Bankura University
Department of Physics
NEP Syllabus
2026

1 Year PG Program
Sem-I (1 year) / Sem-III (2 year)

Category	Course Code	Course Title	Credits	Marks
DSC	PHYS/DSC-8	Nonlinear Dynamics and Relativity	2+2=4	(5+20)+(5+20)=50
DSE	PHYS/DSE-1	A. Advanced Electronics-I, B. Advanced Nuclear Physics-I, C. Quantum Information and Computing-I, D. Cosmology, E. Laser Physics and Nonlinear Optics-I F. Nano Science and Nano-technology -I	4	50
DSC	PHYS/DSC-PR3	Advanced General Laboratory Practicals	4	50
Res Meth	PHYS/DSC-9	Research Methodology and Computer Programming Lab	2+2=4	(5+20)+(5+20)=50
Research Project / Thesis / Patent	PHYS/DSC-10		8	100
		TOTAL	24	300

1 Year PG Program
Sem-II (1 year) / Sem-IV (2 year)

Category	Course Code	Course Title	Credits	Marks
DSE	PHYS/DSE-2	A. Advanced Electronics-II, B. Advanced Nuclear Physics-II, C. Quantum Information & Computing-II, D. Astrophysics, E. Laser Physics and Nonlinear Optics-II F. Nano Science and Nano-technology -II	4	50
DSC	PHYS/DSC-PR4	Advanced General Laboratory Practicals	4	50
Dissertation	PHYS/DSC-11		12	150
Non-Credit	PHYS/IKS-1	Indian Knowledge System	4	50
		TOTAL	20	300

2 Year PG Program
Sem-I

Category	Course Code	Course Title	Credits	Marks
DSC	PHYS/DSC-1	Mathematical Methods-I and Classical Mechanics	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-2	Quantum Mechanics and Atomic Spectroscopy	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-3	Condensed Matter Physics and Electronics-I	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-4	Statistical Mechanics and Nuclear Physics-I	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-PR1	General Practical	4	10+40=50
		TOTAL	20	250

2 Year PG Program
Sem-II

Category	Course Code	Course Title	Credits	Marks
DSC	PHYS/DSC-5	Mathematical Methods-II and Classical Electrodynamics	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-6	Advanced Quantum Mechanics and Nuclear Physics-II	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-7	Molecular Spectroscopy and Electronics-II	2+2=4	(5+20)+(5+20)=50
DSC	PHYS/DSC-PR2	Advanced General Practical	4	10+40=50
General Elective (GE)	PHYS/GE-1	Biophysics	2+2=4	(5+20)+(5+20)=50
		TOTAL	20	250

Sem-III & -IV same as 1 year Sem-I & -II, respectively.

Detailed Syllabus

Semester-I (2 Year) Total Marks: 250 Credit: 20

Paper Code: PHYS/DSC-1, Marks:50 Credit: 4

Title: Mathematical Methods-I & Classical Mechanics

Unit-I: Mathematical Methods-I (Lectures: 25)

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.
5. K.F. Riley, M.P. Hobson, S.J. Bence: Mathematical Methods for Physics and Engineering (Cambridge)

Learning outcome

- The knowledge gathered (viz. complex analysis, differential equations) during this course would have direct applications in other branches of physics, especially in quantum mechanics, electrodynamics, and solid state physics.
- The students will be able to learn different mathematical tools to deal with the different problems of natural phenomena

Unit-II: Classical Mechanics (Lectures: 25)

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.

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

Learning outcome

- Apart from describing the system classically, the Lagrangian and Hamiltonian approaches will be useful in describing a microscopic system too.
- The concept of Hamilton- Jacobi theory will raise the idea of transition of a system from classical to quantum mechanics.
- The students will be able to describe a wide variety of physical phenomena (i.e. Small oscillation, rigid body motion, continuous media and non-linear motion etc) by the Lagrangian and the Hamiltonian formalism, non-linear dynamics to generalize the laws of physics in higher dimensions.

Paper Code: PHYS/DSC-2, Marks: 50 Credit: 4

Title: Quantum Mechanics & Atomic Spectroscopy

Unit-I: Quantum Mechanics (Lectures: 25)

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 and its applications (Harmonic perturbation, Fermi's golden rule), Adiabatic and Sudden approximation.

Infinitesimal rotation, Generator of rotation, Commutation rules, angular momentum and spin, Matrix representation of angular momentum operators and spin operator, 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.

Identical Particles, many-particle systems, Systems of Identical Particles, The Pauli exclusion principle, the periodic-table.

Scattering of a particle by a fixed center of force, scattering amplitude, differential and total cross sections. Scattering by a hard sphere and potential well. Integral equation for potential scattering. Green's function. Born approximation. Method of partial waves, phase shifts, optical theorem. Scattering of Identical Particles. 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
7. N. Zettili: Quantum Mechanics (Wiley)
8. J.J. Sakurai: Modern Quantum Mechanics (Pearson)

LEARNING OUTCOMES

Upon completing this course, students will:

- Understand time-independent and time-dependent perturbation theory, including practical applications.
- Apply perturbation theory to solve problems in atomic and molecular physics.
- Utilize the variational method and the WKB method.
- Learn the principles of scattering theory and identify cross-sections and scattering amplitudes.
- Understand angular momentum, matrices, and spin states.

- Learn about symmetries and their connection to conservation laws.
- Discuss space and time translations, space rotations, spherical tensor operators, and space inversion.
- Analyze systems of identical particles, considering the Pauli Exclusion Principle.
- Explore particle scattering by fixed centers of force, integral equations, and the Born approximation.
- Students will acquire advanced knowledge in quantum mechanics, symmetries, and particle behavior in various contexts.

Unit-II: Atomic Spectroscopy (Lectures: 25)

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. **[10 Lecture hours]**

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. **[5 Lecture hours]**

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. [5 Lecture hours]

Laser in Spectroscopy: Basic elements of a laser, Einstein A B Coefficients, Population inversion, Different energy level lase system, Broadening of spectral lines, absorption spectroscopy, excitation spectroscopy, ionization spectroscopy, saturation absorption spectroscopy, photo acoustic spectroscopy, opto-galvanic spectroscopy, Tera Hertz spectroscopy. [5 Lecture hours]

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

LEARNING OUTCOMES

At the end of the course students will:

- Understand the hydrogen spectrum and how it applies to other monovalent atoms.
- Explore concepts like quantum defects, electron spin, and how magnetic fields affect atomic spectra.
- Learn about the spectra of divalent atoms and the rules governing them.
- Examine hyperfine structure in atomic spectra and its origin.
- Discover X-ray spectra and the principles of screening constants.
- Gain insight into the operation of lasers in spectroscopy, including population inversion and various spectroscopic techniques like absorption, excitation, ionization, and more.

Paper Code: PHYS/DSC-3, Marks: 50 Credit: 4

Title: Condensed Matter Physics & Electronics-I

Unit-I: Condensed Matter Physics (Lectures: 25)

Diffraction Theory: Review of reciprocal lattices and Brillouin zones. General derivation of the amplitude of a scattered wave. Mathematical formulations of the Atomic Form Factor and the Geometrical Structure Factor (SK). Comparative mechanics of X-ray, electron, and neutron diffraction in structural profiling. Ewald construction geometry.

Phonon Dynamics: Quantization of harmonic lattice vibrations; concept of acoustic and optical branches. Dispersion relations and normal modes in monatomic and diatomic linear lattices. Quantization of elastic waves and phonon momentum. Qualitative mechanics of anharmonic crystal interactions and thermal expansion.

Free Electron Quantum Gas: Sommerfeld model for metallic conduction, wavevector parameters, and quantum density of states ($D(\epsilon)$). Derivation of electronic specific heats and Pauli spin paramagnetism. AC conductivity, optical properties, and plasma oscillations. Hall effect topology.

Energy Bands and Electron Dynamics: Bloch's Theorem and the properties of Bloch functions. Detailed evaluation of electron states using the Nearly Free Electron Model and the Tight-Binding Approximation.

Fermi Surface Topography: Number of states in a band, dynamics of electrons in an electric field, definition of the effective mass tensor, and the physical concept of holes. Construction of the Fermi Surface.

Paramagnetism & Localized Moments: Semi-classical vs. quantum treatment of paramagnetism for $J=1/2$. Determination of the Brillouin Function and Van Vleck paramagnetism. Hund's rules for the ground state of an ion. Crystal field effects and the quenching of orbital angular momentum.

Ferromagnetism & Antiferromagnetism: The Weiss molecular field model and the calculation of magnetic susceptibility. Origin of the exchange interaction (Heisenberg model). Ferromagnetic domains and the anatomy of domain walls. Weiss model of Antiferromagnetism, types of antiferromagnetic configurations, and Ferrimagnetism.

Superconductivity Electrodynamics: Experimental hallmarks: Critical temperature (T_c), Meissner-Ochsenfeld effect, and the classification of Type-I and Type-II superconductors. Thermodynamics of the superconducting transition.

Microscopic Theory & Tunneling: The London Equations and derivation of the London penetration depth (λ_L). Core physical tenets of the BCS theory (Cooper pairs, attractive electron-phonon interaction, and the energy gap). Macroscopic quantum phase coherence: AC/DC Josephson Junctions and basic SQUID applications.

Dielectrics & Ferroelectrics: Polarizability and local electric fields. Sources of polarizability: electronic, ionic, and dipolar polarization. Physics of Piezoelectricity and Ferroelectricity.

