BANKURA UNIVERSITY
বাঁকুড়া বিশ্ববিদ্যালয়

SYLLABUS FOR M. Sc. IN PHYSICS
EFFECTIVE FROM 2018 – 2020 SESSION

Course Structure in Physics

	Paper	Core Subjects	Marks	Credit
SEMESTER I	PHYS101C	Mathematical Methods I & Classical Mechanics	50	4
	PHYS102C	Quantum Mechanics I & Classical Electrodynamics I	50	4
	PHYS103C	Solid State Physics I & Electronics I	50	4
	PHYS104C	Atomic Spectroscopy & Nuclear Physics I	50	4
	PHYS105 PR	General Practical	50	4
	106CF	Communicative English and Personality Development	50	0
	PHYS107 IA	IA	50	4
	TOTAL (SEM-I)		**300**	**24**

	Paper	Core Subjects	Marks	Credit
SEMESTER II	PHYS201C	Mathematical Methods II & Advanced Optics	50	4
	PHYS202C	Quantum Mechanics II & Classical Electrodynamics II	50	4
	PHYS203C	Solid State Physics II & Electronics II	50	4
	PHYS204C	Statistical Mechanics I & Nuclear Physics II	50	4
	PHYS205PR	General Practical	50	4
	206EF	1.Yoga and Life Skill 2. Education Value Education and Human Rights	50	0
	PHYS207IA	IA	50	4
	TOTAL(SEM-II)		**300**	**24**

	Paper	Core Subjects	Marks	Credit
SEMESTER - III	PHYS301C	Statistical Mechanics II & Molecular Spectroscopy-I	50	4
	PHYS302C	Computer Applications in Physics & Advanced Quantum Mechanics	50	4
	Major Elective Subjects			
	PHYS303ME	**A**. Advanced Electronics-I **B**. Laser Physics and Nonlinear Optics -I **C**. Nano Science and Nano-technology -I	50	4
	PHYS304ME	**A**. Advanced Electronics-II **B**. Laser Physics and Nonlinear Optics -II **C**. Nano Science and Nano-technology -II	50	4

	Students have to choose either **PHYS303ME A** & **PHYS304ME A OR PHYS303ME B** & **PHYS304ME B OR PHYS303ME C** & **PHYS304ME C.**			
	Minor Elective Subjects			
	PHYS305EID	Biophysics	50	4
	PHYS306PR	Advanced General Practical	50	4
	TOTAL(SEM-III)		**300**	**24**

	Paper	Core Subjects	Marks	Credit
SEMESTER-IV	**PHYS401C**	Molecular Spectroscopy-II & Nonlinear Dynamics	50	4
	PHYS402C	Relativity & Astrophysics	50	4
	PHYS403PR	Computer Practical & Social Out Reach	50	4
	PHYS404PJ	Project	50	4
	Major Elective Subjects			
	PHYS405ME	**A**. Advanced Electronics-III **B**. Laser Physics and Nonlinear Optics -III C. Nano Science and Nano-technology -III	50	4

The following are the options for students for major electives in Semester-IV as per their choice in Semester-III:

Opted in Semester-III	Option offered in Semester-IV
PHYS303ME A & PHYS304ME A	**PHYS405ME A**
PHYS303ME B & PHYS304ME B	**PHYS405ME B**
PHYS303ME C & PHYS304ME C	**PHYS405ME C**

	PHYS406PR	Advanced General Practical	50	4
	TOTAL(SEM-IV)		**300**	**24**

EACH LECTURE IS OF ONE HOUR DURATION

IN THE CORE PAPERS 80% OF THE MARKS WILL BE DETERMINED BY THE END SEMESTER AND 20% OF THE MARKS WILL BE DETERMINED THROUGH MID-SEMESTER.

SEMESTER – I **(TOTAL MARKS 300)** **(CREDIT 24)**

Paper: PHYS101C **[Marks 50]** **[Credit 4]**

Unit - I
Mathematical Methods – I

Complex variable: Functions. Brief review of the areas included in the honours syllabus: analytic functions, Cauchy-Riemann equations, integration in the Complex plane, Cauichy's theorem & integral formula. Liouville's & Moretra's theorem.

Taylor and Laurent series, Singular Points and their classification. Branch Point & branch Cut. Riemann sheets. Residue theorem & its application. Integrals involving branch point singularity.

Linear vector spaces, subspaces, Bases & dimension, Linear dependence and independence, Orthogonality of vectors, Gram-Schmidt Orthogonalisation procedure. Linear operators. Matrix representation. Matrix algebra. Special matrices. Rank of a matrix. Elementary transformations. Elementary and Equivalent matrices. Solution of linear equations. Linear transformations. Change of Basis. Matrix: Eigenvalues and eigenvectors. The Cayley-Hamilton theorem. Diagonalisation of matrices. Bilinear and Quadratic forms. Principal axis transformation. Functions of matrices. Powers, Roots, Exponential and Logarithm of a matrix.

Books Recommended:

1. M. R. Spiegel (Schaum's outline series) – Theory and Problems of Complex Variables.
2. George B. Arfken and Hans J. Weber (Academic Press) – Mathematical Methods for Physicists.
3. J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
4. P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.

Unit -II

Classical Mechanics

Review of Lagrangian and Hamiltonian formalisms in different systems. Legendre transformation. Hamilton's canonical equations and their applications. Lagrangian and Hamiltonian for relativistic particles. Principle of least action.

Canonical Transformation: Equations of point, generating functions, example. Lagrange and Poisson brackets and their applications. Invariance of Poisson bracket under canonical transformation; Equations of motion in Poisson Bracket; infinitesimal canonical transformation; constants of motion and symmetry principles; generators of infinitesimal symmetry transformation; Noether's theorem; integral invariant of Poincare. Conservation theorems and angular momentum relation in Poisson brackets. Liouville's theorem.

Hamilton-Jacobi equation: Hamilton-Jacobi equation for Hamilton's principle and characteristics functions; Physical significance of these functions; Application of Hamilton-Jacobi equation in linear harmonic oscillator, particle falling under gravity etc.; action and angle variables and its importance & applications; Path from classical to quantum mechanics.

Rigid body motion. Heavy symmetrical top with one point fixed on the axis. Fast and sleeping top.

Deformable bodies. Strain and stress tensor. Energy of elastic deformation.

Books Recommended:

1. Classical mechanics-Goldstein
2. Introduction to advances dynamics-McCuskey
3. Mechanics- Landau and Liftshitz.
4. Classical Mechanics- K.C. Gupta
5. Classical Mechanics- Rana and Jog

Paper: PHYS102C **[Marks 50]** **[Credit 4]**

Unit - I

Quantum Mechanics- I

Operator Algebra:

Vector space, concept of state vectors , principle of superposition of states, basis functions, change of basis, Bra and Ket vector and its characteristics, orthonormility, completeness condition and closure property, Hilbert space, Hermitian and Unitary operator and its characteristics, Fundamental postulates of Quantum mechanics, eigenvalue equation, Eigenvalues of Hermitian operator, orthogonality of eigenkets for non-degenerate eigenvalues for Hermitian operator, expectation value, projection operator, theorems of commutations of two operators, Uncertainty principle, Closure property for continuously varying Kets., relation between wave function (Ψ) and state vector $I\Psi>$, operator representation of position and momentum, relation between $\Psi(x)$ and $\Psi(p)$. Use of operator algebra for finding the angular momentum of electron in a spherically symmetric potential. Angular wave functions of the electron in a hydrogen like atom.

Equations of motion: Time dependence of expectation values, Schrodinger, Heisenberg and Interaction pictures, equation of motion in Schrodinger picture, time translation operator, transition to Heisenberg picture, equation of motion in Heisenberg and interaction pictures, stationary states.

Stationary states problem: (a) one dimensional problem, (b) delta function potentials and barriers, (c) three dimensional problems- S.H.O., Hydrogen problem.

Harmonic oscillator with operator algebra:

Creation and annihilation operators, Harmonic oscillator: Dirac's approach, Selection rule, solution of wave functions, Coherent state.

Books Recommended:

1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).
2) 'Quantum Theory' by D. Bohm (Prentice-Hall).
3) 'Quantum Mechanics: Theory and Applications' by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
4) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).

5) ‘Quantum Mechanics’ by Cohen and Tanandji.
6) Prabir Ghosh, Quantum mechanics, Narosa Publication

Unit - II

Classical Electrodynamics- I

Delta and Green function, Inhomogeneous wave equation: it’s solution.

