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<td>RESEARCH METHODOLOGY-I (THEORY)</td>
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**Suggested Optional Soft Courses**

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* Compulsory Subjects
PHYS – 601: Research Methodology- I

Unit I: Continuum Simulations

Unit II: Monte Carlo Simulations
Random number generators, Monte Carlo Simulation, Markov Chain, Metropolis Algorithm, Configuration Bias Monte Carlo method, Wang Landau algorithm to compute density of states, Kinetic Monte Carlo Simulations: Coarse grained atomic simulations

Unit III: Molecular Dynamics Simulations
Euler, Verlet and Velocity-Verlet integrators for Newtons equations for MD, Interaction potential including long range interactions, Energy minimization techniques, Constant energy and constant temperature simulations, Free energy calculations, Statistical mechanics and treatment of simulation data, Visualisation of structure and data, Electronic degrees of freedom: Car - Parinello method.

Unit IV: Electronic Structure Simulations
Hartree and Hartree Fock methods. Beyond Hartree Fock: Wavefunction expansion and perturbation methods. Hohenberg-Kohn theorems, Degenerate ground state, Kohn-Sham equations - Spin polarised systems, definition of exact exchange within DFT, Local density approximation, Nonlocal correlations to LDA, Generalized Gradient approximation, Self interaction correction, Pseudopotential theory,

Unit V: Simulation Exercises
1. Solve heat diffusion equation using explicit and implicit finite difference method.
2. Solve Poisson equation using finite element method
3. FDTD method to simulate propagation of electromagnetic wave in dielectric media.
4. Simulation of 2D Ising model on a triangular lattice
5. Simulation of Q state Potts model on a 2D square lattice and compute density of states using Wang Landau algorithm
7. Molecular dynamics simulation of a Lennard Jones liquid

Text books:
5. J.D. Hill, L. Subramaiah and A.Maiti, Molecular Modeling Techniques in Material Science, (Taylor and Francis, 2005)
Phsy 602 RESEARCH METHODOLOGY – II Credits 4

Unit I:
5 Hours

12 Hour

Unit II

Unit III
10 Hours

UNIT – IV:
10 Hours

UNIT – V:
12 Hours
Vacuum Techniques – Basic idea of conductance, pumping speed – Pumps: Mechanical Pump – Diffusion pump – Gauges – Thermocouple gauge – Penning gauge – Pirani gauge – Hot Cathode gauge – Low temperature systems – Cooling a sample over a range up to 4 K – Measurement of low temperatures-Deposition Techniques-Thermal Evaporation-Sputtering-Pulsed Laser Deposition

UNIT – VI:
12 Hours

Textbooks

Supplementary reading
PHYS-603 LASER SPECTROSCOPY AND ITS APPLICATIONS

Unit I
Absorption and emission of light, Einstein’s Coefficients, Discrete and continuous spectra. Transition Probabilities; Semi classical description of light and matter interaction; Line widths and profiles of spectral lines. Various broadening mechanisms

Unit II
Spectroscopic instrumentation: Spectrographs, mono-chromators Interferometers –Light detectors (Thermal detectors, Photo-emissive detectors, Photocells, Photomultipliers, Photodiodes and optical multichannel analyzer). Measurement of fast transient events - Lasers-(Basic elements and its characteristics). Lasers as spectroscopic light sources, fixed frequency and tunable lasers- Single mode and multimode lasers

Unit III
Nonlinear Optical Mixing Techniques (Second and third harmonic generation, Sum and difference frequency generation) Nonlinear absorption, Doppler limited absorption and fluorescence spectroscopy with lasers. Laser Raman Spectroscopy

Unit IV

Unit V Applications:
Laser Photochemistry, Laser Isotope separation, Laser monitoring of the atmosphere, Laser Spectroscopy in biology, optical heterodyne detector, and Medical applications of laser spectroscopy

Books:
2. S Svanberg, Atomic and Molecular Spectroscopy- Basic Aspects and practical applications (Springer Verlag).
PHYS-604  MAGNETISM AND MAGNETIC MATERIALS

Unit I - Theoretical Background
(i) Fundamentals: Concept of magnetic moments - magnetic orderings - phase transitions magnetic susceptibility - magnetization - coercive field and remanance.
(ii) Disordered magnetics: Basic relations characterizing the behavior of a substance in magnetic field tensors of diamagnetic and paramagnetic susceptibility - classification of magnetic substances - diamagnetism - paramagnetism.
(iii) Ordered magnetics: Different types of magnetic structures in crystals - ferromagnetism, antiferromagnetism and ferromagnetism - magnetic symmetry - basic type of interaction in ordered magnetics - molecular field theory - the Curie and Neel points. Domain structure of ferromagnetic crystals and magnetization processes.
(iv) Anisotropy of ferromagnetic crystals: Peculiarities of the description of ferromagnetic crystals - magnetostriction anisotropy in ferromagnetic of different symmetry - magnetic anisotropy energy corresponding to zero strains zero stresses - equilibrium directions of spontaneous magnetization - magnetic anisotropy measurement.
(v) Magneto-elastic effect

Unit II - Materials of interest
Soft magnetic materials - hard magnetic materials - thin films - ferrites - weakly ferrimagnetic crystals (canted anti ferromagnetics) - reorientation transition layered magnetic thin films - multilayer - DMS, GMR, CMR (Nano particle)

Unit III - Synthesis mechanisms

Unit IV - Characterization
Particle size density - porosity - lattice constant using X-ray - Mossbauer spectroscopy, NMR, FMR, MOKE, MCD - Hall Effect field measurement - VSM (Low and high field magnetic field and temperature)

Unit V - Latest developments and applications
Essentials of crystal field theory - exposure to Ligand field theory - Magnetic sensors - Magnetic multi layer - Magnetic recording media - Stoners model - Andersons model explaining electrical conduction of ferrites (Localized bands) - Neutron scattering - Magnetite

Text Books
1. Magnetism: Principles And Applications - Derek craik, John Wiley & Sons LTD- 1995

References
4. Traves D, J.Appl. Phys, 36(1965)1035
PHYS-605 FIBRE OPTICS COMMUNICATIONS

Unit I Linear And Nonlinear Waves
Simple pendulum-Small and large oscillations-Duffing oscillator-Dissipative effects-Physical applications-Solitons-Methods to solve solitons -Soliton equations (K-dV,mK-dV, Sine-Gordon and nonlinear Schrodinger equation).

Unit II Maxwell Equations And Waveguides
Maxwell equations-Refractive index-Frequency and intensity dependence of polarisation-Dielectric susceptibility-First order and higher order susceptibilities –Wave equation – Wave propagation in a conducting and anisotropic media.

Unit III Optical Fibres

Unit IV Nonlinear Effects In Fibre
Self phase modulation( SPM) – Cross phase modulation(XPM) – Self steepening and focusing effects – Nonlinear retarded effects (SRS & SBS) – optical and spatial Solitons – Mathematical modeling – Wave length and time division multiplexing-Femto second solitons- SIT solitons (basic ideas).

Unit V Solitons In Optical Communications

TOTAL :45hrs

Books For Study And Reference
PHYS-606 ADVANCED COMPUTATIONAL PHYSICS

Unit I: Monte Carlo Simulations (10 Lectures)

Unit II: Simulating Chaotic Systems (10 Lectures)

Unit III: Solving Partial Differential Equation (10 Lectures)
Finite difference method – Explicit and Implicit methods – Stability analysis – Application to diffusion equation – Solving Poisson equation – Introduction to finite volume and finite element methods.

Unit IV: Fast Fourier Transform (5 Lectures)

Unit V: Computer Lab (15 Lectures)
1. Simulating paramagnetic to ferromagnetic phase transition in 2d Ising model on a square lattice.
2. Chaos in logistic map – Bifurcation diagram, Cobweb diagram, Lyapunov exponent as a function of parameter.
3. FFT of periodic, multi-periodic, quasi-periodic, chaotic and stochastic signals.
4. Fractal dimension of Lorenz attractor
5. Solution of diffusion equation

Text Books & References:
5. Numerical Recipes in Fortran, Press et al.
PHYS-607  MAGNETIC NANOPARTICLE

Unit I

Unit II.
Various techniques for nanomaterials synthesis (specially, chemical route and mechanical milling/alloying route) and their aspects. Understanding of nanomaterials of various dimensions. Possible applications of magnetic nanoparticles.

Unit III.
Proposed models for magnetic nanoparticles and applications. Variation of magnetic parameters (e.g. Particle Magnetization, particle anisotropy, magnetic ordering temperature) with particle size. Inter-particle interactions and surface magnetism.

Unit IV.
Special topics (preliminary idea): Super paramagnetism, Collective magnetic Oscillation, Exchange bias effect, Magnetic Quantum Tunneling effect, Magneto- resistance and magnetic nanoparticle.

Books for reference:
PHYS-608 QUANTUM OPTICS & QUANTUM INFORMATION PROCESSING

UNIT I
Quantum theory of radiation; Quantization of free electromagnetic field; Fock states, Lamb shifts, Quantum beats, coherent & squeezed states of the field, Quantum distribution theory & partially coherent radiation (Q-representation and Wigner- Weyle distribution)

UNIT II

UNIT III

UNIT IV
EPR paradox; hidden variable & Bell’s theorem; Quantum calculation of the correlation in Bell’s theorem; Bell’s theorem without inequalities (GHZ equality). Quantum Cryptography (Bennett- Brossard protocol ) Quantum Non demolition measurement.

UNIT V
Quantum circuits; Quantum search algorithm, Quantum Computers-Physical realization, Condition for quantum computation, Different implementation schemes for quantum computation; Quantum information theory (Distinguishing Quantum states, Data compression, Classical & Quantum information & noisy Quantum channels), Entanglement as physical resonance, Quantum key distribution and security of quantum key distribution.

Text Books
1. M.O.Scully & M.Suhail Zubairy, Quantum optics.
2. M A Nielsen & I L Chuang, Quantum Computation & Quantum Information.
PHYS-609 SOLID STATE SPECTROSCOPY

Unit I Atomic Spectroscopy - Free Ion
The Free-ion; free ion terms for d2 and f2 configuration; Spin-orbit Coupling; Energy level states for d2 and f2 configuration; Ground states for fN configuration; Rare earth free-ions; Coulomb and Spin-orbit energies - Intermediate coupling. [Chapter III of Figgis and Chapter II of Hufner]

Unit II Ligand Field - Introduction
The concept of ligand field; The scope of ligand field theory; The Physical properties affected by ligand fields; Ligand fields and f electron systems; The magnetic properties of actinide element compounds. [Chapter I and Chapter XIII of Figgis]

Unit III Group Theory
Sketch of Group theory; Kramer’s degeneracy; Crystal field splitting - D3h symmetry; Product of two representations - Selection rules; Examples of selection rules -D3h symmetry; Applications of theoretical results to the analysis of experimental data.[Chapter III of Hufner].

Unit IV Optical Spectra of Rare Earth Ions
Judd-Ofelt theory for the parametrization of intensities; Radiative properties; Upconversions in rare earths; Luminescent properties of Eu3+ and Tb3+ ions. [Chapter III of Hufner].

Unit V Trivalent Rare Earth Ions in Crystal Field
Introduction; Parametrization of crystal field splittings; The spin Hamiltonian; Examples of crystal field parametrization; Model description of the crystal field. [Chapter III of Hufner]

Unit VI Rare Earth Lasers
Introduction; Principles of laser action; Typical rare earth lasers; Nd:YAG and Nd:glass lasers; Energy level scheme of the Nd in YAG [Chapter XI of Hufner]

Unit VII Optical Instruments and Spectral Analyses
Spectrographs and Spectrophotometers for UV, VIS and IR regions; Absorption and Emission spectra; Temperature dependent spectra; Axial, Sigma and Pi polarizations spectral measurements.

Text Books for References
PHYS- 610 ION BEAMS IN NANOTECHNOLOGY

Unit – I
Introduction: Effect of size on material properties, Quantum size effect and density of states, low dimensional systems and their applications. Introduction to microscopy: SEM, STM, AFM, TEM and their application in nanotechnology.(12 hours)

Unit – II
Ion – Solid interactions: Stopping and range of ions in solids, elastic collisions and kinematics, swift heavy ions, Coulomb explosion and thermal spike models, Nano track formation and its applications in nano technology.(10 hours)

Unit – III
Ion beam techniques: RBS, ERDA, NRA and PIXE, Ion channeling, defect analysis, lattice location and lattice strain measurements, Quantum well intermixing and band-gap tuning. (12 hours)

Unit – IV
Ion beams in nano-technology: Ion irradiation of surfaces, surface roughness, formation of nanopores, hillocks and self assembled nanodots, embedded nanoparticles and their applications in optoelectronics, Focused ion beams, nano-scale fabrication, ion beam milling and nanolithography.(14 hours)

Books:
Unit I General
Linear waves-ordinary differential equations (ODEs)-Partial differential equations(PDEs)- Methods to solve ODEs and PDEs.- Numerical methods –applications-Nonlinear oscillators-Nonlinear waves-Nonlinear ODEs-Nonlinear PDEs.

Unit II Coherent Structures

Unit III Solitons In Physical Systems
Derivation of Korteweg-de-Vries(KdV) equation, Modified K-dv equation, Nonlinear Schrodinger equation and Burger’s equation – Physical significance.

Unit IV Chaos In Physical Systems

Unit V Applications

References:
PHYS-612 SEMICONDUCTOR LASER PHYSICS

Unit I
Essential Semiconductor Physics Band theory, doping, heavy doping, recombination and generation of photons, non equilibrium carrier statistics. Refractive index of a semiconductor laser cavity.

Unit II
Laser Fundamentals: Population inversion in semiconductors, p-n homo junction laser and its output characteristics, active region and threshold current, optical properties of the junction, gain in semiconductors.

Unit III
Double Hetero Structure: Materials and growth techniques – brief outlook, electronic properties of hetero junctions, optical properties of hetero-junctions, lateral mode control.

Unit IV
Quantum Wells: Semiconductor quantum wells, density of states in 2-D systems, optical transitions, gain, strained quantum wells, optical and electrical confinement.

Unit V
Diode Laser Modeling: Rate equations of idealized diode laser, gain compression, small signal rate equations, real laser diodes: InGaAsP/InP quantum well lasers, three level rate equation models for quantum well SCH lasers.

Books:
PHYS-613 AQUSTIC, DIELECTRIC TECHNIQUE AND ITS APPLICATION TO LIQUID SOLUTIONS

Unit 1
Sound propagation, velocity of plane wave in medium, absorption of plane longitudinal waves in low velocity liquids, general considerations and relaxations, propagations of ultrasonic longitudinal waves in a relaxing medium.

Unit 11
Generation and detection of ultrasonic waves, optical diffraction method, ultrasonic interferometer, pulse technique, pulse propagation, pulse overlap, sing around technique, velocity measurements, systems of velocity measurements, applications to liquids, mixtures, polymers and solid substances.

Unit 111
Thermo elastic effect, physical description, phenomological analysis, attenuation and velocity change due to thermo elastic effect, dislocation damping, description, attenuation and velocity, anomalous ultrasonic velocity effects associated with dislocation behavior, the generations of harmonics in crystalline solids due to dislocations, some selected experimental result, interactions of spin wave and ultrasonic waves, in ferromagnetic crystals, experimental observations concerning spin waves and ultrasonic waves.

Unit 1V
The electrical properties of water molecules, dielectric theory, static dielectric constant, dielectric constant in strong electric field, dielectric loss, and dispersion, dispersion conductivity, experimental technique, microwave dielectric properties of water.

Unit V
Classification of liquid, potential functions, structural determinations, motion in liquids, equations for pair distribution function, Kirkwood super approximation, critical properties of van der Waals fluid, one dimensional ising model, Onsager’s solution.

Books for study and reference:
1. A J Mathewson, Molecular acoustics, wily-inter science 1971
6. C A Ctronon, Introduction to Liquid state Physics, John Willy and Sons.
PHYS-614 BIOPHYSICS

Unit I Life and Its Physical Basis (10 Lectures)
What is life? – Life and energy – Forces and energies at nanometer scales – Intermolecular interactions and electrostatic screening – Chemical bonding and stability of molecules – Chemical composition of living systems.

Unit II Thermodynamic basis of life (10 Lectures)
Heat, temperature, chemical equilibrium, Boltzmann distribution – Energy type and the second law of thermodynamics – Brownian motion – Chemical kinetics and catalysis – Metabolism in animals and photosynthesis in plants.

Unit III The Cell (15 Lectures)

Unit IV Proteins: Structure and Function (10 Lectures)
From linear polymer to functioning molecular machine: the role of weak interactions – The structural organization within proteins: primary, secondary, tertiary, and quaternary levels of organization – Varieties of proteins: globular and fibrous – The stability of proteins as measured by free energy and denaturation – Motions within proteins – How enzymes work – Proteins as binding machines: measurement of binding and thermodynamic analysis.

Unit V Nucleic Acid and Genetic Information (10 Lectures)
Deciphering the genetic code – Why a double helix – How structure stores information – The Replication process – From DNA to RNA to protein – How DNA is packed in the cell nucleus.

Text Books & References:
PHYS-615 SOLID STATE IONICS

Unit I
Types of Ionic solids- Fast Ions Solids-Point Defect type-Sub Lattice type – Fast Ionic materials – alkali metal ion conductors - β aluminas- Silver ion conductors- Cation conductors- Oxygen ion conductors – Halide ion conductors – Proton conductors –Electronic conductors with ionic transport.

Unit II

Unit III

Unit IV

Unit V

Text Book:
2. S. Chandra, Superionic Solids.
PHYS-616 ADVANCED SOLID STATE PHYSICS

Unit I Thermal Properties Of Materials
Introduction- specific of solids-classical model-Einstein’s model-Density of state-Debye’s model-Thermal conductivity of solids- thermal conductivity due to electrons-thermal conductivity due to phonons-thermal resistance of solids

Unit II Free Electron In Crystals
Introduction-electron in one dimensional potential well-electron in three dimensional potential well- quantum state and degeneracy-the density of state-Fermi Dirac distribution function-effect of temperature on Fermi distribution function-the electronic specific heat.

Unit III Super Conductivity

Unit Iv High Temparature Super Conductivity
Introduction – High temperature cuprate super conductors-Crystallography of cuprate-thermal and transport properties-Normal state properties of high Tc – oxides specific heat capacity-the role of phonons-RVB theory-super conducting devices applications.

Text Books :
1. Philip Philip, Advanced solid state physics, overseas press
2. Haug, rouf Advances in solid state physics, Springer.
3. Ashroft / Mermin,Solid state physics, Thomson books.

Reference Books:
1. Henry Ehren Reich and David Turrebut,Solid state physics, Academic press.
PHYS – 617 PALEOMAGNETISM:
PALEOMAGNETIC RECONSTRUCTION OF CONTINENTS

Unit I Basics Of Paleomagnetism
Various types of remanent magnetism Natural remanent magnetism, Thermo remanent magnetism Chemical remanent magnetism, Viscous remanent magnetism Isothermal remanent magnetism Piezo remanent magnetism.Oriented samples and their collection – Measurement of magnetic directions. 12 Hr

Unit II Instruments And Laboratory Techniques
Astatic Magnetometer Spinner Magnetometer Cryogenic Magnetometer Magnetic susceptibility meter. Techniques of Alternating field Demagnetisation, Thermal Demagnetisation, Chemical Demagnetisation. 12 Hr

Unit III Statistical Methods And Presentation Of Paleomagnetic Data
Fisher statistics, Computation of Mean remanent magnetic directions Characteristic magnetic directions-Virtual geomagnetic pole positions- Apparent polar wander path (APWP)– using stereonet- Molleweids projection- Comparison of APWPs for different purposes– Assigning age to unknown geologic formation- Correlation of movement of different continents. 15 Hr

Unit II Reversal Earth’ S Magnetic Field
Normal and reversal of magnetic poles – polarity of time scales, frequency of reversals Superchrons-Permian– Kiaman magnetic reversal, Cretaceous normal superchron. Sea floor spreading, plate tectonics-Marine magnetic anomalies. 10 Hr

Unit V Paleomagnetic Reconstruction
Paleomagnetic signatures in rocks-Geodynamics of different tectonic regions. Reconstruction of continents- Columbia super continent-Phanerozoic super continent Rodinia supercontinent, Eumarica-Gondwanaland-Pangea-their breaking and movement indifferent direction to the present positions. 11 Hr

Books:
2. E.Irwing, Paleomagnetism and its Applications to Geological and Geophysical Problems, Wiley, New York (1964)
Unit I Basics of Vacuum Technology


Unit II Collision processes in gases discharge mechanism

Collision cross-section, Elastic and Inelastic Collisions, ionization, excitation, relaxation, recombination, three body recombination, dissociation, ion-neutral collision, Charge transfer, Meta-stable-collisions, total collision cross-section, breakdown mechanism of gases, Gaseous discharge, Characteristic of dc Glow discharge, positive column, cathode sheath, negative glow, negative glow and Faraday dark space, Analysis of positive column, Analysis of cathode region.

Unit III Plasma and Plasma Parameters

Definition of plasma, electron and ion temperature, plasma potential, sheath formation and floating substrate, Debye shielding, The Contact Potential, sheath formation and Bohm criterion, cathode sheath, Plasma oscillations, electron & ion oscillation, Ambipolar diffusion.

Unit IV Plasma sources and Applications

Limitations of dc glow discharges, RF discharges, Inductive discharges, power transfer efficiency, matching network, electron-cyclotron resonance discharges, helicon-discharges, surface wave discharges, DBD discharges, characteristics and application of respective discharges, hollow cathode discharge, planer magnetron discharge, plasma etching, dc sputtering, rf sputtering, thin film formation, plasma nitriding, PECVD for nano-material fabrication, Tokomaks & ITER and challenges of controlled fusion

Unit V Experimental Demonstration

- Dependence of breakdown voltage on pressure and electrode gap (Paschen Curve).
- To measure the plasma parameters by double Langmuir prob
- To launch an ion-acoustic wave and demonstrate collective behavior of the plasma
- Measurement of plasma parameters of pulsed dc discharges
- Characterization of dc magnetron discharges and estimation of sputtering yield
- Studying the conditions for atmospheric pressure plasmas (Dielectric Barrier Discharges)

Text Books


Reference Books

PHY-619 QUANTUM MECHANICS IN NONCOMMUTATIVE PHASE SPACES

Unit I

Unit II

Unit III

Unit IV
Noncommutative Quantum Mechanics in Phase Space: Generalized deformed products in phase space – postulational formulation of noncommutative quantum mechanics in phase space – derivations of Schrödinger and other dynamical equations

References:
2. R. Courant and D. Hilbert, Methods of Mathematical Physics.
PHYS-620 QUANTUM COMPUTATION

Unit-I Classical & Quantum Information Theory

Unit-II Foundations Of Quantum Mechanics

Unit-III Quantum Entanglement
entanglement - the resource of q-communication - measure of entanglement - non-separability of epr pairs - hidden quantum information - Einstein locality - bell inequalities - the aspect experiment and the uses of entanglement.

Unit-IV Quantum Computation

Books
Unit-I: Point Defects In Ionic Crystal
Vacancies and Interstitials atoms-Frenkel and Schottky type defects-Point defects generated by dopant ions- Conductive electrons and holes in ionic crystals
Types of Ionic solids: Fast Ionic materials; alkali metal ion conductors - β aluminas- Silver ion conductors- Cation conductors- Oxygen ion conductors – Halide ion conductors – Proton conductors

Unit-II: Diffusion Process In Ionic Crystals

Unit-III: Lithium Ion Batteries
Basic concepts of rechargeable lithium batteries- Materials for lithium secondary batteries-Active materials for positive electrodes; Layered oxide cathodes, Spinel oxide cathodes and high voltage materials. Active materials for positive electrodes; Lithium metal, carbon based materials, Composites of Sn, Sb and Al and nitrides and phosphides. Inorganic ceramic electrolytes; Perovskite, Nasicon and Lisicon type and Lithium metal halides, nitrides and phosphides.

Unit-IV: Synthesis And Characterization Techniques
Solid state and wet chemical methods for preparation of polycrystalline ceramic materials- thin film; thermal evaporation, RF sputtering, Pulsed laser deposition (PLD) Structure; Comparison of X-ray and Neutron diffraction, Raman- thermal analysis (TG, DTA and DSC), Microscopic; SEM and TEM, electrical conductivity; ac impedance.

Unit-V: Battery Technology
Primary and secondary batteries-Sodium- Sulfur batteries-polymer lithium batteries- All Solid state thin film Lithium ion batteries.
Electrochemical devices: Electrochromical display, electric double-layer capacitors and electrochemical memory devices.
Sensing devices: Ion sensors -Oxygen sensors -Sensors for Combustible gases; CO, Alcohol and H₂ sensor.
Photo-Electrochemical devices: Photo-regenerative secondary batteries- Application of photo-intercalation.

References:
3. Azaroff; Introduction to Solids (TMH, New Delhi)
PHYS 622 ADVANCES IN NONLINEAR OPTICS

Unit – I
12 hours
Origin Of Optical Nonlinearities
Classical theory of anharmonic oscillators. Wave equations description of nonlinear optical susceptibilities
Quantum mechanical treatment of nonlinear optical susceptibilities, Frequency and intensity dependence of
polarization and dielectric susceptibility First order and higher order susceptibilities

Unit II
12 hours
Second order optical nonlinearities:
Second harmonic generation –sum and difference frequency generation, parametric processes- Simple theory and
calculation of nonlinear polarization –Various phase matching technique in SHG

Unit III
12 hours
Third order optical nonlinearities:
Third harmonic generation, Four wave mixing, Kerr Nonlinearity, Intensity dependent effect, Self Phase
modulation, Cross phase modulation Stimulated Raman Scattering (SRS) Stimulated Brillioun Scattering,
Parametric gain –Parametric amplification and oscillation

Unit IV
12 hours
Applications: Frequency mixing and upconversion Difference frequency generator, Optical Phase Conjugation-
Theory and Applications, Photorefractive effect and applications, Solitons-Theory and applications – Optical
bistability.

Unit V
12 hours
Nonlinear optical materials (Structure property relations and its applications):
Nonlinear Optics of Organics and Polymers, Liquid Crystal, Photorefractive materials, Organic doped glasses,
Rare earth doped glasses and crystals, Semiconductors, Optical Fibers and Photonic Crystals Fibers, Ferroelectric
Materials and other Novel optical materials

Text Books
1. Nonlinear Optics- Robert W Boyd
2. Nonlinear Photonics-Y Guo, C K Kao, E.H Li, K. S.Chiang
3. Principles of Nonlinear Optics- Y R Shen
4. Nonlinear Optics – N. Bloembergen
5. Nonlinear Optics of Organic Molecules and Polymers- H S Nalwa and S Miyata
6. Optical Phase Conjugation-R A Fischer
7. Quantum Electronics- A Yariv

Supplementary Reading
1. Handbook of Nonlinear Optics-R Sutherland
PHY-623 ATOMIC MANY BODY PHYSICS

Unit I
Many body Hamiltonian –Hartree fock and Dirac Fock formalism - restricted HF equations- unrestricted HF equations.

Unit II
Many body perturbation theory applied to coulombs s interaction Second quantization-Wick’s theorem – size extensively- size consistency-configuration interaction.

Unit III
Diagrammatic formalism-Coulombs interaction diagrams-JLV theorems-Correspondence between MBPT terms and diagrams.

Unit IV
Coupled cluster formalism-Closed shell coupled cluster –open shell coupled cluster formalisms.

Reference Books:
1. A. Lindgren and J. Morrisson, Atomic many body theory, Publisher Springer (Jun 1982).