Recommended books:

1. C. Kittel, Introduction to Solid State Physics, John Wiley & Sons (8th Edition or newer). (Comprehensive reference across all units)
2. J. P. Srivastava, Elements of Solid State Physics, Prentice Hall India. (Excellent operational reference for analytical derivations)
3. M. Ali Omar, Elementary Solid State Physics: Principles and Applications, Addison-Wesley.
4. N. W. Ashcroft and N. D. Mermin, Solid State Physics, Cengage Learning.
5. John Singleton, Band Theory and Electronic Properties of Solids, Oxford University Press (Oxford Master Series in Condensed Matter Physics).
6. M. Tinkham, Introduction to Superconductivity, McGraw-Hill / Dover Publications. (Definitive reference for Unit IV)
7. H. Ibach and H. Lüth, Solid-State Physics: An Introduction to Principles of Materials Science, Springer.

LEARNING OUTCOMES

Upon successful completion of this course, students will be able to:

- (Analyze & Evaluate): Apply reciprocal lattice vector calculus to advanced diffraction phenomena; evaluate scattered wave amplitudes using atomic form factors and geometric structure factors for complex bases.
- (Understand & Synthesize): Model the dispersion relationships of collective acoustic/optical modes in linear mono/diatomic lattices, deduce normal mode quantization into phonons, and analyze thermal variations using the electronic specific heat framework.
- (Analyze & Evaluate): Compute energy band layouts, analyze electron dynamics in varying electric fields via the effective mass tensor, map Fermi surfaces using tight-binding and nearly-free electron approximations, and interpret topological phenomena like the Hall effect.
- (Apply & Evaluate): Formulate the electrodynamics of superconductors using London equations, explain the microscopic pairing mechanism of BCS theory, analyze macroscopic quantum tunneling across Josephson junctions, and characterize cooperative magnetic systems using the Weiss molecular field model.
- (Skill Development): Execute computational simulations of band structures, dispersion curves, or magnetic susceptibility profiles using open-source tools (Python, Scilab, or specialized quantum simulation engines).

Unit-II: Electronics-I (Lectures: 25)

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, MOSFETS, LED, LASER, Solar cell, Tunnel diode, Gunn diode and IMPATT.

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

Harmonic self-oscillators: Condition of oscillations, Steady state operation of self-oscillator; nonlinear equation of self- oscillator; examples.

Op-Amp Circuits: Characteristics of ideal and practical op-amp; Derivation of CMRR, Applications of opamp: inverting, non-inverting, buffer, adder, subtractor, difference, differentiator, integrator Nonlinear amplifiers using op-amps, log amplifier, anti-log amplifier, regenerative comparators; Precession rectifiers, 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

LEARNING OUTCOMES

At the end of the course

- Students will recognize the underlying physics of semiconductor devices.
- The course enable students to solve voltage current equations in transistor and operational amplifier circuits.
- The students will be able to design the transistor amplifiers, different response of them in different frequency zones
- The condition of oscillation and different oscillator design will be done by students
- The students will learn the opamp based circuits in details.

Paper Code: PHYS/DSC-4, Marks: 50 Credit: 4

Title: Statistical Mechanics & Nuclear Physics-I

Unit-I: Statistical Mechanics (Lectures: 25)

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. Microcanonical, Canonical and Grand canonical ensembles. Partition function formulation, Distribution functions: Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. [2 Lecture hours]

Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He4, Superfluidity in He4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids. [4 Lecture hours]

Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Fermi energy, equation of state of an ideal Fermi gas, Sommerfeld Expansion, evaluation of chemical potential and specific heat of an ideal Fermi gas, Landau levels, Landau diamagnetism, Pauli Paramagnetism. [6 Lecture hours]

Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation. [3 Lecture hours]

Phase transitions: Landau theory of phase transitions: First and Second order phase transitions, Spontaneous and Explicit Symmetry Breaking in Landau Theory. Onset of hysteresis in first order phase transitions. Critical phenomena and critical indices. Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein- Smoluchowski's theory. [5 Lecture hours]

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. [5 Lecture hours]

Recommended books:

1. Introduction of atomic spectroscopy: H E White
2. Sanchez Bowley, Introductory Statistical Mechanics, Oxford University Press
3. R. K. Pathria, Statistical Mechanics
4. K. Huang, Introduction to Statistical Mechanics
5. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
6. F. Reif, Fundamentals of Statistical and Thermal Physics.
7. Kadanoff, Statistical Mechanics. World Scientific.
8. R. Kubo, Statistical Mechanics. (Collection of problems)
9. L.E. Reichl, A Modern course in statistical physics, Wiley-VCH, 4th Ed.
10. S.K. Ma, Modern Theory of Critical Phenomena, Westview Press, 1st Ed

LEARNING OUTCOMES

At the end of the course students will:

- Give an account of the relevant quantities used to describe macroscopic systems, thermodynamic potentials and ensembles.
- Give an account of the macroscopic and microscopic description of temperature, entropy and free energy and their descriptions in terms of probabilities.
- Give an account of the theory of statistical mechanics and the approximations making a statistical description possible.
- Explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics.
- Apply the theory to understand gases and crystals and, in addition, be able to construct microscopic models, and from these derive thermodynamic observables.
- Describe the importance and consequences of quantum mechanics for macroscopic particle systems, both for ideal gases and strongly interacting systems.
- Understand the role of cooperative physics in emergent phenomena such as quantum magnetism and phase transition
- Understand and appreciate the role of symmetry in facilitating universality during phase transitions in many-particle systems, as well as give an account of critical phenomena and corresponding scaling laws.

- Understand the strengths and limitations of the models used and be able to compare different microscopic model

Unit-II: Nuclear Physics-I (Lectures: 25)

Properties of nuclei: static and dynamic, parity and isospin of nuclei, Determination of nuclear size: mirror nuclei, muonic atoms and electron scattering methods, charge and mass distribution, charge form factor. Magnetic dipole moment and electric quadrupole moment; Experimental determination. [5 Lecture hours]

Two-nucleon problem and nuclear forces: Deuteron problem; ground state and excited states, spin dependence of nuclear force, charge symmetry and charge independence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces. Form of nucleon-nucleon, nucleon-nucleus, nucleus-nucleus potential; Exchange nature of nuclear forces, elementary discussion on Yukawa's theory. [8 Lecture hours]

Alpha, Beta and Gamma decay: Basics alpha decay process, alpha decay systematics, theory of alpha 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. [6 Lecture hours]

Nuclear structure: Liquid drop model, Bethe-Weizsacker binding energy/mass formula, Fermi gas model, 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. [6 Lecture hours]

Recommended books:

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)
6. S.S.M. Wong: Introductory Nuclear Physics (PHI)

LEARNING OUTCOMES

At the end of the course students will:

- Learn comprehend nuclear properties, static and dynamic, including parity and isospin.
- Familiarize themselves with methods to determine nuclear size and charge/mass distribution.
- Understand magnetic and electric moments, and how they are experimentally determined.
- Understand the Deuteron problem, spin-dependent nuclear forces, charge symmetry, and charge independence.
- Explore nuclear force potentials, exchange forces, and elementary discussions on Yukawa's theory.
- Gain knowledge of various nuclear models, their predictions, and the role of spin-orbit interactions.

- Explain alpha, beta, and gamma decay processes, selection rules, and experimental evidence.

Paper Code: PHYS/DSC-PR1, Marks: 50 Credit: 4

Title: 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.
11. Determination of particle size of an unknown specimen
12. Measurement of magnetic susceptibility using Quincks method

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

(End of Semester-I)

Semester-II (2 Year) Total Marks: 200 Credit: 20

Paper Code: PHYS/DSC-5, Marks: 50 Credit: 4

Title: Mathematical Methods-II & Classical Electrodynamics

Unit-I: Mathematical Methods-II (Lectures: 25)

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.
4. W. Joshi (Wiley Esstern) – Matrices and Tensors
5. K.F. Riley, M.P. Hobson, S.J. Bence: Mathematical Methods for Physics and Engineering (Cambridge)

Learning outcome:

- The knowledge gathered (viz. differential equations, integral trans form, linear algebra) during this course would have direct applications in other branches of physics, especially in quantum mechanics, electrodynamics, solid state physics.
- Introduction of Tensor analysis will be effectively helpful while studying general theory of relativity, advanced quantum mechanics as well as advanced electrodynamics.

Unit-II: Classical Electrodynamics (Lectures: 25)

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.

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
6. Electricity and magnetism: e. M. Purcell, d. J. Morin
7. Marion- Classical Electrodynamics
8. Jackson- Classical Electrodynamics
9. Panofsky & Phillips- Classical Electrodynamics
10. Chen- Plasma Physics
11. Griffith-Electrodynamics

LEARNING OUTCOMES

At the end of the course

- Students will learn to solve inhomogeneous wave equation.
- The course enable students to solve moving charge particle problem.
- Students will learn the theory of radiation from a localized oscillating charges.
- The students will learn the classical theory of radiation.
- Understand dispersion and absorption, applying the Kramers-Kronig relation.
- Learn MHD equations and analyze MHD waves, including Alfven waves.
- Explore plasma drift motions and recognize instabilities in plasma columns.
- Understand plasma oscillations and their Debye screening length.
- Analyze the impact of external magnetic fields on wave propagation.
- Comprehend waveguides, their modes, and resonant cavities.
- These skills will empower students to comprehend and analyze phenomena in electromagnetism, plasma physics, and waveguides.

Paper Code: PHYS/DSC-6, Marks: 50 Credit: 4

Title: Advanced Quantum Mechanics & Nuclear Physics-II

Unit-I: Advanced Quantum Mechanics (Lectures: 25)

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 $\gamma5$ 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).
5. Advanced Quantum Mechanics, F. Schwabl

LEARNING OUTCOMES

On completion of the course, the student should be able to:

- Understand Klein-Gordon and Dirac equations, including their application in electromagnetic fields.
- Analyze the non-relativistic limit and magnetic properties of particles.
- Explore Dirac spinors, $\gamma5$ matrix, and bilinear covariants..
- Learn about Dirac's hole theory, charge conjugation, and antiparticles.
- Gain insights into classical and quantum field theory, including Lagrangian and Hamiltonian formalism, field quantization, and commutation relations.

