Faculty of Sciences

Course Structure and Syllabi

M. Sc. (Physics)

2024

(New Education Policy 2020)

As Per Latest Module of UGC

Department of Physics

Indira Gandhi National Tribal University

Amarkantak 484887

Structure of M.Sc. (Physics) Courses

Department of Physics

Course Structure of M.Sc. Courses (2024-2028)

	Two Years M.Sc. (Physics) Programme	
Course Code	**Semester-I**	**Credits**
MPH-101T	Advanced Classical Mechanics	4
MPH-102T	Classical Electrodynamics-I	4
MPH-103T	Quantum Mechanics-I	4
MPH-104T	Mathematical Methods in Physics-IV: Special Mathematical Techniques	4
MPH-111P	Advanced Physics Lab-1	2
MPH-112P	Advanced Physics Lab-2	2
	Total Credits	20
	Semester-II	
MPH-201T	Statistical Thermodynamics	4
MPH-202T	Mathematical Methods in Physics-V: Special Mathematical Methods	4
MPH-203T	Advanced Numerical Techniques in Physics	4
MPH-204T	Instrumentation Techniques	4
MPH-211P	Lab: Great Experiments in Physics	4
MPH-251	Dissertation (Optional) (Project Work+Dissertation+*Viva-Voce*)	12
	Total Credits	20
	Semester III	
MPH-301T	Nuclear and Particle Physics	4
MPH-302T	Quantum Mechanics-II	4
MPH-303T	Condensed Matter Physics-I	4
MPH-304T	Elective-1	4
MPH-311P	Nuclear Physics Lab	2
MPH-312P	Advanced Electronics and Instrumentation Lab	2
	Total Credits	20
	Semester IV	
MPH-401T	Relativistic Quantum Mechanics & Quantum Field Theory (Quant. Mechanics-III)	4
MPH-402T	Electrodynamics-II (Electrodynamics in Matter and Medium)	4
MPH-403T	Condensed Matter Physics-II	4
MPH-404T	Elective-2	4
MPH-451	Project with Dissertation	4
	Total Credits	20
	List of Elective Courses	
Group-A	1. General Theory of Relativity and Cosmology (MPH-304A1)	4
	2. Astrophysics (MPH-404A2)	4
Group-B	1. Physics of Functional Materials & Devices (MPH-304B1)	4
	2. Nanomaterials and Their Properties (MPH-404B2)	4
Group-C	1. Particle Physics-I (MPH-304C1)	4
	2. Particle Physics-II (MPH-404C2)	4

Group-D	1. Digital Electronics (MPH-304D1)	4
	2. Microwave Electronics (MPH-404D2)	4
Group-E	1. Ionospheric Physics (MPH-304E1)	4
	2. Atmospheric Physics and Weather Science (MPH-404E2)	4
	One Year M.Sc. (Physics) Programme	
Course Code	**Semester I**	**Credits**
NMPH-101T	Nuclear and Particle Physics	4
NMPH-102T	Quantum Mechanics-II	4
NMPH-103T	Condensed Matter Physics-I	4
NMPH-104T	Elective-1	4
NMPH-111P	Nuclear Physics Lab	2
NMPH-112P	Advanced Electronics and Instrumentation Lab	2
	Total Credits	20
	Semester II	
NMPH-201T	Relativistic Quantum Mechanics & Quantum Field Theory (Quantum Mechanics-III)	4
NMPH-202T	Electrodynamics-II (Electrodynamics in Matter and Medium)	4
NMPH-203T	Condensed Matter Physics-II	4
NMPH-204T	Elective-2	4
NMPH-251	Project	2
	Dissertation /Presentation on the Dissertation	2
	Total Credits	20
	List of Elective Courses	
Group-A	1. General Theory of Relativity and Cosmology (NMPH-104A1)	4
	2. Astrophysics (NMPH-204A2)	4
Group-B	1. Physics of Functional Materials & Devices (NMPH-104B1)	4
	2. Nanomaterials and Their Properties (NMPH-204B2)	4
Group-C	1. Particle Physics-I (NMPH-104C1)	4
	2. Particle Physics-II (NMPH-204C2)	4
Group-D	1. Digital Electronics (NMPH-104D1)	4
	2. Microwave Electronics (NMPH-204D2)	4
Group-E	1. Ionospheric Physics (NMPH-104E1)	4
	2. Atmospheric Physics and Weather Science (NMPH-204E2)	4

Syllabi

Two Years M.Sc. (Physics) Programme

Two Years M.Sc. (Physics)

Semester-I

MPH-101T: Advanced Classical Mechanics Credit(s):4

Unit-I

Lagrangian and Hamiltonian Dynamics: Constraints, holonomic and non-holonomic constraints, D'Alembert's Principle and Lagrange's Equation, velocity dependent potentials, simple applications of Lagrangian formulation. Hamilton Principle, Calculus of Variations, Derivation of Lagrange's equation from Hamilton's principle. Extension of Hamilton's Principle for nonconservative and nonholonomic systems, Method of Lagrange's multipliers, Conservation theorems and Symmetry Properties, Noether's theorem. Conservation of energy, linear momentum and angular momentum as a consequence of homogeneity of time and space and isotropy of space.

Unit-II

Generalized momentum, Legendre transformation and the Hamilton's Equations of Motion, simple applications of Hamiltonian formulation, cyclic coordinates, Routh's procedure, Hamiltonian Formulation of Relativistic Mechanics, Derivation of Hamilton's canonical Equation from Hamilton's variational principle. The principle of least action.

Unit-III

Inertia Tensor: Inertial tensor. Moment and Product of Inertia. Rotational Dynamics. Pseudo forces. Coriolis forces. Similarity transformations.

Unit-IV

Canonical transformation, integral invariant of Poincare: Lagrange's and Poisson brackets as canonical invariants, equation of motion in Poisson bracket formulation. Infinitesimal contact transformation and generators of symmetry, Liouville's theorem, Hamilton-Jacobi equation and its application.

Unit-V

Action angle variable adiabatic invariance of action variable: The Kepler problem in action angle variables, theory of small oscillation in Lagrangian formulation, normal coordinates and its applications. Orthogonal transformation, Euler's theorem, Eigenvalues of the inertia tensor, Euler equations, force free motion of a rigid body.

Suggested Readings

1. Herbert Goldstein, C. Poole, John Safko: Classical Mechanics, Pearson (2011).
2. L. D. Landau and E.M. Lifshitz: Mechanics, Pergamon Press (1969).
3. A. K. Raychoudhary, Classical Mechanics, Oxford University Press (1983).
4. N. C. Rana and P. S. Joag: Classical Mechanics, Tata McGraw Hill (2017).
5. Ronald L. Greene: Classical Mechanics with Maple, Springer (1995).
6. N. Mukunda and G. Sudarshan, Classical Dynamics: A Modern Perspective, HBA Books (1973).

Course Outcome (CO) of Atomic and Molecular Physics

Upon completion of this course, students would be able to:

CO-1. Have a deep understanding of Newtonian, Lagrangian and Hamiltonian Mechanics.

CO-2. Solve the non-Newtonian equations of different configurations using various techniques.

CO-3. Understand the niceties rotational motion and rigid body dynamics.

CO-4. Learn the idea of Lagrangian dynamics and its applications.

CO-5. Develop computational techniques based on "Advanced Classical Mechanics."