Liénard–Wiechert potential, Fields of a uniformly moving charge, Fields of an accelerated charge: Fields, radiation (power) and angular distribution from a charge at low velocity (non-relativistic), radiation (power) from a charge at linear motion and circular motion or orbit, angular distribution of power for linearly accelerated charges, relativistic correction,

Bremsstrahlung-Cerenkov radiation. Radiation from a localised oscillating charges, near and far zone field, multipole expansion, dipole and quadrupole radiation, centre-fed linear antenna, classical theory of electron: radiation reaction from energy conversation: Lorentz theory, self-force.

Books Recommended:
1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics
6. ELECTRICITY AND MAGNETISM: E. M. PURCELL, D. J. MORIN

Paper: PHYS103C [Marks 50] [Credit 4]

Unit - I

Solid State Physics- I

Crystal structure and X-ray diffraction: Lattices and Unit cells, Symmetry, Reciprocal lattice, Brillouin Zone, Simple crystal structures: FCC, BCC, HCP, NaCl, ZnS and diamond, Waves in crystals, X-ray diffraction, Laue and Bragg condition, Ewald construction, derivation of amplitude of scattered wave, atomic form factor, crystal structure factor, geometrical structure factor, X-ray, electron and neutron diffraction.
Imperfection in solids: Different types of defects and dislocation, point defects and line defects, defect concentration, disorder.

Crystal binding: General considerations about bonding: ionic bonds, covalent bond, van der Walls-Fluctuating dipole forces-or molecular bonding, metallic bonding, hydrogen bonds.

Lattice vibrations: Lattice dynamics, harmonic approximation, vibration of monatomic and diatomic linear lattices, dispersion relations and normal modes, quantization of lattice vibration and phonons, anharmonic crystal interactions and thermal expansion (qualitative discussion only)

Magnetic properties of solids: Diamagnetism, paramagnetism – semi-classical treatment-paramagnetism for J=1/2, Brillouin function-van Vleck paramagnetism; ground state of an ion and Hund's rules, crystal field-quenching of orbital momentum, ferromagnetism-Weiss model, magnetic susceptibility, effect of a magnetic field, origin of the molecular field, anti-ferromagnetism-Weiss model, magnetic susceptibility, types of antiferromagnetic order, ferrimagnetism, ferromagnetic domains and domain walls, exchange interactions.

Books recommended:

1. F.C.Phillips: An introduction to crystallography (wiley)(3rd edition)
2. Charles A Wert and Robb M Thonson: Physics of Solids
3. J. P. Srivastava: Elements of solid state physics (Prentice Hall India; 2nd edition).
4. Christmaan-solid state physics (academic press)
5. A R Verma & O N Srivastava, Crystalolgraphic application to solid state physics

Unit - II

Electronics- I

Semiconductor Devices:

p-n junction physics- Fabrication steps; thermal equilibrium condition; depletion capacitance; current-voltage characteristics; charge storage and transient behavior; junction breakdown; heterojunction.

Characteristics of semiconductor devices- BJT, JFET, MOS, LED, Solar cell, Tunnel diode, Gunn diode and IMPATT.

Active Circuits:

Transistor amplifiers- Basic design consideration; high frequency effects; video and pulse amplifier; resonance amplifier; feedback in amplifiers.

Harmonic self-oscillators - Steady state operation of self-oscillator; nonlinear equation of self-oscillator; examples.

Op-Amp Circuits:

Characteristics of ideal and practical op-amp; Nonlinear amplifiers using op-amps- log amplifier, anti-log amplifier, regenerative comparators; Active filters; precision rectifiers; ADC and DAC circuits; Op-amp based self-oscillators: sinusoidal and relaxation oscillators; Voltage regulator.

Books Recommended:

1. J D Ryder, Electronics Fundamental and application, PHI
2. Gaykwad, Operational Amplifier.
3. Zee, Physics of semiconductor devices.
4. Milman and Grable, Microelectronics. Tata MacGraw Hill.
5. Chattopadhyay and Jain, Analog integrated circuits
6. Chattopadhyay and rakshit, Electronic Circuit analysis

Paper: PHYS104C **[Marks 50]** **[Credit 4]**

Unit - I
Atomic Spectroscopy

General discussion in Hydrogen spectra, Hydrogen-like systems, Spectra of monovalent atoms, quantum defect, penetrating and non-penetrating orbits, introduction to electron spin, spin-orbit interaction and fine structure, relativistic correction to spectra of hydrogen atom, Lamb shift, effect of magnetic field on the above spectra, Zeeman and Paschen-Back effect.

Spectra of divalent atoms: Singlet and triplet states of divalent atoms, L-S and j-j coupling, branching rule, magnetic field effects, Breit's scheme, complex spectra, equivalent electrons and Pauli Exclusion Principle.

Hyperfine structure in spectra of monovalent atoms, origin of X-rays spectra, screening constants, fine structure of X-ray levels, spin-relativity and screening doublet-laws, non-diagram lines, Auger effect.

Laser in Spectroscopy: Broadening of spectral lines, absorption spectroscopy, excitation spectroscopy, ionization spectroscopy, saturation absorption spectroscopy, photo acoustic spectroscopy, opto-galvanic spectroscopy, Tera Hertz spectroscopy.

Recommended books:
1. Introduction of atomic spectroscopy: H E White
2. Laser Spectroscopy: A Corney
3. Laser in Chemistry: D L Andrew
4. Physics of Atoms and Molecules: Bransden and Joachain

Unit - II

Nuclear Physics- I

Properties of nuclei: static and dynamic, parity and isospin of nuclei, Determination of nuclear size: mirror nuclei, muonic atoms and electron scattering methods, charge form factor. Magnetic dipole moment and electric quadrupole moment; Experimental determination. NMR.

Two-nucleon problem and nuclear forces: Deuteron problem; ground state and excited states, two-nucleon scattering, partial wave analysis, phase-shift, scattering length, n-p and p-p scattering, charge symmetry and charge independence of nuclear forces. Form of nucleon-nucleon potential; Exchange nature of nuclear forces, elementary discussion on Yukawa's theory.

Nuclear models : Introduction; Fermi gas model: Derivation of Fermi energy and ground state kinetic energy for nucleons, Spherical shell model: Extreme single particle model: Spin orbit interactions and reproduction of magic numbers; Predictions of shell model: Ground state spin

parity; Magnetic dipole moment and electric quadrupole moment; Single particle model; Introduction to Collective model.

Nuclear reactions: Direct and compound nuclear-reactions, Reciprocity theorem; experimental verification of Bohr's independence-hypothesis, resonance reactions, Breit-Wigner one-level formula, Transfer reactions; Optical model.

Particle accelerators: Pelletron, tandem principle, Synchrotron and synchrocyclotron, colliding beams, threshold energy for particle production.

Books Recommended:

1. Nuclear Physics- S. N. Ghoshal (S. Chand Publications)
2. Nuclear Physics- D. C. Tayal (Himalaya Publications)
3. Introductory Nuclear Physics- K. S .Krane (Wiley India)
4. Nuclear Physics: Theory and Experimental- H. S. Hans (New Age International)
5. Nuclear Physics: Theory and Experiment- R. R. Roy and B. P. Nigam (John Wiley and Sons)

Paper: PHYS105PR [Marks 50] [Credit 4]

General Practical
List of experiments

Group A:

1. Determination of wavelength of light from He-Ne laser by Michelson interferometer
2. Determination of e/m by magnetron valve/magnetic focusing method
3. Determination of (i) Rydberg constant, (ii) ionization potential and (iii) quantum defect of an alkali atom.
4. Determination of Stefan's constant and hence computation of the Planck's constant
5. Determination of Hall voltage and carrier concentration of a given semiconductor
6. Determination of speed of ultrasonic waves in an aqueous medium
7. Study of optical characteristics of a LED and determination of band gap of the material of LED.
8. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.
9. To draw the plateau curve of a GM counter and hence to determine the statistical variation of counts of the GM Counter.
10. Determination of wavelength of sodium light using Lloyd's mirror.

Group B:

1. Study the current mirror biasing and V_{BE} multiplier based voltage reference.
2. Study the transistor amplifier in common emitter (CE) mode.
3. To draw the LDR characteristics at different intensities and to find out the value & the dark resistance of the LDR.
4. To study the transfer characteristics of different networks and to study the phase transfer characteristics of a given two-port network (RC) by using CRO.
5. To design a three bit parallel adder.
6. Study on op-amp based linear and nonlinear amplifier.
7. To design RC-phase shifter oscillator.

8. Study the input and output voltage characteristics of Schmitt trigger circuit.
9. To Construct and test the operation Pre-emphasis & de-emphasis circuits by plotting frequency response using Op-amp.
10. To Study the amplitude modulation technique and determine the modulation index.