Unit-II: Nuclear Physics-II (Lectures: 25)

Two-body scattering Experimental n-p scattering data, Partial wave analysis and phase shifts, scattering length, magnitude of scattering length and strength of scattering, Significance of the sign of scattering length; Scattering from molecular hydrogen and determination of singlet and triplet scattering lengths, effective range theory, low energy p-p scattering. [5 Lecture hours]

Nuclear reaction: Different types of reactions, Quantum mechanical theory, Resonance scattering and reactions — Breit-Wigner dispersion relation; Compound nucleus formation and break-up, Statistical theory of nuclear reactions and evaporation probability, Optical model; Principle of detailed balance, Transfer reactions. [5 Lecture hours]

Nuclear fission and fusion: Basics of fission and fusion, Experimental features, spontaneous fission, liquid drop model theory of fission, barrier penetration, statistical model, Basics of fusion reaction, characteristics of fusion, solar fusion. Elementary ideas about astrophysical reactions, Nucleosynthesis and abundance of elements. [5 Lecture hours]

Reactor Physics: Basic components of a fission and fusion reactor. 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. Radioactive fission products, concept of prompt and beta-delayed neutrons. [5 Lecture hours]

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. [5 Lecture hours]

Recommended books:

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)
6. S.S.M. Wong: Introductory Nuclear Physics (PHI)

LEARNING OUTCOMES

At the end of the course, students will:

- Interpret n-p scattering data and perform partial wave analysis, including phase shifts and scattering length.
- Analyze the significance of the sign of scattering length and apply it to molecular hydrogen scattering.
- Utilize effective range theory and study low-energy p-p scattering.
- Apply quantum mechanics to understand different types of nuclear reactions, resonance scattering, compound nucleus formation, and statistical theory.
- Understand the basics of nuclear fission and fusion, experimental features, barrier penetration, and their implications in astrophysics and element abundance.
- Understand reactor physics components, neutron slowing down, and critical reactor size.
- Analyze high-energy physics concepts, including elementary particle classification and properties, quark theory, and interaction strengths.

Paper Code: PHYS/DSC-7, Marks: 50 Credit: 4

Title: Molecular Spectroscopy & Electronics-II

Unit-I: Molecular Spectroscopy (Lectures: 25)

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

Introduction of quantization of energy. Regions of the spectrum. The intensities of spectral lines.

Microwave 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. Microwave Oven.

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 CO2 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.

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.

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)

Learning outcome:

- The student should be able to achieve advanced knowledge about the interactions of electromagnetic radiation and matter and their applications in spectroscopy.
- This course would also motivate students to pursue research careers, especially in material sciences and associated fields.
- The concept of Group Theory will be of immense use in studying various symmetry properties in high energy physics, quantum mechanics as well as condensed matter physics.

Unit-II: Electronics-II (Lecture: 25)

Passive Network: 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, no detailed analysis is required), Attenuators,

High Frequency Transmission Line: 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.

Elements of Communication Electronics: 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.
Digital Circuits: 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.
5. S.M. Sze, Physics of semiconductor devices
6. Milman and Grable, Microelectronics. Tata MacGraw Hill.
7. B. C. Sarkar and S. Sarkar, Analog Electronics, DamodarPrakashani
8. B. C. Sarkar and S. Sarkar, Digital Electronics.
9. D. Roy Chowdhuri and Jain, Analog integrated circuits, New age Publishers
10. Chattopadhyay and Rakshit, Electronic Circuit analysis
11. Roddy and Coolen, Electronic Communication systems. PHI.

LEARNING OUTCOMES

At the end of the course

- Students will recognize the underlying physics of semiconductor devices.
- The course enable students to solve voltage current equations in transistor and operational amplifier circuits.
- Students will be able to understand and solve problems from digital electronics.
- The course will develop skill to apply their knowledge in engineering fields and industry

Paper Code: PHYS/DSC-PR2, Marks: 50 Credit: 4

Title: Advanced General Practical

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. 8085 Microprocessor Practicals.
10. Band-gap determination from thermal variation of resistivity

Group B:

1. Study of ESR
2. Phase identification of an unknown sample from its X-ray diffraction pattern
3. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
4. Studies on antenna theory
5. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
6. Studies on Time-delayed Hyperchaotic Oscillator,
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.
11. Determination of efficiency of GM counter.

Paper Code: PHYS/GE-1, Marks: 50 Credit: 4

Title: Biophysics

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 neuronal cells, Ion channels and ion pumps, Action membrane potential and its propagation, Synaptic transfer of action potentials, Hodgkin-Huxley model of neuron (qualitative description).

Biophysics of hearing: Sound as 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.

LEARNING OUTCOMES

The students are expected to learn the thermodynamics and fluid mechanics associated with biological systems, the physics of neurons, the physics of nuclear fission and nuclear reactors, nuclear fusion and tokamaks, nuclear radiation hazards, and radiation dosimetry.

(End of Semester-II)

Sem-I (1 Year)/ Sem-III (2 Year)   Marke: 300   Credits: 24

Paper: PHYS/DSC-8   Marks 50   Credit 4

Title: Nonlinear Dynamics & Relativity

Unit-I: Nonlinear Dynamics   (Lectures: 25)

Dynamical System, motion in 1D and 2D spaces, 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. Poincare-Bendixon theorem. Planar flows: saddle point, nodes, foci, centers and nonhyperbolic critical points.

Bifurcation theory: saddle-node, pitchfork, Hopf, period doubling, homoclinic, codimension-2 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, solitary waves and soliton interaction, Application of KdV equations, nonlinear Schoedinger equation.

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

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 Nonlinear Fiber Optics (Academic Press).

LEARNING OUTCOMES:

At the end of the course

1. Students will recognize the impact of nonlinearity on the natural phenomena.
2. Students will be able to solve paradigmatic problems in physics that can not be solved using the conventional linear approach.
3. Students can apply the knowledge to understand the problems from biology, chemistry, and engineering.
4. Since this course is inherently interdisciplinary, therefore, it will help students for developing skills to pursue research in the multidisciplinary fields.

Unit-II: Relativity (Lectures: 25)

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

Learning Outcomes:

Upon successful completion of this course, students will be able to:

- Explain the Equivalence Principle, Principle of General Covariance, and their physical implications.
- Use tensors, metrics, Christoffel symbols, and curvature tensors to describe curved spacetime.
- Understand the structure and derivation of the Einstein Field Equations.
- Derive and interpret the Schwarzschild metric, including its geodesics and physical consequences.
- Quantitatively describe the three classical tests of General Relativity - perihelion precession of Mercury, bending of light, and gravitational redshift.
- Describe the Schwarzschild black hole, event horizon, and gravitational collapse.
- Apply GR concepts in astrophysics, cosmology, and gravitational wave physics.

Paper: PHYS/DSE-1 Marks 50 Credit 2

PHYS/DSE-1A: Advanced Electronics-I (Lectures: 50)

Microwave and High-Speed Semiconductor Devices (12 Hours)

Microwave frequency range and limitations of conventional oscillators, Microwave vacuum devices (basic principles only): Klystron, Reflex Klystron, Magnetron, Travelling Wave Tube, **Microwave semiconductor devices:** Gunn diode, IMPATT and TRAPATT diodes, GaAs and InP devices, MESFET, HEMT. Applications of microwave devices.

Optical Electronic Devices (10 Hours)

Laser fundamentals and laser resonators, LEDs and semiconductor lasers, Photodiodes and photoconductors, Electro-optic modulation (amplitude and phase modulation), Optical couplers and evanescent wave coupling, Introduction to fibre optic components.

Microwave Engineering (12 Hours)

Microwave transmission lines, Standing Wave Ratio (SWR), Quarter-wave transformer, Smith chart, Stub matching, **Waveguides:** Rectangular, Circular, Coaxial. Waveguide attenuation, Microwave resonators, **Microwave measurements:** Frequency, Power, Impedance.

Antennas (8 Hours)

Radiation mechanism, Dipole antenna, Antenna arrays, Reflector antennas, Microstrip antennas, Coplanar waveguide structures, Introduction to beam steering.

Signals, Sampled Data and Control Systems (8 Hours)

Fourier, Laplace and Z transforms (applications only), Sampled-data systems, Feedback principles, Stability concepts, Servo systems, Automatic control systems.

Books Recommended
Textbooks

1. D. M. Pozar, Microwave Engineering, 4th Edition, Wiley.
2. S. O. Kasap, Optoelectronics and Photonics: Principles and Practices, Pearson.
3. J. Millman and C. C. Halkias, Integrated Electronics, McGraw-Hill.
4. B. P. Lathi, Linear Systems and Signals, Oxford University Press.
5. K. Ogata, Modern Control Engineering, Pearson.
6. David M. Pozar, Microwave Engineering, 4th Edition, Wiley.
7. S. Y. Liao, Microwave Devices and Circuits, Pearson.
8. Robert E. Collin, Foundations for Microwave Engineering, Wiley.
9. Ajoy Ghatak and K. Thyagarajan, Optical Electronics, Cambridge University Press.
10. B. B. Laud, Lasers and Nonlinear Optics, New Age International.
11. Constantine A. Balanis, Antenna Theory: Analysis and Design, 4th Edition, Wiley.
12. M. Gopal, Control Systems: Principles and Design, McGraw-Hill.
13. B. P. Lathi, Linear Systems and Signals, Oxford University Press.