MPH-102T: Classical Electrodynamics–I Credit(s): 4

(Electrodynamics in Vacuum or Free Space)

Unit-I: Electric Potential and Multipoles

Dipole radiations: Retarded potentials. Electric dipole and multi-pole radiations. Magnetic dipole radiations. Radiation from an arbitrary distribution of charges. Radiation from a point charge: Lienard-Wiechert potentials. The fields of a point charge in motion. Power radiated by a point charge.

Unit-II: Electromagnetism (Without Matter and Medium)

The idea of Four Potentials. Deriving Electro-magnetic field tensor using four potentials.

Relativistic electrodynamics using potential formulation: Field tensor and Electrodynamics in tensor notations. *Maxwell's equations in potential formulation*. Relativistic transformations of electro-magnetic fields

Unit-III: Gauge Transformations in Relativistic Electromagnetism

Lorentz' Force and the Electromagnetic Field. The origin of covariant derivative for Electrodynamics. Gauge transformations. Coulomb's gauge and Lorentz' gauge. Energy Momentum Tensor of the Electromagnetic Field.

Unit-IV

Wave propagation in radiation scenario. Frequency and wave-vector transformations. Reflection and refraction of electro-magnetic waves. Origin of refractive index. Dispersion.

Unit-V

Radiation reaction: The Abraham-Lorentz' formula. The physical origin of the radiation reaction.

Special radiative processes: Bremstrahlung. Synchrotron radiations. Cerenkov radiations. Fundamentals of magneto-hydrodynamics and plasma.

Suggested Readings

1. L. D. Landau & Lifshitz: Classical Theory of Electrodynamics; Pergamon Press (1984).

2. L. D. Landau & Lifshitz: Electrodynamics of continuous media; Pergamon Press (1984).

3. J. D. Jacksson: Classical Electro-dynamics; John Wiley (1998).

4. David J. Griffiths: Introduction to Electro-dynamics; Prentice Hall/Pearson (2015).

5. Panofsky and Phillip: Classical Electricity and Magnetism, Dover Publication (2005).

Course Outcome (CO) of Classical Electrodynamics-I

Upon completion of this course, students would be able to:

CO1: Explain classical electrodynamics based on Maxwell's equations including its formulation in covariant form.

CO2: Solve the electromagnetic problems with the help of electrodynamic potentials and super-potentials, and make a detailed account for gauge transformations and their use

CO3: Formulate and solve electrodynamic problems in relativistically covariant form in four-dimensional spacetime.

CO4: Calculate the electromagnetic radiation from localized charges which move arbitrarily in time and space, taking into account retardation effects.

CO5: Calculate the electromagnetic radiation from radiating systems, like oscillating electric and magnetic dipoles (aerials, localized charge and current distributions)

MPH-103T: Quantum Mechanics-I Credit(s):4

Unit-I

Linear spaces and Operators: Vector spaces, Linear independence, Bases, dimensionality and Isomorphisms. Linear transformations, inverses, matrices, similarity transformations, Eigenvalues and Eigenvectors. Inner product, orthogonality and completeness, complete orthogonal set, Gramm-Schmidt orthogonalization procedure, Eigenvalues and Eigenvectors of Hermitian and Unitary transformations, diagonalization. Function space and Hilbert space. Complete orthonormal sets of functions.

Unit-II

Structure of Quantum Mechanics: Postulates of QM, Hilbert space; Hermitian and unitary operators; Orthonormality, completeness and closure. Dirac's *Bra* and *Ket* Representations. Matrix Representation and change of basis. Operators and observables, significance of eigenvector and eigenvalues, Commutation relation. Uncertainty principle for arbitrary Operators. Time-Evolution in Quantum Mechanics and Three Pictures. Fundamental Theorems of Quantum Mechanics.

Unit-III

Quantum Linear Harmonic Oscillator: Creation and annihilation operators. Occupation number. Quantization of creation and annihilation operators. Number operator. Coherent states and time-evolution of coherent states.

Unit-IV

Angular Momentum-I: Orbital angular momentum and Quantum Mechanics of rotations. Orbital angular momentum operators and their properties. Theory of Hydrogen-like atoms. Quantum Mechanics of rotations.

Infinitesimal rotations. Euler angles. Three-dimensional oscillators. Rotation-vibration spectra of diatomic molecules.

Unit-V

Angular Momentum-II: Total angular momentum. Angular momentum operators: $\hat{J}_x, \hat{J}_y, \hat{J}_z, \hat{J}, \hat{J}^2$ and $\hat{J}_+$, and $\hat{J}_-$. Angular momentum eigen-values. Angular momentum matrices corresponding to spin half particles: Pauli's spinors and their properties.

Spin angular momentum. Stern-Gerlack experiment. Larmour's precession.

Total angular momentum and spin-orbit ($L-S$) coupling. Addition of angular momentum. Clebsch-Gordon coefficients. Selection rules.

***Suggested Readings*:**

1. Ashok Das and A.C. Melissions: Quantum Mechanics- A Modern Approach, Gordon and Breach Science Publishers.
2. Albert Messiah: Quantum Mechanics, Dover Publications
3. L. I. Schiff: Quantum Mechanics, Mc-Graw Hill.
4. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe: Quantum Mechanics, Wiley.
5. J. J. Sakurai: Modern Quantum Mechanics, Pearson Education.
6. E. Merzbecher: Quantum Mechanics, John Wiley.

Course Outcome (CO) of Quantum Mechanics-I

Upon completion of this course, students would be able to:

CO-1: Understand the fundamentals of Quantum Mechanics specifically the 'Operator Mechanism in Quantum Mechanics'.

CO-2: Understand the 'Premise and Postulates of Quantum Mechanics'and make them understand Dirac's 'Bra and Ket representation'.

CO-3: Understand the theory of 'Quantum Linear Harmonic Oscillator' and 'The Idea of Creation and Annihilation Operators' and apply it in research in Advanced Physics.

CO-4: Understand- 'Theory of Angular Momentum in Quantum Mechanics' and apply it to 'Hydrogen-like Atom' and 'Spectroscopic Techniques'.

CO-5: Understand and apply the mathematical techniques of 'Total Angular Momentum' including 'selection rules' and 'Chlebsch-Gordon Coefficients'.

MPH-104T: Advanced Mathematical Methods in Physics-V (Elective) Credit(s): 04

(Special Mathematical Methods)

Unit-I: Special Mathematical Techniques

Dirac Delta Function: Definition. Representation and Properties of Dirac Delta Function.

Green's Function. Gamma and Beta functions. Sterling's formula.

Unit-II: Fourier Series

Periodic functions. Fourier series and series expansion of periodic functions. Orthonormal properties. Dirichlet's conditions. Asymptotic behaviour and Fourier series. Convergence. Summation of series. Rieman's Zeta function. Examples.

Unit-III: Matrices

Properties of Matrices. Orthogonal, Hermitian, Unitary, Identity, Nilpotent and Idempotent Matrices. Matrices as Operators. Diagonalization of Matrices. Eigen-Values and Eigen-Vectors of Matrices. Solving Linear equations by using Matrices.

Unit-IV: Groups and Symmetries

Groups and subgroups. Cosets. Quotient Groups. Cyclic groups. Normal subgroups. Groups defined on Matrices. Lie-groups. Special Orthogonal Groups $SO(n)$. Special Unitary Groups $SU(n)$. Specific cases of $SU(2)$ and $SU(3)$ Groups.

Unit-V: Vector Spaces

Vector Spaces. Dual spaces. Liner Dependence and Linear Independence. Inner Product of Vector Spaces. Linear Transformations. Important Inequalities: Cauchy-Schwarz inequality, Triangle inequality; and Gram determinant inequality. Group Morphisms.

