of networks, design features of communication network,examples, TYMNET, ARPANET, ISDN, LAN.Mobile radio and satellite - time division multiplex access (TDMA) frequency division multiplex access(FDMA) ALOHA, Slotted ALOHA, Carrier sense multiple access (CSMA) Poisson distribution protocols.

### **Unit – III**

Microprocessor and Micro-computers: Microprocessor and architecture, Pin out and pin functions of 8086/8088 Internal microprocessor architecture, bus buffering and latching ,Bus timings, ready and wait states, minimum mode versus and maximum mode. Real and protected mode of memory addressing, memory paging, addressing modes, data addressing modes, programme memory addressing mode, stack memory addressing modes, instruction sets, data movement instruction, arithmetic and logic instruction, programme control instruction, clock generator (8284A),

### **Unit –IV**

Memory and I/O Interface : Memory devices, ROM,RAM.,DRAM, SRAM, Address decoding , 3 to 8 line decoder 74LS138, 8086, and 80386(16 bits) Memory interface, , Introduction to I/O interface , Interfacing using 8255, Introduction to PIT 8254, Basic Communication device(UART) pin diagram and functioning of 16550 Interrupts: Basic interrupt processing, Hardware interrupt, expanding the interrupt structure, 8259A PIC.

### **Text and Reference books.**

1. Principles of communication systems :Taub and Schilling (ii Edn THM ,1994)
2. Principles of communication systems: Taub and Schilling GoutamSaha Third Edition
3. Communication systems : Simon Haykin (iii Edn John Wiley & Sons)
4. The intel microprocessors 8086/80188,80386,80486, Pentium and Pentium processor architecture, programming and interfacing : Barry B. Brey (PHI iv Edn, 1999)
5. Microprocessor and interfacing ,programming and hardware : Douglas V. Hall (ii Edn, Mc GrawHill International edn. 1992)
6. The 80x86 IBMPC compatible computer: Muhammad Ali Maxidi and J .G. Mazidi (ii Edn.Prentice –Hall International.)

## Semester IV Paper 15 (Core Elective E2.6) Methods of Theoretical Physics II

Many Body theory

### **Unit I: Second Quantization / Occupation Number Formalism**

Wave functions for identical particles, symmetrized basis for Fermions and Bosons, one-particle and two-particle operators and their matrix elements in symmetrized basis; Number space representations of the basis, creation and annihilation operators, commutation relations; Representation of operators in terms of creation and annihilation operators; Equation of motion for operators in number space.

### **Unit II: Simple Applications**

Electron gas: Hartree-Fock approximation, ground state energy and single particle energy in paramagnetic and ferromagnetic states, role of exchange term; Ground state of interacting bosons, Bose-Einstein condensate; Spectrum of elementary excitations, superfluidity.

### **Unit III: Green's Functions and Linear Response Theory**

One-particle and two-particle Green's functions; Ground state energy and linear response in terms of Green's functions; Analytic properties of Green's functions; Equations of motion for Green's functions

### **Unit IV: Perturbation Theory**

Interaction representation; Gell-Mann-Low theorem for ground state energy; Perturbation expansion for Green's functions, Wick's theorem; Diagrammatic representation, Dyson's equation, self energy; Polarization; Application to interacting Fermi gas: Dilute Fermi gas, Landau theory, Screening of coulomb interaction, random phase approximation for electron gas.

### **Text and Reference Books :**

1. Stanley Raimis: Many-Electron Theory, *North Holland Publishing Co.*, (1972)
2. F. Mandl : Introduction to Quantum Field theory, *Interscience Publishers Inc.*, 1961
3. Abrikosov: Quantum Field Theoretical Methods in Statistical Physics
4. Fretter &Walecha: Quantum Theory of Many particle Systems
5. March, Young and Sampantha : The Many Body problems in Quantum Mechanics
6. Mattuch: Feynman Diagram Techniques.

