M.Sc. Physics Syllaaus

M. Sc. Physics(CBCS)
1st semester

SR NO	COURSE TYPE	COURSE CODE	COURSE NAME	Lecture	Tutorial	Practical	CREDIT	MARKS		TOTAL
								INTERNAL	EXTERNAL	
1	MAJOR	MSCP101	Mathematical Physics	4	0	0	4	30	70	100
2	MAJOR	MSCP102	Classical Mechanics	4	0	0	4	30	70	100
3	MAJOR	MSCP103	Quantum Mechanics	4	0	0	4	30	70	100
4	MAJOR	MSCP104	Electronics	4	0	0	4	30	70	100
5	MINOR	MSCP105	Physics Laboratory – I	0	0	4	4	30	70	100
6	MINOR	MSCP106	Physics Laboratory - I	0	0	4	4	30	70	100
			TOTAL	16	0	8	24	180	420	600

M. Sc. Physics(CBCS)
2nd semester

SR NO	COURSE TYPE	COURSE CODE	COURSE NAME	Lecture	Tutorial	Practical	CREDIT	MARKS		TOTAL
								INTERNAL	EXTERNAL	
		MSCP201	Electrodynamics	4	0	0	4	30	70	100
		MSCP202	Condensed Matter Physics	4	0	0	4	30	70	100
		MSCP203	Atomic and Molecular Physics	4	0	0	4	30	70	100
		MSCP204	Computational Physics	4	0	0	4	30	70	100
		MSCP205	Physics Laboratory – III	0	0	4	4	30	70	100
		MSCP206	Physics Laboratory - IV	0	0	4	4	30	70	100
			TOTAL	16	0	8	24	180	420	600

M. Sc. Physics(CBCS)
3rd semester

SR NO	COURSE TYPE	COURSE CODE	COURSE NAME	Lecture	Tutorial	Practical	CREDIT	MARKS		TOTAL
								INTERNAL	EXTERNAL	
		MSCP301	Statistical Mechanics	4	0	0	4	30	70	100
		MSCP302	Project – I / Advanced Physics Laboratory	0	0	6	6	50	100	150
		MSCP303	**Departmental Elective Paper-I**	4	0	0	4	30	70	100
		MSCP304	**Departmental Elective Paper-2**	4	0	0	4	30	70	100
		MSCP305	Open Elective (CBCS)	0	0	4	4	30	70	100
		MSCP306	FIELD VISIT	0	0	2	2	20	30	50
			TOTAL	12	0	12	24	190	410	600

M. Sc. Physics(CBCS)
4th semester

SR NO	COURSE TYPE	COURSE CODE	COURSE NAME	Lecture	Tutorial	Practical	CREDIT	MARKS		TOTAL
								INTERNAL	EXTERNAL	
		MSCP401	Nuclear and particle Physics	4	0	0	4	30	70	100
		MSCP402	**Departmental Elective Paper-3**	0	0	6	4	30	70	100
		MSCP403	**Departmental Elective Paper-4**	4	0	0	4	30	70	100
		MSCP404	Project - II	0	0	12	12	100	200	300
			TOTAL	12	0	12	24	180	420	600

Departmental Elective Papers

Paper Code	Paper Title
E1	Properties of condensed matter
E2	Experimental technique in Physics
E3	Electronic Structure of Material and Semiconductors
E4	Low Dimensional Material

Open Elective Papers form the Department of Physics

Paper Code	Paper Title
O–1	Physics in Everyday life
O–2	Industrial Nanotechnology

M.Sc. (Physics)

MSCP101: Mathematical Physics	**Credit: 4**

Rationale: This course is designed to fill up the gaps at undergraduate level. It intends to develop competency in the applied mathematical skills required at higher-level physics. Students will be trained with the rigor required to solve a wide range of problems in the physical sciences.

Catalogue description: Selected topics with application to physics in vectors and matrices, linear algebra theory, complex variables, Green's functions, partial differential equations, integral transforms and equations are covered widely followed by topics involving special functions and hyper geometric functions, solutions for special types of wave functions so as to specialise in other areas of physics.

Pre-requisite: Basic vectors and matrices, functions and derivatives, sets, integral properties.

Course contents:

Unit.1.Matrices and Tensors: Vector spaces and matrices, orthogonal and unitary matrices, Hermitian matrices, eigenvectors and eigenvalues, diagonalisation of matrices, tensors: covariant and contra variant tensors, symmetric and skew symmetric tensors, line elements and metric tensor, geodesics, covariant and contra variant derivatives, Christoffel's symbols, Riemann curvature tensors.

Unit.2.Complex Analysis: Complex algebra, graphical representation, derivatives of complex functions, analytic functions, Cauchy-Riemann condition, harmonic functions, complex integration, Cauchy's integral theorem and formula, Taylor series, Laurent series and singularities, Cauchy's residue theorem and its applications, conformal mapping and its applications.

Unit.3.(a)Group Theory: Groups, subgroup, invariant subgroups, factor groups, generator of groups, conjugacy groups, homomorphism and Isomorphism, group representations, reducible and irreducible representations, lie group, SO(2) & SU(3), group theory applications.

(b)Fourier Series and Integral Transformation: General properties of Fourier series and its applications. Fourier and Laplace transforms and their applications.

Unit.4.(a)Ordinary Differential Equations and Special Functions: Properties of beta and gamma functions and their relationship, Pochhamer symbols, series solution-Frobenius' methods in Legendre, Laguerre, Hermite, Bessel functions, hyper geometric and confluent functions (recursion relations, generating functions, Rodrigue's formulae, their relations and orthogonality). **(b) Partial Differential Equations:** Solutions for Laplace, wave, and Helmholtz equations by the method of separation of variables and Green's function method.

Text Books:

1. Mathematical Methods for Physicists 7th ed.- George B. Arfken, Weber, and Harris, Academic Press. (2011).
2. Matrices and Tensors for Physics 3rd ed.- A.W. Joshi, New Age (1995).

Reference books:

1. Advanced Engineering Mathematics 8 ed-E. Kreyzig, Wiley (2006).
2. Elements of Group Theory for Physicists 5th ed.-A.W. Joshi, New Age International Publishers(2018).

MSCP102: Classical Mechanics	**Credit: 4**

Rationale: This core course is designed according to advanced learning of mechanics. The course aims to develop a comprehensive knowledge and mathematical skills to solve practical problems in physics. Special emphasis has been given to understand various basic principles of mechanics and their applications.

Catalogue description: The course begins mechanics with the Lagrangian and Hamiltonian formulations. It introduces Hamilton's principle, variational principle, canonical transformation and Hamilton-Jacobi theory and method of separation of variables. Next the mechanics of central force, rigid body and the phenomenon of small oscillations have been given. Relativistic classical mechanics applied to special theory of relativity is also added.

Pre-requisite: General Newtonian mechanics, rotational and planetary motion, principle of relativity.

Course contents:

Unit.1.Lagrangian Dynamics and Hamiltonian Formulation: Constraints, Lagrange's and Hamilton's equations from D'Alembert's principle and variational principle, velocity dependent potentials; applications of Lagrange's equations of motion, Hamilton's principle, Lagrange's equations from Hamilton's principle, conservation theorems for energy, linear and angular momentum, phase space and Hamilton's canonical equations of motion from variational principle.

Unit.2.Canonical Transformation and Hamilton Jacobi Theory: Modified variational principle and canonical transformation, Lagrange and Poisson brackets and other canonical invariants, Jacobi identity, angular momentum- Poisson bracket relations, Hamilton-Jacobi equation, method of separation of variables; method of action-angle variables and its examples.

Unit.3: (a) Central Force Motion: Reduction of two body problem to one-body problem, general properties of central force, effective potential, motion in a central force field – general solution, inverse square law force. Kepler's laws and laws of gravitation, orbits of artificial satellites, satellite parameters, Virial theorem, scattering in a central force field and in laboratory co-ordinates.