Suggested References:

1. George Arfken, Mathematical Methods for Physicists, Academic Press (2012).
2. L. A. Pipes, Applied Mathematics for Engineers & Physicists, McGraw Hill (1970).
3. Merle C. Potter and Jack Goldberg: Mathematical Methods, Prentice Hall (1987).
4. Fredrick W. Byron and Robert W. Fuller: Mathematics of Classical and Quantum Physics, Dover Publications (1970).
5. V. Balakrishnan, Mathematical Physics, Ane Books Pvt Ltd. New Delhi (2018).
6. Tulsi Dass and S.K. Sharma: Mathematical Methods in Classical and Quantum Physics, Universities' Press (Orient Longman) (1998).

Course Outcome (CO)

CO-1: To learn to apply special mathematical function appropriately in solving problems in physics, understand the Dirac Delta and other distributions and be able to derive their various properties

CO-2: To learn to use Fourier transform to obtain the Fourier series of periodic functions in physics; and apply transform methods to solve elementary differential equations of interest in physics and engineering.

CO-3: To learn to apply of matrix diagonalization, matrix operations and matrix transformations.

CO-4: To be able to identify symmetries in Mathematics and Physics and associate appropriate group characteristics with them.

CO-5: To learn the properties of Linear Vector Spaces and their transformations.

MPH-111P: Advanced Physics Lab-1 Credit(s): 2

Students have to perform any 10 experiments

1. To verify *Hartmann's formula* using constant deviation spectrograph.
2. To study *ESR* and determine *g*-factor for a given spectrum.
3. To find e/m of electron using *Zeeman effect*.
4. To determine *internal friction* at the *grain boundaries of solids* using *torsional pendulum*.
5. To study a *driven mechanical oscillator*.
6. To study *coupled pendulums*.
7. To study the *dynamics of a lattice* using electrical analog.
8. To study the variation of rigidity of a given specimen as a function of the temperature.

11. Verification of *Bragg's law* using microwaves.

Suggested Readings:

1. P. R. Sasi Kumar, Practical Physics (2006) PHI Pub.
2. K. Ventat Raman, R. Raja and M. Sunder Rajan, Experimental Physics (2014) Scintech Publications.
3. S. K. Ghosh, A Text Book of Practical Physics (2008) New Central Book Agency.
4. D. Chattopadhyay and P. Rakshit, An Advance Course in Practical Physics (2011) New Central Book Agency.

MPH-112P: Advanced Physics Lab-2 Credit(s): 2

Students are required to perform any 10 experiments from the following:

1. To determine velocity of sound in air using CRO.
2. To determine velocity of sound in liquids using Ultrasonic interferometer.
3. To determine velocity of sound in solids by pulse-echo method.
4. To study Faraday effect and Verdent's constant of a given material
5. To study wavelength of an unknown light source using Compact Disk.
6. To determine the distance between grooves of a Compact Disk.
7. To study electro-optic modulation.
8. To study magnet-optic modulation.
9. To determine the particle size of a given (unknown) material.
10. To study Raman scattering using LASER source.

Suggested Readings

1. P. R. Sasi Kumar, Practical Physics, PHI Pub. (2006).
2. K. V. Raman, R. Raja and M. S. Rajan, Experimental Physics, Scintech Pub. (2014).
3. S. K. Ghosh, A Text Book of Practical Physics, New Central Book Agency (2008).
4. D. Chattopadhyay & P. Rakshit, Advance Course in Practical Physics, New Central Book Agency (2011).

Semester-II

MPH-201T: Statistical Thermodynamics   Credit(s): 4

Unit-I

Elementary Probability Theory: Preliminary concepts, Random-walk problem, Binomial distribution, mean values, standard deviation, various moments, Gaussian distribution, Poisson distribution, mean values. Probability density, probability for continuous variables. **Extensive and Intensive Variables**: laws of thermodynamics, Legendre transformations and thermodynamic potentials, Maxwell relations, applications of thermodynamics to (a) ideal gas, (b) magnetic material, and (c) dielectric material. The laws of thermodynamics and their consequences.

Unit-II

Statistical Description of System of Particles: State of a system, microstates, ensemble, basic postulates, behavior of density of states, density of state for ideal gas in classical limit, thermal and mechanical interactions, quasi-static process. Statistical thermodynamics: Irreversibility and attainment of equilibrium, Reversible and irreversible processes. Thermal interaction between macroscopic systems, approach to thermal equilibrium, dependence of density of states on external parameters, Statistical calculation of thermodynamic variables.

Unit-III

Canonical and Grand Canonical Ensembles: Concept of statistical distribution, phase space, density of states, Liouville's theorem, systems and ensemble, entropy in statistical mechanics Connection between thermodynamic and statistical quantities micro canonical ensemble, equation of state, specific heat and entropy of a perfect gas, using micro canonical ensemble. Canonical ensemble, thermodynamic functions for the canonical ensemble, calculation of mean values, energy fluctuation in a gas, grand Canonical ensemble, thermodynamic functions for the grand canonical ensemble, density fluctuations.

Unit-IV

Partition Functions and Statistics: Partition functions, Properties, partition function for an ideal gas & calculation of thermodynamic quantities, Gibbs Paradox, validity of classical approximation, translational, rotational & vibrational contributions to the partition function of an ideal diatomic gas. Specific heat of a diatomic gas, ortho & para-Hydrogen.

Maxwell-Boltzmann Gas Velocity and Speed Distribution: Chemical potential, Free energy and connection with thermodynamic variables, First and Second order phase transition; phase equilibrium.

Unit-V

Formulation of Quantum Statistics: Density Matrix, ensembles in quantum statistical mechanics, simple applications of density matrix. Theory of simple gases: Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac gases. Statistics of occupation numbers, Evaluation of partition functions, Ideal gases in the classical limit.

Ideal Bose System: Thermodynamic behavior of an Ideal Bose gas, **Bose-Einstein condensation**. Thermodynamics of Black body radiation, Stefan-Boltzmann law, Wien's displacement law. Specific heat of solids (Einstein and Debye models).

Ideal Fermi System: Thermodynamic behavior of an ideal Fermi gas, degenerate Fermi gas, Fermi energy and mean energy, Fermi temperature, Fermi velocity of a particle of a degenerate gas. **Black Holes, White Dwarfs and Chandrashekhar Limit.**

Suggested Readings

1. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill (1927).
2. K. Huang, Statistical Mechanics, John Wiley & Sons (1987).
3. L. D. Landau and E. M. Lifshitz, Statistical Physics, Butterworth-Heinemann (1996).
4. Richard P. Feynman, Lectures on Statistical Mechanics, CRC Press (1998).

Course Outcome (CO) of Statistical Thermodynamics

Upon completion of this course, students would be able to:

CO1. Describe and apply the concepts of microstate and macro-state of a model system.

CO2. Describe and apply the concepts and roles of entropy and free energy from the view point of statistical mechanics

CO3. Describe and apply the Boltzmann distribution and the role of the partition function

CO4. Apply the machinery of statistical mechanics to the calculation of macroscopic properties resulting from microscopic models of magnetic and crystalline systems

CO5. Describe and apply Fermi-Dirac and Bose-Einstein distributions; state whereever they are applicable; and appreciate how they differ and show when they reduce to the Boltzmann distribution.