Reference Books

1. S. Y. Liao, Microwave Devices and Circuits, Pearson.
2. R. E. Collin, Foundations for Microwave Engineering, Wiley.
3. C. A. Balanis, Antenna Theory: Analysis and Design, Wiley.
4. A. Ghatak and K. Thyagarajan, Optical Electronics, Cambridge University Press.
5. B. C. Sarkar, Microwave Engineering, Khanna Publishers.

LEARNING OUTCOMES:
After successful completion of this course, students will be able to:

- Explain the operating principles of microwave vacuum tubes and semiconductor microwave devices, and evaluate their applications in high-frequency electronic systems.
- Describe the working principles and characteristics of optical electronic devices, including lasers, LEDs, photodetectors, optical modulators, and optical couplers.
- Analyze microwave transmission lines, waveguides, resonators, impedance matching techniques, and microwave measurement methods for practical engineering applications.
- Apply the principles of antenna theory to understand radiation characteristics, antenna arrays, microstrip antennas, and modern antenna technologies.
- Use Fourier, Laplace, and Z-transforms in the analysis of sampled-data systems and explain the role of feedback in the stability and performance of control systems.

PHYS/DSE-1B: Advanced Nuclear Physics-I (Lectures: 50)

Properties of nuclei: static and dynamic, parity and isospin of nuclei, Determination of nuclear size: mirror nuclei, muonic atoms and electron scattering methods, charge and mass distribution, charge form factor. Magnetic dipole moment and electric quadrupole moment; Experimental determination. [5 Lecture hours]

Two-nucleon problem and nuclear forces: Deuteron problem; ground state and excited states, spin dependence of nuclear force, charge symmetry and charge independence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces. Form of nucleon-nucleon, nucleon-nucleus, nucleus-nucleus potential; Exchange nature of nuclear forces, elementary discussion on Yukawa's theory. [8 Lecture hours]

Alpha, Beta and Gamma decay: Basics alpha decay process, alpha decay systematics, theory of alpha 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. [6 Lecture hours]

Nuclear structure: Liquid drop model, Bethe-Weizsacker binding energy/mass formula, Fermi gas model, 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. [6 Lecture hours]

Recommended books:

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)
6. S.S.M. Wong: Introductory Nuclear Physics (PHI)

LEARNING OUTCOMES

At the end of the course students will:

- Learn comprehend nuclear properties, static and dynamic, including parity and isospin.
- Familiarize themselves with methods to determine nuclear size and charge/mass distribution.
- Understand magnetic and electric moments, and how they are experimentally determined.
- Understand the Deuteron problem, spin-dependent nuclear forces, charge symmetry, and charge independence.
- Explore nuclear force potentials, exchange forces, and elementary discussions on Yukawa's theory.
- Gain knowledge of various nuclear models, their predictions, and the role of spin-orbit interactions.
- Explain alpha, beta, and gamma decay processes, selection rules, and experimental evidence.

PHYS/DSE-1C: Quantum Information and Computing-I (Lectures: 50)

1. Introduction and overview: [4 Lectures]

Definition of information, Quantitative measure of information, Shannon's first coding theorem, History of quantum computation and quantum communication, the concept of qubits.

2. Basic ideas of computational models and complexity classes: [6 Lectures]

Elementary idea of complexity of an algorithm, Turing machine, Deterministic Turing machine, Probabilistic Turing, Reversible Turing machine, Circuit model of computation, Computational complexity and related issues.

3. Mathematical tools and simple quantum mechanics for quantum computing: [6 Lectures]

Vector space, The Cn vector space, Inner product space and Hilbert space, Bases and linear independence, $C2$ space, The space spanned by a single Qubit, Outer product, Relation between bases, Subspace (basis for a vector space adapted to a subspace, Direct sum and sum, Linear operators, Null space, range and rank of a linear operator, Inevitability (invert sub space of a linear operator). Pauli matrices, Gram-Schmidt procedure, Eigenvalues and eigenvectors, Hermitian operators, Normal, unitary and positive operators, Diagonalizable operator and spectral decomposition, Tensor products, Trace, Postulates of quantum mechanics (Postulate 1: The State of a System, Postulate 2: Observable Quantities Represented by Operators, Postulate 3: Measurements, Postulate 4: Time Evolution of the System),

Density operator and density matrix, Density operator of pure and mixed states, Positive maps (Completely and noncompletely), More general evolution by Kraus Operator (trace out the environment and the study the principle system)

4. Bloch sphere and Qubit: [4 Lectures]

State space of a qubit, Density operator and Bloch vector. (locate any given state on a Bloch sphere), plots of maximally mixed , mixed and pure state on Bloch sphere, Quantum measurement and find probability corresponding Bloch sphere state.

5. Entanglengement: [10 Lectures]

The meaning of entanglement, EPR paradox, Bell's inequality and nonlocality, Basic algebra for quantum computing, Bell measurement and entanglement, Partial trace, Quantum bit commitment and quantum coin tossing, Schmidt decomposition, Partial transpose and test of entanglement, Entanglement witness, State discrimination, Trace distance and, Measures of entanglement, Schmidt measure, Peres-Horodecki Criterion and its limitations, Von Neumann entropy of the, Negativity, Concurrence and entanglement of formation, State purification, Holevo bound, Bloch sphere, Nocloning theorem, No-go theorems.

6**. Quantum algorithms: [12 Lectures]**

Deutsch’s algorithm, Deutsch Jozsa (DJ) algorithm, Grover’s algorithm, Simon’s algorithm, Classical approach, Quantum approach, Complexity analysis, Shor’s algorithm, Basic ideas of number theory, Euclid’s algorithm, Period of the modular exponential function, Continued fraction representation, The strategy, Quantum Fourier transformation, Main (quantum) part of the algorithm, Solution of Pell’s equation and the principal ideal problem.

7**. Experiments/Simulations: [8 Lecture]**

Basic necessary codes (python 3)

For loop and range function, random number, the math function, if else statement, elif satement, Flag Variable, string, List, Array, user define function, use of numpy, scipy, matplotlib

Different matrix operations (without using module) (a) Addition of matrix (b) Subtraction of matrix (c) Transpose of a matrix (d) Exponent of a matrix (Cayley Hamilton theorem).

Find eigen value eigen vector of a given matrix (Hermitian/Non Hermitian) [for non hermitian case plot real part vs imaginary part of eigen value for the given system]. Code for classical and quantum logic gates.

State (you can assume any basis state) evolution of a given hamiltonian (matrix). Find the probability vs time graph for a given range of time (you can use module).

Code for Partial Transpose and partial trace of a given system or matrix. States and operator using python (a) Density matrices (b) Pauli sigma properties (c) Harmonic Oscillator operators(creation and annihilation) (d) Quantum communication relation using python (e) Cat vs coherent states in a Kerr resonator and the role of measurement.

Python coding for Fourier transform (a) Continuous Fourier transform, (b) Discrete Fourier Transform

Recommended Books:

1. Quantum Computation and Quantum Information, Michael A. Nielsen, Isaac L. Chuang
2. Quantum Computing Explained, David McMahon. WILEY-INTERSCIENCE. A John Wiley & Sons,
3. Vector Spaces and Matrices in Physics ; M. C. Jain, CRC Press, 2001
4. Elements of Quantum Computation and Quantum Communication, Anirban Pathak.
5. Computational Physics , Problem solving with python, Rubin H. Landau, Manuel J. Paez, Cristian C. Bordeianu.
6. Quantum Information theory. M. Wilde, Cambridge University Press, 2013.
7. An Introduction to Quantum Computing. P. Kaye, R. Laflamme and M. Mosca. Oxford University Press, New York, 2007.
8. Quantum Optics-An introduction; Mark Fox.

LEARNING OUTCOMES

On completion of the course, the students will:

- Learn the definition of information and understand quantitative measures of information, including Shannon's first coding theorem. Gain knowledge about the history of quantum computation and communication, along with the concept of qubits.
- Explore the basics of classical and quantum computational models and complexity classes, covering concepts like Turing machines, circuit models of computation, and computational complexity.
- Acquire mathematical tools and fundamental quantum mechanics concepts necessary for quantum computing, including vector spaces, Hilbert spaces, Pauli matrices, and density

operators. Understand the Bloch sphere and qubit state representation, along with quantum measurements.

- These skills prepare students for more advanced topics in quantum computing and quantum information theory.
- Understand the concept of entanglement, the EPR paradox, Bell's inequality, and nonlocality inquantum mechanics. Gain proficiency in the algebra and mathematics used in quantum computing. Learn about various aspects of entanglement, including Bell measurements, partial trace, quantum bit commitment, Schmidt decomposition, and measures of entanglement such as Von Neumann entropy, negativity, concurrence, and entanglement of formation.
- Explore quantum gates and circuits, including single qubit gates, two qubit gates, and quantum circuit optimization. Develop skills in analyzing and optimizing quantum circuits, considering gate count, depth, width, and total cost.
- Dive into quantum algorithms, including Deutsch's algorithm, Deutsch-Jozsa algorithm, Grover’s algorithm, Simon's algorithm, and Shor's algorithm. Understand the quantum approaches to solving computational problems and analyze their complexity.
- Gain insights into quantum error correction, including error models, classical vs. quantum errors, and quantum error correction codes. Learn about fault-tolerant quantum computation, the threshold theorem, and decoherence-free subspaces.
- Develop programming skills in Python, including matrix operations, eigenvalue and eigenvector calculations, state evolution, partial transpose and trace calculations, density matrices, Pauli sigma matrices properties, harmonic oscillator operators, Fourier transforms, and logic gate implementations.These skills prepare students to work with quantum systems and quantum computation, both in theory and through practical programming and simulations.

PHYS/DSE-1D: Cosmology (Marks: 50) (Credit: 4)

Observational Basis and Introduction to Cosmology (5 Lectures)
Historical development of cosmology; Olbers paradox and its resolution; Hubble's Law and the expanding Universe; Cosmological Principle (homogeneity and isotropy); observational evidence for Big Bang cosmology; brief overview of the standard model.

Homogeneous Isotropic World Models (8 Lectures)
Friedmann-Robertson-Walker (FRW) metric; Friedmann equations; matter-dominated solutions; radiation-dominated solutions; radiation-matter equality; cosmological parameters; critical density; open, closed, and flat Universe models; distance measures (luminosity distance, angular diameter distance); age of the Universe; CDM concordance model.

Physics of the Early Universe (Big Bang Physics) (8 Lectures)
Thermal history of the Universe; thermodynamics in expanding backgrounds; neutrino decoupling; cosmic neutrino background; Sakharov conditions and baryogenesis; Big Bang Nucleosynthesis (BBN); neutron-proton freeze-out; light element abundances; constraints on baryon density; recombination and decoupling; Saha equation.

Cosmic Microwave Background Radiation (CMBR) (9 Lectures)
Origin and discovery of CMB; decoupling era and last scattering surface; Saha ionization equation; evolution of neutral fraction; CMB anisotropies; dipole anisotropy; primary anisotropies (acoustic

oscillations); angular power spectrum; acoustic peaks and baryon acoustic oscillations; secondary anisotropies (Sunyaev-Zeldovich effect, Integrated Sachs-Wolfe effect); Silk damping; CMB polarization (E-mode and B-mode).

Achievements, Problems, and Inflation (6 Lectures)

Successes of the Hot Big Bang model; horizon problem; flatness problem; monopole problem; coincidence problem; entropy problem; inflationary paradigm; basic mechanism (scalar field/inflaton); slow-roll; different models of inflation (chaotic, new, hybrid); dark energy (cosmological constant vs. dynamical models/ quintessence).

Galaxies - Properties and Dynamics (4 Lectures)

Milky Way as a galaxy; galaxy types and morphological classification (Hubble sequence); dynamics of galaxies; rotation curves and dark matter; galaxy properties; scaling relations (Tully-Fisher, Faber-Jackson, Fundamental Plane - qualitative discussion).

Module 7: Large Scale Structure Formation (6 Lectures)

Origin of inhomogeneities (primordial fluctuations from inflation); gravitational instability; Jean's criterion in expanding Universe; linear perturbation theory; evolution of density fluctuations; spherical collapse approximation; halo model; Press-Schechter mass function; Zel'dovich approximation; cosmological N-body simulations (principles and methods; qualitative discussion).

Large Scale Structures of the Universe (4 Lectures)

Redshift surveys of galaxies (2dF, SDSS, DESI); measures of galaxy distribution (two-point correlation function); power spectrum and baryon acoustic oscillations; cosmic web (filaments, voids, sheets, clusters); peculiar velocities and redshift-space distortions; weak gravitational lensing; galaxy clusters as cosmological probes.

Tutorials (10 Hours):

Problem-solving sessions covering Friedmann equations, cosmological distances, recombination physics, BBN, CMB power spectrum, inflation, structure formation, correlation functions, and power spectra.

References:

1. Peacock, J.A. - Cosmological Physics, Cambridge University Press (Primary)
2. Dodelson, S. - Modern Cosmology, Academic Press
3. Weinberg, S. - Cosmology, Oxford University Press
4. Peebles, P.J.E. - Principles of Physical Cosmology, Princeton University Press
5. Liddle, A. - An Introduction to Modern Cosmology, Wiley
6. Kolb, E.W. & Turner, M.S. - The Early Universe, Taylor & Francis
7. Narlikar, J.V. - Introduction to Cosmology, Cambridge University Press
8. Raychaudhuri, A.K. - Theoretical Cosmology, Oxford University Press
9. Ryden, B. - Introduction to Cosmology, Addison-Wesley
10. Carroll, S. - Spacetime and Geometry, Addison-Wesley

Learning Outcomes:

Upon successful completion of this course, students will be able to:

- 1. Derive the Friedmann-Robertson-Walker (FRW) metric and solve the Friedmann equations for various epochs (radiation, matter, and -dominated).

- 2. Describe the sequence of events in the early Universe (nucleosynthesis, recombination, decoupling) using Saha and Boltzmann equations.
- 3. Relate CMB anisotropies (primary and secondary) to physical parameters via the angular power spectrum and identify effects like Silk damping, and analyze the polarization of the CMB.
- 4. Critically evaluate the limitations of the standard Hot Big Bang model and explain the motivation, mechanisms, and predictions of inflationary cosmology.
- 5. Apply linear perturbation theory, the spherical collapse model, and the Zel'dovich approximation to describe the growth of large-scale structures.
- 6. Interpret galaxy redshift surveys, correlation functions, power spectra, baryon acoustic oscillations (BAO), and the nature of the cosmic web.
- 7. Explain the evidence for dark energy, distinguish between the cosmological constant and dynamical models (quintessence), and understand current observational constraints.
- 8. Understand the principles of cosmological N-body simulations and their role in testing structure formation models.

PHYS/DSE-1E: Laser Physics & Nonlinear Optics-I (Lectures: 50)

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

Laser speckle and Laser safety:
Spatial frequency filtering- principle and its application. Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard

Books Recommended:

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

LEARNING OUTCOMES

- On completion of the course, the student should be able to:
- Learn the fundamental principles of lasers, including population inversion and rate equations. Understand laser construction and pumping mechanisms.

- Comprehend optical beam propagation and Gaussian beams.
- Learn about different laser resonators and their design.
- Study Q-switching techniques and ultrafast pulse generation.
- Explore various types of lasers, including gas, solid-state, chemical, and semiconductor lasers.
- Understand laser safety and hazards, along with safety measures and standards.

PHYS/DSE-1F: Nano Science and Nano-technology -I (Lectures: 50)

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.

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.

PHYS/DSC-PR3: Advanced General Practicals (Lectures: 50)

List of Experiments

Group A:

11. Determination of temporal coherency of a laser light source and compare it with an incoherent source
12. Determination of spatial coherency of a laser light source and compare it with an incoherent source
13. Study of magneto-optic effect (Faraday effect)
14. Study of electro-optic effect (Pockels effect)
15. Study of Zeeman effect
16. Design of active band-pass filters and to verify the Barkhausen criteria
17. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
18. Design of astable multivibrator using 555 Timer.
19. 8085 Microprocessor Practicals.
20. Band-gap determination from thermal variation of resistivity

Group B:

12. Study of ESR
13. Phase identification of an unknown sample from its X-ray diffraction pattern
14. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
15. Studies on antenna theory
16. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
17. Studies on Time-delayed Hyperchaotic Oscillator,
18. Studies on laser diodes and its application in optical communication
19. Finding Speed of light in air using laser.
20. To study and characterize a quantum dot structure.
21. To verify Raman Effect.
22. Determination of efficiency of GM counter.

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.

PHYS/DSC-9: Research Methodology & Computer Applications in Physics (Lectures: 50)

Unit-I: Research Methodology

Foundations of Research in Physics (5 Lectures)

Meaning and objectives of research; Motivation in research; Research and scientific method; Basic vs. applied research; Experimental, theoretical, and computational research; Qualitative vs. quantitative; Steps of the scientific method: question, data collection, hypothesis, experiment, analysis, inference, communication; Identifying a research problem; Sources of research problems; Criteria for a good research problem; Purpose of literature review; Reliable academic sources; Predatory journals; Major journals in physics; Structure of a research proposal; Defining objectives, scope, and methodology; Statement of hypothesis; Working hypothesis; Testing hypotheses; Research design: meaning and concepts; Designs for different types of research; Library, laboratory, and field research; Independent and dependent variables; Qualitative and quantitative variables; Discrete and continuous variables; Sampling methods: meaning and characteristics; Steps in sampling design; Types and advantages.

Statistical Methods and Data Analysis (6 Lectures)
Primary vs. secondary data; Tabular and diagrammatic methods; Scatter plots; Measures of central tendency: Mean, Median, Mode; Arithmetic, Geometric, and Harmonic mean; Measures of dispersion: Range, Mean Deviation, Variance, Standard Deviation, Coefficient of Variation; Probability theory: Basic aspects; Conditional probability; Probability of combination of events; Probability distributions: Binomial, Poisson, and Normal (Gaussian) distributions; Applications in physics; Types of errors: systematic, random, instrumental; Propagation of errors; Normal law of errors; Standard error and probable error; Significant figures; Least square method; Linear and non-linear regression; Correlation coefficient; Hypothesis testing: t-test, chi-square (χ^2) test; ANOVA; F-test; Regression analysis; Goodness of fit; Confidence intervals; Plotting techniques; Graphical representation; Effective tables and graphs; Multivariable correlations; Partial correlation; Bayes theorem.

Scientific Writing and Communication (8 Lectures)
Components of a research paper: Abstract, Introduction, Methods, Results, Discussion, Conclusion; Differences in structure and purpose between thesis and research paper; Layout of a research report/PhD thesis; Citation styles (APA, MLA, Chicago, etc.); Bibliography management; Tools: Zotero, EndNote; Introduction to LaTeX; Document structure; Mathematical typesetting; Bibliography with BibTeX; Seminar presentations; Poster presentations; Effective communication of research findings; Writing research proposals: Structure and components; Funding agencies; Proposal evaluation criteria; Writing review articles; Short communications; Technical and survey reports; Making effective tables and graphs; Visual communication of results.