(b)Rigid Bodies: Kinematics of rigid body motion, orthogonal transformations, Euler's theorem and its applications, finite and infinitesimal rotations, rate of change of a vector, the rigid body equation of motion, Coriolis effect, angular momentum and kinetic energy of motion about a point, the inertia tensor and the moment of inertia, the principal axis transformation, Euler equations of motion.

Unit.4(a). Small Oscillations: Lagrange's equations of motion for small oscillations, eigen value equation and normal coordinates and frequencies for systems with many degrees of freedom, problems for small oscillations-parallel, double, linear triatomic molecule and vibration strings.

(b)Relativistic classical mechanics: Review of special theory of relativity - Lorentz transformations; 4-vectors, 4-dimensional velocity and acceleration; 4-momentum and 4-force; decay of a particle and elastic scattering; covariant Lagrangian and Hamiltonian of a relativistic particle.

Text Books:

1. Classical Mechanics 3rd ed -Herbert Goldstein, Pearson Education(2011).
2. Classical Mechanics 1st ed.- N. Rana & Pramod Joag, Mc Graw Hill(2013).

Reference Books:

1. Mechanics: Vol. 1 3rd ed -L.D. Landau &E.M. Liffshitz, Butterworth-Heineman (1982).
2. Mathematical Methods of Classical Mechanics 2nd ed- V.I Arnold, K. Vogtmann, A. Weinstein, Springer(2013).

MSCP103: Quantum Mechanics **Credits:4**

Rationale: This core course will enable the students to apply the concept of quantum mechanics for problem solving at atomic and subatomic scale to describe the behaviour of matter and energy through critical thinking in physical world.

Catalogue Description: This course gives the concept of basic quantum mechanics and mathematical skills required to study of structure of atoms and nuclei. It gives idea about the relation between momentum and energy at different situations and interaction of quantum particles. Conceptual idea about the quantum particles in relativistic world is also enlightened.

Pre-requisite: Matrix and linear algebra, In depth knowledge of calculus sequence, exposure to ordinary differential and partial differential equations.

Course contents:

Unit-1: Introduction to Quantum Mechanics: Heisenberg's uncertainty principle, probabilistic interpretation of wave packets, Hilbert Space and wave functions, Dirac notation, matrix representations of vectors and operators, postulates of quantum mechanics, time evolution of expectation values-symmetry and conservation laws for linear and angular momentum, energy, parity, time reversal, time independent and dependent Schrodinger equation and its applications-particle in different potentials.

Unit-2: Theory of Angular Momentum: General formalism of angular momentum, eigen values and eigen functions of L^2 and L_z and commutation relations, rotations and addition of angular momentum, Clebsh-Gordon Coefficients, coupling of orbital and spin angular momenta.

Unit-3: (a) Perturbation Theory: Time-independent and dependent perturbation theory: non-degenerate and degenerate cases and applications, Fermi's golden rule, variational principle, WKB approximation and their applications, adiabatic and sudden approximations- electric dipole selection rules,

(b) Scattering Theory: Scattering cross-section, scattering amplitude, laboratory and centre of mass coordinate systems, Born approximation and its validity, partial waves analysis, scattering by a central potential and its applications scattering of identical particles and its examples.

Unit-4: (a) Identical Particle: Symmetric and anti-symmetric wave functions, collision of identical particles, spin angular momentum, spin and space wave functions for many-electron system.

(b) Relativistic Quantum Mechanics: Klein-Gordon equation and its interpretation, particle in a coulomb field, Dirac equation for free particle, covariant form of Dirac equation, Dirac matrices, probability density, plane wave solution, negative energy states. spin of Dirac particles.

Text Books:

1. Quantum Mechanics: Concepts and Application, 2nd ed- Nouredine Zettili, Wiley India Pvt. Ltd (2016).
2. Quantum Mechanics: Theory And Applications 5th ed.- Ajoy Ghatak and S.Lokanathan, Macmillan Publiser(2012).

Reference books:

1. Quantum Mechanics, 4th ed- L.I. Schiff J. Bandhyopadhya, McGraw Hill Education (2017).
2. The Principles of Quantum Mechanics 4th ed., - P. A. M. Dirac, Clarendon Press(1981).

MSCP104:Electronics	**Credits:4**

Rationale: This core course enables the students to comprehend the theory, concepts, characteristics and working principles of basic electronic devices and their activities in electronic circuits. The knowledge acquired by the students helps them to design, test, troubleshoot, and rectify faults in electronic circuits.

Catalogue Description: The course gives the understanding of the basics of electric circuits and circuit elements and the characteristics of various electronic components and their applications. In-depth knowledge of the op-amp is introduced in the third unit. It also focuses on the basics of digital electronics, its designing, and applications.

Pre-requisite: Fundamental knowledge of electronic components and circuit theorems, basic knowledge of atomic theory, band theory: concept of hole, knowledge of solving differential equations.

Course contents :

Unit-1: Network Theory: Elements of electronic circuits, DC and AC circuits with resistor, inductor, capacitor, network theorems, Thevenin's and Norton's equivalent circuits, maximum power transfer theorem: impedance matching, mach analysis, loop analysis and node analysis techniques, equivalent networks.

Unit-2: Semiconductor Devices: Semiconductor diode and its temperature dependence characteristics, junction capacitance, applications of p-n junction diode, Zener diode and its applications, varactor diode, tunnel diode, photodiode, light emitting diode, Gunn diode, bipolar junction transistor – various configurations, h parameters, biasing schemes, applications, transistor based amplifier, field effect transistors: JFET and MOSFET, characteristics, parameters, applications of FET and MOSFET (amplifiers).

Unit-3: Operational Amplifier: Differential amplifiers - DC analysis, OP-AMP: characteristics and different parameters of OP-AMP, open loop and closed loop configurations, OP-AMP with negative feedback: voltage series feedback – effect of feedback of OP-AMP parameters, practical OP-AMP circuits: mathematical operations, instrumentation amplifier. Oscillators: principle, types, frequency stability and response. The phase shift oscillator and LC tunable oscillator. OP-AMP in nonlinear applications- comparators, function generators, multi-vibrators.

Unit-4 (a) Digital Electronics: Number systems; logic families; logic gates; Boolean algebra; simplifying Boolean expressions; arithmetic circuits (adder, subtractor); flip-flops; registers; counters –design of counters, memories. A/D and D/A conversion: resolution and speed; various circuits. digital integrated circuits –RTL, DTL, TTL, ECL, MOS, CMOS, logic – characteristics, microprocessors.

(b) Digital Communication System: Digital communication, continuous wave modulation and pulse modulation, modem, multiplexing, satellite communication.

Text Books:

1. Electronic Principles 7th ed- Albert Malvino, David J. Bates, Tata McGraw Hill Pvt. Ltd (2013).
2. Integrated Electronics Jacob Millman, Christos Halkias and Chetan Parikh, McGraw Education(2017).

Reference books:

1. An Introduction to Analog & Digital Communications 2nd ed.- M. M Simon Haykin, Wiley(2012).
2. Op-Amps and Linear Integrated Circuits 4th ed.- R G Gayakwad, Pearson Education(2015).

MSCP105: Physics Laboratory I

Section A: Analog Electronics

1. Draw the [V-I] characteristic & calculate cut-in voltage, reverse Saturation current and static & dynamic resistances of –(a) A silicon diode (b) A Germanium diode (c) A Schottky diode (d) A switching diode
2. Draw the [V-I] characteristic of a Silicon diode & calculate cut-in voltage, reverse Saturation current and static & dynamic resistances at five different temperatures.
3. Draw the [V-I] characteristic of two different Zener diode & calculate cut-in voltage, reverse Saturation current, break down voltage .
4. Compare the Ripple Factor, Efficiency, Peak Factor and regulation characteristics of half wave rectifier, full wave rectifier and Bridge rectifier.
5. Study of Ripple and Regulation characteristics of full wave rectifier with and without capacitor filter.
6. To study Zener diode as voltage regulator (a) When input voltage in fixed and Load is variable and determine load regulation (b) When input voltage is varied and load is fixed to determine line regulation
7. To study the temperature dependence of reverse saturation current in a junction diode and hence to determine the band gap.
8. Draw the characteristics of a LDR and a photodiode for five different light illumination conditions.
9. Compare the Junction capacitance of a PN Junction diode and Schottky Diode.
10. To determine the value of Planck's constant (a) using a photoelectric cell (b) using Light emitting diode
11. To draw the static input and output characteristics curves of a transistor in CB configuration and determine its 'h' parameters
12. To draw the static input and output characteristics curves of a transistor in CE configuration and determine its 'h' parameters
13. To draw the common source drain characteristics and the transfer characteristics of a JFET and hence to determine the FET parameters.
14. To Determine the band gap by measuring the resistance of a thermistor as a function of temperature.
15. Study of the Common Emitter Amplifier/Common Collector/Common Base and for evaluation of Operating Point, Voltage Gain , Input and Output Impedance, Current Gain of the Amplifier.
16. To study and Measure the Frequency Response of FET Amplifier and measure the Various Parameters of FET Amplifier.
17. To study an emitter follower circuit and (a) plot the frequency response curve (b) measure the voltage, gain and current gain (c) find the input and output impedance of the circuit
18. To construct and study a small signal common emitter R-C coupled transistor amplifier and (a) plot the frequency response curve (b) find the mid-band voltage gain, input impedance and output impedance
19. To study an emitter follower circuit and (a) plot the frequency response curve (b) measure the voltage, gain and current gain and (c) to find the input and output impedance of the circuit
20. Study of Wien Bridge oscillator and effect on Output frequency with variation in RC combination
21. Study of Phase Shift oscillator and effect on Output frequency with variation in RC combination
22. Study of Colpitt Oscillator and effect on Output frequency with variation in LC combination.
23. Study of Hartley Oscillator and effect on Output frequency with variation in RC combination.
24. Study of Clap Oscillator and effect on Output frequency with variation in RC combination.
25. For a given OP-AMP the Transfer curve of OP-Amp and measure (i) input offset voltage (ii) offset current (iii) input bias current (iv)CMRR (v)Slew rate
26. To study the OP-AMP as an (a) Inverting amplifier (b) Non-inverting amplifier (c)A unity gain buffer (d) differential amplifier
27. Study of Operational Amplifier as an Adding Amplifier, average amplifier and Scaling Amplifier

28. To study the performance of an OP-AMP as a Differentiator and Integrator.
29. To construct a logarithmic amplifier and antilog(exponential) amplifier using an OP AMP and to study its performance
30. Study of an OP-AMP as voltage to current and current to voltage Converter
31. To study the performance of a simple voltage comparator using OP-AMP
32. To study the performance of the weighted-resistor digital-to-analog (D/A) converter using OP-AMP
33. To study the performance of R-2R ladder digital-to-analog (D/A) converter using OP-AMP
34. Study of Operational amplifier as a comparator and zero crossing detector and to study Operational amplifier as a schmitt trigger.
35. Study of Z, Y and h parameter of a passive two port network
36. Verification of (a) Thevenin`s Theorem (b) Norton`s Theorem (c) Maximum Power Transfer (d) Reciprocity Theorem (e) Superposition Theorem (f) Tellegen`s Theoram
37. To Study of AC bridges (a) Maxwell`s Capacitance Bridge (b) De Sauty`s Bridge (c)Schering Bridge (d) Owen`s Bridge (e) Anderson`s Bridge (f) Maxwell`s Inductance Bridge (g) Kelvin`s Bridge
38. To Study of RC circuit to verify $X_c = \frac{1}{c\omega}$ and LC circuit to verify $X_L = L\omega$
39. To study of resonance in series RLC circuit and determine its Q factor
40. To study of resonance in parallel RLC circuit and determine its Q factor
41. Plot the frequency response of (a) Low Pass Filter determine High cut-off frequency, band gain of the filter (b) Low Pass Filter determine Low cut-off frequency, band gain of the filter (b) Band pass filter and determine low cut-off frequency and high cut off frequency

Section B: Digital Electronics

1. Introduction to Digital Laboratory Equipment’s & IC to study basic gates and verify their truth tables.
2. To realize Basic gates (AND,OR,NOT,XOR,XNOR) From Universal Gates(NAND & NOR).
3. Construction of AND,OR,NOT,XOR,XNOR using resistor, diode and transistor.
4. Design and construction of half adder, half subtractor, full adder and full subtractor using Universal gates.
5. Design and construction of half subtractor and full subtractor using Universal gates.
6. Design and construction of binary to gray code conversion circuit & Vice-Versa.
7. Design and construction of binary to XS-3 code conversion circuit & Vice-Versa.
8. To design and implement encoder and decoder
9. To design and implement multiplexer and demultiplexer
10. Four-bit parity generator and comparator circuits
11. Design of combinational circuit for BCD to decimal conversion to drive 7-segment display using multiplexer.
12. To design and construct basic flip-flops (RS, JK and D Type)using Universal logic gates
13. Realization of Universal Register using JK flip-flops and logic gates.
14. Realization of Universal Register using multiplexer and flip-flops.
15. To design and construct of Synchronous Up/Down counter.
16. To design and construct Asynchronous Up/Down counter.
17. Realization of Ring counter and Johnson’s counter.
18. Design of Sequential Counter with irregular sequences. 20 Programming on microprocessor

MSCP106: Physics Laboratory II

Sl. No.	*Name of Experiment*	*Aim of Experiment*
1	Hall Effect Experiment	Measurement of Hall Coefficient, Carrier Density and Carrier Mobility of a given sample.
2	Magnetoresistance	Measurement of magnetoresistance of a given sample.
3	Dielectric Constant in Liquid	Measurement of dielectric constant of a non – conducting liquid.
4	Quinck's Tube Method Experiment	Measurement of magnetic susceptibility of a given substance in liquid form by Quinck's Tube method.
5	Four Probe Set-up *(semiconductor)*	Measurement of resistivity and energy band bap of a given semiconductor chip as a function of temperature.
6	Planck's Constant	Determination of Planck's constant and hence verify the inverse square law of radiation using different colour filters.
7	Ultrasonic Interferometer	Measurement of ultrasonic velocity in liquid
8	Zeeman effect	a. Measurement of Bohr magneton b. Analysis of polarization of a light beam
9	Franck-Hertz Experiment	To measure the excitation potential of an atom of a given sample.
10	P-N Junction	To study the following parameters; a. Reverse saturation current . b. Temperature coefficient of junction voltage and energy band gap. c. Depletion capacitance and its variation with reverse bias.
11	Malus Law Experiment	To verify Malus law using a plain glass plate and a polaroid.

MSCP201: Electrodynamics Credits: 4

Rationale: Electrostatistics and magnetostatics are introduced so as to link from the undergraduate levels to advanced levels on electromagnetic theory. Electromagnetic Theory covers the basic principles of electromagnetism so as to enable students for understanding physical phenomena and principles in postgraduate and research levels.

Catalogue description: This course consists of two parts mainly: E&M theory with emphasis on the relativistic effects and wave physics.

Pre-requisite: Vector algebra and tensor, calculus, classical mechanics, methods for solutions of differential equations, concepts of relativity, and concepts of fluid mechanics.

Course contents:

Unit.1. Electromagnetic Field: Poisson`s and Laplace's equations, uniqueness theorems, multipole expansion, boundary value problems and its applications; scalar and vector potentials in magnetostatics, Maxwell's equations, energy in electromagnetic fields, Poynting theorem, momentum in electromagnetic fields, Maxwell equations in terms of electromagnetic potentials, non-uniqueness of EM potentials, Coulomb and Lorentz gauges.

Unit.2. Electromagnetic Interaction with Matter: Electromagnetic(EM) waves and propagation in different media, boundary conditions, reflection and refraction of EM waves, Fresnel formulae, Brewster's law and degree of polarization, total internal reflection and critical angle, reflection from a metallic surface, propagation of EM waves between conducting planes, wave guides: TE and TM modes, rectangular and cylindrical wave guides.

Unit.3. Fields of Moving Charges: Retarded potentials, Lienard-Wiechert potentials, field of a point charge in uniform rectilinear motion, radiation from an accelerated charged particle at low and high velocity. Radiating System*:* oscillating electric dipole, radiation from an oscillating dipole, linear antenna, antenna arrays.

Unit.4. Relativistic Electrodynamics: Transformation equation for current density and charge density, vector and scalar potentials, the electromagnetic field tensor, transformation equation for electric and magnetic field, covariance of Maxwell`s equations in four-tensor form, transformation law of Lorentz force.

Text Books:

1. Introduction to Electrodynamics- D. J. Griffiths, (4ed,2015)Pearson .
2. Classical Electrodynamics – J. D. Jackson, (3ed, 2007) Willey India.

Reference Books:

1. Feynman Lecture, Vol II (millennium ed,2012) Pearson
2. Foundation of Electromagnetic Theory, J.R. Reitz, R W Christy and F.J. Millford (2008) Addison Wesley
3. Classical Electrodynamics, W. Greiner, (1998) Springer.

MSCP202: Condensed Matter Physics Credit: 4

Rationale: This core course is designed to learn a comprehensive knowledge about the solid state physics. It gives a wide scope of learning a variety of mechanism, principles, and phenomenon in different materials.

Catalogue Description: This course introduces the crystallography in depth related to solid-state. Basic mechanism of thermal and electrical conductivity, optical and magnetic properties of solids has been given. The theory of superconductivity and its recent development has been added.

Pre-requisite: Basic of crystallography, thermal and electrical conductivity,

Course Contents:

Unit.1 Crystal Physics: Crystal solids, unit cells, two- and three-dimensional Bravais lattices, crystal systems, crystal planes and Miller indices, close packed structures, symmetry elements in crystals, point groups and space groups, crystal structure factor and determination: X-ray, electron and neutron diffraction, Ewald construction, reciprocal lattices and its applications to diffraction techniques, bonding in crystal: the van der Waals bond, cohesive energy of inert gas solids, ionic bond, cohesive energy and bulk modulus of ionic crystals, Madelung constant, the covalent bond, metallic bond; defects in crystals: point defects, line defects, Burger's vector, dislocation density, surface defects, grain boundaries and stacking faults.

Unit.2 Thermal and Electrical Conductivity in Solid: Thermal conductivity of solids: Einstein and Debye models; continuous solid; linear lattice; acoustic and optical modes; dispersion relation; attenuation; density of states; quantization of lattice vibrations, the concept of phonons and quantization; phonon momentum, inelastic scattering of neutrons by phonons, surface vibrations. Brillouin zones; thermal expansion, Boltzmann's transport equation, electrical and thermal conductivities of solid, Wiedemann-Franz law, Free electron theory of metals; Hall effect in metal, electrons in periodic lattice: Bloch theorem, the Kronnig- Penney model, band theory, classification of solids on the basis of band theory, effective mass of electron and hole, Fermi surface and Fermi gas, Fermi level, carrier concentration in extrinsic and intrinsic semiconductors.

Unit.3. Optical and Magnetic properties: Absorption and transmission in solid, scattering of light, optical transitions, excitons, activators, Franck-Condon principle, colour centres, photoluminescence and thermoluminescence, polarization, dielectric constants, Clausius-Mossotti relation, sources of polarization, frequency dependent of dielectric constants, ferroelectrics and piezo-electrics, origin of magnetism – various theories, temperature dependence, dia , para and ferromagnetic materials, domain structure, ferromagnetic domains, antiferromagnetism, magnetic hysteresis and coercive force.

Unit.4. Superconductivity: Superconductivity and its historical perspective, critical temperature, type-I and type II superconductors, persistent current, effect of magnetic field, Meissner effect, thermodynamics of superconductors, London and Pippard equations, Ginzburg-Landau equation, Giaever tunnelling, Josephson junction, superconducting quantum interference devices(SQUID), Cooper pair, BCS theory; energy gap; high Tc superconductors, applications of superconductors.

Text Books:

1. Introduction to Solid State Physics -C. Kittel (2019) Wiley India
2. Solid State Physics – A.J. Dekker (2014) Macmillian India.
3. Superconductivity –J.B Ketterson and S.N.Song, (1999) Cambridge Univ. Press

Reference Books:

1. Introduction to Solid State Physics – H.P. Myers, (2ed, 1997) CRC Press
2. Solid State theory – F. Seitz, (1957) Academic Press.
4. Superconductivity -Snoke

MSCP203: Atomic and Molecular Physics Credit: 4

Rationale: This core course intends to give a deep understanding about constitution of atoms and molecules though different kinds of spectra produced by them.

Catalogue Description: In the course, fundamental approximations of one- and multi-electron atoms are discussed quantum mechanically, where the effects due to spin, the fine structure, and the hyperfine structure are also taken into consideration. It also gives the deep understanding of interaction between atoms and their effect in different types of molecules. Some spectroscopic methods used to study atoms and molecules are also discussed.

Pre-requisite: Idea of quantum mechanics – various perturbation techniques and Knowledge of solving differential equations

Course Contents:

Unit-1: Fundamentals of Atomic Physics: Vector atom model, Larmor precession, spectroscopic terms, Lande g factor. Fine structure of hydrogen atom - spin-orbit interaction, relativistic correction, intensity of fine structure lines, Lamb shift, hyperfine structure of spectral lines, determination of nuclear spin. Ground state of two-electron atoms and their spectra– perturbation theory and vibrational method, para and ortho states, Pauli exclusion principle, excited states, doubly excite states, Auger effect, resonance.

Unit-2: Many Electron Systems and Alkali Spectra: Hund's rule, L-S and j-j coupling schemes, fine structure of sodium d line, Lande interval rule, central field approximation, Thomas-Fermi model, Hartee-Fock method and self-consistent field, the idea of Hartee-Fock equations, density functional theory. The spectra of alkali atoms using quantum defect theory, selection rules for electronic and magnetic multiple radiations, oscillator strengths, Thomas Reich-Kuhn sum rule. Zeeman effect, Paschen-Back Effect, Stark effect, hyperfine structure, spectral broadening.

Unit-3: Fundamentals of Molecular Physics: Born-Oppenheimer approximation, Rotational spectra of diatomic molecules: rigid rotator model, Isotopic effect of rotational spectra, intensity of rotational spectra, non-rigid rotator, vibrational spectra of diatomic molecules: enharmonic effect, diatomic vibrating rotator, interaction of rotational vibration, breakdown of Born-Oppenheimer approximation, electronic spectra of diatomic molecules: Fortrat diagram, electronic structure of polyatomic molecules.

Unit-4: Molecular Spectroscopy: Raman spectroscopy: classical and quantum theory, rotational and vibrational structure of Raman spectrum of diatomic molecule, intensity alterations, applications of IR & Raman spectroscopy, resonance spectroscopy, electron spin resonance (ESR): nuclear interaction and hyperfine structure, relaxation effects and applications; nuclear magnetic resonance (NMR): interaction of nuclear magnet with external field, chemical shift, spin–spin interaction and applications; Mossbauer effect and its applications.

Text Books:,

1. Introduction to Atomic spectra – White, (1934), McGraw-Hill, US
2. Molecular Spectra and Molecular Structure–Herzberg (1950) D.Van Nostrand Company
3. Physics of Atoms and Molecules - B H Bransden and C J Joachain, (2014) Pearson Prentice Hall

Reference Books:

1. Atomic spectra & atomic structure- Gerhard Hertzberg (2ed,2010) Dover publication, New York.
2. Molecular structure & spectroscopy, G. Aruldhas, (2ed, 2007) Prentice – Hall of India, New Delhi.
3. Fundamentals of molecular spectroscopy, Colin N. Banwell Elaine M. McCash, Tata McGraw –Hill (1996)
4. Mossbauer Effect: Principles and Applications – G K Werthiem (1964), Academic Press

MSCP204: Computational Physics Credit: 4

Rationale: This core course intends to teach students to develop mathematical models and use computer programming for simulating real world physical problems.