MPH-202T: Mathematical Methods in Physics-V: Special Mathematical Techniques

(Elective) **Credit(s): 4**

Unit-I: Orthogonal Curvilinear Coordinates

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems and their Physical Perspective. Scale factors and transformations. Area and volume elements.

Unit-II: Vector Calculus

Vector Calculus: Vector Differentiation. Scalar and Vector Fields. Ordinary and Partial Derivative of a Vector *wrt* coordinates. Space Curves. Unit Tangent Vector and Unit Normal Vector. Directional Derivatives and Normal Derivative. Gradient of a Scalar Field and its Geometrical Interpretation. Divergence and Curl of a Vector Fields. Laplacian Operators. Vector Identities. Idea of Jacobian. Vector Integration**:** Ordinary Integral of Vectors. Line, Surface and Volume Integrals. Flux of a Vector Field. Gauss' Divergence Theorem, Green's Theorem and Stokes Theorem.

Unit-III

Introduction to Tensors. The idea of Covariant, Contravariant and Mixed tensors of rank 1, 2 and 3. Raising and Lowering tensors. Transformations. Levi-Civita tensor. Algebra of tensors. Calculus of tensors. Christoffel symbols of First and Second kind. Covariant differentiation of tensors. The idea of Geodesics.

Unit-IV: Complex Variables

Complex Variables: Limits and continuity. Analytical functions. Cauchy- Riemannn conditions. Differentiation. Cauchy Integral theorem. Cauchy integral formula. Derivatives of analytical functions. Liouville's theorem.

Complex Variables: Functions of complex variable. Conformal mappings and representations.

Unit-V: Complex Variables

Power series: Taylor's series and McLaurin's series. Singularities. Idea of Residues. Complex Integration.

The idea of Analytic continuation. **Saddle Point Function**.

***Suggested Books*:**

1. George Arfken, Mathematical Methods for Physicists, Academic Press (2012).
2. L. A. Pipes, Applied Mathematics for Engineers & Physicists, McGraw Hill (1970).
3. Merle C. Potter and Jack Goldberg: Mathematical Methods, Prentice Hall (1987).
4. Fredrick W. Byron and Robert W. Fuller: Mathematics of Classical and Quantum Physics, Dover Publications (1970).
5. V. Balakrishnan, Mathematical Physics, Ane Books Pvt Ltd. New Delhi (2018).
6. Tulsi Dass and S.K. Sharma: Mathematical Methods in Classical and Quantum Physics, Universities' Press (Orient Longman) (1998).

Course Outcomes (CO)

CO-1: To learn the idea of curvilinear coordinates and to be able to make transformations from one-co-ordinate system to another proficiently.

CO-2: To understand the idea of vector and scalar fields. To learn to apply techniques of gradient of scalar, and divergence and curl of vector fields in Physics wherever need be.

CO-3: To learn to use of Fourier and Laplace transformations to solve differential equations, apply techniques of complex variables, to the study of special functions of mathematical physics.

CO-4: To learn to solve partial differential equations with appropriate initial or boundary conditions; and understand Group theory, special unitary groups.

CO-5: To learn to solve mathematical problems arising in physics by a variety of mathematical techniques.

MPH-203T: Advanced Numerical Techniques in Physics (Elective) Credit(s): 4

Unit–I:

Introduction - Representation of integers and real numbers; Accuracy, range, overflow and underflow of number representation; error propagation and instability. Introduction: Solutions of algebraic and transcendental equations - Bisection, Regula Falsi, Secant method, Newton-Raphson Method

Unit–II:

Solution of System of Equations using Iteration Method - Cramers's rule, Matrix inversion method, Gauss elimination method, Gauss Jordan method. Iterative method of Solution -Jacobi method, Gauss-Seidel, Relaxation Method.

Unit–III:

Interpolation with equal intervals- Newton's Backward and Forward formula. Central Difference Interpolation: gauss's Forward and backward formula, Sterling Formula, Bessel Formula

Interpolation with unequal intervals – Lagrange's Formula, Newton divided difference.

Unit–IV:

Numerical Differentiation and Integration–Maxima and minima, Newton-Cotes quadrature formula, Trapezoidal formula, Simpson's 1/3 and 3/8 formula, weddles's rule. Romberg Method.

Unit–V:

Numerical Solutions of Ordinary Differential Equations- Picard's Method, Taylor Series Method, Euler Method, Modified Euler Method, Runge-Kutta Formula – First, Second , Third And Fourth Order Method. Milne's Method.

Suggested Readings

1. B.S. Grewal, "Numerical methods in *Engineering and Sciences*", 43rd Edition, Khanna Publishers, New Delhi (2014).

2. P. Kandasamy "*A Text book on Engineering Mathematics*", 3rd Edition, S. Chand & Company Ltd. (2009).

3. S. S. Sastry, "*Numerical Methods*", 4th Edition , Prentice Hall of India (2008).

4. N.P. Bali *et. al*, "*A Text book on Engineering Mathematics*", Laxmi pub.(p) Ltd (2001).

5. Erwin Kreyszig, "*Advanced Engineering Mathematics*", John Wiley Publications (1999).

6. R.K. Jain & S. R. K. Iyengar, "*Numerical Methods*", New Age International (P) Ltd. (2008).

7. E. Balagurusamy, Numerical Methods, Tata McGraw Hill (2017).

MPH-204T: Instrumentation Techniques (Elective) Credit(s): 4

Unit-I: Classification of Instruments

Absolute and Secondary instruments, indicating instruments, control, balancing and damping, construction details, characteristics, errors in measurement.

Watt-meters: Induction type, single phase and three phase wattmeter's, compensations.
Energy meters: AC Induction type single phase and three phase energy meter compensation, creep, error, testing.
Frequency meters: Vibrating reed type, electrical resonance type
Transducer: Strain Gauges, Thermistors, Thermocouples. Linear Variable Differential Transformer (LVDT) Capacitive Transducers, Peizo-Electric transducers. Optical Transducer, Torque meters, inductive torque transducers, electric tachometers, photo electric tachometers.

Unit-II
Electronic Instruments
CRO: Block Diagram, sweep generation, vertial amplifiers, use of CRO in measurement of frequency, phase, Amplitude and rise time of a pulse.
Digital Multimeter: Block diagram, principle of operation, Accuracy of measurement
Electronic Voltmeter:
Transistor Voltmeter, Block diagram, principle of operation, accuracy of measurement: metering amplifier.

Unit-III
Power Semiconductor Devices
Power Diodes: Types, characteristics
Thyristors: SCR, Static V-I characteristics of SCR, two transistor analogy of SCR, dynamic characteristics of SCR, Gate characteristics of SCR, Thyristor ratings, DIAC, TRIAC, GRO, UJT.
Power Transistors: Power BJT, Power MOSFETS, IGBT.
Triggering Circuits: R- Triggering, R-C Triggering, UJT triggering, Design of UJT triggering circuit, Cosine law triggering, triggering circuit using pulse train.
Thyristor commutation circuits: Class-A, Class-B, Class-C, Class-D, Class-E, Class-F commutation circuits.

Unit-IV
Sensors and Transducers

Basic concepts and Classification: Introduction, System Configuration, Problem Analysis, Basic Characteristics of Measuring Devices, Calibration
Transducer classification: Introduction, Electrical Transducer, Classification, Basic Requirements of a Transducer. Introduction, Principles of Transduction, Digital Transducers, Level Measurements
Strain Measurement: Introduction, Factors affecting Strain Measurements, Types of Strain Gauges, Theory of Operation of Resistance Strain Gauges, Types of Electrical Strain Gauges, Materials for Strain Gauges, Gauging Techniques and Other Factors, Strain Gauge Circuits, Temperature Compensation, Applications.