## Semester IV Paper 15 (Core Elective E2.7) Nonlinear Dynamics II

### **Unit I**

Lorenz equations, chaos on a strange attractor, chaotic cryptography, Lorenzmap, properties of Lorenz system (Ch. 7 of ref. 1)

One dimensional Maps: Piecewise linear maps, logistic map, smooth 1-d maps, applications (ch. 2 of ref. 2)

### **Unit 2**

Strange attractors: What is fractal, box counting dimension, generalized Baker map, dimension spectrum, introduction to multifractal. Singularity spectrum, partition function formalism (Ch. 3 and 9.1 9.2 of ref. 2, ch. 11, 12 of ref. 1)

### **Unit 3**

Chaos in Hamiltonian systems:

Hamiltonian systems, perturbation of integrable systems, chaos and KAM tori describable by 2-d maps, higher dimensional systems, strongly chaotic systems, succession of increasingly random systems (Ch. 7 of ref. 2)

### **UNIT IV:**

Control and synchronization of chaos: controlling chaos, controlling steadily running chaotic process, synchronization, generalized synchronization, phase synchronization

Elementary idea of quantum chaos: Energy and wavefunctions of chaotic bounded time independent systems, periodic systems, chaotic scattering (ref. 10 and 11 of 2)

### **Reference books:**

1. S. W. Strogatz : Nonlinear Dynamics with Applications to Physics, Biology, Chemistry and Engineering. (Perseus)
2. Edward Ott : Chaos in Dynamical Systems (Cambridge University Press)
3. Quantum Chaos - An Introduction, H. J. Stöckmann, (Cambridge Univ. Press), 1999
- 4.. Classical and Quantum Dynamics, Dittrich and Reuter, 3rd Edition, (Springer Verlag), 2003.

## Semester IV Paper 16 (Foundation course F2.1) Spectroscopic applications

### **Unit-I**

Principle of spectroscopic instruments, UV-VIS visible: Absorption of light, radiation sources, sample holder, monochromator, radiation detectors, samples holder, monochromator, radiation detector, single and double beam experiment.

Infrared and Raman spectroscopy, predicting number of active modes of vibration, analysis of representative spectra of metal complexes with various functional groups at the coordination sites, organic and inorganic functional group identification through IR spectroscopy.

### **Unit-II**

NMR phenomenon, spin  $\frac{1}{2}$  nuclei, ( $^1\text{H}$ ,  $^{13}\text{C}$ ,  $^{31}\text{P}$  and  $^{19}\text{F}$ ),  $^1\text{H}$  NMR, Zeeman splitting, effect of magnetic field strength on sensitivity and resolution, chemical shift  $\delta$ , chemical and magnetic equivalence of spins, spin-spin coupling constant J.

Electronic spectroscopy, basic principle, electronic transitions in organic, inorganic and organometallic molecules and application to structure elucidation.

### **Unit-III**

Electron paramagnetic resonance (EPR) spectroscopy of inorganic and organic compounds with unpaired electrons, determination of electronic structure, Zeeman splitting, g values hyperfine and superhyperfine coupling constant.

Mossebauer spectroscopy-Mossebauer effect, recoilless emission and absorption, hyperfine interaction, chemical isomer shift, magnetic hyperfine and quadrupole interaction and interpretation of spectra.

### **Unit-IV**

Mass spectroscopy, basic principles, ionization techniques, isotope abundance, molecular ion, high resolution MS, soft ionization methods, ESI-MS and MALDI-MS, illustrative example from macromolecules and supramolecules studies of inorganic/coordination and organometallic representative compounds.

Text books

- 1 Electronic paramagnetic transitions of metal ions, A Abragam, B Bleaney, Oxford University Press, 1970.
2. Physical methods for chemist, R S Drago, Saundevis 1992.
- 3.Fundamentals of molecular spectroscopy, C. N. Bawell and E.M. Mc cash, 4<sup>th</sup>ed, MCGRAW-Hill, 1994.
- 4.NMR spectroscopy, H. Gunther, 2<sup>nd</sup> edition John Wileny and Sons, 1995.