Research Ethics and Intellectual Property (6 Lectures)
Plagiarism: Meaning and types; Self-plagiarism; Why and how to avoid it; Tools for checking plagiarism: Turnitin; Policy for use of AI in paper writing; Intellectual Property Rights: Meaning and types; Patents, copyrights, trademarks; Patent writing; Types of applications; Disclosure for an invention; Responsible authorship; Order of authors; Collaboration ethics; Ethical considerations in physics research; Professional conduct; Peer review process; Scientific evaluation; Critically evaluating scientific literature.

Tutorials (15 Hours)
Problem-solving sessions covering research problem formulation, statistical analysis (mean, median, mode, dispersion, probability distributions, error propagation), curve fitting and regression, hypothesis testing (t-test, chi-square test), numerical methods (solving equations, integration), LaTeX workshop, research paper analysis, plagiarism and ethics case studies, and research proposal writing.

References

1. Kothari, C.R. & Garg, G. – Research Methodology: Methods and Techniques, New Age International
2. Kumar, R. – Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications
3. Bevington, P.R. & Robinson, D.K. – Data Reduction and Error Analysis for the Physical Sciences, McGraw-Hill
4. Taylor, J.R. – An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books
5. Booth, W., Colomb, G. & Williams, J. – The Craft of Research, University of Chicago Press
6. Turabian, K. – A Manual for Writers of Research Papers, Theses, and Dissertations, University of Chicago Press
7. Rajasekar, S., Philominathan, P. & Chinnathambi, V. – Research Methodology, arXiv: physics/0609001
8. Marder, M.P. – Research Methods for Science, Cambridge University Press
9. Spiegel, M.R. & Stephens, L.J. – Statistics, Schaum's Outline Series
10. Agrawal, B.L. – Basic Statistics, New Age Publishers

Unit-II: Computer Applications in Physics

Elements of C Programming Language (2 Lectures)
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.

Introduction to Python programming (3 Lectures)
The Python Interpreter, Python console, Jupyter and python IDEs; Setting up and using python on GNU/Linux, Windows and Android operating systems; Simple Input and Output; Variables; Mathematical Operators; list, string, tuple, set, dictionary; Control flow and decision control: logical loop structure; Functions and lambdas; Object and class; Files: reading and writing. Python namespaces, installation, design and import of modules in python.

Scientific Computing in Python (3 Lectures)
Introduction to the Numerical Python (numpy), Scientific Python (scipy), and matplotlib modules.Numpy arrays; Initialization and basic operations; resizing; slicing of arrays; array as a matrix; 2D plotting with matplotlib; plot with external data. Fast Fourier Transform (FFT) and the Danielson-Lanczos/Cooley-Tukey algorithms. Implementation of FFT using numpy/scipy. Sparse matrices in scipy, types of sparse matrices. Linear algebra operations with numpy arrays using numpy-BLAS. Determination of eigenvalues and eigenfunctions of simple Fermionic and Bosonic systems.

Numerical Methods in Scientific Computing with Python (10 Lectures)
Representation of real and complex numbers, statistical calculations, factorial, infinite series, iterative methods: logistic map; binary search. Imprecisions in integer and floating point arithmetic. Interpolation of datasets using the Lagrange polynomial. Numerical root finding: Bisection method, False position method, Newton-Raphson method.Solution of system of simultaneous linear equations:

Gauss elimination, Gauss-Seidel method, LUdecomposition algorithm. Numerical integration using Newton-Cotes quadratures: Trapezoidal and Simpson‟s 1/3rd methods.

Numerical solutions of Differential Equations (7 Lectures)
Ordinary Differential Equations: Simple Euler and Runge-Kutta methods. Application in physics problems: damped harmonic oscillator, forcing and resonance; self sustained oscillation (van der Pol oscillator, Lorenz and Roessler oscillator); Henon- Heiles potential problem; visualization in phase space and Poincare sections. Partial Differential Equations: Laplace and Wave equations. Schrodinger equation and solutions to the eigenvalue problem for simple systems.

(1. Instructor should demonstrate the installation of Python, Matplotlib, NumPy, and Scipy in Windows and Linux. 2. Emphasis will be given to solve physical problems and their visualizations. 3. Assignments should be given to the students at a regular interval.)
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

LEARNING OUTCOMES
On completion of the course, the student should be able to:
- Translate a theoretical or algorithmic model into code that enables computation, logically subdivide a computational model into a set of manageable computational tasks, and organize their code accordingly, choose among computational algorithms and computational tools to produce a solution, debug, test, and validate computational models, and extract physical insight from a computation.
- Use the Python programming language to numerically solve physics problems, focussing on the use of Python‟s numeric modules SciPy (Scientific Python), Numpy (Numerical Python), and graphics module Matplotlib (MATLAB-like Plotting Library).
- Apply Monte Carlo simulations, curve-fitting and interpolation of datasets, numerically solve systems of nonlinear equations, ordinary differential equations, multiple integrals, perform computational linear algebra, solve optimization problems, perform signal analysis using Fast Fourier Transforms etc
- Formulate and computationally solve any tractable problem in physics

PHYS/DSC-10: Research Project/Thesis/Patent (Marks: 100) (Credits: 8)

In this module the student will undertake background studies or learn experimental/observational techniques that are needed to do the project work. At the end of the semester, the student will provide a literature review report (not exceeding 2000 words) and make a presentation of the study followed by an open viva-voce

Project-II: Formulation of Project Proposal
In this module the student will formulate the techniques and global goal of their project work. At the middle of the semester the student will make an open presentation to propose the project and show preliminary results to justify the feasibility of the work. The student will also submit a synopsis (not exceeding 500 words) where they will provide the methodology/techniques and the global goal for their project work.

END OF SEMESTER-I (1 Year) OR SEMESTER-III (2 Year)

Sem-II (1 Year)/ Sem-IV (2 Year) Marke: 250 Credits: 24

Paper: PHYS/DSE-2 Marks 50 Credit 4

PHYS/DSE-2A: Advanced Electronics-II (Lectures: 50)

Integrated Circuit Technology (10 Hours)

Hybrid and monolithic ICs, **Semiconductor fabrication:** Diffusion, Ion implantation, Oxidation, Epitaxy, Lithography, etc. CMOS and bipolar IC technologies, Packaging and testing.

Analog and Digital Integrated Circuits (12 Hours)

Analog ICs: Differential amplifier, **Operational amplifier applications:** Comparator, Schmitt trigger, Active filters. Sample-and-hold circuits, Analog multiplexers, Phase-Locked Loop (PLL), Frequency synthesizer.

Digital ICs: Logic families: TTL, CMOS, ECL. Combinational circuits, Sequential circuits, **Programmable logic devices:** PAL, GAL, PLA, FPGA (Introduction).

Memories and Embedded Systems (8 Hours)

RAM and ROM, Static and Dynamic RAM, PROM, EPROM, EEPROM, Flash memory, Introduction to microprocessors and microcontrollers, Architecture of 8086 (overview only), Basic architecture of modern microcontrollers, Interfacing concepts and applications.

Communication Systems (12 Hours)

Analog communication: AM, FM and PM, QAM (concept). **Pulse communication:** PAM, PWM, PPM, PCM. **Digital communication:** ASK, FSK, PSK, QPSK, MSK. **Noise in communication systems:** Additive noise, Receiver performance, Shannon capacity (basic concept).

Optical, Satellite and Wireless Communication (8 Hours)

Fibre optic communication system, Optical power budget, Multiplexing techniques, **Satellite communication:** Orbits, Link budget, Transponders. **Cellular communication:** Cell concept, Frequency reuse, TDMA, FDMA and CDMA (overview), Introduction to wireless communication systems.

Books Recommended:

Integrated Circuits and Electronics

1. Jacob Millman and Arvin Grabel, Microelectronics, McGraw-Hill.
2. Sedra and Smith, Microelectronic Circuits, Oxford University Press.
3. Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, McGraw-Hill.
4. R. A. Gayakwad, Op-Amps and Linear Integrated Circuits, Pearson.
5. Morris Mano and Michael Ciletti, Digital Design, Pearson.

Microprocessors and Embedded Systems

6. Ramesh S. Gaonkar, Microprocessor Architecture, Programming and Applications with the 8085, Penram.
7. Douglas V. Hall, Microprocessors and Interfacing, McGraw-Hill.
8. Muhammad Ali Mazidi, Janice Mazidi, and Rolin McKinlay, The 8051 Microcontroller and Embedded Systems, Pearson.

Communication Systems

9. Simon Haykin, Communication Systems, Wiley.
10. B. P. Lathi and Zhi Ding, Modern Digital and Analog Communication Systems, Oxford University Press.
11. John G. Proakis and Masoud Salehi, Digital Communications, McGraw-Hill.

Optical and Satellite Communication

12. Gerd Keiser, Optical Fiber Communications, McGraw-Hill.
13. Dennis Roddy, Satellite Communications, McGraw-Hill.

LEARNING OUTCOMES

After successful completion of this course, students will be able to:

- Explain semiconductor integrated circuit fabrication technologies and compare CMOS and bipolar integrated circuits.
- Analyze and design analog and digital integrated circuits using operational amplifiers, logic families, programmable logic devices, and phase-locked loops.
- Describe the organization and operation of semiconductor memories, microprocessors, and microcontrollers, and explain their interfacing concepts.
- Explain the principles of analog, digital, and pulse modulation techniques, and evaluate the performance of communication systems in the presence of noise.
- Describe the operating principles and applications of optical fibre communication, satellite communication, and modern wireless communication systems.

PHYS/DSE-2B: Advanced Nuclear Physics –II [50 Lectures]

Two-body scattering Experimental n-p scattering data, Partial wave analysis and phase shifts, scattering length, magnitude of scattering length and strength of scattering, Significance of the sign of scattering length; Scattering from molecular hydrogen and determination of singlet and triplet scattering lengths, effective range theory, low energy p-p scattering. [5 Lecture hours]

Nuclear reaction: Different types of reactions, Quantum mechanical theory, Resonance scattering and reactions — Breit-Wigner dispersion relation; Compound nucleus formation and break-up, Statistical theory of nuclear reactions and evaporation probability, Optical model; Principle of detailed balance, Transfer reactions. [5 Lecture hours]

Nuclear fission and fusion: Basics of fission and fusion, Experimental features, spontaneous fission, liquid drop model theory of fission, barrier penetration, statistical model, Basics of fusion reaction, characteristics of fusion, solar fusion. Elementary ideas about astrophysical reactions, Nucleosynthesis and abundance of elements. [5 Lecture hours]

Reactor Physics: Basics components of a fission and fusion reactor. 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. Radioactive fission products, concept of prompt and beta delayed neutrons. [5 Lecture hours]

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. [5 Lecture hours]

Recommended books:

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)
6. S.S.M. Wong: Introductory Nuclear Physics (PHI)

LEARNING OUTCOMES

At the end of the course students will:

- Interpret n-p scattering data and perform partial wave analysis, including phase shifts and scattering length.
- Analyze the significance of the sign of scattering length and apply it to molecular hydrogen scattering.
- Utilize effective range theory and study low-energy p-p scattering.
- Apply quantum mechanics to understand different types of nuclear reactions, resonance scattering, compound nucleus formation, and statistical theory.
- Understand the basics of nuclear fission and fusion, experimental features, barrier penetration, and their implications in astrophysics and element abundance.
- Understand reactor physics components, neutron slowing down, and critical reactor size.
- Analyze high-energy physics concepts, including elementary particle classification and properties, quark theory, and interaction strengths

PHYS/DSE-2C: Quantum Information Processing –II [50 Lectures]

1. Quantum gates and quantum circuits: [5 Lecture]

Single qubit gates, Two qubit gates, Three qubit gates, Quantum circuits, Entangled circuits(Bell, GHZ, W, Cluster N-qubit), Quantitative measures of quality of a circuit, Gate count or circuit cost, Garbage bit, Quantum, Depth and width of a circuit, Total cost, Circuit optimization rules, Moving rule, Template matching.

2. Quantum error correction: [5 Lecture]

Quantum error correction, Basic idea of an error model, How to correct classical errors, Difference between classical error and quantum error, Correction of quantum bit flip error: A 3-qubit code, Correction of phase flip error: A 3-qubit code, Fault-tolerant quantum computation, Threshold theorem for quantum computation, Decoherence and decoherence free subspace, Decoherence free subspace.

3. Quantum teleportation and super dense coding: [7 Lecture]

Different types of teleportation schemes, Perfect and probabilistic teleportation, quantum information splitting, Hierarchical quantum information splitting Modified teleportation schemes, Remote state preparation, Modified remote state preparation schemes, Superdense coding.

4. Quantum cryptography: [18 Lecture]

History of cryptography, Jargon related to cryptography, some interesting classical ciphers, RSA and its limitations, Different aspects of quantum cryptography, Development of QKD protocols, BB84 protocol, Elementary idea of decoy state, B92 protocol, GV protocol: QKD with orthogonal state, Ping-pong protocols, CL protocol, LM05 protocol, PPGV protocol, DLL and modified DLL(DLLGV), DSQC protocol and its modifications , The DSQC protocol with arbitrary, A QSDC protocol from Protocol, Protocols of quantum dialogue, Ba An protocol, Generalized protocol of quantum dialogue, Applications of quantum dialogue protocols in the socialist millionaire problem, Various attacks in the protocols, efficiency.

5. Quantum Noisy Channel: [5 Lecture]

The Depolarization Channel, The Bit Flip and Phase Flip Channels, Amplitude Damping, phase damping, Distance measures for classical information, Trace distance, Fidelity, Relationships between distance measures, preservation of information in quantum channel.

6. Experiments/Simulations: [10 Lecture]

Basic Quantum Computing with Qiskit (python 3)

Hands on coding in IBM Q lab (qiskit)

1. Perform different gate operation (taught in the course) by using qiskit and locate on bloch sphere and for phase information use Q-sphere. (ii) Establish Bell state, GHZ state and W state in IBM Q lab (Qiskit) or Jupyter notebook (a) Draw the circuit and then measure it. (b) Plot probability Histogram and explain the circuit is entangled or not. (c) Run above circuits on real quantum computer and show the noise in quantum computer by using histogram plot (probability).
2. For a given Quantum circuit, write the code and draw the circuit by using qiskit. Contract Teleportation circuit (a) Draw it (b) Measure and simulate it, execute for given number of shots (like 2000) (c) plot histogram.
3. (iii) Bernstien – Vazirani Algorithm implement by using qiskit, and show that classical computer need more tries but quantum computer do that by one try. Establish the Grover Search algorithm on qiskit.
4. (iv) Implement Shor's Algorithm (you can use in build qiskit modules), Deutsch-Jozsa Algorithm, Simon's Algorithm, Superdense coding, Quantum Key Distribution, Quantum Fourier Transform and Quantum Phase Estimation, Quantum Counting.

Recommended Books:

1. Quantum Computation and Quantum Information, Michael A. Nielsen, Isaac L. Chuang
2. Quantum Computing Explained, David McMahon. WILEY-INTERSCIENCE. A John Wiley & Sons,
3. Vector Spaces and Matrices in Physics; M. C. Jain, CRC Press, 2001
4. Elements of Quantum Computation and Quantum Communication, Anirban Pathak.
5. Computational Physics , Problem solving with python, Rubin H. Landau, Manuel J. Paez, Cristian C. Bordeianu
6. Quantum Information theory. M. Wilde, Cambridge University Press, 2013.
7. An Introduction to Quantum Computing. P. Kaye, R. Laflamme and M. Mosca. Oxford University Press, New York, 2007.
8. Quantum Optics-An introduction; Mark Fox.

LEARNING OUTCOMES

On completion of the course, the students will:

- Understand different quantum teleportation schemes, including perfect and probabilistic teleportation, quantum information splitting, and superdense coding.

- Explore the history and jargon related to cryptography, classical ciphers, and the limitations ofRSA.
- Learn about various aspects of quantum cryptography, including the development of quantumkey distribution (QKD) protocols like BB84, B92, and GV, as well as protocols for quantumdialogue, socialist millionaire problems, and potential attacks on these protocols.
- Gain knowledge of quantum noisy channels, including depolarization, bit flip, phase flip,amplitude damping, and phase damping channels, along with distance measures for classical and quantum information.

PHYS/DSE-2D: Astrophysics (Marks: 50) (Credit: 4)

Observational Foundations and Basic Stellar Properties (8 Lectures)

Topics: Electromagnetic spectrum; telescopes and detectors; diffraction limit; angular resolution; blackbody radiation (Planck spectrum, Wien's law, Stefan-Boltzmann law); stellar distances (parallax); binary stars (visual, spectroscopic, eclipsing); mass determination; extrasolar planets; stellar spectra; OBAFGKM sequence; Hertzsprung-Russell diagram.

Stellar Structure and Nuclear Energy Generation (10 Lectures)

Topics: Hydrostatic equilibrium; Virial theorem; mass continuity; radiative energy transport; opacity; mean free path; random walk; energy conservation; equation of state (ideal gas, radiation pressure); nuclear reactions (p-p chain, CNO cycle); Coulomb barrier; Gamow energy; reaction rates; scaling relations; convection.

Stellar Evolution and Compact Remnants (12 Lectures)

Topics: Post-main-sequence evolution (red giant, helium flash, horizontal branch, AGB); planetary nebulae; white dwarfs (degeneracy pressure, mass-radius relation, Chandrasekhar mass, cooling); brown dwarfs; core-collapse supernovae; neutron stars (properties, equation of state); pulsars (identification, Crab pulsar, magnetic dipole radiation); black holes (Schwarzschild radius, event horizon, gravitational redshift, time dilation).

Accretion Physics and Interacting Binaries (4 Lectures)

Topics: Roche lobes and mass transfer; accretion disks (temperature profile, luminosity); Eddington luminosity; cataclysmic variables; novae; Type Ia supernovae; X-ray binaries; millisecond pulsars.

Interstellar Medium and Star Formation (8 Lectures)

Topics: Molecular clouds; Jeans instability; cloud collapse; protostar formation; H II regions; Strömgren sphere; ionization front; recombination; ISM components (21 cm line, molecular tracers, dust); heating and cooling mechanisms (forbidden lines); star clusters; initial mass function.

Galaxies and Active Galactic Nuclei (8 Lectures)

Topics: Structure of the Milky Way; rotation curves and dark matter; gravitational lensing (Einstein angle, microlensing); galaxy demographics (spirals, ellipticals, irregulars); galaxy clusters (virial mass, intracluster medium); active galactic nuclei (quasars, Seyfert galaxies, radio galaxies); unification model; supermassive black holes.

References:

1. Maoz, D. – Astrophysics in a Nutshell, Princeton University Press
2. Carroll, B.W. & Ostlie, D.A. – An Introduction to Modern Astrophysics
3. Shapiro, S.L. & Teukolsky, S.A. – Black Holes, White Dwarfs and Neutron Stars
4. Binney, J. & Merrifield, M. – Galactic Astronomy
5. Peterson, B.M. – An Introduction to Active Galactic Nuclei

Learning Objectives:

Upon successful completion of this course, students will be able to:

- 1. Apply observational techniques and blackbody radiation laws to determine stellar properties.
- 2. Analyze binary star systems to determine stellar masses.
- 3. Derive and apply the fundamental equations of stellar structure.
- 4. Explain nuclear reactions as the energy source of stars.
- 5. Describe the evolution of stars from formation to compact remnants.
- 6. Apply the physics of degenerate matter to white dwarfs and neutron stars.
- 7. Explain pulsar emission mechanisms and identify pulsars with rotating neutron stars.
- 8. Describe basic properties of black holes, including the Schwarzschild radius and event horizon.
- 9. Analyze accretion disk physics and calculate Eddington luminosities.
- 10. Apply the Jeans criterion to star formation and calculate Strömgren radii.
- 11. Interpret galactic rotation curves and explain the evidence for dark matter.
- 12. Classify galaxies and active galactic nuclei based on their observed properties.

PHYS/DSE-2E:Laser Physics and Nonlinear Optics -II

Nonlinear Optics:
Introduction, nonlinear 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 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

LEARNING OUTCOMES
On completion of the course, the student will be able to:

- Learn the fundamentals of nonlinear optics, covering topics such as nonlinear polarization and second harmonic generation.
- Understand phase matching, including methods like angle, temperature, and birefringence-based phase matching.
- Analyze higher-order nonlinear processes like third harmonic generation and resonance enhancement.
- Explore chemical applications and separation processes, including isotope enrichment.
- Comprehend laser-tissue interaction and its effects on human skin.
- Apply laser technology in medical science, including surgical treatments and ultrashort pulse effects on chemical reactions.
- These skills enable students to work with nonlinear optics in a wide range of applications, from chemistry to medical science.

PHYS/DSE-2F: Nano Science and Nano-technology -II (Lectures: 50)

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: PHYS/DSC-PR4 Marks 50 Credit 4

PHYS/DSSC-PR4: Advanced General Laboratory Practicals [Marks 50] [Credit 4]

List of Experiments

Group A:

21. Determination of temporal coherency of a laser light source and compare it with an incoherent source
22. Determination of spatial coherency of a laser light source and compare it with an incoherent source
23. Study of magneto-optic effect (Faraday effect)
24. Study of electro-optic effect (Pockels effect)
25. Study of Zeeman effect
26. Design of active band-pass filters and to verify the Barkhausen criteria
27. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
28. Design of astable multivibrator using 555 Timer.
29. 8085 Microprocessor Practicals.
30. Band-gap determination from thermal variation of resistivity

Group B:

23. Study of ESR

24. Phase identification of an unknown sample from its X-ray diffraction pattern
25. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
26. Studies on antenna theory
27. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
28. Studies on Time-delayed Hyperchaotic Oscillator,
29. Studies on laser diodes and its application in optical communication
30. Finding Speed of light in air using laser.
31. To study and characterize a quantum dot structure.
32. To verify Raman Effect.
33. Determination of efficiency of GM counter.

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.

Paper: PHYS/DSC-11 Marks 150 Credit 12

PHYS/DSC-11: Dissertaion

Teacher specific topic are to be provided

Project-III: Dissertation
A final dissertation (not exceeding 5000 words) pertaining to the project work undertaken by the student will be submitted for evaluation of the work.

Project- IV Defense Seminar and Open Viva
Students will be expected to defend their thesis in an open seminar and a viva voce will follow.

Project-V Comprehensive Viva
Students will be examined through a comprehensive viva by a board of examiners consisting internal and external members on the basis of the submitted dissertation.

PHY-IKS1: Indian Knowledge System (50 Marks, 50 Lectures)

1. Introduction to Indian Knowledge Systems (4 lectures)
Definition, scope and methodology of IKS; Vedic corpus, Vedāṅgas, Upavedas, Itihāsas and Purāṇas; Pramāṇa (Pratyakṣa, Anumāna, Śabda), Prameya and Vaiśeṣika categories (padārthas); Caturdaśa Vidyāsthāna; Para and Apara Vidyā; scientific inquiry and evolution of Siddhānta.

2. Indian Physics (12 lectures)
Vaiśeṣika atomism; adṛṣṭa as a philosophical principle explaining natural processes beyond direct observation; Pañcamahābhūta and comparison with modern concepts of matter and physical properties; karma, vega, saṃyoga, vibhāga and causality; concepts of gravitation in Siddhānta Śiromaṇi and Sūrya Siddhānta with qualitative comparison to Newtonian gravitation; traditional units of time and distance; cyclic cosmology; concepts of light, vision and reflection.

3. Indian Mathematics (12 lectures)
Decimal place value and zero; Bhūta-saṃkhyā, Kaṭapayādi and Āryabhaṭa numeration; Śulba Sūtras; trigonometry; Brahmagupta's quadratic equations; Bhāskara II's Chakravāla method; Kerala School, convergence of infinite series; Piṅgala's binary representation, recursion and Meru-prastāra.

4. Indian Astronomy (12 lectures)
Vedāṅga Jyotiṣa; Āryabhaṭa, Brahmagupta, Bhāskara II and Nīlakaṇṭha; celestial coordinates; Pañcāṅga; planetary models; Manda and Śīghra corrections; ayanāṃśa; eclipse computation with lunar nodes; Jantar Mantar, Śaṅku and water clock; comparison with modern astronomy.

5. Metallurgy & Materials (4 lectures)
Delhi Iron Pillar; Wootz steel; archaeological evidence from Zawar zinc mines; Rasārṇava, Rasaratnasamuccaya; Ras-śālā and metallurgical techniques.

6. Architecture, Engineering & Health (6 lectures)
Indus–Sarasvati planning; Vāstu and Śilpa Śāstra; acoustic properties of Vittala temple pillars, Konark sundial, Ellora engineering; Ayurveda, Yoga, preventive healthcare, Triguṇa and comparison with modern psychology.

Learning Outcomes

- Explain the methodology of Indian scientific traditions.
- Describe major contributions to Indian physics, mathematics, astronomy and metallurgy.
- Compare selected concepts from Indian scientific traditions with modern scientific theories, identifying similarities and differences.
- Interpret translated excerpts from primary scientific texts.
- Critically evaluate historical scientific claims using textual and archaeological evidence.
- Apply traditional computational methods to interdisciplinary scientific problems.

Suggested References

1. Mahadevan, B., Bhat, V.R. & Pavana, R.N. Introduction to Indian Knowledge System: Concepts and Applications. PHI, 2022.
2. Balachandra Rao, S. Indian Mathematics and Astronomy: Some Landmarks. Bhavan's Gandhi Centre.
3. Datta, B. & Singh, A.N. History of Hindu Mathematics (2 vols.).
4. Ramasubramanian, K., Sule, A. & Vahia, M. (Eds.) History of Astronomy in India: A Handbook.
5. Subbarayappa, B.V. A Concise History of Science in India.
6. Joseph, G.G. Indian Mathematics: Engaging the World from Ancient to Modern Times.
7. Primary texts: Vaiśeṣika Sūtra; Vedāṅga Jyotiṣa; Āryabhaṭīya; Sūrya Siddhānta; Siddhānta Śiromaṇi; Śulba Sūtras; Rasārṇava; Rasaratnasamuccaya.

General Practical
LIST OF EXPERIMENTS:
Group A:

13. Determination of wavelength of light from He-Ne laser by Michaelson interferometer
14. Determination of e/m by magnetron valve/magnetic focusing method
15. Determination of (i) Rydberg constant, (ii) ionisation potential and (iii) quantum defect of an alkali atom.
16. Determination of Stefan's constant and hence computation of the Planck's constant
17. Determination of Hall voltage and carrier concentration of a given semiconductor
18. Determination of speed of ultrasonic waves in an aqueous medium
19. Study of optical characteristics of a LED and determination of band gap of the material of LED.
20. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.
21. To draw the plateau curve of a GM counter and hence to determine the statistical variation of counts of the GM Counter.
22. Determination of wavelength of sodium light using Lloyd's mirror.
23. Determination of particle size of an unknown specimen
24. Measurement of magnetic susceptibility using Quincks method

Group B

11. Study the current mirror biasing and VBE multiplier based voltage reference.
12. Study the transistor amplifier in common emitter (CE) mode.
13. To draw the LDR characteristics at different intensities and to find out the value & the dark resistance of the LDR.
14. 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.
15. To design a three bit parallel adder
16. Study on op-amp based linear and nonlinear amplifier
17. To design RC-phase shifter oscillator
18. Study the input and output voltage characteristics of Schmitt trigger circuit
19. To Construct and test the operation Pre-emphasis & de-emphasis circuits by plotting frequency response using Op-amp.
20. To Study the amplitude modulation technique and determine the modulation index

Advanced General Practical
List of Experiments
Group A:

31. Determination of temporal coherency of a laser light source and compare it with an incoherent source
32. Determination of spatial coherency of a laser light source and compare it with an incoherent source
33. Study of magneto-optic effect (Faraday effect)
34. Study of electro-optic effect (Pockels effect)
35. Study of Zeeman effect

36. Design of active band-pass filters and to verify the Barkhausen criteria
37. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
38. Design of astable multivibrator using 555 Timer.
39. 8085 Microprocessor Practicals.
40. Band-gap determination from thermal variation of resistivity

Group B:

34. Study of ESR
35. Phase identification of an unknown sample from its X-ray diffraction pattern
36. Studies on Gunn oscillator in the microwave frequency region (Microwave workbench)
37. Studies on antenna theory
38. Studies on van der Pol oscillator: Sinusoidal and relaxation oscillations
39. Studies on Time-delayed Hyperchaotic Oscillator,
40. Studies on laser diodes and its application in optical communication
41. Finding Speed of light in air using laser.
42. To study and characterize a quantum dot structure.
43. To verify Raman Effect.
44. Determination of efficiency of GM counter.