All the students will be divided into two groups i.e. Group A & Group B and that will be decided by the Department

Paper: 106CF [Marks 50] [Credit 0]

Communicative English and Personality Development

Note: The foundation courses are to be conducted by the University. The course shall have internal assessment only. However, the candidates are required to obtain Satisfactory to become eligible for the final semester examination/ award of the PG Degree.

Paper: PHYS107IA [Marks 50] [Credit 4]

To be decided by the ***DC**

SEMESTER – II (TOTAL MARKS 300) (CREDIT 24)

Paper: PHYS201C [Marks 50] [Credit 4]

Unit - I

Mathematical Methods- II

Special functions: Hermite, Bessel, Laguerre and Legendre functions.

Integral transforms. Fourier & Inverse Fourier transforms. Fourier transform of derivatives. Convolution theorem. Momentum representation. Laplace & Inverse Laplace transforms. Laplace transform of derivatives. Integration of transforms. Laplace convolution theorem. Solution of ordinary and partial differential equations by Fourier and Laplace transform methods.

Green's functions for ordinary and partial differential equations of mathematical physics. Integral equations. fredholm and volterra equations of the first and second kinds. Solution of integral equations using Integral transforms, Generating functions, Neumann series, separable (degenerate) kernels, Hilbert – Schmidt theory.

Tensor analysis, Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and anti-symmetric tensors.

Books Recommended

1. George B. Arfken and Hans J. Weber (Academic Press) – Mathematical Methods for Physicists.
2. J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
3. P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.
3. W. Joshi (Wiley Esstern) – Matrices and Tensors

Unit - II
(Advanced Optics)

Historical background of laser, Einstein coefficients and stimulated light amplification: population inversion, creation of population inversion in three level & four level lasers.

Gas Laser: CO_2 laser, Solid State Laser: Host material, Nd:YAG laser, Liquid laser: Dye laser, Semiconductor laser.

Laser beam propagation, properties of Gaussian beam, resonator, stability, various types of resonators, resonator for high gain and high energy lasers, Gaussian beam focusing.

Origin of nonlinearity, susceptibility tensor, phase matching, second harmonic generation.

Importance of coherence, Principle of holography and characteristics, applications.

Principle of Q-switching, Pockel and Kerr Effect.

Detection of optical radiation: Human eye, thermal detector (bolometer, pyro-electric), photon detector (photoconductive detector, photo voltaic detector and photo-emissive detector), p-i-n photodiode, Avalanche Photo Diode.

Books recommended:
1. Principles of lasers: O Svelto
2. Solid State Laser Engineering: W Koechner
3. Laser: B A Labgyel
4. Gas laser: A J Boom
5. Methods of Experimental Physics Vol. 15B ed.: C L Tang
6. Industrial Application of Lasers: J F Ready
7. Handbook of Nonlinear Optics: R L Sutherland
8. Laser and electrooptics: C C Davis

Paper: PHYS202C [Marks 50] [Credit 4]

Quantum Mechanics- II

Time independent perturbation theory (first and Second order corrections) and its application (anharmonic oscillator, Stark effect in hydrogen atom, Ground state energy of Helium atom). Variational method and its application for finding the ground state of Helium atom. WKB method and its application. Time-dependent perturbation theory: Harmonic perturbation, Fermi's golden rule, Sudden approximation.

Infinitesimal rotation, Generator of rotation, Commutation rules, Matrix representation of angular momentum operators, Spin, Pauli spin matrices, Rotation of spin states, Coupling of two angular momentum operators, Clebsch-Gordan co-efficients.

Symmetries, Invariance principle and Conservation laws, Space and Time translation, Space rotation, Irreducible spherical tensor operators, Wigner-Eckert theorem and its applications, Space inversion, Time reversal.

Scattering of a particle by a fixed center of force, scattering amplitude, differential and total cross sections. Method of partial waves, phase shifts, optical theorem. Scattering by a hard sphere and potential well. Integral equation for potential scattering. Green's function. Born approximation. Yukawa and Coulomb potential.

Books Recommended:

1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).
2) 'Quantum Theory' by D. Bohm (Prentice-Hall).
3) 'Quantum Mechanics: Theory and Applications' by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
4) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).
5) 'Quantum Mechanics' by Cohen and Tanandji.
6) Prabir Ghosh, Quantum mechanics, Narosa Publication

Unit - II

Classical Electrodynamics- II

Dispersion and absorption: Lorentz electromagnetic theory. Kramers-Kronig relation.

Magneto-hydrodynamic (MHD) equations, magnetic, viscosity, pressure, Reynolds number, etc. MHD waves. Alfven waves and velocity, Hartmann flow and Hartmann number

Orbit theory of drift motions in a plasma. Pinch effect. Instability in pinched plasma column. Plasma oscillations, short wavelength of plasma oscillation and Debye screening length

Propagation of EM waves through plasma. Effect of external magnetic field on wave propagations: ordinary and extraordinary rays.

Wave guides and resonant cavities: Basic concept of wave guides, TE & TM modes, Rectangular waveguide, circular waveguide, resonant cavities, rectangular cavity resonator-TE, TM modes. Power loss in a cavity-Q of a cavity.

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics

Paper: PHYS203C **[Marks 50]** **[Credit 4]**

Unit - I

Solid State Physics-II

Free electron theory. Fermi energy, wave vector, velocity and temperature, density of states. Electronic specific heats. Pauli spin paramagnetism. Sommerfeld's model for metallic conduction. AC conductivity and optical properties, plasma oscillations. Hall effects.

Energy bands in solids. The Bloch theorem. Bloch functions. Review of the Kroning-penney model. Brillouin zones. Number of states in the band. Nearly free electron model. The tight binding model. The Fermi surface. Electron dynamics in an electric field. The effective mass. Concept of hole. (Elementary treatment)

Superconductivity. Critical temperature high-Tc superconductors. Meissner effect. Type I and type II superconductors. Thermodynamics of superconducting transition. London equation. London penetration depth. Energy gap. Basic ideas of BCS theory. Josephson junction and some applications;.

Dielectric and optical properties of solids: Dielectric constant and polarizability, sources of polarizability, dipolar polarization in solids, ionic polarizability, electronic polarizability, piezoelectricity, ferroelectricity.

Books recommended:

1. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
2. Ibach & Luth: Solid State Physics
3. M. Ali Omar: Elementary solid state physics (Addison-wesley)
4. C. Kittel: Solid-state physics (Wiley eastern) (5th edition).
5. Superconductivity: M. Tinkham

Unit - II

Electronics-II

Four-terminal two-port network – parameters for symmetrical and unsymmetrical networks; image, iterative and characteristic impedances; propagation function; lattice network; Bisection theorem and its application.
L-C filters-LPF, HPF, BPF and BRF type constant-k prototype filters; m-derived filters (principle only), Attenuators,

Distributed parameters; primary and secondary line constants; Telegraphers' equation; Reflection co-efficient and VSWR; Input impedance of loss-less line; Distortion of em wave in a practical line.

Principles of analog modulation- linear and exponential types; comparison among different techniques; power, bandwidth and noise immunity consideration; Generation of transmitted carrier and suppressed carrier type AM signals; principles of FM and PM signal generation.

Principles of detection of different types of modulated signals (TC and SC types).

Modulation techniques in some practical communication systems: AM and FM radio, VSB AM and QAM technique in TV broadcasting.

Logic functions; Logic simplification using K-maps; SOP and POS design of logic circuits; MUX as universal building block.
RCA, CLA and BCD adder circuits; ADD-SHIFT and array multiplier circuits.
RS, JK and MS-JK flip-flops; registers and counters.

Books Recommended:

1. R P Jain, Modern digital electronics, Tata mac'Hill.
2. J.D.Ryder, Networks line and fields.
3. Frazier, Telecommunications
4. Roddy and Coolen, Electronic Communication systems. PHI.

Paper: PHYS204C **[Marks 50]** **[Credit 4]**

Unit - I
Statistical Mechanics- I

Scope and aim of statistical mechanics. Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, Ensemble, Density of phase points. Liouville's equation and theorem.

Stationary ensembles: Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuation in energy and particle. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature.

Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Pure and Mixed states.

Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector.

Distribution functions. Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.

Books Recommended:

1. R. K. Pathria, Statistical Mechanics
2. K. Huang, Introduction to Statistical Mechanics
3. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
4. F. Reif, Fundamentals of Statistical and Thermal Physics.
5. Kadanoff, Statistical Mechanics. World Scientific.
6. R. Kubo, Statistical Mechanics. (Collection of problems)

Unit - II

Nuclear Physics- II

Beta and Gamma decay: Fermi's theory of beta decay, allowed and forbidden transitions, selection rules, non-conservation of parity in beta decay, Wu's experiment; direct evidence for the neutrino, gamma–decay and selection rules.