## Semester IV Paper 16 (Foundation course F2.2) Optics and Optical Instruments

### **Unit-1**

General theory of image formation, Cardinal points of an optical system, thick lens and lens combination, telescopic combinations, telephoto lens and eyepieces, Aberration in images; chromatic aberration, monochromatic aberration and their reductions, aspherical mirrors and correction plates, meniscus lens, entrance and exit pupil, need for multiple eyepiece, Ramsden and Huygens eyepiece, microscope and telescope, astronomical telescope.

### **Unit-2**

Principle of superposition, coherence optical path retardation, fringes in thin film, localized fringes, two slit interference, Newton's rings and applications, Michelson interferometer and its applications,

Diffraction; Fresnel type- half period zone, rectilinear propagation, straight edge, Fraunhofer type-Diffraction at a slit, half period zone, circular aperture, plane transmission, reflection, blazed and concave grating, resolving power of grating, Rayleigh criterion of resolution, resolving power of prism and grating.

Refraction- refraction in uniaxial crystal, double image prism, plane, circular and elliptical polarized light, Nicol's prism, optical rotation in liquid crystals.

### **Unit-3**

Optical instruments- magnifying glass, principle of photo camera, pinhole, lens and SLR camera, video camera, angular magnification, aperture, camera lucida, collimator and compound microscope, lens, periscope, binocular, field glass, jeweler's glass, projector, eyeglasses and its principle, prism spectroscope.

### **Unit-4**

Holography: Importance of coherence, Principle of holography and characteristics, Recording and reconstruction, classification of hologram and application, non-destructive testing, optical fibre waveguides (step index, graded index, single mode), attenuation in fibre, couplers and connectors, LED,

X-ray –Principle and process of X-ray image (radiographs) production, factors affecting radiographs, Computed Tomography, principle and working of fluoroscopy, principle and working of CT-scanning, Ultrasound, working principle, imaging by us waves, Doppler ultrasound, magnetic resonance imaging, its working principle.

### **References;**

1. Optics by Ajay Ghatak
2. Fundamental of optics by Jetkins and white
3. Optics and spectroscopy by R. Murugesan, kiruthigunsivaprakash.
4. Basic physics of X-ray imaging, Carl A Carlsson and Gudrun AlmCarlsson, 1996
5. Collaborative radiology by Chales De Kahn, 2013

## **Semester IV (Subject Centric Core Course S 2.1) Nonlinear Geophysics**

### **UNIT-I: NON LINEAR ELASTICITY**

Kinematics of Deformation: Deformation gradient tensor, the strain tensors, homogeneous deformations, deformation of surface and volume elements, material and spatial coordinates, analysis of stress, Cauchy and Poila stresses, Cauchy's stress tensor, Cauch's equation of motion, balance laws, Constitutive equations for elasticity.

### **UNIT-II: NON LINEAR WAVES**

Linear Wave equation, dispersion relation, non linear equations, effect of non linearity, difussive waves, dispersive waves, Solotary waves, soliton, Schrodinger equation, relationship between KdV and Schrodinger equation.

### **UNIT-III NON LINEAR SYSTEM**

Geometrical view of Dynamical system, Singular points, Limit cycles, Phase plane trajectories, bifurcation diagram, examples of bifurcation equations, Chaotic dynamics, stochastic description of dynamical system, various types of bifurcation, Catastrophe theory in Geophysics.

### **UNIT-IV FRACTALS AND MULTIFRACTALS**

Self Similarity, Self affinity, Cantor sets, Fractal dimension of geometry, fractal in time series, Box Correlation integral method, counting method, multifractal, Generalized dimension, Dq-q analysis, Application of fractals and multifractal in earthquake studies, gravity and magnetic field methods.

### **References:**

1. T.S. Parkar Deformation of Elastic Solids.
2. P.L.Bhatnagar Non Linear waves in one dimensional dispersive systems
3. Derek P.Atherton Stability of Non Linear Systems
4. Nicolis and Nicolis, Irreversible Phenomenons and dynamical system analysis in geosciences
5. B.B.Mandelbrot, The fractal geometry of nature
6. Parker and O.L.Chua Practical Numerical Algorithms for Chaotic System
7. D.L.Turcotte Fractals in Geophysics
8. V.P.Dimri Applications of fractals in Geophysics

## **Semester IV (Subject Centric Core Course S 2.2) Experimental Techniques in Physics**

### **Unit 1: Radiation Sources, Detectors and Sensors**

Different types of radiations (X-rays, UV-VIS, IR, microwaves and nuclear) and their sources

Detectors: gamma-rays, X-rays, UV-VIS, IR, microwaves and nuclear detectors

Sensors: Sensor's characteristics, Classification of sensors, Operation principles of sensors such as electric, dielectric, acoustic, thermal, optical, mechanical, pressure, IR, UV, gas and humidity with examples

### **Unit 2: Structural Characterization and Thermal Analysis**

X-ray Diffraction – Production of X-rays, Types (continuous and characteristics), Bragg's diffraction condition, principle, instrumentation (with filters) and working, Techniques used for XRD – Laue's method, Rotating crystal method, Powder (Debye-Scherrer) method, Derivation of Scherrer formula for size determination Neutron Diffraction: Principle, Instrumentation and Working

Thermal analysis: Principle, Instrumentation and Working: Thermo-gravimetric (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC); Graphical analysis affecting various factors. Numericals

### **Unit 3: Morphological and Magnetic Characterization**

Optical Microscopy: Principle, Instrumentation and Working of optical microscope.

Electron Microscopy: Principle, Instrumentation and Working of Scanning Electron Microscope (SEM), Field Emission Scanning Electron Microscope (FESEM) – Advantages over SEM, Transmission Electron Microscope (TEM), Selected Area Electron Diffraction (SAED)

Probe Microscopy: Principle, Instrumentation and Working of Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM)

Magnetic Characterization: Principle, Instrumentation and Working of Vibrating Sample Magnetometer (VSM), Analysis of Hysteresis loop, SQUID Technique:

Principle, Instrumentation and Working. Numericals

### **Unit 4 : Spectroscopic Analysis**

Spectroscopic characterization (principle, instrumentation and working): Infra-Red (IR), Fourier Transform Infra-Red (FTIR), Ultraviolet-Visible (UV-VIS), Diffused Reflectance Spectroscopy (DRS), X-ray Absorption (XPS), Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR). Numericals.

### **Reference Books:**

1. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy, (Wiley-Eastern Limited, Bombay)
2. Instrumentation: Devices and Systems, C.S. Rangan, G.R. Sarma and V.S.V. Mani, Tata Mc Graw Hill Publishing Co. Ltd.
3. Instrumental Methods of Chemical Analysis, G. Chatwal and S. Anand, Himalaya Publishing House
4. Instrumental Methods of Analysis by H.H. Willard , L.L. Merritt, J.A. Dean, CBS Publishers
5. Characterization of Materials, John B. Wachtman & Zwi. H. Kalman, Pub. Butterworth Heinemann (1992)
6. Elements of X-ray diffraction, Bernard Dennis Cullity, Stuart R. Stock, (Printice Hall, 2001 - Science – 664

## **Semester IV (Subject Centric Core Course S 2.3) Communication electronics**

### **UNIT I**

Modulation AM and FM (Transmission and reception): Modulation, AM generation, Power consideration, Balanced modulator, SSB transmission, AM detection, AGC, Radio receiver characteristics, signal to noise ratio, FM analysis, noise considerations, generation, direct method and reactance tube method, FM transmitter, AFC, FM Propagation, phase discriminator.

### **UNIT II**

(Propagation of radio waves) Ground wave, sky wave and space wave propagation. Ionosphere (Eccles- Larmer theory, magneto ionic theory).

### **UNIT III**

(Antenna and TV) Antenna, HF antenna, Yagi antenna, loop antenna, Satellite communication, parabolic reflector, dish antenna, Fundamentals of image transmission, vestigial transmission, TV camera tubes, image orthicon, vidicon, TV transmitter, TV receiver and picture tubes.

### **UNIT IV**

(Transmission Lines) Voltage and current relations on transmission line, propagation constant, characteristic impedance, impedance matching, quarter wave T/L as impedance transformer, attenuation along coaxial cable, cables of low attenuation, propagation of radio waves between two parallel lines, wave guide modes, TE<sub>10</sub> mode and cut off wavelength, cavity resonator, light propagation in cylindrical wave guide, step index and graded index fibers, attenuation and dispersion in fibers.

### **Books Recommended:**

1. George Kennedy & Davis: Electronics Communication Systems
2. Millar & Beasley: Modern Electronics Communication
3. R.R Gulani: Monochrome and colour television (Wiley Eastern Limited)
4. Taub and Schilling: Principle of Communication Systems (TMH)
5. Simon Gaykuti: Communication Systems (John Wiley & Sons Inc. 1994)

(This course cannot be offered to students opting for elective Applied Electronics E1.5 and E2.5)

## **Semester IV (Subject Centric Core Course S 2.4) ElectroAcoustics**

### **Unit – I:**

Fundamentals of ultrasonic, Acoustics interaction with liquids, Velocity in fluids, Absorption due to heat conduction and viscosity, single relaxation, internal degrees of freedom, Relaxation in binary mixtures, Normal and associated liquid essential difference in low and high amplitude ultrasonic wave propagation of low amplitude waves, ultrasonic generators piezoelectric effect. Propagation in Solids Attenuation due to electron phonon interaction; Phonon-Phonon interaction, Measurement Techniques, optical method, interference method, Pulse method, Sign-around method. Applications of ultra-sound in industrial and medical fields.

### **Unit - II**

Architectural Acoustics, Classical ray theory. Decay of sound in live and in dead rooms, Measurement of reverberation time. Effect of absorption on reverberation, Sound absorption coefficient, absorbing materials and their uses. Fundamentals of musical scales. Physics of musical instruments. Public address system and music sound system for auditoria. Instruments used for acoustical tests. Underwater acoustics, Velocity of Sound in Sea-water, sound transmission loss in sea-water. Refraction Phenomena, Masking by noise and by reverberation, Passive detection hydrophone systems.

### **Unit – III**

Loud Speakers, idealized direct radiator, Typical cone Speaker, Effect of voice coil parameters, Horn Loudspeakers, pressure response, Woofer, midrange and tweeter, Crossover net works, Fletcher Munsion Curves, Baffles; Infinite type, vented type and acoustic suspension type, Microphones, Moving coil type, Carbon microphones, condenser microphones, Cardioid type, Polar response, Rating of microphone responses. Reciprocity theorem and calibration. RIAA equalization Preamplifiers, Tone control circuits, Equalization amplifiers, Noise filters, Dolby Noise Reduction, High Fidelity Stereo amplifiers, Recording and reproduction of sound.

### **Unit – IV**

Noise Decibels and levels, dB Scales in acoustics, Reference Quantity for acoustic Power, intensity and pressure, Determination of overall levels from band levels, Basic sound measuring system using sound level meter. Octave band analyzer. Acoustic Calibrator, Definition of Speech interference levels (SIL), Noise criteria for various spaces. Nomogram relating SPL in octave bands to loudness in Tones, Computation of LL and SIL. .

Text and Reference books:

1. Fundamentals of Acoustics: Kinsler and Fry, (Wiley Eastern).
2. Acoustics: Leo L. Beranek (John Wiley and Sons.).
3. Noise Reduction: L. L. Beranek.
4. Fundamentals of Ultrasonic: J. Blitz.
5. Ultrasonic Absorption: A. B. Bhatia.
6. Acoustical Test and Measurements: Don Davis