Catalogue Description: The paper provides the skill of C programing for scientific computation so that student can use this knowledge for solving various mathematical and physical problems. It provides the knowledge of various numerical techniques used to solve mathematical problems which cannot be solved analytically and some basic idea of simulation of scientific problems.

Pre-requisite: Fundamental knowledge of computers, basic mathematical skill.

Course Contents:

Unit-1: Fundamentals of Computer Programming: Various programming languages and packages, algorithm and flowcharts, programming in C: constants, variables, expressions, conditional statements, loops, arrays, logical expressions, control statements, functions, structures, pointers, bit operation, files in C, solving problems using C programming language.

Unit-2: Numerical Computations: Errors in numerical computations, general error formula, linear and quadratic convergence – Aiken's acceleration formula, roots of nonlinear equations: iteration method, bisection, Newton-Raphson, secant method, system of nonlinear equations: Gauss elimination method, Gauss-Jordan method, inverse of a matrix using Gauss-Jordan method, iterative methods: Gauss-Jacobi method, Gauss- Seidel method, eigen value problem, LU decomposition methods, Newton's method for nonlinear systems, interpolation and curve fitting: method of least squares, fitting a straight line and a parabola, fitting different types of data into a straight line, method of group averages.

Unit-3: **Finite Difference Calculus:** Operators in finite difference calculus, Newton's forward and backward difference formula, Gauss forward and backward difference formula, Stirling's formula, Lagrange's interpolation formula, Newton's general interpolation formula, numerical differentiation: derivatives using different interpolation formulae, maxima and minima of a function, numerical integration: general quadrature formula, trapezoidal rule, Simpson's rule, two and three point Gaussian quadrature formulae, double integration, Gauss- Legendre integration, ordinary differential equations: initial value problem - Euler's method, modified Euler's method, Runge-Kutta method, Tylor's series method, Picard's method; boundary value problem, partial differential equation- Laplace equation, Poisson equation, heat equation, wave equation, numerical solutions of Schrodinger's equations and electrostatic field problems.

Unit-4: Simulation: A system and its model, basic nature of simulation, simulation of continuous and discrete systems; stochastic simulation: generation of random numbers with different probability distributions; Monte Carlo method, molecular dynamics, density functional theory, electromagnetic wave analysis, high-performance computing.

Text Books:

1. An Introduction to Numerical Analysis by Kendall E. Atkinson (2008), John Wiley &Sons.
2. Computer Oriented Numerical Methods by V. Rajaraman (1993), PHI Learning

Reference Books:

1. Programming in C by Balguruswamy (7ed,2007)McGraw-Hill

MSCP205: Physics Laboratory III

The aim of this laboratory course is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. It highlights the use of computational methods to solve problems.

SECTION A : Fundamental C programming skills will be taught to the student through a number of programs related to various topics of C programming		
	To print sample strings like with different formats using escape sequences.	
	To print different data types in 'C' and their ranges.	
	To initialize, assignment & printing variables of different data types	
	To use constants, variables and data types, operators and expressions	
	To use manipulators for data formatting	
	To use control statements (decision making and looping statements) ➔ *If- else* statement, *if- else if* statement , nested if, switch statement ➔ *for* loop, *while* loop, *do-while* loop , nested loop ➔ Conditional and unconditional looping	
	To use jumping statements - switch, goto, break . continue ternary operator	
	To use arrays (1D & 2D) and strings	
	To use 'functions'	
	To use 'structures and unions'	
	Mathematical operation of matrices	

SECTION B: In this section, use of different numerical techniques through computer programming will be explained.

	Root of polynomial equations : Bisection method, Ragula-Falsi method, Newton Raphson method, Muller's method	
	Solution of system of equations: Gauss Elimination method, Gauss-Jordan method, factorization method, Gauss-Seidal iteration method, power method	
	Interpolation: Newton's forward interpolation method, Newton's backward interpolation method, Lagrange's interpolation method, Newton's divided difference method	
	Differentiation and integration : Derivatives using forward difference formula	
	Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule	
	Picard method, Taylor's method, Euler's method, Euler's modified method, Runge-Kutta method, Milen's method, Adams-Bashforth method	
	Solution of differential equations: Solution of Laplace equation, solution of Poisson's equation, solution of Heat equation, solution of wave equations, solution of Schrodinger equations	
	Curve fitting: Method of least squares, method of group averages, method of moments	

SECTION C: In this section, using numerical techniques and computer programing, different types of physics problems are solved using simulation.

MSCP206: Physics Laboratory IV

Sl. No.	*Name of Experiment*	*Aim of Experiment*
1	Hall Effect in Metal	Determination of Hall Coefficient of a given sample.
2	Nuclear Magnetic Resonance (NMR)	Determination of g-factor by NMR spectrometer.
3	Four Probe Set-up for Large Sample	Mapping the resistivity of the given thin film.
4	Dielectric Constant	To study the dielectric constant and determination of Curie temperature of a given ferroelectric ceramics.
5	Four Probe *(very low to high resistive sample)*	Measurement of resistivity of a given thin film at different temperatures.
6	Guoy's Method	Determination of magnetic susceptibility of a given metal sample.
7	Hysteresis Loop Tracer	To study the following parameters; a. Coercivity b. Saturation Magnetisation c. Retentivity
8	Fourier Analysis	To study the Fourier components of a complex wave.
9	Lattice Dynamics	a. Study of the dispersion relation for the mono and di-atomic lattice. b. Determination of the cut-off frequency of mono-atomic lattice.
10	Dielectric Constant	To study the dielectric constant and determination of Curie temperature of a given ferroelectric ceramics.
11	G M Counter	a. To determine plateau and optimal operating voltage. b. To verify the inverse square relationship between distance and intensity of radiation c. To investigate the attenuation of radiation via absorption of beta –particles.
12	Faraday effect	a. To observe the interaction of light and matter b. To measure Verdet constant for several materials and hence to determine the value of e/m.

MSCP301: Statistical Mechanics   Credit: 4

Rationale: Advanced levels of thermodynamics from under graduate levels are targeted so as to familiarise and apply in other domains of physics. Integrated treatment of thermodynamics and statistical mechanics is a must for in depth understanding.

Catalogue description: This course offers an introduction to probability, statistical mechanics, thermodynamics and explores topics to modern statistical mechanics. Topics include: classical statistical mechanics, interacting systems, quantum statistical mechanics, and identical particles. Concepts in statistical mechanics include macroscopic variables and thermodynamic equilibrium, fundamental assumptions of statistical mechanics, and micro canonical and canonical ensembles.

Perquisite: Undergraduate thermodynamics and quantum physics, *vibrations and waves, differential equations,* elementary concepts of errors.

Course content:

Unit. 1. Statistical Thermodynamics: Specification of states, connection between thermodynamics and statistical thermodynamics, Phase space, trajectories and density of states, macroscopic and microscopic states, postulates of equal a priori probability, Liouville's theorem, Ensembles and their types, Entropy of mixing, Gibb's paradox, Energy and Density fluctuations, density matrix

Unit. 2. Partition Functions and ensembles: Concept of partition function and derivation of thermodynamic quantities for each ensembles, classical ideal gas, free energy, chemical potential, Boltzmann partition function and classical partition function, Application to an ideal diatomic gas, Classical harmonic oscillator, magnetic dipoles in a magnetic field. Inadequacy of classical theory, Quantum mechanical ensemble theory, equivalence of various ensembles, ensembles in quantum statistical mechanics., Virial and equipartition theorems in different ensembles.

Unit. 3. Statistical Distributions: Connection between entropy and probability, M.B, F.D and B.E statistics ,Applications of three different statistics in classical ideal gas , equipartition theorem, Ideal Fermi and Bose Gas, Equation of state, Landau Diamagnetism, De Hass Van Alphen Effect, Pauli paramagnetism, photons, phonons, Bose-Einstein condensation, liquid Helium, thermionic and photoelectric emissions, **Unit.4. Probability and Phase Transitions :** Fundamental of probability, random variables, special distributions – Normal, Gaussian and Poisson distributions, phase transitions, first and second order phase transitions, critical indices and dimensionality, Ising model, Onsager Relations and applications

Text Books:

1. Statistical Mechanics, K. Huang, John Willey and Sons (2nd Edition) (1987).
2. Statistical Mechanics, R.K. Pathria, Bufferworgh Heinemann (2nd Edition) (2006)
3. Fundamentals of Statistical Mechanics, B.B. Laud, New Age International Publication (2003)

Reference Books

1. Fundamentals of Statistical and Thermal Physics, - F. Reif, McGrawHill International Edition (1985)
2. Statistical and Themal Physics: An introduction, By Loknathan, S., Gambhir, R.S. PHI Lesrning Pvt. Ltd. (2008)
3. Statistical Mechanics – B.K. Agarwal and M. Eisner
4. Statistical Mechanics – S.K. Singh
5. Statistical Physics – J.K Bhattacharya

MSCP401: Nuclear and Particle Physics — Credit: 4

Rationale: This core course explores the fundamental physics about the structure of matter at the subatomic level which will enable students to follow up recent progress of nuclear and particle physics.

Catalogue description: It has covered wide range of nuclear phenomena. At the end of this course, it will provide with advanced academic training in the fields of particle physics.

Perquisite: Calculus, tensors, basic concepts of chemistry.

Course outline:

Unit. 1. Properties of Nucleus & Nuclear Forces: Shape and size, mass and relative abundances, spin and parity, binding energy & nuclear stability, nuclear compositions, quantum properties of nucleon states, radioactivity: laws of radioactivity, radioactive dating, radioactive series, theory of alpha, beta & gamma decays and their properties, nuclear forces: properties of nuclear forces, two nucleon systems-deuteron with potentials, n-p and p-p/n-n interactions at different energies, exchange forces and tensor forces, Yukawa's hypothesis, meson theory of nuclear force.

Unit. 2. **Nuclear Models**: Fermi gas model, liquid drop model and Bethe-Weizsacker formula, their applications; shell model and shell structure, extreme single particle shell model with potentials – square well, harmonic oscillator; spin orbit interaction, magic numbers, predictions of the shell model; collective nuclear model; superconductivity model (qualitative idea only).

Unit. 3. Nuclear Reactions: Types of nuclear reactions and conservation laws, nuclear reaction kinematics, nuclear scattering cross section determinations, compound nucleus disintegration, Breit-Wigner dispersion formula (one level), direct reactions, nuclear transmutation reactions, nuclear fission and fusion, nuclear reactors.

Unit. 4. Particle Physics: Broad classification of elementary particles and particle interactions in nature, conservation laws, symmetry classifications of elementary particles- Gell-Mann-Nishijima scheme, CPT conservation, quark hypothesis, particle accelerators and detectors: linear accelerators, cyclotron, synchrotron, gas-filled counters, scintillation detectors.

Text Books:

1. Concepts of Nuclear Physics: Bernard L Cohen. McGraw Hill (2017)
2. Nuclear Physics - D C Tayal , Himalaya Publishing House (2011)
3. Nuclear Physics – Irving Kaplan, Narosa (2002)

Reference Books

1. Nuclear and Particle Physics - Prof W.E. Burcham ,The late M. Jobes , Prentice Hall (1994)
2. Atomic Nucleus, R.D. Evans
3. Subatomic Physics, Frauenfelder and Henley, Prentice-Hall,
4. Nuclei and Particles, E. Segre.
5. Atomic and Nuclear Physics: Gopalakrishnan , MacMillan (
6. Concepts of Modern Physics: A. Beiser

E1: Properties of condensed matter Credit: 4

Rationale: This elective course aims to develop an in depth knowledge about properties materials of various class. Special emphasis has been made on the understanding of theory and application of magnetic and dialectic materials.

Catalogue content:: The course is designed to learn the thermal and electrical conductivity from classical to quantum level. Theory and concept of magnetic, dielectric and ionic material is incorporated. The diffusion mechanism and surface properties of material is also elaborated in the course.

Perquisite: Basic principles of thermal and electrical conductivity, energy band, p-n junction and diffusion in solid.

Course content:

Unit1 : Thermal and Transport Properties : Phonon phonon interaction , electron-phonon interaction, polaron, electron-electron interaction, Boltzmann transport equation, electrical conductivity of metals, impurity scattering and resistance, Wiedeman Franz law, thermoelectric effects, transport properties in presence of magnetic field – magnetoresistance, Hall effect, two band model, K-space analysis of electron motion in a uniform magnetic field, magnetoresistance for open orbits, cyclotron resonance, Azbel-Kaner resonance, Energy level and density of state in a magnetic field, Landau diamagnetism, de-Haas-van Alphen effect, quantum Hall effect. Kubo formula for electrical conductivity, various transport coefficients

Unit 2: Magnetic Properties: Quantum theory of magnetism, Landau diamagnetism, magnetism in rare-earth and iron group atoms, Van-Vleck Paramagnetism and Pauli paramagnetism, temperature dependence of magnetic materials, Heisenberg exchange interaction in ferromagnetic material, magnetic domains –magnetostatic energy, magnetostrictive energy, Neel and Bloch wall, Bloch $T^{3/2}$ law, Neel model of antiferromagnetism and ferrimagnetism. magnetic anisotropy and magnetostatic interactions- direct, exchange, indirect exchange and itinerant exchange, spin waves - magnons, measurement of magnon spectrum, magnetic resonance and crystal field theory, Jahn-Teller effect, pinning effects, Kondo effect, spin glass, solitons.

Unit 3: Dielectric and Ionic properties: Dialectic properties in solid – polarization, electrical conduction, dielectric loss, breakdown of dialectics, nonlinear dielectrics – ferroelectrics, junction capacitor, piezoelectric, electrets, impedance spectroscopy, complex dielectrics, eclectic modulus. Ionic conduction in solid: defect in solid, conduction mechanism, Nernst Einstein equation, cataonic, protonic and anionic conductor, temperature and frequency dependent of conductivity, hopping mechanism, universal power law (Jonscher's Power Law) oxygen ion conductor, solid electrolyte, fuel cell, SOFC.

Unit. 4. Diffusion and surface properties: Various types of diffusion, Fick's laws of diffusion, Kirdendall effect, surface diffusion, generalised Hooke's law strain energy function cauchy relations. Propagation of elastic waves through cubic crystals. Determination of elastic constants. Surface and interface: structure of surfaces, electronic surface structure: surface charge density, surface events: surface plasmon, surface phonons, surface cleaving and interaction of gases with surfaces, adsorption on surface: physisorption, chemisorption, Langmuir Blodgett films, crystal face dependence, charge density effects from chemisorption, surface energy, surface tension, particle curvature and the Young-Laplace equation,

Text Books:

1. Solid-State Physics: Introduction to the Theory - James D. Patterson, springer (2009)
2. Solid State Physics - Neil W. Ashcroft , N. Mermin, Cengage (2003)

Reference Books:

1. Solid State Physics: An Introduction - Philip-Hofmann , Weinheim, Germany (2015)
2. Kittel's Introduction to Solid State Physics- Charles Kittel, Wiley India (2019)
3. Introduction To Solids Paperback – Leonid Azaroff (McGraw Hill) 1 Jul 2017

E2: Experimental technique in Physics Credit: 4

Rationale: This elective course is designed to learn a variety of experimental techniques associated with different instrumentation. This enables the students to acquire the necessary knowledge and working environment with the instruments for experimental research.

Catalogue Description: It introduces various approaches for study materials using of X-rays diffraction and electron and laser based microscopic techniques and theory behind them. A number spectroscopic techniques as well as thermal analysis techniques used to characterize materials is also discussed in this course. It also discussed the various techniques used for production of Low pressure and low temperature. A brief idea about the various types of errors appears in physics experiments and theory behind them is also enlighten in the course.

Pre-requisite: Fundamentals of X-ray diffraction, basic techniques of pressure and temperature measurements, Principle of lasers and spectroscopy, quantum mechanics.

Course Outline:

Unit 1:(a) Theory of Errors: precision and accuracy, error analysis, propagation of errors, Statistical theory of errors in different distributions normal, Gaussian and Poisson distributions

(b) X-rays and Its applications: Diffraction of X-ray, various X-ray diffraction methods, X-ray powder diffraction method -indexing of powder lines, Laue's method, rotational/oscillation method, determination of crystal structure and lace parameter, small angle x-ray diffraction and its applications. XPS, XRF and their applications.

Unit 2: Production of Low pressure and Low temperature: Production of low pressure -Rotary, oil diffusion, turbo molecular, getter and cryo pumps; gauges – Mcleod thermoelectric (thermocouple, thermistor and pirani), penning, hot cathode partial pressure measurement; leak detection; gas flow through pipes and apertures; effective pump speed; vacuum components, production of low temperature: Gas liquifiers; Cryo-fluid baths; liquid He cryostat design; closed cycle He refrigerator; low temperature measurement.

Unit 3: Lasers and spectroscopy: Lasers: Temporal and spatial coherence, Einstein coefficients, the threshold condition, two, three and four level laser systems, modes of a rectangular cavity and open planar resonator, quality factor, mode selection, The Ruby laser, The Helium-Neon laser, carbon dioxide (CO_2) laser, spectroscopic techniques and applications: Laser cooling, BE Condensation, Confocal microscopy, UV-Vis spectroscopy, FTIR spectroscopy, luminescence spectroscopy, Raman spectroscopy.

Unit 3: Analytical Instrument: Electron microscopy (SEM, TEM, HRTEM), scanning probe microscopy (AFM, MFM, STM), thermal analysis using DTA, TGA, DSC; electronic transport analysis using current vs voltage characteristics: two probe and four probe techniques, various types of contacts, dielectric and impedance spectroscopy, spectrum analyser, interferometers.

Text Books:

1. Elements of X-Ray Diffraction - BD Cullity , Pearson Education India (2014)
2. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press (2008).

Reference Books:

1. Physical methods for Materials Characterization, P. E. J. Flewitt and R K Wild, IOP Publishing (2003).

E3: Electronic Structure of Material and Semiconductors **Credit: 4**

Rationale: This elective course offers some advance topics of condensed matter related to electronic structures, energy bands and transport of charge carriers in materials .

Catalogue description: In this paper more stress is given on the understanding of advance theories of electronic band structure, charge carriers in semiconductors and its transport at quantum level. In-depth study of organic conducting and semiconducting materials is also incorporated.

Perquisite: Band theory of solids, fundamental idea of semiconductor, brief idea of organic materials, in-depth knowledge of quantum mechanics,

Course content:

Unit1: Energy band structures in solid: Band structure determination using nearly free electron approximation and the tight binding approximation, other methods for calculating band structure: independent electron approximation, valence band wave functions, cellular method, muffin-tin potentials, augmented plane wave (APW) method, green function (KKR) method, orthogonolized Plane wave (OPW) method, pseudopotential model, study of energy bands in solid on the basis of density: Practical DFT in a many body calculation and its reliability.

Unit 2: Semiconductor devices: Densities of carriers in extrinsic semiconductors and their temperature dependence , Fermi level, degenerate and non-degenerate semiconductors, bandgap engineering, carrier transport phenomena in semiconductor solids, drift and diffusion, transport by drift process: low field, high field and very high field (Impact ionization), Einstein relation, hole pair generation and recombination: band to band (direct and indirect band gap transitions) and intra band (impurity related) transitions, free - carrier & phonon transitions, excitons : origin, electronic levels and properties Radiative and nonradiative recombination (Shockley - Read - Hall and Auger) processes, carrier transport - continuity equations, optical constants: Kramers - Kronig relations, p – n Semiconductor junctions - Homo and hetero Junctions, minority and majority carrier injection, Semiconductors auantum structures, hetrojunctions and superlattices , Semiconductor photonic structures: 1D, 2D and 3D photonic crystals. Active and passive optoelectronic devices: performance and response enhancement

Unit 3: Organic Semiconductor

Conducting polymers- concept of solitons, polarons, biolarons, doping in conducting polymers, common conducting polymers, properties and applications of conducting polymers, PLED, sensors actuators. polymer organic semiconductor, electrical and optical properties of organic semiconductors, organic light emitting diodes (OLED) , way to perceive colors, conventional, transparent, inverted and flexible OLEDs, Hole injection, hole transport, emissive, electron transport and electron injection layers organic LEDs, organic thin films transistors (OTFT), OTFT based display technology, organic laser-Lasing process, optically pumped lasing structures, applications; Organic multilayer, photodetectors; organic photovoltaic cells;

Unit 4: Quantum Transport: Quantum electron transport, double barrier Resonant tunnelling structures, Coherent tunnelling and sequential tunnelling, negative differential resistance, single electron tunnelling, Coulomb blockade. ballistic transport, hopping conductivity, phase coherence, Aharonv-Bohm effect, quantized conductance, Landauer formula, quantum Hall effect, Kondo effect, Quantum electronic devices: single electron transistor, short channel MOS transistor, split-gate Transistor, electron eave transistor, quantum computer.

Text Books:

1. Solid State Physics - Neil W. Ashcroft , N. Mermin (1976)
2. Semiconductor Physics and Devices, 4th ed. – Donald Neamen and Dhrubes Biswas McGraw Hill(2017)
3. Solid-State Physics: Introduction to the Theory - James D. Patterson, springer (2009)

Reference Books:

1. Solid State Physics: An Introduction - Philip-Hofmann , Weinheim, Germany (2015)
2. Kittel's Introduction to Solid State Physics- Charles Kittel, Wiley India (2019)
3. Introduction To Solids Paperback – Leonid Azaroff (McGraw Hill) 1 Jul 2017

E4 : Low Dimensional Material Credit: 4

Rationale: This elective course is designed primarily to motivate the students to recent developing field of materials at nanoscale. Students can learn the theoretical development as well experimental techniques for their future research in this frontline area.

Catalogue description: The course introduces the fundamental of nanostructures, their properties, synthesis & characterization techniques and applications. Theory behind the magnetic nanostructures and their properties are incorporated in details.

Perquisite: Properties of metal and semiconductors, electrical conductivity mechanism and quantum mechanics.

Course content:

Unit. 1. Semiconductor nanostructures: Semiconductors at low dimension, clusters, artificial atomic clusters, novel properties of semiconductor clusters, electronic states in semiconductor nanostructures, Quantum mechanical treatment of quantum wells, wires and dots, Effective mass approximation theory and other models for determination of electronic structures in semiconductor nanostructures, Strong and weak confinement in semiconductor nanostructures, various classes of semiconductor nanostructures, optical properties of semiconductor nanostructures, phonons. Surface energy and surface tension at nanoscale, curvature and the Young-Laplace equation, chemical potential, DLVO theory, nucleation, Ostwald ripening, sintering

Unit 2. Nanostructure materials: Metallic nanostructures: properties of metal nanostructures, surface plasmons , Lorentz oscillator model, surface Plasmon resonance, Mie theory, stability of metal nanostrucrues ; Carbon at nanoscale: fullerene, carbon cluster, carbon nanotubes, graphene . Nanocomposites: metal-polymer nanocomposites, diblock copolymer based nanocomposites, Polymer/CNTs and Polymer/Nanoclay based composites, core-shell structured nanocomposites, ceramic based metal nanocomposites using SiC, CeO_2, TiO_2, ZrO_2 PTFE, CNT etc.

Unit 3 Synthesis and characterization of nanomaterials: Synthesis of nanomaterials, growth and morphology, nucleation, ostwald ripening, sintering, synthesis processes: thermal evaporation, RF sputtering, chemical bath deposition, chemical vapour deposition (CVD), pulsed laser deposition, ball milling, self-assembled mono layers, Epitaxy, Molecular beam epitaxy, pulsed laser deposition, lithography, characterization of nanomaterials using X-ray diffraction, electron microscopy, EDAX , AFM, MFM, STM, absorption and luminescence spectroscopy, , scanning near-field optical microscopy, Raman spectroscopy.

Unit 4: Magnetism at Nanoscale: Superparamagnetsm, spintronics, spin valve, Giant magnetoresistance, MR ratios, applications in spin valve and read heads, comparison of GMR and AMR, oscillation of coupling energy, non-coupling type GMR, CPP and CIP GMR, GMR in nano-grains, mechanism of GMR. Tunnel magnetoresistance: ferromagnetic tunnel junctions, experiments for TMR, phenomenological theory of TMR, MR ratio and spin polarization, factors influencing TMR, MR ratio for Fe/MgO/ Fe system, oscillations in TMR, tunnel junctions with manganites, Heusler alloys, nanoscale graunules, Coulomb blockade in tunnel junctions, ballistic magneto resistance

Text Books:

1. A Textbook of Nanoscience and Nanotechnology – T. Pradeep, McGraw Hill (2017)
2. Nanoscience and Nanotechnology: Fundamentals of Frontiers - Shubra Singh, M.S. Ramachandra Rao, Wiley (2013)
3. Characterization of Nanophase materials, Ed. Z L Wang, Willet-VCH (2000).

Reference Books:

1. Introduction to Low Dimensional Semiconductors- J.H.Davis, Cambridge university Press (1998)
2. Optical Properties of Semiconductors- U.Woggon, Springer-Verlag, (2000)

OPEN ELECTIVE PAPER

O1 : Physics in Everyday life **Credit: 4**

1. Physics and Life: Brief history of development of physics &its roles and importance to society and life, Life: Information, Matter, Energy and Temperature; Form and Forces; Fluids in the Body; Animals in Motion; Locomotion; Waves–the Carriers of Information; Sound; Body Electronics and Magnetic Senses; Continuity equation and its applications; Energy and metabolism of human body , Survival in cold and hot climates.

2. Language of Physics and its applications to other fields: Functions; differentiation; integration; Expansion of a function; differential equations and solutions applicable to physics and other fields; vector analysis; Measures of Central Tendency; Probability distribution functions and its applications; Matrix and their properties (only ideas); Beta and Gamma functions and their properties (Definitions and formulae & their applications only); Ideas of polarisation and magnetisation, Essential physical principles related to life process.

3. Non-conventional energy and Atmospheric physics: Wind Energy, Solar Energy, photovoltaic- solar cells & its applications, Ocean energy; Energy from Bio-mass; biochemical, thermo- chemical conversion of biomass; Geothermal Energy; Small hydropower: Assessment of hydropower, working principle of different types of turbines.

Physics of atmosphere, Composition and structure of the earth's atmosphere: physical and dynamic processes on layers, vertical variation of temperature; Residence time, Photochemical pollution, Atmospheric aerosol, Atmospheric pressure, Escape velocity, Ozone, Ozone hole, Ozone in polar region; Greenhouse effect and gases, Global warming, Principal forces acting on air masses (Gravitational force, Pressure gradient, Coriolis inertial force, Frictional force, Cyclones , anticyclones, Global convection, Global wind patterns).

4. Electronics in everyday life: Electrical charge, Ohm's law, electrical energy, power, watt, consumption of electrical power–kWh, resistance, capacitance, inductance, multimeter. AC and DC currents – RMS and peak values, House wiring , overloading, Earthing – construction of proper earthing, short circuiting – Fuses – color code for insulation wires, Inverter, UPS – online UPS and ofine UPS, generators and Electrical switches. Transformers. Semiconductor electronic devices – diode, transistor – applications. Electrical appliances: Electrical bulbs, Fluorescent lamps, LED lamps, electrical fans, water heater, electrical iron, mixer–grinder, Air conditioner and refrizarators, microwave oven, Voltage Stabilizer, induction cooker. Communication systems: Basic concepts of radio transmitter and receiver – Basic concepts of TV Transmitter and receiver, TV antennas – Dipole antenna – Folded dipole – Yagi antenna, Yagi antenna design, Dish antenna, DTH system, Mobile communication system, MODEM. Other modern way of communications.

OPEN ELECTIVE PAPER

O2 : Industrial Nanotechnology **Credit: 4**

1. Nanodimensional Materials: 0D, 1D, 2D structures − Size Effects − Fraction of Surface Atoms − specific Surface Energy and Surface Stress − Effect on the Lattice Parameter − Phonon Density of States − the General Methods available for the Synthesis of Nanostructures − precipitative − reactive − hydrothermal/ solvothermal methods − suitability of such methods for scaling

2.(a) Nanotechnology in electronic and electrical industry: Advantages of nano electrical and electron− ic devices −Electronic circuit chips − Lasers − Micro and Nano−Electromechanical systems − Sensors, Actu− ators, Optical switches, Bio−MEMS −Diodes and Nano−wire Transistors − Data memory −Lighting and Dis− plays − Filters (IR blocking) − Quantum optical devices − Batteries − Fuel cells and Photo−voltaic cells − Electric double layer capacitors − Lead−free solder − Nanoparticle coatings for electrical products

2(b) Nanotechnology in Pharmaceutical and Chemical Industry: Nanoparticles in bone substitutes and dentistry − Implants and Prosthesis − Reconstructive Intervention and Surgery − Nanorobotics in Surgery

− Photodynamic Therapy − Nanosensors in Diagnosis− Neuro−electronic Interfaces − Protein Engineering − Drug delivery − Therapeutic applications. Nanocatalyts − Smart materials − Heterogenous nanostruc− tures and composites − Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes)

− Molecular Encapsulation and its applications − Nanoporous zeolites − Self−assembled Nanoreactors − Organic electroluminescent displays

3(a) Nanotechnology in agriculture and Food Technology Nanotechnology in Agriculture −Precision farming, Smart delivery system − Insecticides using nanotechnology − Potential of nano−fertilizers − Nan− otechnology in Food industry − Packaging, Food processing − Food safety and bio−security − Contaminant detection − Smart packaging

(b) Nanotechnology in textiles and Cosmetics: Nanofibre production − Electrospinning − Controlling morphologies of nanofibers − Tissue engineering application − Polymer nanofibers − Nylon−6 nanocom− posites from polymerization − Nano−filled polypropylene fibers − Bionics− Swim−suits with shark−skin− effect,Soil repellence, Lotus effect − Nano finishing in textiles (UV resistant, antibacterial, hydrophilic, self

−cleaning, flame retardant finishes) − Modern textiles (Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear) Cos- metics – Formulation of Gels, Shampoos, Hair−conditioners (Micellar self−assembly and its manipulation)

− Sun−screen dispersions for UV protection using Titanium oxide − Color cosmetics

4. Economic impact of Nanotechnology:

Socio−Economic Impact of Nanoscale Science − Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria − The Emerging Nano Economy: Key Drivers, Challenges, and Opportunities − Transcending Moore's Law with Molecular Electronics and Nanotechnology − Semiconductor Scaling as a Model for Nanotechnology Commercialization − Sustaining the Impact of Nanotechnology on Productivity, Sustainability, and Equity.

References:

1. Mark A. Ratner and Daniel Ratner,*Nanotechnology: A Gentle Introduction to the Next Big Idea,*
2. Bharat Bhushan,*Springer Handbook of Nanotechnology,*
3. Neelina H. Malsch (Ed.),*Biomedical Nanotechnology,*

4. Jennifer Kuzma and Peter VerHage, *Nanotechnology in agriculture and food production, ,*
5. P. J. Brown and K. Stevens, *Nanofibers and Nanotechnology in Textiles,*