Interaction of radiation with matter and detectors: Mechanism, Bohr's Ionization formula, Radiation detectors – Multi wire proportional counter, Scintillation counter; Cerenkov detector; solid state detectors.

Reactor Physics : Slowing down of neutrons in a moderator, average log decrement of energy; slowing down power and moderating ratio, slowing down density; Fermi age equations, Four-factor formula; buckling and critical size of reactors.

High energy physics : Types of interaction in nature-typical strengths and time-scales, conservation laws, charge-conjugation, Parity and Time reversal, CPT theorem, Gell-Mann-Nishijima formula, intrinsic parity of pions, resonances, Relativistic kinematics; Symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quark-confinement, asymptotic freedom.

Books Recommended:

1. Nuclear Physics- S. N. Ghoshal (S. Chand Publications)
2. Nuclear Physics- D. C. Tayal (Himalaya Publications)
3. Introductory Nuclear Physics- K. S .Krane (Wiley India)
4. Nuclear Physics: Theory and Experimental- H. S. Hans (New Age International)
5. Nuclear Physics: Theory and Experiment- R. R. Roy and B. P. Nigam (John Wiley and Sons)

Paper: PHYS205PR **[Marks 50]** **[Credit 4]**

General Practical

LIST OF EXPERIMENTS:

Group A:

1. Determination of wavelength of light from He-Ne laser by Michaelson interferometer
2. Determination of e/m by magnetron valve/magnetic focusing method
3. Determination of (i) Rydberg constant, (ii) ionisation potential and (iii) quantum defect of an alkali atom.
4. Determination of Stefan's constant and hence computation of the Planck's constant
5. Determination of Hall voltage and carrier concentration of a given semiconductor
6. Determination of speed of ultrasonic waves in an aqueous medium
7. Study of optical characteristics of a LED and determination of band gap of the material of LED.

8. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.
9. To draw the plateau curve of a GM counter and hence to determine the statistical variation of counts of the GM Counter.
10. Determination of wavelength of sodium light using Lloyd's mirror.

Group B

1. Study the current mirror biasing and VBE multiplier based voltage reference.
2. Study the transistor amplifier in common emitter (CE) mode.
3. To draw the LDR characteristics at different intensities and to find out the value & the dark resistance of the LDR.
4. To study the transfer characteristics of different networks and to study the phase transfer characteristics of a given two-port network (RC) by using CRO.
5. To design a three bit parallel adder
6. Study on op-amp based linear and nonlinear amplifier
7. To design RC-phase shifter oscillator
8. Study the input and output voltage characteristics of Schmitt trigger circuit
9. To Construct and test the operation Pre-emphasis & de-emphasis circuits by plotting frequency response using Op-amp.
10. To Study the amplitude modulation technique and determine the modulation index

All the students will be divided into two groups i.e. Group A & Group B. Those students who have done Group A experiments in Semester-I will have to opt Group B experiments in Semester-II and vice versa.

Paper: 206EF [Marks 50] [Credit 0]

1. Yoga and Life Skill

2. Education Value Education and Human Rights

Note: The foundation courses are to be conducted by the University. The course shall have internal assessment only. However, the candidates are required to obtain Satisfactory to become eligible for the final semester examination/ award of the PG Degree.

Paper: PHYS207IA [Marks 50] [Credit 4]

To be decided by the Departmental Committee

SEMESTER – III (TOTAL MARKS 300) (CREDIT 24)

Paper: PHYS301C [Marks 50] [Credit 4]

Unit - I
Statistical Mechanics- II

Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He^4, Superfluidity in He^4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids. Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism.

Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian.

Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation.

General remarks. Phase transition and critical phenomena. Critical indices. Landau's order parameter theory of phase transition.

Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein-Smoluchowski's theory.

Books Recommended

1. Sanchez Bowley, Introductory Statistical Mechanics, Oxford University Press
2. R. K. Pathria, Statistical Mechanics
3. K. Huang, Introduction to Statistical Mechanics
4. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
5. F. Reif, Fundamentals of Statistical and Thermal Physics.
6. Kadanoff, Statistical Mechanics. World Scientific.
7. R. Kubo, Statistical Mechanics. (Collection of problems)

Unit -II

Molecular Spectroscopy - I

Born-Oppenheimer approximation and separation of electronic and nuclear motions in molecules. Band structures of molecular spectra.

Microwave and far infrared spectroscopy: Energy levels of diatomic molecules under rigid rotator and non-rigid rotator models. Selection rules. Spectral structure. Structure determination. Isotope effect. Rotational spectra of polyatomic molecules. Stark effect.

Infrared spectra: Energy levels of diatomic molecules under simple harmonic and anharmonic (no deduction necessary for this one) models. Selection rules and spectral structures. Morse potential energy curves. Dissociation energies. Isotope effect. Rotational – vibrational coupling. Parallel and perpendicular modes. Symmetry properties of molecular wave functions and nuclear spins.

Raman spectroscopy. Rotational, Vibrational, Rotational-Vibrational Raman spectra. Stokes and anti-stokes Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra.

Vibrational spectra of poly atomic molecules. Normal modes. Selection rules for Raman and infrared spectra. Complementarity of Raman and infrared spectra. Normal modes of CO_2 molecule. Normal modes of other simple triatomic molecules.

Electronic spectra of diatomic molecules:

Vibrational band structure. Progressions and sequences. Isotope shifts. Deslandres tables. Molecular constants in the ground and excited electronic states and crude idea of molecular bonding.

Rotational structure of electronic spectra. P-, Q- and R- branches. Band head formation and shading of bands.

Intensity distribution in the vibrational structure of electronic spectra and Franck-Condon principle. Hund's coupling. Experimental determination of dissociation energy.

Books Recommended:

1. G. Herzberg. 'Molecular Spectroscopy (Diatomic Molecules)' Van-Nostrand.
2. G. M. Barrow. 'Molecular Spectroscopy'. McGraw-Hill.
3. J.Michael Hollas. ' Modern spectroscopy'. John-Wiley & sons.
4. C. L. Banwell and E. M. McCash. 'Fundamentals of Molecular Spectroscopy' Tata- McGraw-Hill..
5. G.Aruldhas 'Molecular Spectroscopy'.
6. Bransden and Joachin. 'Atoms and Molecules'
7. F.A.Cotton. 'Chemical application to Group theory'**.**
8. M. Hammermesh. 'Group Theory'. Addison-Wesley
9. M. Tinkham. 'Group Theory and Quantum Mechanics;. McGraw-Hill.
10. G. G. Hall. 'Applied Group Theory'. Longmans, Green.
11. A. W. Joshi. 'Group Theory'. Wiley Eastern Ltd..
12. N. Deo : Group Theory (Tata McGraw Hill)

Paper: PHYS302C [Marks 50] [Credit 4]

Computer Applications in Physics

Computer fundamentals:

Functional units-CPU, Memory, I/O units; Information representation- integral and real number representation; Character representation: Alphanumeric codes; BCD, Gray, ASCII codes; Error detection and error correcting codes; Hamming codes; CRC codes.

CPU- programmers model; instruction set and addressing modes of a generic CPU; RISC and SISC; Storage System- primary and secondary memory; semiconductor, magnetic and optical memory; cache memory; virtual memory; memory management; IO Units – keyboard, mouse, VDU, printers; (principle of operation only). Computer Networks- motivation, classification, topology, technology (qualitative description); Internet- structure, TCP/IP protocol, internet services; Introduction to WWW.

Representation of integers and real numbers; Accuracy, range, overflow and underflow of number representation; error propagation and instability.

Solution of polynomial equations- bisection, Newton-Raphson algorithm.

Solution of system of simultaneous equations- Gauss elimination, Gauss-Seidel, LU decomposition algorithms. Interpolation- Newton interpolation formula. Numerical integration – trapezoidal formula, Simpson's formula, Romberg formula. Numerical solution of differential equations- Euler, Runge-Kutta formula. Numerical solution of partial differential equations- description of algorithms only. Monte Carlo technique of numerical integration.

Computer Software and Operating Systems:

System software and application software; Translator programs; Loaders and linkers; Operating systems- classification; Elements of DOS, Windows, and Linux- basic commands.

Elements of C Programming Language:

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

Elements of Python Programming Language:

Basics of the python interpreter. Setting up and using python Modules, functions in python. Variables and scoping.

Basic python objects and native datatypes: Basic arithmetic operations and operators. Control flow and decision control.

Lists in python. Errors and exceptions. Scientific computing in python using numpy/scipy.

Introduction to software packages:

Computational package: Scilab, Sage math, plotting software: Matplotlib, gnuplot. Document processing software: Latex, Lyx, Open office.

Books Recommended:

1. Sastry, Introductory Methods of Numerical Analysis. PHI
2. Kyayszig, Advance Engineering Mathematics. John Willey, 9th Ed.
3. Tanenbaum, Computer Network, Prentice Hall.
4. B. A. Ferourzan, Data Communication and Networking, McGraw Hill.
5. Tanenbaum, Operating system. Prentice Hall.
6. Gottfried, Programming with C. Schaum series.
7. Balaguruswamy, ANSI C. TMH.
8. Kanetkar, Let Us C, BPB Publications

Unit – II

Advanced Quantum Mechanics

The Klein Gordon (KG) equation. Covariant notations. Free particle energy, negative energy and negative probability density, KG equation in e-m field.

The Dirac equation. Properties of the Dirac matrices. The Dirac particle in an external electromagnetic field. The non-relativistic limit of the Dirac equation and the magnetic moment of the electron.

Covariant form of the Dirac equation. Lorentz covariance of the Dirac equation. Boost as hyper rotation, boost, rotation, parity and time reversal operation on the Dirac wave function.

Conjugate Dirac spinor and its Lorentz transformation. The γ^5 matrix and its properties. Bilinear covariants and their properties.

Boosting the wave function from the rest frame. Plane wave solutions of the Dirac equation and their properties. Energy and spin projection operators.

Dirac's hole theory and charge conjugation. Feynman-Stuckelberg interpretation of antiparticles.

Books Recommended:

1. Relativistic Quantum Mechanics – J.D.Bjorken and S.D.Drell, McGraw-Hill, New York (1964).
2. Relativistic Quantum Mechanics- Walter Greiner, Springer-Verlag (1990)
3. Advanced Quantum Mechanics – J.J.Sakurai, Addison-Wesley Publishing Company, Inc. (1967).
4. Relativistic Quantum Mechanics and Quantum Fields – T-Y Wu and W-Y Pauchy Hwang, Allied Publishers Limited (2001).

Major Electives

Paper: PHYS303ME [Marks 50] [Credit 4]

A. Advanced Electronics-I

Microwave Devices: Problems of microwave generation in conventional oscillators.

Vacuum tube devices: Klystron and Reflex Klystron, Magnetrons, Slow wave structure and Travelling wave tubes,

Solid state devices: Gunn diode, Impatt, Trapatt, transistors, GaAs-InP FET, HEMT.

Optical Devices: Laser and Laser resonator, LEDs, Photodiodes, Photo conductor.

Microwave measurements (Frequency, power, impedance).

Optical modulator: Electro optics modulation (amplitude and phase).

Optical coupler: Coupling of light from one fiber to other with the use of evanescent wave

Analysis of networks and systems: Sample data system. Z-transform, Fourier and Laplace transforms.

Microwave Waveguides: Standing wave ratio, Quarter wave transformer, Smith Chart, Stub matching. Wave guides coaxial, rectangular and cylindrical; Waveguide attenuation, Resonators.

Antenna theory: Antennas-dipole, Antenna arrays, reflectors, steering strip, microstrip and coplanar structure.

Books Recommended

1. P. Bhattacharya - Semiconductor opto electronics devices.
2. R E Collin - Foundations of Microwave engineering.
3. S.Y.Liao – Microwave Devices on circuits.
4. J. Ryder – Networks, Lines and Field.
5. A. Papoulis – Signal Analysis
6. Electronic and Radio Engineering – F. E Terman.
7. Microwaves – K. C. Gupta.
8. Optoelectronics and Fibre Optic Communication –C. Sarkar.
9. Photonics – A. Yariv and P. Yeh.

Paper: PHYS304ME [Marks 50] [Credit 4]

A. Advanced Electronics -II

IC Technology: Hybrid and monolithic IC; Semiconductor processing diffusion, implantation, oxidation, epitaxy, lithography; Si IC technology-MOS and Bipolar; Packaging and testing.

Analog Integrated Circuits. Differential amplifier, OP-AMP comparator; continuous time filters, switched capacitance implementation of sample data filters; analog multiplexers, PLL and frequency synthesizer.

Digital Integrated Circuits: Logic families – TTL, ECL, MOS, MESFET; design of combinational and sequential circuits – MUX, decoder/ encoder, registers, counters, gate arrays; programmable logic devices – PAL, GAL, PLA, Programmable gate arrays.

Application specific ICs: ICs for analog communication; Digital signal processing ICs; Speech and image processing.

Memories: Sequential and Random access memories; RAM bipolar and MOS static and dynamic memories; programmable memories PROM, EPROM, EEPROM.

Microprocessor and their applications: Architecture of 8 bit (8085) and 16 bit (8086) microprocessors; addressing modes and assembly language programming of 8085 and 8086. 8086 machine cycles and their timing diagrams; Interfacing concepts memory and I/O interfacing; Interrupts and interrupt controllers; microprocessor based system design; comparison of different microprocessors.

Books Recommended:

1. Geiger, Allen and Strader – *VLSI – Design Techniques for Analog and Digital Circuits*.
2. Gray and Meyer – *Analysis and Design of Analog Integrated Circuits*.
3. A P Mathur – *Microprocessors.*
4. R S Gaonkar – *Microprocessor Architecture, Programming and Applications with 8085/ 8085A* (2^{nd} Ed.).
5. D V Hall – *Microprocessor and Interfacing*.
6. Lin and Gibson – *Microprocessor*.
7. S Soelof – *Applications of Analog Integrated Circuits*.

Paper: PHYS303ME [Marks 50] [Credit 4]

B. Laser Physics and Nonlinear Optics -I

Basic Laser Principle: Summary of black body radiation, Quantum theory for evaluation of the transition rates and Einstein coefficients-allowed and forbidden levels-metastable state; population inversion; rate equations for three level and four level lasers, threshold of power calculation, various broadening mechanism, homogeneous and inhomogeneous broadening

Basic Laser System: Basic concept of construction of laser system, various pumping system, pumping cavities for solid state laser system, characteristics of host materials and doped ions.

Optical beam propagation: Paraxial ray analysis, wave analysis of beams and resonators, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law-Gaussian beam focusing

Resonators: Stability of resonators-'g' parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application. Rabi oscillation and frequency

Q-switching: Giant pulse theory, different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching Pockel and Kerr effect), acoustooptic Q-switching, dye Q-switching, Raman-Nath effect.

Ultrafast Phenomenon: Principle of generation of ultrafast pulses, basic concepts for measurement of fast processes, Streak techbique, Stroboscopy, sampling technique, nonlinear optical methods for measuring ultrashort pulses

Different laser systems:

Gas Laser: (i) molecular gas lasers- CO_2 laser & N_2 laser; (ii) ionic gas laser – Ar^+ laser
(iii) gas dynamic laser; (iv) high pressure pulsed gas laser
Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances
(iii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser
Chemical Laser: HF laser, HCl laser
Excimer laser; Fibre laser**,** Free electron laser; semiconductor laser

Books Recommended:

1. Principles of lasers- O Svelto
2. Solid State Laser Engineering- W Koechner
3. Quantum Electronics- A Yariv
4. The Physics and Technology of Laser Resonator- D R Hall & P E Jackson
5. Introduction to optical electronics- K A Jones
6. Laser- B A Langyel
7. Gas laser- A J Boom

Paper: PHYS304ME [Marks 50] [Credit 4]

B. Laser Physics and Nonlinear Optics -II

Laser Safety:
Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard

Nonlinear Optics:
Introduction, nonlinearities of the polarization, generation of second harmonic, D.C., sum and difference frequency generation, anharmonic oscillator model, Miller's rule, crystal symmetry, coupled amplitude equation, Manley-Rowe relation

Phase Matching:
Basic idea of phase matching, quasi-phase matching method, various methods of phase matching (angle, temperature, birefringence etc.) critical and noncritical phase matching, collinear and non-collinear phase matching, expression of angle band-width ($\Delta\theta$) and wavelength band-width ($\Delta\lambda$) in phase matched second harmonic generation, idea of tangential and dispersion phase matching

Second Harmonic Generation:
Basic equation, conversion efficiency and parameters affecting doubling efficiency, various methods of enhancing conversion efficiency, second harmonic generation with Gaussian beam, intra-cavity second harmonic generation

Higher Order Nonlinear Processes:
Four wave mixing processes-third harmonic generation, resonance enhancement of nonlinear susceptibilities, different phase matching techniques, generation of tunable deep UV and IR radiation, stimulated Raman scattering, inverse Raman scattering, anti-stokes coherent Raman scattering, application in spectroscopy

Chemical Application:
Selective excitation reaction, different separation processes, principle of isotope separation, uranium enrichment, Ultrashort pulses in chemical reaction.