Unit-V

Pressure Transducer: Introduction, Diaphragms, Other Elastic Elements, Transduction Methods, Force-Balance Transducer, Solid State Devices, Thin Film Pressure Transducers, Piezoelectric Pressure Transducer, Vibrating Element Pressure Sensors, Pressure Multiplexer, Pressure Calibration

Temperature Transducer: Introduction, Temperature Scales, Mechanical Temperature Sensors, Resistance- Type Temperature Sensors, Platinum Resistance Thermometer, Thermistors. Thermocouples, Solid-State Sensors, Quartz

Thermometer, Temperature Measurement by Radiation Methods, Optical Pyrometer, Calibration of Thermometers.

Force and Torque transducer: Introduction, Force-Measuring Sensor- Load Cell, Effect of Temperature Variations, Dynamic Response of Elastic Transducers, Digital Force Transducers, Force-Balance Device, Hydraulic Load Cell, Electronic Weighing System, Torque Measurement.

Vibration Transducers: Introduction, Characteristic of Vibration, Analysis of Vibration-Sensing Devices, Vibration- Sensing Devices, Signal Conditioners, Shock Measurements, System Characteristics, Vibration Exciters, Calibration.

***Suggested Readings*:**

1. D.V.S. Murty, Instruments and Transducers, PHI (2022).

2. M.H. Rashid, Power Electronics, Pearson Publication (2017).

3. J. Jacob, Power Electronics Principles and Applications, Cengage Learning (2001).

4. V.R. Murthy, Power Electronics, Oxford Publication (2005).

5. A.K. Sawhney, A Course in Elec. & Electronic Measurement and Instrumentation, Dhanpat Rai & Sons, New Delhi (1995).

6. W.O. Cooper, Electronic Instrumentation and measurement techniques, Prentice Hall of India Limited, New Delhi (1992).

7. Larry Jones & A foster Chin, Electronic measurement and Instrumentation systems, Pearson (1990).

8. Golding E.W., Electronic Measuring Instruments, Wheeler & Company, Calcutta (1993).

9. C.S. Rangan, G.R. Sarma, V.S.V. Mani, Instrumentation Devices and Systems, Tata McGraw Hill publishers (2017).

(Microprocessor & Microcontrollers)

10. Krishna Kant, “Microprocessors and Microcontrollers”, Prentice Hall of India (2013).

11. Yu-Cheng Liu, Glenn A. Gibson, “Microcomputer Systems: The 8086 / 8088 Family – Architecture, Programming and Design”, Second Edition, Prentice Hall of India (2007).

12. Mohamed Ali Mazidi, J. Gillispie Mazidi, Rolin Mc Kinlay, The 8051 Microcontroller, Pearson (2012).

13. Doughlas V. Hall, ―Microprocessors and Interfacing, Programming and Hardware, TMH (2012).

14. A.K. Ray, K.M. Bhurchandi, "Advanced Microprocessors and Peripherals" 3rd edition, Tata Mc Graw Hill (2012).

(Experimental Techniques)

15. J. Yarwood, High vacuum techniques, Chapman & Hall (1967).

16. A. Roth, Vacuum Technology, North-Holland Publishing Company, Amsterdam (1982).

17. G.K. White, Experimental Techniques in Low Temperature Physics, Oxford (1968).

18. L.C. Jackson, Low temperature physics, Methuen, London (1950).

19. O.V .Lounasmas, Experimental Principles & Methods Below 1 K, Academic press, New York (1974).

20. R.E. Smallman and K.H.G. Ashbee, Modern Metallography, Pergamon Press, Oxford (1966)

21. D.K. Bowen and C.R. Hall, Microscopy of materials, (The MacMillan Press Ltd., London (1975).

22. L.E. Murr, Electron Optical Applications in Materials Science, McGraw Hill, New York, (1970).

23. B. Welz, Atomic Absorption Spectroscopy, Verlag Chemie, New York (1976).

24. R.J. Reynolds, K. Aldous and K.C. Thompson, Atomic absorption spectroscopy, Charles Griffin and Company Ltd., London (1970).

25. C. Vandecasteele and C.B. Block, Modern Methods for Trace Element Determination (John Wiley & Sons, New York (1993).

26. D.A. Skoog and J.J. Leary, Principles of Instrumental Analysis, Saunders College publishing (1992).

27. Straughan & Walker, Spectroscopy, Vol. 1, Chapman & Hall, London (1976).

MPH-211P: Great Experiments in Physics   Credits: 2

NB: Students are required to perform any 10 experiments

1. *Frank-Hertz'* experiment: To determine Planck's constant.

2. *Millican's Oil Drop experiment*: To determine e/m of electron.

3. *Thomson's experiment*: To determine e/m of electron.

4. *Bragg's experiment*: To study diffraction of X-Rays in solids.

5. *Compton Effect*: To study of Compton scattering of γ- rays.

6. *Faraday's experiment*: To study Electromagnetic Induction and Laws of Electrolysis.

7. *Joule's experiment*: To determine of mechanical equivalent of heat.

8. *Davisson Germer's* experiment: To study diffraction of X-Ray in solids.

9. *Stern-Gerlach experiment*: To study of spin of (electrons) fundamental particles.

10. Michelson's Interferometer: To perform experiment of interference with Michelson's Interferometer.

11. *Hall effect*: To study *Hall effect* and determine *Hall coefficient*.

12. Thomson's method: e/m To determine e/m of electron.

Suggested Readings

1. Morris H. Shamos, Great Experiments in Physics, Dover Publications Inc. (New York 1959).

2. Adrian C. Melissinos and Jim Napolitano, Experiments in Modern Physics, Academic Press (2003).

MPH-251: Dissertation/Research Project Credit(s): 12

BPH-851	**Dissertation (Optional)** **Components of 12 Credits: Project Work+Dissertation+*Viva-Voce***	**12**

Semester-III

MPH-301T: Nuclear and Particle Physics Credit(s): 4

Unit-I: Interaction of radiation and charged particle with matter (No derivation)

Law of absorption and attenuation coefficient; Photoelectric effect, Compton scattering, pair production; Klem-Nishina cross sections for polarized and unpolarized radiation, angular distribution of scattered photon and electrons, Energy loss of charged particles due to ionization, Bremstrahlung; energy target and projectile dependence of all three processes, Range-energy curves; Straggling.

Unit-II: Nuclear Models

(i) Nuclear Shell Model: Single particle and collective motions in nuclei: Assumptions and justification of the shell model, average shell potential, spin orbit coupling; single particle wave functions and level sequence; magic numbers; shell model predictions for ground state parity; angular momentum, magnetic dipole and electric-quadrupole moments; and their comparison with experimental data; configuration mixing; single particle transition probability according to the shell model; selection rules; approximate estimates for the transition probability and Weisskopf units: Nuclear isomerism.

(ii) Unified (Collective) Nuclear Model: Collective variable to describe the cooperative modes of nuclear motion; Parametrization of nuclear surface; A brief description of the collective model Hamiltonian (in the quadratic approximation); Vibrational modes of a spherical nucleus, Collective modes of a deformed even-even nucleus and moments of, inertia; Collective spectra and electromagnetic transition in even nuclei and comparison with experimental data; Nilsson model for the single particle states in deformed nuclei.

Unit-III: Nuclear gamma and Beta decay: Electric and magnetic multipole moments and gamma decay probabilities in nuclear system (no derivations), Reduced transition probability, Selection rules; zero- zero transition. General characteristics of weak interaction; nuclear beta decay and lepton capture; electron energy spectrum and Fermi- Kurie plot; Fermi theory of beta decay (parity conserved selection rules Fermi and Gamow-Teller) for allowed transitions; ft-values; General interaction Hamiltonian for beta decay with parity conserving and non-conserving terms; Forbidden transitions, Experimental verification of parity violation; The V-A interaction and experimental evidence.

Unit-IV: Experimental Techniques: Gas filled counters; Scintillation counter, Cerenkov counters; Solid state detectors; Surface barrier detectors; Electronic circuits used with typical nuclear detectors; Multiwire proportion chambers; Nuclear emulsions, techniques of measurement and analysis of tracks; Proton synchrotron; Linear accelerations; Acceleration of heavy ions.

Introduction to Particle Accelerators: Palletrons. Lenear Accelerators. Cyclotrons. Large Particle Colliders.

Unit-V

Fundamental Particles: Relativistic energy and momentum of particles. Scalar particles. Mesons.
Particle Classification: Fermions and Bosons. Fundamental and Composite Particles.
Types of Particle Interactions (Introduction only): Quantum Electrodynamics (QED). Strong Interactions or Quantum Chromodynamics (QCD). Weak Interactions.
Symmetries and Quantum Numbers: Parity (P), Time-reversal (T), Charge Conjugation (C), and CP and CPT operations and symmetries. CPT Theorem.

Suggested Readings:

1. J. M Blatt and V. F. Weisskopf: Theoretical Nuclear Physics Springer-Verlag(1979).
2. R. D. Evans: The Atomic Nucleus, McGraw-Hills (1955).
3. H. Enge: Introduction to Nuclear Physics, Addition-Wesley (1970).
4. E. Segre: Nuclei and Particles, Benjamin (1977).
5. W. E. Burcham: Elements of Nuclear Physics, ELBS, Longman (1988).
6. B. L. Cohen: Concept of Nuclear Physics, Tata Mc-Graw Hills (1988).
7. I. Kaplan: Nuclear Physics, Addison Wesley (1963).
8. R. M. Singru, Introductory Experimental Nuclear Physics (1972).
9. M. K. Pal: Nuclear Structure: Affiliated East-West Press (1982).
10. R. R. Roy and B. P. Nigam: Nuclear Physics, Willey-Eastern (1979).
11. David Griffiths: Introduction to Elementary Particles, Wiley (2008).
12. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/
13. W.E. Burcham & M. Jobes, Nuclear and Particle Physics, Addison Wesley, Longman (1995).

Course Outcome (CO) of Nuclear Physics

Upon completion of this course, students would be able to:

CO-1: Understand basic Nuclear Physics properties.

CO-2: Understand basic properties of nucleus and develop nuclear models.

CO-3: Understand Nuclear reaction dynamics and apply wherever applicable.

CO-4: Analyse the properties of nuclear structure and apply it in nuclear research.

CO-5: Understand nuclear reactions and apply it in the nuclear power generation.

MPH-302T: Quantum Mechanics- II   Credit(s): 4

Unit-I

Density Matrices: Basic definition and properties. Pure and Mixed states.

Quantum Entanglement. Quantum Teleportation (Introduction).

Quantum Computing: Basic Idea of Quantum Computation and Quantum Information Theory. Quantum Logic Gates. Single and Multi-qubit Operations.

Unit-II: Time Independent Approximation Methods

Variational Methods, WKB method, tunneling.

Perturbation Theory: Non-degenerate perturbation theory, degenerate case, Stark effect, Zeeman effect and other examples.

Unit-III

Time-dependent Perturbation Theory: Interaction Picture; Constant and harmonic perturbations; Fermi Golden rule; Sudden and adiabatic approximations. Beta decay as an example.

Unit-IV

Scattering Theory: Differential cross-section, scattering of a wave packet, integral equation for the scattering amplitude, Born approximation, method of partial waves, low energy scattering and bound states, resonance scattering.

Unit-V

Symmetries in Quantum Mechanics: Symmetry Operations and Unitary Transformations, conservation principles, space and time translation, rotation, space inversion and time reversal, symmetry and degeneracy.

Identical Particles: Meaning of identity and consequences; Symmetric and anti-symmetric wavefunction; incorporation of spin, symmetric and antisymmetric spin wave function of two identical particles, Slater's determinant, Pauli exclusion principle.

Suggested Readings

1. P.A.M. Dirac, Principles of Quantum Mechanics, Oxford Science Publications (1981).
2. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics (Vol. I), Wiley (2020).
3. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics (Vol. II), Wiley (2020).
4. Albert Messiah, Quantum Mechanics, Dover Publications (2014).
5. L. I. Schiff, Quantum Mechanics, Mc-Graw Hill (1969).
6. J. J. Sakurai, Modern Quantum Mechanics, Pearson Education (1980).
7. E. Merzbecher, Quantum Mechanics, John Wiley (1958).
8. J. Powel and B. Craseman, Quantum Mechanics, Springer (1972).
9. Thomas F. Jordan, Linear Operators in Quantum Mechanics, John Wiley & Sons, Inc. (1968).
10. Ashok Das and A.C. Melissinos, Quantum Mechanics, Adisson-Wesley (1986) (Reprinted CRC Press).
11. V. K. Thankappan, Quantum Mechanics, New Age International Pub. (2012) (3rd Edition).
12. Quantum Mechanics, Schaum's (Series) Outlines, McGraw Hill (2014).

Course Outcome (CO) of Quantum Mechanics-II

Upon completion of this course, students would be able to:

CO-1: Understand the idea of 'Quantum Computers', 'Quantum Entanglements' and contribute to in the development of 'Quantum Information Theory'.

CO-2: Understand various 'Time Independent Approximation Methods in Physics' such as 'WKB Approximation', 'Variational Method', and ''.

CO-3: Understand 'Time Dependent Perturbation Methods' and further explore the transitions.

CO-4: Understand nitty-gritty of 'scattering theory' and apply it in the properties of matter.

CO-5: Understand 'symmetries in Quantum Mechanics' and apply it in the advanced research.

CO-6: Understand- 'Theory of Angular Momentum in Quantum Mechanics' and apply it to 'Hydrogen-like Atom' and 'Spectroscopic Techniques'.

CO-7: Understand and apply the mathematical techniques of 'Total Angular Momentum' including 'selection rules' and 'Chlebsch-Gordon Coefficients'.

MPH-303T: Condensed Matter Physics-I Credit(s): 4

Unit-I

Structure Factor: Static structure factor and its relation with the pair correlation function. Determination of structure factor by X-ray and neutron scattering. Inelastic neutron scattering and dynamic structure factor, space time correlation function and its relation with dynamic structure factor, properties of space time correlation function. Langevin's equation for Brownian Motion and its modifications. Velocity auto-co-relation function, mean square displacement, Relation between velocity auto-correlation function and diffusion coefficient.

Unit-II

Liquid Metals: Metallic interactions: Kinetic energy, electrostatic exchange and correlation, Pseudopotential formalism, diffraction model, structure factor, form factor for local and nonlocal potentials, energy eigen states, dielectric screening. Energy wave number characteristics, calculation of phonon dispersion of liquid metals. Band structure energy in momentum and direct space. Ziman's resistivity formula, Green function method for energy bands in liquid metals.

Unit-III

Quantum Liquids: Distinction between classical and quantum liquids, criteria for freezing, phase diagram of He4, He I and He II Tisaza's two fluid model, entropy filter, Fountain effect, superfluid film vehicle, Viscosity and specific heat of He4, first sound, second sound, third sound and fourth sound, Landau theory: Rotons and Phonons, t-matrix theory of superfluid He. Basic differences in superfluidity in He3 and He4.

Unit-IV

Exotic Solids: Structure and symmetries of liquids, liquid crystals and amorphous solids. Aperiodic solids and quasicrystals; Fibonacci sequency, Penrose lattices and their extension to 3-dimensions, Special carbon solids. Fullerenes and tubules; formation and characterization of fullerenes and tubules. Single wall and multi-wall carbon tubules. Electronic properties of tubules. Carbon nanotubule based electronic based devices Definition and properties of nano-structured materials. Methods of synthesis of nanostructured materials.

Special experimental techniques for characterization of nano-structured materials. Quantum size effect and its applications.

Unit-V

Quantum Dots. Introduction to quantum dots as semi-conductor nanocrystals. Their structure and properties. Colloidal synthesis. Fabrication and Electro-chemical assembly.

Suggested Readings

1. P.A. Egelstaff, An Introduction to the Liquid State (Chapters 2, 3, 5, 6, 7 & 8), Clarendon Press (1994).
2. Jean P. Hansen and I.R. McDonald, Theory of Simple Liquids (Ch. 3, 5, 7 & 9) Academic Press (2013).
3. D. Pines and P. Nozier, The Theory of Quantum Liquid, West View Press Inc. (1989).
4. W.A. Harison: Pseudopotentials in the Theory of Metals Benjamin, W.A. Benjamin Inc. (1966).
5. N.H. March, W.H. Young and S. Sampanthar, Many Body Problems in Quantum Mechanics, Cambridge University Press (1967).
6. N.H. March and M.P. Tosi, Atomic Dynamics in Liquids, Springer (1976).
7. March, Tosi and Street: Amorphous Solids and the Liquid State, Plenum (1985).
8. Kittel, C., Introduction to Solid State Physics, John Willey (2007).
9. Omar, M.A., Elementary Solid State Physics, Pearson Education (1999).
10. Srivastava, J.P., Elements of Solid State Physics, Prentice Hall of India (2008).
11. Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Cengage Learning (2008).
12. Dekker, A.J., Solid State Physics, Macmillan (2003).

MPH-304T: Elective-1 Credit(s): 4

MPH-311P: Nuclear Physics Lab Credit(s): 2

Students have to perform any 8 experiments from the following:

1. To study G.M. detector characteristics and determine operating voltage of a G.M. tube.
2. To study random nature of radioactive decay using G.M. counter.
3. To determine the resolving time of G.M. counting set up (single and double source methods).
4. To study the absorption of β- particles and determine end point energy using G.M. counter.
5. To determine absorption coefficient of γ- rays.
6. Study of secular equilibrium in radioactive decay.
7. To determine end point energy of β- particles using Scintillation counter.
8. To study Compton scattering of γ- rays using Scintillation counter.

9. Study of absorption curve of α- particles using semiconductor detectors.

10. Study of specific energy loss and straggling of α- particles using semiconductor detectors.

***Suggested Readings*:**

1. G.F. Knoll, Radiation Detections and Measurement, Wiley India (2010).
2. S.S. Kapoor and Ramamurthy; Experimental Nuclear Physics: Tata McGraw Hill (2010).
3. J. Varma, Experiments in Nuclear Physics, New Age Publishers, New Delhi (2000).
4. R. M. Singru, Introductory Experimental Nuclear Physics (1972).

MPH-312P: Advanced Electronics and Instrumentation Lab Credit(s): 4

1. To study OP-AMP as inverting and non-inverting amplifier.
2. To study IC7805 and its applications.
3. To study IC740 and its applications.
4. To study IC741 and its applications.
5. To study IC555 and its applications.
6. To study microprocessors 8085 and 8086 and their applications.
7. To record observations on **Atomic Absorption Spectrometer** and analyze it.
8. To record observations on **Fluorescent Spectrometer** and analyze it.
9. To record observations on **Ultra Violet/Visible Spectrometer** and analyze it.
10. To record observations on **FTIR** and analyze it.
11. To record observations on **X-Ray Diffraction (XRD) Spectrometer** and analyze it.

Semester-IV

MPH-401T: Relativistic Quantum Mechanics and Quantum Field Theory

(Quantum Mechanics-III) Credit(s): 4

Unit-I: Relativistic formulation of Quantum Mechanics

Klein-Gordon equation. Covariance and solution of Klein-Gordon equation. Dirac’s equation. Covariance and solution of Dirac’s equation. Symmetries of Dirac’s equation. Bilinear covariants.

Unit-II: Quantum Fields

Classical Lagrangian field theory, 'Euler-Lagrange's equation, Lagrangian density for electromagnetic field. Occupation number representation for simple harmonic oscillator, linear array of coupled oscillators. Quantization of identical bosons. Second quantization of the real and complex Klein Gordan field. The meson propagator.

Unit-III

The occupation number representation for fermions. Second quantization of the Dirac filed. The fermion propagator. The electromagnetic interaction and gauge invariance. Covariant quantization of the free electromagnetic field. The photon propagator.

Unit-IV

S-matrix formulation: *S*-matrix expansion. Wick's theorem. Diagrammatic representation in configuration space, the momentum representation, Feynman diagrams of basic processes, Feynman rules of QED.

Path Integral Formalism: Applications

Unit-V

Specific Processes: Applications of *S* matrix formalism: Coulomb scattering, Bhabha scattering, Moller scattering, Compton scattering and Pair Production. Weak interaction by means of V-A theory.

***Suggested Readings*:**

1. J. D. Bjorken and Sidney Drell, Relativistic Quantum Mechanics, Tata McGraw Hill (2013).

2. F. Mandal & G. Shaw, Quantum Field Theory, John Wiley (1986).

3. S. Weinberg, Quantum Theory of Fields-I, Cambridge University Press (2013).

4. S. Weinberg, Quantum Theory of Fields-II, Cambridge University Press (2013).

5. S. Weinberg, Quantum Theory of Fields-III, Cambridge University Press (2013).

6. M.E. Peskin and D.V. Shröder, Introduction to Quantum Field Theory, Addisson-Wesley (2021).

(Now Republished by CRC Press)

7. J. M. Ziman: Elements of Advance Quantum Theory, Cambridge University Press (1975).

8. A. Zee, Quantum Field Theory in Nut-Shell, Princeton University Press (2010).

9. Bilenky, S.M., Introduction to Feynmann Diagrams, Elsevier (2013).

10. Chang, S.M., Introduction to Quantum Field Theory, World Scientific (2010).

Course Outcome (CO) Electrodynamics-II

Upon completion of this course, students would be able to:

CO1: Explain classical electrodynamics based on Maxwell's equations including its formulation in covariant form.

CO2: Solve the electromagnetic problems with the help of electrodynamic potentials and super-potentials, and make a detailed account for gauge transformations and their use

CO3: Formulate and solve electrodynamic problems in relativistically covariant form in four-dimensional spacetime.

CO4: Calculate the electromagnetic radiation from localized charges which move arbitrarily in time and space, taking into account retardation effects.

CO5: Calculate the electromagnetic radiation from radiating systems, like oscillating electric and magnetic dipoles (aerials, localized charge and current distributions)

MPH-402T: Classical Electrodynamics-II Credit(s): 4

(Classical Electrodynamics in Matter and Medium)

Unit-I

Special techniques for calculating potentials

Laplace's Equation: Laplace's equation in one dimension. Solution of Laplace's equation in two dimensions. Laplace's equation in three dimensions. Boundary conditions and Uniqueness theorems. Conductors and second uniqueness theorem.

Unit-II

The Method of Images: The classic image problem. The induced surface charge. Other image problems

Multi-pole Expansion: Approximate potentials at large distances. The monopole and dipole terms. Origin of coordinates in multi-pole expansion. The electric field of an electric charge.

Unit-III

Electro-magnetic waves in conducting and non-conducting media

Electro-magnetic waves in non-conducting media: Monochromatic plane waves in vacuum. Energy and momentum of electro-dynamic waves. Propagation through linear media. Reflection and transmission at normal and oblique incidence

Unit-IV

Electromagnetic Waves in Conductors: The modified wave equation. Monochromatic plane waves in conducting media. Reflection and transmission at conducting surface.

Dispersion: The frequency dependence of $\varepsilon, \mu \text{ and } \sigma$. Dispersion in non-conductors. Free electrons in conductors and plasma.

Guided Waves and Transmission Lines: Wave guides. TE waves in rectangular wave-guides. The coaxial transmission lines.

Unit-V

Magneto-Hydrodynamics and Plasma Physics

Introduction and definitions. MHD equations. Magnetic Diffusion: Viscosity and Pressure. Pinch effect: instabilities in pinched plasma column. Magneto-hydrodynamics waves. Plasma Oscillations: Short wave length limit of plasma oscillations and Debye shielding distance.

Suggested Readings

1. L. D. Landau & Lifshitz: Classical Theory of Electrodynamics; Pergamon Press (1984).
2. J. D. Jackson: Classical Electro-dynamics; John Wiley (1998).
3. David J. Griffiths, Introduction to Electro-dynamics, Prentice Hall (2015).
4. Panofsky & Phillip, Classical Electrodynamics and Magnetism, (2012).
5. Sadiku, N.O., Principles of Electromagnetics, Oxford University Press (2015).
6. William, Hyatt and John A. Buck, Engineering Electromagnetics, McGraw Hill (2010).

MPH-403: Condensed Matter Physics-II Credit(s): 4

Unit-I

Phase Transformation and Alloys: Equilibrium transformation of first and second order. Equilibrium diagrams. Phase rule. Interpretation of phase diagrams. Substitutional solid solutions. Vegard's law, intermediate phases, Hume-Rothery rules. Interstitial phases (carbides, nitrides, hydrides, borides). Martensitic transitions. structure factor of liquid metal alloys, behaviour of s(q), radial distribution function g(r) and relationship between s(q) and g(r)

Unit-II

Disordered Systems: Disorder in condensed Matter, Substitutional, positional and topographical disorder. Short and long range order. Spinning, sputtering and ion-implantation techniques, glass Transition, glass formatino ability, nucleation and growth processes. Anderson model for random system and electron localization, mobility edge, qualitative application of the idea of amorphous semiconductors and hopping conduction. Metal glasses, Models for structure of metal glasses. Structure factor of binary metallic glasses and it relationship with the radial distribution functions. Discussion of electric, magnetic and mechanical properties of glassy system.

Unit-III

Structure determination/characterization: Basic theory of X-ray diffraction. Indexing of Debye-Scherer patterns powder samples, examples from some cubic and non-cubic symmetries. Neutron diffraction-basic interactions, cross section, scattering length and structure factor. Mossbauer effect, hyperfine parameters-Isomer shift, quadrupole splitting and Zeeman splitting. Application 0Valence and coordination, site symmetry magnetic behaviour. Discussion in context of Fe57.

Unit-IV

Electronic Structure Determination: Basic principles of X-ray, photo-emission and positron annihilation techniques. qualitative discussion of experimental arrangement and typical results for both simple as well as transition metals.

Unit-V

Semiconductor: Lattice properties of 4^{th} group elements; structure, physical constants, influence of impurities, diffusion of impurities, influence of lattice defects, Fermi level and electron-hole distribution in energy band, simplified and improved models for isolators and intrinsic semiconductor. Models of an impurity semiconductor, Intrinsic and extrinsic semiconductors, Hydrogenic model of impurity levels, temperature dependence of Fermi level in extrinsic semiconductor, conductivity in semiconductor, carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors Band-gap. Direct and indirect gap semiconductors. Effect of temperatures and impurities in semiconductor, introduction to amorphous semiconductor. Quantum Hall Effect.

***Suggested Readings*:**

1. P.A. Egelstaff, An Introduction to the Liquid State (Chapters 2, 3, 5, 6, 7 & 8), Clarendon Press (1994).

2. Jean P. Hansen and I.R. McDonald, Theory of Simple Liquids (Ch. 3, 5, 7 & 9) Academic Press (2013).

3. D. Pines and P. Nozier, The Theory of Quantum Liquid, WestView Press Inc. (1989).

4. W.A. Harison: Pseudopotentials in the Theory of Metals Benjamin, W.A. Benjamin Inc. (1966).

5. N.H. March, W.H. Young and S. Sampanthar, Many Body Problems in Quantum Mechanics, Cambridge University Press (1967).

6. N.H. March and M.P. Tosi, Atomic Dynamics in Liquids, Springer (1976).

7. March, Tosi and Street: Amorphous Solids and the Liquid State, Plenum (1985).

8. 1. Kittel, C., Introduction to Solid State Physics, John Willey (2007).

9. Omar, M.A., Elementary Solid State Physics, Pearson Education (1999).

10. Srivastava, J.P., Elements of Solid State Physics, Prentice Hall of India (2008).

11. Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Cengage Learning (2008).

12. Dekker, A.J., Solid State Physics, Macmillan (2003).

MPH-404T: Elective-2 Credit(s): 4

Syllabi of Special Elective Courses

MPH-304A1: General Relativity and Cosmology Credit(s): 4

Unit-I

Principle of equivalence. Metric formulation and tensor nature of gravitational field. Gradient, divergence, curl, and Laplace in . Christoffel symbols of the first and second kind. Covariant differentiation. Bianchi identity. Curvature and torsion in Riemannian Geometry.

Unit-II

Geodesics and equation of motion in the curved space. Riemann curvature tensor. Weyl tensor, Conformal curvature tensor. Ricci tensor. Energy Momentum tensors. Energy Momentum tensors for Electro-magnetic field. Energy-Momentum tensor for perfect fluid; and Energy-Momentum tensor for dust-like case.

Unit-III

Einstein's field equation and gravitation. Schwarzchild metric and solutions of Einstein's equation.
Three crucial tests of Einstein's theory of gravitation: Advance of the perihelion of Mercury; Bending of the light beam in the presence of gravitating object; and, Gravitational Red-shift. Gravitational lensing. Killing vectors.

Unit-IV

Singularities of Schwarzchild metric. Krüskal-Szekere's coordinates and Penrose diagrams.
Einstein's equation from Action principal. Theory of gravitational waves. Ray-Chaudhary equation. Vaidya metric.

Unit-V: Cosmology

Einstein's model of Universe. De-Sitter Universe. Pressure, density, and energy tensors in the Einstein and de Sitter Universes.
Friedman-Robertson-Walker-Lemaitre model of the Universe. Particle horizon. Event horizon. Luminosity distance. