School of Pure & Applied Physics
Mahatma Gandhi University
M.Sc. Physics Syllabus

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	SPAPM**ZZ**E1755	X-RAY CHARACTERISATION METHODS
	SPAPM**ZZ**E1756	MULTIFERROIC MATERIALS AND APPLICATIONS
	SPAPM**ZZ**E1757	STAR GALAXIES AND COSMOLOGY
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	SPAPMIII O82	Physics of Nanomaterials

SPAPMIC1701 BASIC ELECTRONICS

UNIT 1

Operational Amplifiers (20hrs)

Ideal operational amplifier-characteristics, feedback types; Applications-basic scaling circuits, current to voltage and voltage to current conversion, Summing amplifiers, Integrators and Differentiators, Differential amplifiers, Instrumentation amplifiers, Logarithmic amplifiers, Analog computation, Active filters, Oscillators, Wave generators, comparators, peak detector ,Sample and hold circuit.

UNIT II

Digital Electronics (18 hrs)

Binary adders, Decoder and encoder, multiplexers and demultiplexers, FFs, registers, counters, A/D and D/A converters, IC 555 timer and its applications- PLL, astable, monostable multivibrators.

UNIT III

Microprocessors and Microcontrollers (16 hrs)

8085 Microprocessor **-** Architecture, addressing modes, instruction set, simple programming, I/O and memory interfacing, 8255 programmable peripheral interface- operating modes, Basics of microcontrollers, comparison between microprocessor and microcontroller.

UNIT IV

Communication Electronics (18 hrs)

Amplitude modulation, Single side band techniques- balanced modulator, phase shift method, Radio receivers-superheterodyne receiver, AM receiver, detection and AGC, Frequency modulation-theory and generation, FM receiver, Pulse communication, types of modulation-PAM,PWM,PPM,PCM

Digital communication- error detection and correction, Frequency and time division multiplexing.

Text Books

1. **Opamps and Linear Integrated Circuits, Ramakant .A. Gayakwad**
2. **Integrated Electronics, Jacob Millman and C.C.Halkias.**
3. **Microprocessor Architecture, Programming, and Applications with the 8085/8080A, Ramesh.S.Gaonkar**
4. **The 8051 Microcontroller Architecture, Programming & Applications, Kenneth.J.Ayala**
5. **Electronic Communication Systems, Kennedy and Davis**

Reference Books

1. **Digital Principles and Applications, Malvino and Leach**
2. **Electronic Communications, Roody & Coolen**

SPAPMIC1702 MATHEMATICAL PHYSICS I

UNIT I Vector Analysis (15 hrs)

Basics of Vector Algebra and its physical concepts, Gradient, Divergence and Curl, vector integration, Gauss's theorem, Green's theorem and Stokes theorem, Potential theory, Gauss's Law and Poisson's Equation, Dirac Delta function and its properties**,** Orthogonal curvilinear coordinates-Gradient, Divergence, Curl and Laplacian. Evaluation of line, surface and volume integrals

Unit II Matrices and Linear Vector Spaces (15 hours)

Matrix algebra, Matrix multiplication, Transportation and Hermitian conjugate, Trace and determinants, Inverse of matrix, orthogonal and unitary matrices, Linear vector spaces, Metric space, Schmidt orthogonalisation, Linear operators, dual space, ket and bra notation, Hilbert space, Function spaces, Basis, orthogonal expansion of separable Hilbert spaces, Bessel's inequality, Parseval's formula

UNIT III Complex analysis (18 hours)

Functions of a complex variable – The derivative and Cauchy Reimann conditions – Line integrals of complex functions – Cauchy's integral theorem **-** Cauchy's integral formula – Taylor's series – Laurent's series – Residues – Cauchy's residue theorem – Singular points of an analytic function – The point at infinity – Evaluation of residues – Evaluation of definite integrals by contour integration **-** Method of steepest descent (Stirlings formula)

UNIT III Special functions and their differential equations (20 hours)

Gamma and Beta functions and its properties. Frobenius method for solving second order ordinary differential equations with variable coefficients. Bessel, Legendre, Hermite equations. Recurrence relations, Generating functions and Rodrigues formulae for the Bessel, Legendre and Hermite functions. Linear differential operators, adjoint operators, Greens identity, Eigen values and Eigen functions, Sturm-Liouville operators

Text books

1. Mathematical Methods in Classical and Quantum Physics – T Dass & S K Sharma
2. Mathematical Methods for Physicists – G B Arfken & H J Weber
3. Complex Variables and Applications – Churchill

References

1. Theory and problems of vector analysis – M Spiegel, Schaum's outline series, McGraw Hill
2. Introduction to Mathematical Physics – Charlie Harper, Prentice Hall
3. Applied Mathematics for Engineers and Physicists – Pipes and Harvill
4. http://nptel.ac.in/courses/111105035/#

Mathematics through ICT –(Students may experiment with)
Geogebra
Wolfram Alpha

SPAPMIC1703 CLASSICAL MECHANICS

Unit I:- **Lagrangian and Hamiltonian formulation (20 hours)**

A review of Newtonian Mechanics of a particle and system of particles. Conservation laws. Lagrangian formalism, constraints and their classifications. Generalized co-ordinate. Principle of virtual work, D'Alembert's principle. Lagrange's equations and its applications. Velocity Dependent potential, Dissipative force, Generalised Momentum, cyclic co-ordinates, conservation laws and symmetry properties. Homogeneity of space and time. Variational Principle , Hamilton's principle, Lagrange's equation from Hamilton's principle, the Principle of least action.

(20 hrs)

Unit II:- **Hamiltonian mechanics and Hamilton-Jacobi theory**

Hamiltonian formalism, Hamiltonian of a system, Hamilton's equations of motion, integrals associated with cyclic co-ordinate , Canonical transformations, Poisson Brackets and their properties, equations of motion- Hamilton-Jacobi Theory-Hamilton's Characteristic function- Harmonic Oscillator problem in Hamilton's-Jacoby method- Action Angle variable- Harmonic Oscillator and Kepler Problem in Action-angle variable.

(20 hrs)

Unit III**:- Motion of rigid bodies and Fluid Mechanics**

Kinematics of rigid body motion. Infinitesimal rotations, Coriolis force, rigid body equation of motion. Central force motion, Scattering & centre of mass. Theory of small oscillations, normal modes of the system- Fluid Mechanics- equation of state and equation of continuity- Bernoulli's theorem- interpretation of Lagragian formalism of continuous system- sound vibration in gases. (20 hrs)

Unit IV:- **Perturbation Theory and Chaotic Dynamical Systems**

Classical Perturbation theory- Time dependent perturbation- Simple pendulum with finite amplitude- Kepler problem- Chaotic Dynamical system- conservative system- integrable systems- KAM theorem (qualitative Idea)– nonlinear perturbation- Hamiltonian-chaos. Dissipative systems- continuous systems- Duffing oscillator- discrete systems -Logistic maps-fixed points- period doubling- limit cycle- chaotic Attractors- Lyoponov exponent- fractals and their dimension- Koch curve

(18hrs)

References:-

1. Classical Mechanics - H. Goldstein
2. Classical Mechanics - R. Douglas Gregory
3. Classical Mechanics - N. C Rana & P . S. Joag
4. Classical Mechanics - G. Aruldhas
5. Chaotic Dynamics - G.L. Baker & J.P. Gollub
6. Deterministic Chaos - N .Kumar, University Press

SPAPMIC1704 CLASSICAL ELECTRODYNAMICS

UNIT I

Electrostatics & Magnetostatics (18 hours)

Gauss's law and its applications, Poisson and Laplace equations, the electrostatics potential, electrostatic field due to point charges and continuous charge distribution, Electric field energy, Boundary value problems and their solutions, Multipole expansion, Biot-Savart law, Ampere's theorem, Magnetics field of a steady current, the divergence and curl of **B**, Applications of Ampere's law, the vector and scalar potentials.

UNIT II

Time varying fields (18 hours)

Electromagnetic induction and Faraday's law, Maxwell's displacement current, Maxwell's equations in free space and linear isotropic media, boundary conditions on the fields at interfaces, time dependent scalar and vector potentials, Gauge invariance, Coulomb and Lorentz Gauge, magnetic field energy, conservation laws, continuity equation, Poynting's theorem, Maxwell's stress tensor and conservation of momentum.

UNIT III

Electromagnetic radiation & Guided waves (20 hours)

Electromagnetic waves in free space, Dielectrics and conductors, reflection and refraction at interfaces, Polarization, Fresnel's law, interference, coherence and diffraction, waveguides and transmission lines, Transmission line equations and wave characteristics, skin effect, Modes in rectangular wave guide, Retarded potentials, The Lienard- Wiechert potentials, radiation from moving point charges and oscillating electric and magnetic dipoles, dispersion relations in plasma.

UNIT IV

Relativistic Electrodynamics (16 hours)

Lorentz transformation equations, Lorentz invariance of Maxwell's equations, Transformations of electromagnetic fields under Lorentz transformation, electrodynamics in tensor notation, potential formulation of relativistic electrodynamics, Four potential of a field, Dynamics of charged particles in static and uniform electromagnetic fields.

Text Books

1. **Introduction to Electrodynamics(2nd edn.)- D J Griffiths, Prentice Hall of India.**
2. **The Classical Theory of Fields(4th edn) L D Landau and E M Lfshitz, Pergamon.**
3. **Classical Fields – L D Landau and E M Lifshitz.**
4. **Electrodynamis and Radiative systems – Jordan and Balmian**

Reference Books

1. **Introduction to Relativity- R Resnick.**
2. **Classical Electrodynamics- J B Marion.**
3. **Electrodynamics of continuous media- Landau and Lifshitz.**
4. **Classical Electrodynamics- J D Jackson.**
5. **Introduction to Modern Optics- G R Fowles**

SPAPMIIC1706 QUANTUM MECHANICS –I

UNIT I (18 hours) Postulates of Quantum Mechanics

The Hilbert space and wave functions – Linear vector space and Hilbert space - Dirac Bracket notation- Operators - Commutator algebra - generalized Heisenberg uncertainty relations – eigen values and eigen functions of an operator – Representation in Discrete bases – change of bases and Unitary Transformations – Representation in continuous bases, Connecting Position and Momentum bases- Matrix and Wave Mechanics - Postulates of quantum mechanics- principle of superposition – state of a system –Observables and Operators – Measurements in Quantum Mechanics – Poisson brackets and commutators – Ehrenfest's theorems

UNIT II (18 hours) Representations and stationary states

Schrodinger , Heisenberg and Interaction representation - time dependent Schrodinger equation and continuity equation - time independent Schrodinger equations – 1 D Harmonic Oscillator – eigen values and eigen states – creation and annihilation operators – 3 D problems in spherical coordinates – Free particle in spherical coordinates - spherically symmetric potentials - particle in a three dimensional box, three dimensional isotropic harmonic oscillator and Hydrogen atom- energy eigen values and eigen functions.

UNIT III (18 hours) Approximation methods

Time independent perturbation theory (degenerate and nondegenerate cases) - wave function and correction to energy to second order - anharmonic oscillator. Degenerate case: secular equation- corrections to eigen values and eigen functions in the first approximations for a double degenerate level - first order Stark and Zeeman effect in hydrogen. WKB approximation (Quasi classical case): Boundary conditions in quasi classical case- Connection formula- quasi classical motion in a centrally symmetric field- Quantization condition - Penetration through a potential barrier.

UNIT IV (18 hours) Angular momentum

Rotations in Classical and Quantum Mechanics - operators for infinitesimal and finite rotations- Commutation relations of angular momentum operator- Generalised angular momentum operators - eigen values and eigen functions of the angular momentum operator - matrix representation – Pauli spin matrices - addition of angular momenta - Clebsch – Gordon coefficients for $j_1 = ½$, $j_2 = ½$

Text and Reference Books

1. Quantum Mechanics – Concepts and Applications - N Zettili
2. Quantum Mechanics – W Greiner
3. Quantum Mechanics – L D Landau & E M Lifshitz
4. Quantum Mechanics - G Aruldas

SPAPMIIC1707 MATHEMATICAL PHYSICS II

UNIT I Fourier Series, Fourier Transforms, Laplace Transforms (18 hrs)
Fourier series – Dirichlet's conditions – Fourier series of even and odd functions – complex form of Fourier series – Fourier integral and its complex form – Fourier transforms – Fourier sine and cosine transforms – Convolution theorem and Parseval's identity – Laplace transform of elementary functions – Inverse Laplace transforms – methods of finding inverse Laplace transforms – Heaviside expansion formula – solutions of simple differential equations

UNIT II Differential Geometry, Elements of Probability Theory (18 hrs)
Definition of tensors – metric tensor – covariant, contravariant and mixed tensors – differentiable manifolds and tensors – parallel transport – equation of geodesics –Christoffel symbols and curvature – Riemann curvature tensor – Ricci tensor and Ricci scalar. Elementary probability theory – random variables – Binomial, Poisson and Normal distributions – Central Limit Theorem

UNIT III Group Theory (20 hrs)
Definition of groups **-** examples – matrix groups – transformation groups – cosets – conjugacy classes – Lagrange's theorem – invariant subgroups – factor groups – homomorphism – homomorphism theorem – isomorphism – direct product of groups – representation of groups – matrix, faithful, unitary, reducible and irreducible representations – Schur's lemma – orthogonality theorem – Lie groups and Lie algebras – definition of Lie group – representation of SU(2) SO(3)

UNIT IV Green's Functions (16 hrs)
Definition and physical significance of Green's functions – translational invariance – eigen function expansion of Green's function – Green's functions for ordinary differential operators – first order linear differential operators and second order linear differential operators (eg forced harmonic oscillator) – Green's functions for partial differential operators – Laplace equation – solution of boundary value problems using Green's functions

Text books

1. Mathematical Methods in Classical and Quantum Physics **-** T Dass & S K Sharma
2. Mathematical Methods for Physicists **-** G B Arfken & H J Weber
3. Classical Theory of Fields **-** L D Landau & E M Lifshitz

References

1. Mathematics for physicists – Susan M Lea
2. Mathematical Methods for Physics and Engineering – K P Riley, M P Hobson S J Bence
3. Applied Mathematics for Engineers and Physicists – Pipes and Harvill
4. Mathematical physics –Eugine Butkov
5. http://nptel.ac.in/courses/111105035/#

Mathematics through ICT –(Students may experiment with)
Geogebra
Wolfram Alpha

SPAPMIIC1708   STATISTICAL PHYSICS

UNIT I Thermodynamics and Statistical theory (18 hours)

Laws of thermodynamics and their consequences. Thermodynamic potentials and Maxwell's relations. Chemical potential. Phase equilibrium. The macroscopic and microscopic states – Contact between statistics and thermodynamics – The classical ideal gas – Entropy of mixing and the Gibb's paradox – Phase space of a classical system – Liouville's theorem and its consequences – The micro canonical ensemble – Quantum states and phase space – The equipartition theorem - The Virial theorem

UNIT II The Canonical and Grand Canonical Ensembles (16 hours)
Equilibrium between a system and heat reservoir – a system in the canonical ensemble – Thermodynamical relations in a canonical ensemble – the classical systems – Energy fluctuations in the canonical ensemble: correspondence with micro canonical ensemble – Equilibrium between a system and a particle energy reservoir – A system in the grand canonical ensemble – Physical significance of statistical quantities – Density and energy fluctuations in the grand canonical ensemble: Correspondence with other ensembles

UNIT III Quantum Statistics (18 hours)
Quantum mechanical basis – Statistical distribution – An ideal gas in quantum mechanical micro canonical ensemble and other quantum mechanical ensembles – Detailed balance – Partition functions and other thermodynamic quantities of mono-atomic and diatomic molecules. Thermodynamic behavior of a Bose gas – Thermodynamics of Black body radiation – The Planck distribution law – Bose Einstein condensation – Thermodynamic behavior of an ideal Fermi gas – Pauli paramagnetism – Electron gas in metals and thermionic emission

UNIT IV Theory of Phase Transitions and Fluctuations (20 hours)
Problem of condensation – Theory of Yang and Lee – Bragg – Williams approximation– comparison with experiment near transition temperature - Ising model and it's solution for a linear chain – Equivalence of the Ising model to other models – Lattice gas and binary alloy – Brownian motion – Langevin equation – Random walk problem – Diffusion equation–- Introduction to non-equilibrium processes - Boltzmann transport equation.

References:

1. Statistical Mechanics - R K Pathria
2. Statistical Mechanics - K Huang
3. Statistical Mechanics-Donal A McQuarrie
4. Introductory Statistical Mechanics –Roger Bowley
5. Statistical Mechanics – Donald A. Mc Quarrie
6. Statistical Mechanics and Properties of Matter – E S R Gopal
7. Fundamentals of Statistical and Thermal Physics-Federick Reif

SPAPMIIC1709 SOLID STATE PHYSICS

Unit I : Crystal Lattice (18 hours)

Crystal structure: Unit cell, Bravais lattices, Miller indices, Reciprocal lattice, Bragg's law. Lattice defects: Point defects, Schottky and Frenkel defects – Equilibrium concentration of defects, Color centres. Line defects – Edge and screw dislocations, Dislocation energy, Plane defects.

Lattice vibrations: Vibrations in one dimensional monatomic and diatomic lattices, Quantization of lattice vibrations, Phonon momentum. Inelastic scattering by phonons. Lattice heat capacity: Classical theory of specific heat, Einstein model, Debye model, Anharmonic crystal interactions.

Unit II : Free electron theory and Band theory (18 hours)

Free electron theory: Drude-Lorentz classical theory, Free electron gas in one and three dimensions, Quantum state and degeneracy, Density of states, Fermi-Dirac distribution and effect of temperature, Electronic specific heat, Electrical conductivity and ohm's law. Hall effect.

Band theory of metals: Energy bands, Bloch theorem, Kroning-Penny model, Brillouin zones, Number of states in the band, Effective mass. Band theory of semiconductors: Carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors, Electrical conductivity of semiconductors, Hall effect in semiconductors.

Unit III : Magnetic properties (18 hours)

Diamagnetism and paramagnetism: Langevin's theory of diamagnetism and paramagnetism, Quantum theory of paramagnetism, Comparison with theory and experiment - Rare earth group and iron group ions, Paramagnetic susceptibility of conduction electrons.

Ferromagnetism: Weiss molecular field theory, Heisenberg's exchange interaction, Ferromagnetic domains, Bloch wall, Spin waves, Dispersion relation for spin waves, Magnons, Magnon specific heat. Antiferromagnetism and ferrimagnetism. Two sub-lattice model of Anti ferromagnetism, Neel's model of ferrimagnetism.

Unit IV : Dielectrics and Superconductivity (18 hours)

Dielectric properties: Polarization, Dielectric constant, Local electric field, Dielectric polarizability, Clausius-Mossoti Relation, Types of polarizability, Frequency dependence of polarizability. Ferroelectricity: Ferroelectric crystals and their properties, Classification of ferroelectric materials, Dipole theory of ferroelectricity.

Superconductivity: Meissner effect, Type I and Type II superconductors, Thermodynamics of super conducting transition, London equation, Basic ideas of BCS theory – Flux quantization – Josephson effects (AC & DC) - High Tc superconductors.

Text Books

1. Introduction to Solid State Physics – C Kittel
2. Solid State Physics – A J Dekker
3. Solid State Physics: Structure and Properties of Materials - M A Wahab

References

1. Elementary Solid State Physics – M Ali Omar
2. Principles of Solid State Physics – R A Levy
3. Solid State Physics – N W Ashcroft and N D Mermin

SPAPMIIIC1711 QUANTUM MECHANICS II

UNIT I. (18 hours) Scattering Theory

Scattering Cross Sections; Laboratory and CM reference frames – connecting angles and cross-sections; Scattering amplitude of spin-less particles; Scattering Amplitude and Differential cross section - Total scattering cross section; Born Approximation – First Born Approximation – Validity of Born Approximation; Scattering by Coulomb potential; Partial wave analysis for elastic and inelastic scattering; Optical theorem; Scattering by a square well potential.

UNIT II. (18 hours) Identical Particles

The Indistinguishability Principle; Symmetry of wave functions; Spin and Statistics; The Pauli's Exclusion principle; Scattering of identical particles; Spin function for many electron systems; Slater determinants; Sate vector space for a system of Identical particles – Creation and Annihilation Operators – Fermions and Bosons

UNIT III (18 hours)

IIIa. Approximation Methods

Variational method. Time Dependent Perturbation theory - Transition probabilities for constant and harmonic perturbations; Adiabatic and Sudden approximations – Interaction of atoms with radiation – Classical treatment of the incident radiation; Transition rates for Absorption and Emission of radiation – Transition rates within the dipole approximation – Spontaneous emission.

IIIb. Relativistic Quantum Mechanics

Klein-Gordon equation; Difficulties with the Klein-Gordon equation; First order wave equations Dirac equation – Free Dirac Particle ; Equation of continuity - Non-relativistic limit of Dirac equation; Spin and orbital angular momentum of the electron from Dirac equation – Hole theory

UNIT IV (18 hours) Quantum Field Theory

Lagrangian Field theory – Classical field equations - Hamiltonian formulation; Quantization of the field – Bosons and Fermions – Relativistic fields – Quantization of the Klein – Gordon , Dirac and electromagnetic fields - Gupta-Bleular formalism.

Text and Reference Books

Quantum Mechanics - Concepts and Applications N Zettilli
Quantum Mechanics. V M Thankappan
Quantum Mechanics 2nd Edn E Merzbacher
Quantum Field Theory, L.Ryder
Quantum Field Theory, C.Itzykson and J.Zuber

SPAPMIIIC1712 COMPUTATIONAL METHODS IN PHYSICS

UNIT I Interpolation and Curve Fitting (18 hours)

Finite difference operators, Differences of a polynomial, Interpolation with equal intervals - Newton's interpolation formulae, Gauss's interpolation formulae, Bessel's formula, Stirling's formula, Everett's formula, Interpolation with unequal intervals – Lagrange's interpolation formula, Newton's divided difference formula. Basic ideas of Spline interpolation. Curve fitting –method of group averages, least squares method.

UNIT II Numerical differentiation and Integration (18 hours)

Numerical differentiation - derivatives using difference formulae, Differentiation using Lagrange's polynomial and divided difference polynomial. Numerical integration : Newton – Cotes quadrature formula, Trapezoidal rule, Simpson's rule, Romberg's method, Gaussian quadrature method, Numerical double integration. Elementary ideas of Monte Carlo evaluation of integrals.

UNIT III Solution of Algebraic and Transcendental Equations (18 hours)

Solution of algebraic and transcendental equations : Bisection method, Regula-Falsi method, Iteration method, Newton-Raphson method, Secant method, Convergence of solutions. Solution of system of linear equations : Method of determinants, Matrix inversion method, Gauss elimination method, Gauss – Jordan method, LU factorization, Jacobi method, Gauss – Seidel method.

UNIT IV Solution of Differential Equations (18 hours)

Solution of ordinary differential equations: Initial value problems -Taylor's series method, Picard's method. Euler's method, Modified Euler's method, Runge Kutta method, Predictor- corrector methods - Milne's method, Adam - Bashforth's method. Boundary value problems – Finite difference method, Elementary ideas of solution of partial differential equations – Solution of Laplace equation using Finite difference approximation.

Text Books

1. Computational Physics An Introduction - Vesely
2. Introductory methods of numerical analysis – S S Sastry
3. Numerical methods for Mathematics, Science and Engineering – John H Mathews

Reference Books

1. Introductory Computational Physics – Klein and Godunov
2. A first Course in Computational Physics - Paul and Javier
3. An Introduction to Computational Physics – Tao Pang

SPAPMIIIC1713 LASERS AND SPECTROSCOPY

Unit I Atomic Spectroscopy (15 hours)

‘Quantum numbers and spectroscopic terms - spin orbit interaction- Lande g factor – Equivalent and nonequivalent electrons- Zeemen effect and Paschen Back effect-LS and JJ coupling schemes- Hunds rule- Examples of LS and JJ coupling- Lande intervel rule- Stark effect- hyperfine structure.

Unit II Microwave, IR and Raman spectroscopy (20 hours)

Different types of molecules- rotational spectra of diatomic molecules- intensity of spectral lines- Isotopic substitution- non-rigid rotator. Diatomic molecules as harmonic and an-harmonic oscillators- diatomic vibrating rotator – spectrum of CO and CO_2 molecules– Rotational Raman spectra- vibrational Raman spectra - Mutual exclusion principle - structure determination from Raman and IR spectroscopy- Elementary ideas of Nonlinear Raman effect-

Unit III Electronic and Spin Resonance Spectroscopy(20 hours)

Electronic spectra of diatomic molecules- Intensity of spectral lines- Frank-Condon principle- dissociation energy -rotational fine structure of electronic vibrational transitions- Fortrat diagram- pre-dissociation. NMR–Bloch equations- relaxation processes- chemical shift- ESR- hyperfine structure- Mossbauer effect- hyperfine interaction- chemical isomer shift.

UNIT IV Lasers (17 hours)

Spontaneous and stimulated emission; Einstein A and B coefficients-The laser idea – amplification of light – threshold condition, Coherence time coherence length- three- and four-level rate equation analysis. laser systems; solid-state lasers-Ruby laser and Nd-YAG laser, gas lasers-He-Ne and CO_2 laser, dye lasers, semiconductor lasers. Modes of resonators.

Text books

1. Introduction to atomic spectra- HE White
2. Spectra of diatomic molecules- G Herzberg
3. Molecular structure & Spectroscopy G Aruldas
4. Fundamentals of molecular spectroscopy C Banwell
5. Optical Electronics-Ghatak & Thyagarajan
6. Lasers theory and applications - Ghatak & Thyagarajan

Reference Books

1.Spectroscopy volume I and II-Stroaughan and valker
2.Raman spectroscopy D A Long
3.Principles of lasers –O Svelto
4.Quantum Electronics-A Yariv
5.Laser Fundamentals-W T Silfvast

SPAPM IVC1715 NUCLEAR AND PARTICLE PHYSICS

UNIT-I: Nuclear Structure and Models (15)
Basic properties of nucleus:- Nuclear radius, distribution of nuclear charge, skin thickness, isotope shift, nuclear matter distribution, Nuclear binding energy, Magnetic dipole moment - quadruple moment - Liquid drop model - Semi-empirical mass formula of Weizsacker - Nuclear stability - Mass parabolas - Bohr-Wheeler theory of fission - Shell model - Spin-orbit coupling - Magic numbers-Elementary ideas of collective model

UNIT-II: Nuclear Interactions (15)
Nuclear forces - Two body problem - Ground state of deuteron - Meson theory of nuclear forces - Yukawa potential - Nucleon-nucleon scattering - Low energy n-p scattering - Effective range theory - Spin dependence, charge independence and charge symmetry of nuclear forces - Isospin formalism.

UNIT-III: Nuclear reactions (18)
Radioactivity, Types of reactions and conservation laws - Reaction dynamics-Q-value equation Basics of alpha decay and Gamow's theory of Alpha decay, beta decay and energetic of beta decay, Fermi's theory of Beta decay, Kurie plots, Mass of the neutrino, life time, Allowed and forbidden transitions, selection rules and parity violation in beta decay, Neutrino physics - Non-conservation of parity - Gamma decay - Internal conversion - Multipole moments, life times. Energetics of fission process, controlled fission reactions, fusion process and solar fusion, Nuclear radiation detectors.

UNIT-IV: Particle Physics (22)
Elementary particles; Types of interactions between - Hadrons and Leptons - Symmetry and conservation laws; Elementary ideas of CP and CPT invariance - Classification of Hadrons - SU (2) - SU (3) multiplets - Quark model - Gell-mann-Okubo mass formula for octet and decuplet Hadrons – Quantum chromo dynamics (QCD)-Elementary ideas of standard model of weak interaction and QCD

Text books
1. K.S. Krane, 1987, Introductory Nuclear Physics, Wiley, New York.
2. D. C Thayal, Nuclear Physics, Himalaya Pub. House 1997
3. H.A. Enge, 1975, Introduction to Nuclear Physics, Addison Wesle, London.
4. I. Kaplan, 1989, Nuclear Physics, 2nd Edition, Narosa, New Delhi.
5. R.R. Roy and B.P. Nigam, 1983, Nuclear Physics, New Age International, New Delhi.
6. D. Griffiths, 1987, Introduction to Elementary Particle Physics, Wiley-VCH ,2008

Reference Books
1. Y.R. Waghmare, 1981, Introductory Nuclear Physics, Oxford-IBH, New Delhi.
2. Ghoshal, Atomic and Nuclear Physics, Volume 2.
3. J.M. Longo, 1971, Elementary Particles, McGraw-Hill, New York.
4. R.D. Evans, 1955, Atomic Nucleus, McGraw-Hill, New York.
5. B.L. Cohen, 1971, Concepts of Nuclear Physics, TMH, New Delhi.
6. M.K. Pal, 1982, Theory of Nuclear Structure, Affl. East-West, Chennai.

7. W.E. Burcham and M. Jobes, 1995, Nuclear and Particle Physics, Addison-Wesley, Tokyo.

SPAPMZZE1751 BASIC ASTRONOMY

UNIT I Basic Units and measurements (15 hrs)

Co-ordinate systems - sidereal, solar, universal, standard and ephemeris times. Parallax, precession, nutation, aberration,. Proper motion -radial and transverse velocities, space velocity. Units of distance -AU, light year and parsec. Magnitude scale -magnitudes and luminosities (apparent and absolute), color indices, surface temperature. Distance modulus -distances and radii of stars and the masses of stars.

UNIT II The Sun as a star (15 hrs)

Solar structure -photosphere, chromosphere and corona. Activity in the sun -sunspots, flares, solar oscillations, helio-seismology, CME's. The solar system –general characteristics, origin of the solar system, orbits of planets, satellites and comets.

UNIT III The basics of various types of telescopes (21 hrs)

Concepts of sensitivity, resolving power and signal to noise ratio. Optical telescopes -parts, different focii and mountings. Radio telescopes -Interferometers, synthesis telescopes, VLBI. X-ray astronomy -detection and collimation. Infra-red, gamma ray, neutrino and gravitational-wave detectors (basics only). CCD's as detectors.

UNIT IV Generation and Transmission of Radiation (21 hrs)

Radiation mechanisms -Lienard-Wiechert potentials and fields for a point charge, total power radiated by a point charge, Larmor formula and relativistic generalization (all without detailed derivations). Black body, bremsstrahlung, cyclotron, synchrotron, curvature, plasma and inverse Compton radiation. Interstellar extinction - the 21cm line of Hydrogen. Transmission through an ionized medium -Faraday rotation. Doppler, cosmological and gravitational redshifts

Text books
Astrophysics Baidyanath Basu
Astrophysics: Stars & Galaxies K. D. Abhyankar

References
The Physical Universe F. H. Shu
http://study.com/articles/5_Sources_for_Free_Astronomy_Education_Online.html
https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/

Astronomy & Astrophysics through ICT –(Students may experiment with)
Stellarium
SciPOP -IUCAA
https://arxiv.org/abs/1402.3674

SPAPMZZE1752 X-RAY CRYSTALLOGRAPHY

Unit –I: Crystallization methods and processes:

Crystal nucleation and growth, Types of crystallization: Slow Cooling from solution and the melt, Slow Evaporation, Vapour diffusion methods, Liquid-liquid diffusion, Gel growth method. Macromolecular crystallization methods: Factors affecting crystal nucleation and growth. Solvents used in crystallization and its solubility factors.

[18 hrs]

Unit II –X-ray Diffraction theory:

Concept of lattice and reciprocal lattice, Bragg's law in reciprocal space, point groups and space groups. Diffraction of X-rays from an electron, an atom, 1D lattice and a crystal. Atomic scattering factor and structure factor, Intensity of scattering from an hkl plane and various factors affecting the intensity. Elementary ideas about neutron and electron diffraction.

[18 hrs]

Unit III -Structure Determination methods:

X-ray data collection strategies, Determination of symmetry and space group from diffraction data. Fourier transform and calculation of electron density. Phase Problem in crystallography, Structure determination from X-ray data: Direct method, Intrinsic phasing method, Heavy atom method, Equal atom method, Molecular replacement methods, anomalous scattering and absolute structure determination.

[18 hrs]

Unit IV – Accuracy and structure refinement:

The determination of unit cell parameters, Structure refinement strategies, Least-squares refinement based on F and F^2, isotropic and anisotropic refinement strategies. Disorder: substitutional and positional disorder, refinement of disorder. Twinning: merohedral, pseudo- merohedral and non-merohedral twinning, twin law and component identification and refinements. Calculation of Geometrical parameters and estimated standard deviation. Error estimation in the data and the final structure validation.

[18 hrs]

References:

1. An introduction to X-ray crystallography, M. M. Woolfson.
2. Elements of X-ray crystallography, L. A. Azaroff.
3. X-ray Structure Determination, Stout & Jensen.
4. Protein Crystallography, Blundel & Johnson.
5. Crystal Structure Refinement A Crystallographer's guide to SHELXL, P. Muller, R. Herbst-Irmer, A. L Spek, T. R. Schneider, M. R. Sawaya.
6. SHELX Manual, G. M. Sheldrick.

SPAPMZZE1753 LASER PLASMA

Unit 1:- basic plasma properties

Introduction to plasma, Tunnel and over- the- barrier ionization, Electrons in the intense laser field, Definition of Plasma, Concept of temperature, Debye shielding and different plasma parameters, Criteria for Plasma, space field of charge, Relation of plasma physics to ordinary electromagnetics, The dielectric constant of plasma, Mixture of fluids of positive and negative charges, Some aspects of waves in plasmas.

Unit 2:- laser plasma interactions

Light matter interaction, Multi-photon ionization, The stimulated Raman Scattering (SRS) and Stimulated Brillouin Scattering (SBS) in Laser Plasma Interaction, Parametric interaction of three waves, Laser produced Plasma, Different processes in plasma: Free-free process, Bound-free process, Auto ionization and dielectric recombination, Bound-bound transitions, Resonance absorption, Basic equations in laser heating of plasmas, Impact of strong radiation in plasma.

Unit 3:-laser ablation

Laser ablation of the target material and creation of plasma, Dynamic processes during laser plasma generation on solid planar targets, Processes governing formation and acceleration of charged particles in laser plasma namely multiply charged heavy ions, Characterisation of Laser ablation plasmas. Concepts of Nucleation and cavitation, Spherical bubble dynamics, Cavitation bubble collapse, Dynamics of oscillating bubbles.

Applications: Laser generation of plasma jets for applications in laboratory astrophysics, Plasma TV, Inertial Confinement Fusion, Pulsed laser deposition.

Unit 4:- plasma spectroscopy & diagnostic techniques

Fundamentals, Basic requirements for laser induced break down spectroscopy, Spectroscopic density measurement, Spectroscopic temperature measurements, Diagnostic applications of plasma spectroscopy, High resolution imaging of nanostructures.

Basic macroscopic measurements: Electrical measurements, Pressure and momentum measurements, Langmuir probe, Other macroscopic Techniques, Magnetic diagnostics: Magnetic field measurement, Components and component parameters, Typical magnetic probe experiments, Electrical Probes: Sheath formation, The Line broadening mechanism in plasma, Application of Doppler Broadening to the measurement of atom and ion temperature, Diagnostic of dense plasma.Experimental probing of cavitation and bubbling.

References:

1. Introduction to Plasma Physics and Controlled Fusion, Francis F Chen, Second Edition, 1929

2. Principles of Plasma Mechanics, Bishwanath Chakraborty, Wiley Eastern Limited, 1990
3. Plasma Diagnostic Techniques, Richard H Huddlestone and Stanley L Leonard, 1965
4. Principles of Plasma Spectroscopy, Hans R Griem, Cambridge University press, 1997
5. Principles of Plasma diagnostics, I H Hutchinson, Cambridge University Press, 1987
6. Cavitation and BUBBLE Dynamics, Christopher Earls Brennen, Oxford University Press, 1995

SPAPMZZE1754 PLASMA PHYSICS

Introduction & single particle motions (18 hours)

Occurrence of Plasmas in Nature - Definition of Plasma - Concept of Temperature - Debye Shielding - The Plasma Parameter - Criteria for Plasmas - Applications of Plasma Physics - Motion in uniform $\vec{E}$ *and* $\vec{B}$ Fields, $\vec{E} \times \vec{B}$ and Gravitational drifts. - Motion in non-uniform $\vec{B}$ Field - Gradient and Curvature drifts – Magnetic Mirrors - Motion in time varying $\vec{E}$ Field - Motion in time varying $\vec{B}$ Field - Summary of Guiding Centre Drifts

Waves in plasmas (20 Hours)

Relation of Plasma to Ordinary Electromagnetics - The Fluid Equation of Motion. Representation of Waves - Group Velocity . Plasma Oscillations - Electron Plasma Waves - Ion Waves • Validity of Plasma Approximation - Comparison of Ion and Electron Waves. Electrostatic Electron Oscillations Perpendicular to $\vec{B}$ - Electrostatic ion Waves Perpendicular to $\vec{B}$ - The Lower Hybrid Frequency. Electromagnetic Waves with $\vec{B}_0 = 0$. Electromagnetic Waves Perpendicular to $\vec{B}_0$ - Cutoffs and Resonances

Plasma waves, equilibrium & stability (17 Hours)

Electromagnetic Waves Parallel to $\vec{B}_0$ - Hydromagnetic Waves - Alfven waves, Magnetosonic Waves – Hydro-magnetic Equilibrium – Concept of plasma β, - Classification of Instabilities – the Two Stream Instability and the Gravitational Instability.

Nonlinear plasma physics (17 Hours)

Parametric Instabilities – Coupled Oscillators, Frequency Matching, Instability Threshold and Growth Rate – Equations of Nonlinear Plasma Physics– Nonlinear Ion Acoustic waves – the Korteweg – deVries equation. The Ponderomotive Force - Nonlinear Electron Plasma waves – the Nonlinear Schroedinger equation

Text Books:

1. Introduction to Plasma Physics and Controlled Fusion F. F. Chen 2nd edition, Plenum Press
2. Introduction to Plasma Theory – D. R. Nicholson 1st edition, John Wiley & Sons.
3. Chaos and Structures in Nonlinear Plasmas W. Horton & Y. H. Ichikawa 1st edition, Allied Publishers.

Reference Books:

1. Fundamentals of Plasma Physics – J. A. Bittencourt, Springer
2. Fundamentals of Plasma Physics – Paul M. Bellan, Cambridge

SPAPMZZE1755 X-RAY CHARACTERIZATION METHODS

Unit I –Structure and Symmetry in solids:

Introduction to bonding in solids, Basic ideas about crystalline and amorphous materials, crystal packing: HCP and CCP, Interstitial sites, coordination number and Packing fraction, NaCl, CsCl, ZnS, Fluorite, Wurtzite structure, Diamond structure, Cristobalite, Perovskite structure, Corundum Structure, Rutile structure, Spinel Structure, Graphite, Silicate structures, Pyrosilicates, Fullerenes, symmetry in crystals, super symmetry and super lattices. [18 Hrs]

Unit II -Diffraction theory:

Symmetry in crystals. Real lattice and the concept of reciprocal lattice. Point groups and space groups, Geometry of diffraction, Diffraction of X-rays from an electron, an atom, 1D lattice and a crystal. Atomic scattering factor and structure factor. Intensity of scattering from an hkl plane and various factors affecting the intensity. Elementary ideas about neutron and electron diffraction.
[18 hrs]

Unit III -Structure Determination methods:

Determination of symmetry and space group from diffraction data. Fourier transform and calculation of electron density. Phase Problem in crystallography, Elementary ideas about Structure determination from X-ray data: Heavy atom method, Equal atom method and Molecular replacement methods of structure solution. [18 hrs]

Unit IV –Powder and Amorphous materials:

Powder diffraction, Data collection strategies, Rietveld refinement, Direct methods in powder diffraction. Ceramics and Glasses, Preparation of glasses and ceramic materials, Melt spinning, Sputtering. Structural studies of glasses: RDF analysis. EXAFS analysis, Properties of ceramics and glasses. Small angle scattering, wide angle scattering.
[18 hrs]

References:

1. Fundamentals of X-ray crystallography, M.M. Woolfson.
2. Elements of X-ray crystallography, L.A. Azaroff.
3. X-ray Crystallography, Stout & Jensen.
4. Structure Determination from Powder Diffraction Data Ed By W.I.F. David , K.Shankland, L.B. McCusker and Ch. Baerlocher
5. Science of Engineering materials, Srivastava and Srinivasan
6. The Science and Engineering of materials, Askeland.

7. Characterization of Nano-phase materials edited by Zhong Lin Wang
9. Basic Solid State Chemistry, A.R. West.

SPAPMZZE1756 MULTIFERROIC MATERIALS AND APPLICATIONS

Unit I: Structures and properties of advance materials

The symmetry Elements in Crystals, Crystallographic point groups, Effect of crystal symmetry on crystal properties: Neumann's principle, Quantum confinement and its effect to the properties of nanoparticles, Nanomagnetism and giant magnetoresistance (GMR), Superparamagnetism, Spin glass, Electric field versus current control of magnetism in multiferroics.

Unit 1I: Ferroic systems

Ferroelectric materials, Pyroelectric effect, Induced polarization, Orientational polarization, Clausius-Mosotti Equation, Ferrobielectrics and Ferrobimagnetics, Magnetic moments and exchange interaction, coupling between magnetic moments: RKKY coupling, double exchange, Super exchange, Ferromagnetism, Paramagnetism, Antiferromagnetism, Diamagnetism, Ferrimagentism, Giant moment ferromagnetism, Characteristic of spin glass, Common types of magnetism: Modern magnetic oxides: Ferrites, Manganites, Ferroelectric devices and integration.
Nanoenergy generators- piezoelectric and pyroelectric nanogenerators, Fabrication, working, applications etc.

Unit III: Multiferroics

Multiferroics, Basic properties of multiferroic materials, Linear magnetoelectrics, Magnetodielectrics, Magnetoelectric effect, Single phase multiferroics, Multiferroic composites, Lone pair mulltiferroic structure, Multiferroics due to charge ordering, limitations of multiferroic materials, Multiferroic nanoparticles, Applications of multiferroic materials, Dimensionality and size dependent phenomena of multiferroics.

Unit IV: Nanostructure synthesis & Characterization techniques

Sol-gel processing, Ball Milling, Flash evaporation method, Electron beam method, R.F Sputtering, Pulsed laser deposition, Chemical Vapour deposition, Chemical deposition, Magnetic measurements using VSM/PPMS/SQUID, Dielectric spectroscopy, Magneto electric coupling, , Mossbauer spectroscopy, Fundamentals of X-ray diffraction, Quantitative determination of phases, strain and particle size, Scanning electron microscopy, Transmission electron microscopy, Atomic force microscopy, Scanning tunneling microscopy.

<u>References</u>

1. Introduction to Ferroic materials: Vinod K Wadhawan, Gorden and Breach science publisher, 2000
2. Chemistry of nanomaterials : Synthesis, properties and applications - C. N. R. Rao, Achim Muller , Anthony K. Cheetham, Willy, 2004.
3. Synthesis of Nanostructured Materials –Cao, Imperial College Press,2004.
4. Introduction to Nanoscience and Nanotechnology - K K Chattopadhyay and A. N. Banerjee, PHI Learning Private Limited,2013

SPAPMZZE1757 STARS GALAXIES AND COSMOLOGY

UNIT I Stellar structure (18 hrs)
Correlations between stellar properties -M-L relation, HR diagram, physical state of the stellar interior -hydrostatic equilibrium, distribution of mass, estimation of central temperature and pressure, energy generation equations, energy transport by radiation and convection, equations of stellar structure, equation of state for stellar interiors, perfect gas, degenerate gas, sources of opacity

UNIT II Stellar evolution – its end stages (18 hrs)
Nuclear reactions, H burning, CNO cycle, Helium burning, neutrinos, solar neutrino experiments, structure of main sequence stars. Qualitative account of pre-main sequence evolution, early post main sequence evolution, turn off and the ages of stellar clusters, advanced evolutionary stages, degenerate stars.

UNIT III Our Galaxy, galaxies, hierarchical structure in the Universe (18 hrs)
The Galaxy, structure, stellar populations and the formation of the Galaxy. The ISM -components, Giant Molecular Clouds and star formation. Determination of the rotation curve of the Galaxy, its implications regarding dark matter. Classification of galaxies. Hierarchy of structures (groups clusters super-clusters). Active Galactic Nucleii and quasars

UNIT IV General Theory of Realtivity and Cosmology (18 hrs)
The equivalence principle, action for the gravitational field, Einstein's equation (without derivation). What is cosmology -Olber's paradox, Hubble's law. Fundamental assumptions, -homogeneity and isotropy, the FRW metric, the contents of the Universe -dust and radiation, density evolution, critical density, cosmological constant. The uniformity of the CMB, the origin of the anisotropies in the CMB. Conditions in the early universe, big bang nucleo-synthesis. Accelerated expansion, dark energy

Text books

Astrophysics Baidyanath Basu
Astrophysics: Stars & Galaxies K. D. Abhyankar

References

The Physical Universe F. H. Shu
The New Cosmology, Albrecht Unsold
Introduction to Cosmology – J V Narlikar
Theoretical Astrophysics, T. Padmanabhan
https://www.springboard.com/blog/astronomy-for-beginners-free-online-courses/
https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/

Astronomy & Astrophysics through ICT –(Students may experiment with)
VO India
NED – NASA Extragalactic Database
https://www.galaxyzoo.org/
https://einsteinathome.org/

SPAPMZZE1758 GENERAL THEORY OF RELATIVITY

Unit I (20)

Special theory of Relativity and General Tensors

Introduction to Special theory of Relativity, Length contraction and Time dilation, Relativistic velocity and Energy momentum Equation; Tensor Notation and General tensors-Metric tensor-Riemann tensor-Ricci tensor

Unit II (20)

Influence of gravitation on Physical systems

Principle of equivalence – Principle of general covariance- Maxwell's equation with gravitation - Representation of Energy Momentum Equation; Derivation of Energy and Momentum tensor; Action integral - Einstein equations from the action integral - Newtonian limit of Einstein's equations

Unit III (18)

Schwarzschild Line Element and its consequences

Einstein Equation for a Centrally Symmetric gravitational fields; Schwarzschild Solution for centrally Symmetric gravitational Fields – Singularities – Motion in a centrally symmetric gravitational field with application to the Planetary motion; Perihelion shift of mercury and Saturn and Earth - Deflection of light- gravitational slowing down of light and Schwarzschild radius; gravitational waves – propagation of gravitational waves

Unit IV (22)

Stellar structures and Cosmology

Relativistic equation of stellar structures-Newtonian stars-white dwarfs Neutron stars; General Relativistic instability; Spherical Collapse; Black holes and the Kerr Metric; Cosmological Principles- the Robertson – Walker metric and Expansion of Universe; Dynamical Equations of cosmology; Thermal nature of early Universe

Text Books

1. Classical theory of fields- L D Landau & E M Lifshitz
2. An introduction to General Relativity S K Bose, Wiley Earstern Limited

References

3. B F Schutz , A first course in general relativity
4. PAM Dirac, General theory of Relativity

5. Albert Einstein, The special and the general theory
6. J. Hartle, Gravity,
7. R. Wald, General Relativity,
8. S. Hawking and J. Ellis, The Large Scale Structure of Space time,
9. S. Weinberg, Gravitation and Cosmology

SPAPMZZE1759 THEORETICAL PHYSICS

Unit I

Global Symmetries-Galilean, Poincare and Conformal group (20 hours)

Poisson brackets; Galilean group-transformations, generators; graded Poisson brackets, Lie bracket, Lie Algebra, Lie group, Lorentz group , Poincare group and Conformal group – algebra and transformations, invariants and conservation laws, light-cone coordinates, Charge conjugation, Parity and Time reversal transformations and their combinations,

Matrix representations of Lie groups; Determinants in terms commuting and anti-commuting integrals; Classical groups – classification and definitions; Tensor notation; coordinate representations; Differential forms and their integration; Young tableaux; Standard model group – color and flavor; Covering group.

Unit II

Spin (15 hours)

Spinor representation of Lorentz group; 2 component notation, Rotations, spinors, indices, Lorentz transformations, Dirac spinors, Chiral spinors, Chirality and duality; Field equations for massless particles and their solutions; Dimensional reduction, Field equations for massive particles, Stuckleberg formalism, Foldy-Wouthuysen transformation; Twisters; Helicity ; Super Symmetry algebra; Super-coordinates, Super-conformal groups, super twisters

Unit III

Local Symmetries (20hours)

Functional differentiation and integration; Action functional and its properties- bosonic fields and fermionic fields; Field equations; Gauge transformations – global and local, Abelian and Non-abelian, Gauge fixing; Constrained Hamiltonian systems, First class and Second class constraints; Free particles, particles coupled to gauge fields, conservation laws, pair creation; Yang-Mills theories- light cone gauge, plane waves , self duality, twisters and Monopoles.

Unit IV

Hidden Symmetries (20 hours)

Spontaneous breakdown of symmetry – Higgs mechanism and Goldstone theorem; Sigma models, Coset spaces, Chiral symmetry, Stuckelberg fields; Standard model – Chromo dynamics, Electroweak dynamics, Salam-Weinberg theory, families, grand Unified theories; Chiral Supersymmetriy, Supersymmertric actions- covariant derivatives, pre-potentials, gauge fields, Super-symmetry breaking; Extended Super-symmetry.

Text books

1.Fields, W. Seigel
2.Quantum theory of fields Vol.1, S. Weinberg
3.Quantum field theory-A modern introduction, M. Kaku

Reference Books

1.An introduction to quantum field theory, M.E.Peskin and D.V.Schroder
2.An introduction to quantum field theory, G. Sterman
3.Classical theory of fields, Landau and E.M. Lifshitz
4.Quantum field Theory, C. Itzykson and J.Zuber

5.Quantum Field theory and critical phenomenon, J. Zinn-Justin

SPAPMZZE1760 NANOMAGNETISM

I. **Magnetism basics**

Magnetism of free atoms and ions, Atomic moments, Hund's rules and the Landé factor, band theory of magnetism, magnetic anisotropy, domains, magnetic energies (magnetostatic energy, magnetocrystalline energy, magnetostrictive energy), Magnetostriction and the effect of stress; Fine particle and thin films; soft magnetic materials and hard magnetic materials, Magnetic ordering (Dia-, Para-, Ferro-, Antiferro-magnetism), Magnetism in small structures-Single domain particles, superparamagnetism, magnetic ultrathin films, magnetic surface and interface anisotropies, magnetic oxides, magnetic semiconductors, multiferroics. Quantum confinement and its consequences — density of states.

II. **Magnetic order and magnetic interactions**

Spin and orbital moment**,** Magnetic anisotropy**-** Contributions to the anisotropy, spin-orbit interaction and shape anisotropy**,** Surface anisotropy**,** Magnetostriction**,** Magnetic exchange (direct, indirect, and superexchange), Dipolar magnetic interaction, Spin-orbit interaction, Local magnetic moments and spin-polarized electron band structure, Origin of the exchange interaction, Model of localized moments (Ising, Heisenberg), Band model (Stoner), Stoner criterion, One-dimensional Heisenberg model; Two-dimensional XY model; Three dimensional Heisenberg ferromagnet; Three-dimensional antiferromagnet; Magnetism of the electron gas; Stoner model; Spin excitations in Stoner model; RKKY interaction; Field models of magnetization; Exchange model in two dimensions; Micromagnetic approach to magnetisation dynamics, Spin waves and current-induced torques, Domain wall dynamics and spin-orbit torques, Random anisotropy model of amorphous magnet; Landau-Lifshitz equation; Spin waves; Magnetic resonance; Angular momentum and spin; Magnetism of atoms; Quantum mechanics of a large spin; Quantum magnetization curve; Josephson effect; Spin-lattice relaxation of rigid atomic clusters; Spin transport at nanoscale;

III. **Synthesis and characterization of magnetic nanoparticles**

Novel Methods for the Synthesis of Magnetic Nanoparticles- Top-down method, bottom-up approach- Organometallic chemical route, Sol-gel synthesis, colloidal precipitation, hydrothermal synthesis, electrodeposition, etc. Fabrication of Nanomaterials by Physical Methods: Inert gas condensation, Arc discharge, RF- plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy (MBE), Chemical vapour deposition (CVD) method.

Characterization techniques**-** Structural Characterization Techniques-X-ray diffraction (XRD) and Bragg’s law, Crystallite size determination, UV Visible spectroscopy, Infra-red Spectroscopy, Scanning electron microscopy (SEM), XPS, TEM, EDAX, Raman spectroscopy , Neutron diffraction, Thermal analysis – TGA, DTA and DSC; Defect Characterisation Techniques-Positron Annihilation Spectroscopy (PAS); Property Characterisation Techniques- Vibrating sample magnetometry (VSM), Super conducting interference device (SQUID) magnetometry, Alternating Gradient magnetometry, Magneto-optics, Ferromagnetic resonance (FMR), Mossbauer Spectroscopy, Dielectric spectroscopy, Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR), Nuclear Quadrapole Resonance (NQR).

IV. **Magnetic materials and Applications**

Spintronics, Giant Magnetoresistance (GMR), Tunneling Magnetoresistance (TMR), Magnetic Tunnel Junction, Magnetoresistive Random Access Memory (MRAM); Spin Torque Transfer, Spin Torque Transfer Applications- STT-RAM, Current-Induced Domain Wall Motion, Spin Torque Oscillator, spin valves, quantum tunneling, phase transformations: colossal magnetoresistance (CMR); Magnetoresistive Sensors Based on Magnetic Tunneling Junctions; Emerging Spintronic Memories; GMR Spin-Valve Biosensors; Semiconductor Spin-Lasers; Spin Logic Devices and magnetic drug delivery; Magnetic materials in memory device; Magnetic data storage; Environmental Applications of Magnetic Nanoparticles; Nanobiomagnetism**-** magnetic resonance imaging, hyperthermia, magnetic biosensors, biological assay system, lab on- a-chip concept.

References

1. Introduction to Solid State Physics- **C.Kittel**. (*John Wiely & Sons*.)
2. Solid State Physics-**A.J.Dekker** (Machmillan Student Editions)
3. Solid State and Semiconductor Physics-**J.P.Mc kelvy** (Krieger Publications).
4. Principles of Solid State Physics – **R.A. Levy** (Academic Press)
5. Elements of Solid State Physics – **J.P. Srivastava** (Prentice-Hall of India)
6. Quantum theory of Magnetism – *W. Nolting and A. Ramakanth*, Springer
7. Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey.
8. Principles of Nanomagnetism, **Guimarães,** Alberto P., Springer, 2009.
9. Solid State Physics- Ashcroft-Mermin
10. Solid State Physics- Ibach-Lüth
11. Modern Magnetic Materials- O’Handley
12. Physics of Ferromagnetism- Chikazumi
13. Quantentheorie des Magnetismus- Nolting

SPAPMZZE1761 APPLIED PHOTONICS

Basics of optoelectronics

Electronic properties of semiconductors – Energy level and density of carriers in intrinsic nd extrinsic semiconductors – consequence of heavy doping –. - Direct and indirect bandgap semiconductors, -electron-hole pair formation and recombination -recombination life time – p-n junction band diagram Conduction process in semiconductors - open circuit - forward and reverse bias – light emitting diodes – principles - device structures - LED materials, heterojunction high intensity LEDs – double heterostructure – LED characteristics and LEDs for optical fiber communications - surface and edge emitting LEDs.

Optoclectronic devices and detectors

Principle of p-n junction photodiode - absorption coefficient and photodiode materials – quantum efficiency and responsivity - PIN-photodiode – avalanche photodiode – phototransistor - photoconductive detectors and photoconductive gain – noise in photo-detectors – noise in avalanche photodiode - solar energy spectrum - photovoltaic device principles – I-V characteristics - - temperature effects - solar cell materials, device and Efficiencies .

Photonic crystals

Basic concept, Theoretical modeling of photonic crystals. Features of photonic crystas, One dimensional photonic material- Bloch modes, dispersion relation, photonic band gap- Methods of fabrication, photonic crystal optical circuitary, Non linear photonic crystals, photonic crystal fibres (PCF), photonic crystals and optical communications. Photonic crystal sensors.

Nano Photonics

Photons and electrons similarities and differences- Confinement of photons and electrons- Propagation through classically forbidden zone: tunneling, Nano scale optical interactions, Nano scale confinement of electronic interactions -quantum confinement effect. Nano crystals and quantum confined materials. Quantum confined structures as lasing media and super lattice; Optical properties, Metaliic nanoparticles and Nanorods Applications of Metallic nano structures.

Text Books

1. Laser fundamentals, William T. Silfvast, CUP 2nd Edn
2. Optoelectronics and Photonics: Principles and Practices, S.O. Kasap, Pearson 2009
3. Nano Photonics; P N Prasad Wiley Interscience (2003**)**
4. Semiconductor optoelectronic devices: Pallab Bhattacharya, Pearson(2008).
5. Optoelectronics: An introduction to materials and devices, Jasprit Singh, Mc Graw Hill International Edn., (1996).

Reference Books

1. A. Yariv, Quantum Electronics (John Wiley)
2. Y.R. Shen, Nonlinear Optics (John Wiley)

3. William. T. Silfwast, Laser Fundamentals (Cambridge University Press)
4. O.Svelto, Principles of Lasers (Plenum Prss)
5. W. Demtroder, Laser Spectroscopy (Springer-Verlag)
6. R. L Sutherland, Hand Book of Nonlinear Optics (Marcel Dekker Inc, New York)
7. Teich and SaleichFundamentals of photonics

SPAPMZZE1762 ADVANCED SOLID STATE PHYSICS

Band Structure of Solids (18 hours)

Bloch function, Kroning Penny model for an electron in a periodic potential, E-k relationship in various representations, Energy band calculations, Nearly free electron approximation, Tight binding approximation, Wigner-Seitz cellular method, Augmented plane wave method, Orthogonalised plane wave method. Pseudopotential method.

Semiconductor Physics (18 hours)

Density of states, Effective density of states mass action law, Doping: intrinsic vs. extrinsic semiconductors, Charge neutrality, Fermi energy as a function of temperature, Carrier concentration in a intrinsic semiconductor. Electrical conductivity, Hall effect charge carrier diffusion- Diffusion currents, Einstein Relations, Diffusion lengths, Quasi- Fermi energy, Carrier generation and recombination mechanism- direct band to band recombination.

Low Dimensional Quantum Structures (18 hours)

Two dimensional Quantum structures; Quantum Wells- Energy spectrum, density of states, Influence of effective mass, One dimensional structures- Quantum wires, density of states, Infinitely deep rectangular wire, Zero dimensional structures- quantum dotes, density of states, Infinite spherical quantum dot, Optical properties of two dimensional and three dimensional structures, Examples of low dimensional structures.

Quasi Particles in Materials Science (18 hours)

Phonons, Oscillations within a one dimensional diatomic chain of atoms, Vibrations of a three dimensional crystal, Polarons- dielectric polarons, Molecular polarons Holstein's model, Bipolarons, Excitons, Wannier and charge transfer excitons, Frenkel excitons, Plasmons, Dielectric response of an electronic gas, Spin waves, Magnons

References

1. Introduction to Solid State Theory- Otfried Madelung
2. Quantum Theory Of Solids- Eoin O'Reilly
3. Solid State Physics- James D Patterson and Bernard C Bailey
4. Fundamentals of Solid State Engineering - Manijeh Razeghi
5. Solid State Physics for Electronics - André Moliton

SPAPMZZE1763 PHYSICS OF MESOSCOPIC SYSTEMS

Unit-I Introduction to the Physics of Mesoscopic Systems
The Mesoscopic Regime, Prominent Mesoscopic Effects, Aharonov-Bohm Oscillations, The Integer Quantum Hall Effect, The Fractional Quantum Hall Effect, Universal Conductance Fluctuations, Conductance Quantization in Quantum Point Contacts, Persistent Currents in Mesoscopic Rings

Unit-II Theory of Electronic Transport in Mesoscopic Structures
Breakdown of Classical Transport, Linear Response Theory, Definition of the conductance, The Landauer Approach, One-Channel Two-Point Conductance, Multi-Channel Two-Point Conductance, Edge States and Quantum Hall Effect, Resonant versus Sequential Tunneling, Resonant Tunneling, Sequential Tunneling

Unit-III Effects of the Electron-Electron Interaction
The Coulomb Blockade, Transport through Quantum Dots, The Single Electron Transistor, Transport Spectroscopy, Mesoscopic Superconductivity: Josephson effect, RCSJ model, Bloch oscillations, approach to flux and charge Q-bits

Unit-IV Coherent backscattering of light
Introduction, The geometry of the albedo, Definition- Albedo of a diffusive medium, The average albedo, Incoherent albedo: contribution of the Diffuson, The coherent albedo: contribution of the Cooperon, Time dependence of the albedo and study of the triangular cusp, Effect of absorption, Coherent albedo and anisotropic collisions, The effect of polarization, Depolarization coefficients, Coherent albedo of a polarized wave, Experimental results, The triangular cusp, Decrease of the height of the cone, The role of absorption, Coherent backscattering at large, Coherent backscattering and the "glory" effect, Coherent backscattering and Opposition effect in astrophysics, Coherent backscattering by cold atomic gases, Coherent backscattering effect in acoustics, Diffusing wave spectroscopy**,** Spectral properties of disordered metals

References

1. Mesoscopic Physics: An introduction, by Harmans (available online).
2. Introduction to mesoscopic physics, by Y. Imry
3. Electronic Transport in Mesoscopic Systems, by Supriyo Datta
4. "Quantum Transport", Lecture Notes by Yuri M. Galperin (available at http://folk.uio.no/yurig/quTpdf.pdf)

5. "Quantum Transport in semiconductor nanostructures", C. W. J. Beenakker and H. van Houton in "Solid State Physics", vol.44, ed. by Frederick Seitz and David Turnbull, Academic Press (1991).
6. Mesoscopic Physics of Electrons and Photons by *Eric Akkermans, Cambridge University Press*

Other references for specific topics may be suggested during the course

SPAPMZZE1764 NANOPHOTONICS

Module 1:
Fundamentals of photonics and photonic devices – lasers (population inversion, pumping, nanolasers), LEDs (inorganic, organic and polymer LEDs), Optical modulators (acousto-optic and electro-optic), optical fibres and fibre optic components, Frequency conversion, Introduction to Nanophotonics, scope, Propagation and confinement of photons and electrons, tunnelling, band gap, Quantum confinement effects, interaction dynamics, electronic energy transfer and emission

Module 2:
Near field optics and Near field scanning optical microscopy, Fundamentals of Near field microscopy, aperture and aperture-less techniques, near-field probes, Quantum dots, Single molecule spectroscopy, Non-linear optical processes, Aperture-less NSOM, nanoscale enhancement, Time-resolved studies, Heterostructures

Module 3:
Introduction to plasmonics, metallic nanoparticles and nanorods, metallic nanoshells, local field enhancement, sub-wavelength aperture plasmonics, plasmonicc waveguiding, applications of metallic nanostructures, Evanescent wave excitation, dielectric sensitivity, radioactive decay engineering, metal dipole interaction.

Module 4:
Introduction to photonic crystals, Modelling of photonic crystals, Photonic crystal optical circuitry, Non-linear photonic crystals, Photonic crystal fibres, Applications in communication and sensing, Near field imaging of biological systems, Nanoparticles for optical diagnosis, upconverting nanophores for bioimaging

References:

1. Nanophotonics, Praas.N.Prasad, Wiley, 2004

2. Nanophotonics with surface plasmons, Vladimir.M.Shalaev, Stoshi Kawata, Elsevier, 2006
3. Principles of Nanophotonics, Motoichi Ohtsu, Kiyoshi Kobayashi, Makato Naruse, Taylor & Francis; 1 edition (June 6, 2008)
4. Photonic devices, Jia Ming Liu, Cambridge University Press; Reissue edition (June 11, 2009)
5. Integrated Photonics: Fundamantals, Gines Lifante, Wiley; 1 edition (March 14, 2003)
6. Photonic crystals, Kurt Busch, Stefan Lolkes, Wiley, 2006

SPAPMIIIO81 INTRODUCTION TO MATHEMATICAL SCIENCES

Relations and functions: Introduction, Types of Relations, types of Functions, composition of Functions and Invertible Function, Binary Operations.

Trigonometric and inverse trigonometric Functions: Introduction Basic trigonometric functions and its relations, Concepts Properties of Inverse Trigonometric Functions and Applications.

Matrices: Introduction, Matrix, types of Matrices, Operational on Matrices, transpose of a Matrix, symmetric and Skew symmetric Matrices, elementary Operation (Transformation) of a Matrix, Invertible Matrices, Determinant, properties of Determinants, Minors and Cofactors, Adjoint and Inverse of a Matrix, Applications of Determinants and Matrices.

Continuity and Differentiability: Introduction to Continuity, Differentiation, Differentiability, Exponential and Logarithmic Functions, Logarithmic Derivatives of Functions in Parametric Forma, second Order Derivative Mean value Theorem, Applications of Derivatives

Integrals: Introduction, Integration as an Inverse Process of Differentiation, Methods of Integration, Integrals of some particular Functions, Integration by Partial Fractions, Integration by Parts, Definite Integral, Fundamental Theorem of Calculus,, Evaluation of Definite integrals by substitution, some properties of Definite integrals, Applications.

Vector Algebra : Introduction, Some basic Concepts, Types of Vectors, Addition of Vectors, Multiplication of a Vector by a Scalar, |Product of two vectors.

Three Dimensional Geometry : Introduction, Direction Cosines and Direction ratio of a Line, equation of a Line in space, Angle between Two Lines, shortest Distance between Two Lines, Planes, Coplanarity of Two Lines, angle between Two Planes, Distance of a Point from a Plane, Angle between a Line and a plane.

Probability: Introduction, Conditional Probability, Multiplication Theorem on Probability, Independent Events, Baye’s Theorem, random Variables and its Probability Distributions, Bernoulli Trials and Binomial Distribution

References:

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2. Foundations of Mathematical Physical Sciences. Riley Hobson, Cambridge University Press.
3. Advanced Engineering Mathematics, Erwin Kreyszig, Wiley

SPAPMIIIO82 PHYSICS OF NANOMATERIALS

Unit-I
INTRODUCTION

Overview:

When does size matter?
Trend of miniaturization and Moore's law
Scales of various systems
Characterization methods-Direct and Indirect methods

Unit-II
SYNTHESIS, PREPARATION AND FABRICATION

Preparation of Nanomaterials:

Bottom-up approach
Top-down approach

Chemical approaches:

Self assembly
Sol-gel synthesis

Physical approaches:

Molecular beam epitaxy
Atomic layer deposition
Laser Plasma Ablation

Engineering approaches:

Lithography
-Photolithography
-Electron beam lithography
-X-ray lithography
-Focused ion beam (FIB) lithography
Soft lithography
-Micro contact printing
-Molding
-Nanoimprint
-Dip-pen nanolithography
Nano-pattering

Biological approaches:

Unit-III
PROPERTIES AND CHARACTERIZATION OF NANOMATERIALS

Physical properties of nanomaterials:

Melting points and lattice constants
Mechanical properties
Optical properties
-Surface Plasmon Resonance
-Quantum size effects
Electrical Properties
-Surface scattering
-Charge of electronic structure
-Quantum transport
-Effect of microstructure
Magnetic properties
-Fundamental magnetic properties
-Magnetic anisotropy
-Superparamagnetism
-Spin glass
-CMR and GMR materials
-spintronics

Structural characterizations:

X-ray diffraction
Scanning Electron Microscopy
Transmission Electron Microscopy
Scanning Probe Microscopy
-Scanning Tunneling Microscopy
-Atomic Force Microscopy

Chemical characterizations:

FTIR Spectroscopy
Electron Spectroscopy
Ionic Spectroscopy

Functional characterization:

-Optical properties
-Magentic properties
-Electrical properties

Unit-IV

APPLICATIONS OF NANOMATERIALS

Molecular Electronics and Nanoelectronics
Biological applications of nanomaterials
Band gap engineered quantum devices
Nanomechanics
Photonic crystals and Plasmon waveguides
Carbon nanostructures
-Carbon nanotubes
-Graphene

SOCIAL AND ETHICAL ISSUES OF NANOSCIENCE AND NANOTECHNOLOGY

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2. *Nano: The Essentials by T. Pradeep, Tata MacGraw-Hill Publishing Company Limited*
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4. *Nanostructures & Nanomaterials-Synthesis, Properties and Applications- Guozhong Cao, Imperial College Press*
5. *Characterization of Nanophase Materials- Zong Lin Wang, Wiley VCH*
6. *Hand Book of Nanotechnology- Bhushan, Springer (Electronic Copy available)*
7. *Introduction to Solid State Physics- Charles Kittel, Wiley 7th Edition*
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