Laser speckle:
Spatial frequency filtering- principle and its application

Laser in medical science:
Laser tissue interaction, physical effects on human skin of laser beam reflection, absorption, scattering, different interaction mechanism, different surgical treatment. Effects of ultrashort pulses

Books Recommended:

1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Solid State Laser Engineering- W Koechner
4. The Principle of Nonlinear Optics- Y R Shen
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper: PHYS303ME [Marks 50] [Credit 4]

C. Nano Science and Nano-technology -I

Applied crystallography in Nano science and nano materials

Noncrystalline and semicrystalline states, Lattice. Crystal systems, unit cells. Indices of lattice directions and planes. Coordinates of position in the unit cell, Zones and zone axes. Crystal geometry. Symmetry classes and point groups, space groups. Glide planes and screw axes, space group notations, Equivalent points. Systematic absences, Determination of crystal symmetry from systematic absences. Stereographic projections. Standard projection of crystals.

Section II: Introduction to materials, Classification of materials:

Crystalline & amorphous materials, high Tc superconductors, alloys & composites, semiconductors, solar energy materials, luminescent and optoelectronic materials, Polymer, Liquid crystals and quasi crystals, Ceramics.

Synthesis and preparation of Nanomaterials:

Synthesis of bulk nanostructured materials - Sol Gel processing- bulk and nano composite materials - Grinding - high energy ball milling – injection moulding - extrusion - melt quenching and annealing.

Synthetic Technique (Physical and Chemical): Self assembly-Self Assembled Monolayers (SAM) - Vapour Liquid Solid (VLS) approach - Chemical Vapour Deposition (CVD) - Langmuir-Blodgett (LB) films - Spin coating - Templated self assembly Electrochemical approaches: Thin films - Epitaxy -Lithography.

One dimensional and Two dimensional nanostructures: Nanowires and Nanotubes: Evaporation-condensation - Vapor- liquid - solid (VLS) - surface and bulk diffusion – kinetics – growth of various nanowires –control of size –precursors and catalysts - single- and multiwall CNT - Si nanowires – density and diameter – doping in nanowire.

Phase transition in materials

Solid solutions, Phases, Thermodynamics of solutions, Phase rule, Binary phase diagrams, Binary isomorphous systems, Binary eutectic systems, ternary phase diagrams, kinetics of solid reactions. Order disorder phenomenon in binary alloys, long range order, super lattice, short range order. (10 lectures)

Books Recommended:

1. Materials science and Engineering by *V. Raghavan*, Prentice-Hall Pvt. Ltd.
2. Thin Solid Films by *K. L Chopra*

3. Elements of X-ray diffraction by *B. D. Cullity,* Addison-Wesley Publishing Co.
4. Elements of crystallography by *M. A. Azaroff*
5. Engineering Materials by *Kenneth G. Budinski*, Prentice-Hall of India Pvt. Ltd.
6. W. Gaddand, D.Brenner, S.Lysherski and G.J.Infrate (Eds), Handbook of nanoscience, Engg and Technology, CRC Press,2002.
7. G.Cao, Naostructures and Nanomaterials: Synthesis, properties and applications, Imperical College Press, 2004.
8. J.George, Preparation of thin films, Marcel Dekker, InC., New York, 2005.
9. C.N.R.Rao, A.Muller, A.K.Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH Verlag Gmbh&Co, Weinheim, 2004.

Paper: PHYS304ME [Marks 50] [Credit 4]

C. Nano Science and Nano-technology -II

Nanomaterials and their applications

Background to Nanoscience: Defination of Nano, Scientific revolution-Atomic Structure and atomic size, emergence and challengs of nanoscience and nanotechnology, carbon age-new form of carbon (CNT to Graphene), influence of nano over micro/macro, size effects and crystals, large surface to volume ration, surface effects on the properties.

Types of nanostructure and properties of nanomaterials: One dimensional, Two dimensional and Three dimensional nanostructured materials, Quantum Dots shell structures, metal oxides, semiconductors, composites, mechanical-physical-chemical properties.

Application of Nanomaterial: Ferroelectric materials, coating, molecular electronics and nanoelectronics, biological and environmental, membrane based application, polymer based application.

Lattice Imperfections

Point defect, line defect, plane defect, volume defect, dislocation, stacking faults, application, Burger vectors.

Structure of metals, semiconductors and ceramics

Difference between structures of metals and ceramics, close-packed structures: BCC, FCC & HCP metals. Structure of semiconductors: Si, Ge, ZnS, pyrites, chalcopyrite's, ZnO etc.; structure of ceramics: metal oxides, nitrides, carbides, borides, ferrites, perovskites, etc.

Microstructure characterization by direct & indirect methods

Diffraction techniques: interpretation of x-ray powder diffraction patterns, Identification & quantitative estimation of unknown samples by X-ray powder diffraction technique and fluorescent analysis. Theory and method of particle size analysis. Integral breadth method, Warren-Averbach's Fourier method, profile fitting method, Rietveld Method.

Characterization techniques related to nanomaterials

Electron Microscopy techniques: TEM, SEM & STEM. AFM, XPS, EDX. Electron and neutron diffraction.

Books Recommended:

1. X-ray diffraction by *B. E. Warren*, Addison-Wesley Publishing Co.

2. An Introduction to Metallurgy by *Sir Alan Cottrell*, University Press
3. The Structure & Properties of Materials (Volume II) by *J. H. Brophy, R. M. Rose and J. Wulff*, Wiley Eastern Ltd.
4. Structure of Metals, *C. S. Barrett & T. B. Massalski*, McGraw-Hill Book Company.
5. The Optical principles of the Diffraction of X-rays by R. W. James, G. Bell & Sons Ltd.

Paper: PHYS305EID [Marks 50] [Credit 4]

Minor Electives:

Biophysics

Basic concepts and laws of thermodynamics: Isolated system, closed system, Open system; Thermodynamic variables, Thermodynamic equilibrium, Reversible process, Irreversible process; First law of thermodynamics, second law of thermodynamics. Meaning of entropy, Entropy production and the stationary state as the basic principle of life.

Diffusion: Fick's law, equation of continuity; basics of elasticity, viscosity, and surface tension.

Biophysics of neuron: Structure of neoronal cells, Ion channels and ion pumps, Action membrane potenial and its propagation, Synaptic transfer of action potentials, Hodgkins-Huxley model of neuron (qualitative description).

Biophysics of hearing: Sound as a mechanical oscillations of an elastic medium, Quantities used to measure sound, Biophysical function of outer, middle and inner ear; sound pollution.

Non-ionizing electromagnetic radiation and its biological effects, spectrum of electromagnetic radiation, Biophysical effects of ionizing radiation, linear energy transfer.

Physical Methods in Biology and Medicine: Types of radioactive decay, laws of radioactive decay, Basic of x-rays, X-Ray diffraction; Isotope labelling; Photodynamic therapy, ECG, EEG, MRI, Tomography.

Books:

1. Elementary Biophysics: An Introduction, by P. K. Srivastava
2. Physics for the Biological Sciences, by Hallett et al.

Paper: PHYS306PR [Marks 50] [Credit 4]

Advanced General Practical

List of Experiments

Group A:

1. Determination of temporal coherency of a laser light source and compare it with an incoherent source
2. Determination of spatial coherency of a laser light source and compare it with an incoherent source
3. Study of magneto-optic effect (Faraday effect)
4. Study of electro-optic effect (Pockels effect)
5. Study of Zeeman effect
6. Design of active band-pass filters and to verify the Barkhausen criteria
7. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
8. Design of astable multivibrator using 555 Timer
9. Determination of particle size of an unknown specimen
10. Band-gap determination from thermal variation of resistivity

Group B:

1. Measurement of magnetic susceptibility using Quincks method
2. Study of ESR
3. Phase identification of an unknown sample from its X-ray diffraction pattern
4. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
5. Studies on antenna theory
6. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
7. Studies on laser diodes and its application in optical communication
8. Finding Speed of light in air using laser.
9. To study and characterize a quantum dot structure.
10. To verify Raman Effect.

All the students will be divided into two groups i.e. Group A & Group B and that will be decided by the Department

SEMESTER IV (Total 300 Marks) (CREDIT 24)

Paper: PHYS401C [Marks 25] [Credit 2]

Unit - I

Molecular Spectroscopy -II

Hydrogen molecule ion and molecular orbitals. Valence Bond approach in hydrogen molecule. Coulomb and exchange integrals. Electronic structures of simple molecules. Chemical bonding. Hybridizations.

Basic aspects of photo physical processes: radiative and non-radiative transitions; fluorescence and phosphorescence; Kasha's rules. Nuclear Magnetic resonance spectroscopy. Electron spin resonance spectroscopy. Fourier transform spectroscopy. Photo acoustic spectroscopy. Photo electron spectroscopy. Mossbauer spectroscopy.

Group Theory: Definition, postulates, Representation of Groups, Finite and infinite groups, order of a group, Rearrangement theorem. Group multiplication table. Subgroups and Cosets. Lagrange's theorem. Order of an element. Conjugate elements and classes. Cyclic and other distinct groups. Permutation groups. Invariant subgroups, factor groups. Generators. Isomorphism and homomorphism. Illustrations with point symmetry groups.

Books Recommended:

1. G. Herzberg. 'Molecular Spectroscopy (Diatomic Molecules)' Van-Nostrand.
2. G. M. Barrow. 'Molecular Spectroscopy'. McGraw-Hill.
3. J.Michael Hollas. ' Modern spectroscopy'. John-Wiley & sons.
4. C. L. Banwell and E. M. McCash. 'Fundamentals of Molecular Spectroscopy' Tata- McGraw-Hill..
5. G.Aruldhas 'Molecular Spectroscopy'.
6. Bransden and Joachin. 'Atoms and Molecules'
7. F.A.Cotton. 'Chemical application to Group theory'**.**
8. M. Hammermesh. 'Group Theory'. Addison-Wesley
9. M. Tinkham. 'Group Theory and Quantum Mechanics;. McGraw-Hill.
10. G. G. Hall. 'Applied Group Theory'. Longmans, Green.
11. A. W. Joshi. 'Group Theory'. Wiley Eastern Ltd..
12. N. Deo : Group Theory (Tata McGraw Hill)

Unit - II

Nonlinear Dynamics

Dynamical System, constants of motion, phase space, fixed points. Nonlinear dynamical systems in Physics, biology, engineering, etc. Dynamical equations and Stability for linear systems. Flow defined by nonlinear systems of ODEs, linearization and stable manifold theorem. Hartman-Grobman theorem. Stability and Lyapunov functions. Planar flows: saddle point, nodes, foci, centers and nonhyperbolic critical points. Bifurcation theory: saddle-node, pitch-fork, Hopf, period doubling, homoclinic bifurcations. Applications in: Laser model, population dynamics.

Limit cycle oscillations and Chaos: Concept of limit cycle, Poincare-Bendixon theorem; role of nonlinearity: From harmonic oscillator to Van der Pol oscillator, Chaos, Lorenz equation and Rossler equation. Applications in: Chaos in electronic oscillators, chaos in Laser system.

Discrete time nonlinear systems: logistic map, sine circle map, linear stability analysis and the existence of 2-cycles; numerical analysis of the logistic map; universality and the Feigenbaum numbers; bifurcation and chaos, intermittency, crises; Applications in: population dynamics, discrete phase-locked loop system, power electronics.

Dispersion, Dissipation and nonlinearity, Korteweg–de Vries (KdV) equation, solitory waves and soliton interaction, Application of KdV equations, nonlinear Schoedinger equation.

Pattern formation: Reaction-diffusion equation, Turing instability: linear stability analysis.

Books Recommended:

1. Stephen Wiggins, "Introduction to Applied Nonlinear Dynamical Systems and Chaos", Springer-Verlag, Second Edition.
2. Steven Strogatz. "Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering", Levant Publishers, 1994.
3. Edward Ott**,** Chaos in Dynamical Systems**,** Cambridge University Press.
4. Dominic Jordan, Peter Smith, "Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers" (Oxford Texts in Applied and Engineering Mathematics)
5. J K Bhattacharyya, Nonlinear Dynamics
6. Ajoy Ghatak & K Thyaragrajan, Introduction to Fiber Optics (Cambridge University Press).
7. G P Agrawal, Application to Non Linear Fiber Optics (Academic Press).

Paper: PHYS402C [Marks 25] [Credit 2]

Unit – I

Relativity

Brief review of Minkowski's Four Dimensional Space-time.

Vectors and Tensors, Idea of parallel transport and covariant derivatives, covariant derivative of $g_{\mu\nu}$, Geodesics, Curvature tensor and its properties, Bianchi Identities, Ricci tensor, Einstein tensor.

Principles of equivalence, Principle of general covariance, Metric tensors and Newtonian Gravitational potential, Logical steps leading to Einstein's equations of gravitation, Linearised equation for weak fields.

Schwarzschild's exterior solution, singularity, event horizon and concept of black holes, Birkhoff's theorem, Observational tests of Einstein's theory – Precession of Perihelion of the planet Mercury, Bending of light rays in a gravitation field, Gravitational Red shift.

Books Recommended:

1**.** General Relativity and Cosmology (MacMillion, 1978).- J. V. Narlikar
2.Theory of Relativity (Wiley, 1972). - S. Weinberg

3. Introduction to Theory of Relativity (Prentice-Hall, 1969). - P. G. Bergmann
4. Introduction to Special Theory of Relativity.- R. Resnick
5. The Special Theory of Relativity (Prentice Hall of India, 2002) S. Banerji and A. Banerjee
6. Introduction to the Theory of Relativity. - W.G.V. Rosser

Unit - II

Astrophysics

Star formation, Stellar Magnitudes, Classification of stars, H-D classification, Hertzsprung-Russell (H-R) diagram, Virial theorem (derivation is not required), Equations of stellar structure.

Pre-main sequence evolution, Jeans criteria for star formation, Post main sequence stage.

Thermonuclear reactions in stars, pp chains and CNO cycle, Helium burning and subsequent thermonuclear reactions, nucleosynthesis beyond iron, r- and s- processes.

Introduction, Newtonian theory of stellar equilibrium, White Dwarfs, Chandrasekhar Mass Limit (no derivation), Neutron Stars, Tolman-Oppenheimer-Volkoff (TOV) equation (derivation is not required) and its consequences,. Pulsars.
Black holes, Schwarzschild and Kerr black hole (no derivation), event horizon, Penrose process of energy extraction, No Hair Theorem.
Qualitative discussions on: Quasars, Brown dwarfs, Red Giant Stars, Nova, Supernova

Cosmological Principles, Weyl postulate, Hubble's law. Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe, Qualitative discussions on: Expanding universe, Cosmic Microwave Background Radiation.

Introduction, plane waves, radiation of gravitational waves, detection of waves. Theory of gravitational lensing, magnification and amplification of images.

Measurement Techniques:

Principles of Telescope operation, Basic Antenna theory, equations, range etc., Types of Antenna (Dipole antenna, Horn antenna, Hertz antenna, half wave length antenna)

Books Recommended:

1. Textbook of astronomy and astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Theoritical Astrophysics (Vols.I,II,III) – T. Padmanavan (CUP)
3. Introduction to Cosmology – J.V.Narlikar (Cambridge University Poress)
4. General Relativity, Astrophysics and Cosmology – A.K.Raychaudhuri, S.Banerji and A.Banerjee (Springer-Verla, 1992)
5. General Relativity and Cosmology – S. Banerji and A. Banerjee (Elsevier, 2007)
6. The Structure of the Universe – J.V.Narlikar (OUP, 1978)

Paper: PHYS403PR **[Marks 50]** **[Credit 4]**

Computer Practical

* Initially preliminary programs using decision making statements and loop structures to be executed in C and Python.

1. Write the C programming code to solve the 1D time independent Schrodinger equation with boundary conditions.

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x)$$

2. Write the C programming code to solve the van der Pol equation with suitable parameter values.

$$\frac{d^2x}{dt^2} - \mu(1 - x^2)\frac{dx}{dt} + x = 0$$

3. Write the C programming code to solve the Linear Harmonic Oscillator problem.

$$\frac{d^2x}{dt^2} + \omega^2 x = 0$$

4. Write the C programming code to solve the wave equation in free space with specific boundary conditions.

$$\frac{d^2U}{dt^2} = c^2\frac{d^2U}{dx^2}$$

5. Write the C programming code for the solution of simultaneous equations by Gauss-Jordon method.

6. Write the C programming code to simulate the random-walk problem.

7. Write the C programming code to solve the polynomial equation with Newton-Raphson method.

$$2x^3 - 2.5x - 5 = 0$$

8. Write the C programming code to simulate the motion of a dropping ball in state-space, considering the collision between ball and ground as inelastic collision with coefficient of restitution e=0.8.

9. Using Planck's formula write the C programming code to plot the intensity distribution of blackbody radiation at different absolute temperatures.

10. Write the C programming code for multiplication of two matrices.

11. Write the C programming code to plot the probability distribution of getting 'k' number of heads (where, k=1, 2... n) for 'n' number of unbiased coin tosses. Show that more the number 'n' more the sharpness of the distribution. Also show that most disordered state is most probable.

12. Write the C programming code to solve the 1D heat equation with suitable values of parameters and boundary conditions.

$$\frac{dU}{dt} = \frac{k}{s\rho}\frac{d^2U}{dx^2}$$

13. Write the C programming code to solve the Laplace equation of electrostatics with boundary conditions.

$$\nabla^2\varphi = 0$$

- All the above programs also to be executed in Python language.

Unit - II

Social out-reach activity

To be decided by the Departmental Committee

Paper: PHYS404PJ **[Marks 50]** **[Credit 4]**

Project

To be decided by the Departmental Committee

Major Elective

Paper: PHYS405ME **[Marks 50]** **[Credit 4]**

A. Advanced Electronics-III

Review of CW Modulation Technique:
Linear modulation DSB, SSB, VSB, QAM techniques, Exponential modulation FM and PM; AM and FM modulators and demodulators.

Pulse Modulation and Demodulation Techniques:
Sampling the rein PAM, PWM, PPM, Pulse code modulation – coding technique modulation and demodulation.

Digital Modulation Techniques:

ASK, FSK, PSK, DPSK, QPSK, MSK, Principle, modulators and demodulators.

Effect of Noise on Communication System:
Characteristics of additive noise; Performance of AM, FM and PCM receivers in the face of noise; Multi-path effect.

Elements of Information Theory:
Information, average information, information rate, Effect of coding on average information per bit; Shanon's theorem; Channel capacity, an optimum modulation system.

TV Systems:
Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal; Transmitter and receiver systems of broadcast TV; Advanced TV; Cable TV.

RADAR System: Basic pulsed radar system – modulators, duplexer indicators, radar antenna CW radar; MTI radar FM radar; chirped pulse radar.

Optical Communication: Fibre optic communication systems; Power budget equation; Multiplexing; Quantum limit; Incoherent reception; signal-to-noise ratio calculation; Basics of coherent techniques in FOC.

Satellite Communication:
Orbits, Station keeping; Satellite attitude; Path loss calculation; Link calculation; Multiple access techniques; Transponders; Effects of nonlinearity of transponders.

Specialized Communication Systems:
Mobile Communication – Concepts of cell and frequency reuse description of cellular communication standards; Pagers. Computer communication – Types of networks; Circuit message and packet switched networks; Features of network, design and examples of ARPANET, LAN, ISDN, Medium access techniques – TDMA, FDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol.

Books Recommended

1. A B Carlson – *Communication Systems.*
2. D Roddy and J Coolen – *Electronic Communications.*
3. Franz and Jain – *Optical Communication Systems.*
4. A M Dhake – *Television and Video Engineering*.
5. Gulati – *Monochrome and Color TV*.
6. Kennedy and Davis – *Electronic Communication Systems*.
7. Taub and Schilling – *Principle of Communication Systems*.

Paper: PHYS405ME **[Marks 50]** **[Credit 4]**

B. Laser Physics and Nonlinear Optics-III

Sum frequency generation, limitation to upconversion, introductory theory, infrared detection, effect of phase matching, noise properties, image conversion, experimental status, difference frequency generation, effect of phase matching, evaluation of $\Delta\theta$ and $\Delta\lambda$

Optical fibre waveguide, modes in optical fibre, pulse distortion and information rate in optical fibres, distortion in single mpde fibre, fibre losses, coupling of source with fibre, modulation, PCM, multiplexing, WDM, TDM, solitons.

UV-VIS-NIR crystals, assessment of nonlinear crystals (Kurtz powder method, Maker fringe method), chalcopyrites, derivation and characteristics.

Outline of crystal growth method, liquid phase epitaxy, vapour phase epitaxy, metal organic chemical vapour deposition, chemical beam epitaxy, molecular beam epitaxy.

Principle of measurement with laser beam, distance measurement, rotation, fluid velocity measurement, laser range finder

Advantages of remote monitoring of the atmosphere by laser, principles of remote monitoring, different lidar systems, sources of noise and its remedial measures, Raman back scattered lidar

Laser in drilling, cutting, welding, marking, annealing

Principle of optical bistability, different optical logic gates, optical phase conjugation, production of phase conjugated beam, self focusing, optical computing.

Principle of laser cooling & trapping, optical molasses, cooling below doppler limit, magnetic trapping, applications

Books Recommended:

1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Laser remote Sensing:- R M Measures
4. Optical bistability- H M Gibbs
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper: PHYS405ME [Marks 50] [Credit 4]

C. Nano Science and Nano-technology -III

Optical and dielectric properties of materials

Theory of electronic polarization and optical absorption, ionic polarization, orientational polarization. Optical phonon model in an ionic crystal; Interaction of electromagnetic waves with optical modes, polariton, Dispersion curves of transverse optical (TO) phonon and optical photon in a diatomic ionic crystal, LST relation; Metal-insulator transition. UV-VIS, IR, FTIR and Raman spectroscopy. Optical properties of metals & nonmetals, Luminescence,photoconductivity.

Electrical properties of crystalline, nanocrystalline and polymeric materials

Resistivity variation in metals, alloys, semiconductors and nanocrystalline materials, electrical conduction in ionic ceramics, clay materials and conducting polymers. Two-probe and four probe techniques, DC and AC conductivity measurements.

Mechanical Properties of metals and ceramics
Concepts of stress & strain, stress-strain behavior, anelasticity, Plastic deformation, Hardness-Knoop & Vicker's hardness test.

Thermal properties of metals & alloys
Temperature effects on the intensities of Bragg reflections. Influence of temperature on diffraction of X-rays, DTA, TGA, DSC (Outline only). Annealing processes, mechanism of hardening. Quenching, thermal stresses.

Thermoelectric Materials: Concept of phonon, Thermal conductivity specific heat, exothermic and endothermic processes, Different types of thermoelectric materials, Bulk properties, One dimensional and composite thermoelectric materials, Applications.

Nanostructured Magnetism: Nanostructure magnetism, Effect Bulk nanostructuring of magnetic property, Giant and colossal magnetic resistance, Nanomagnetic materials, Paramagnetism in metallic nanoparticles, Semiconduction quantum dots.

Section V: Structure - Property correlation, application aspects of material
Correlation of structure with physical properties of materials, application prospects of materials in different areas.

BOOKS RECOMMENDED
1. Introduction to Ceramics by *W. D. Kingery, H. K. Bowen and D. R. Uhlmann*, John Wiley & Sons
2. Diffraction analysis of the microstructure of materials by *E. J. Mittemeijere and P. Scardi*, Springer
3. Materials Science & Engineering by *William D. Callister*, John Wiley & Sons, Inc.
4. Modern techniques of surface science by *D. P. Woodruff & T. A. Delchar*, Cambridge University Press
5. X-ray spectroscopy by *B. K. Agarwal*, Springer-Verlag.

Paper: PHYS406PR **[Marks 50]** **[Credit 4]**

Advanced General Practical

List of Experiments

Group A:

1. Determination of temporal coherency of a laser light source and compare it with an incoherent source
2. Determination of spatial coherency of a laser light source and compare it with an incoherent source
3. Study of magneto-optic effect (Faraday effect)
4. Study of electro-optic effect (Pockels effect)
5. Study of Zeeman effect

6. Design of active band-pass filters and to verify the Barkhausen criteria
7. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
8. Design of astable multivibrator using 555 Timer
9. Determination of particle size of an unknown specimen
10. Band-gap determination from thermal variation of resistivity

Group B:

1. Measurement of magnetic susceptibility using Quincks method
2. Study of ESR
3. Phase identification of an unknown sample from its X-ray diffraction pattern
4. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
5. Studies on antenna theory
6. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
7. Studies on laser diodes and its application in optical communication
8. Finding Speed of light in air using laser.
9. To study and characterize a quantum dot structure.
10. To verify Raman Effect.

All the students will be divided into two groups i.e. Group A & Group B. Those students who have done Group A experiments in Semester-III will have to opt Group B experiments in Semester-IV and vice versa.

***DC** : Departmental Committee.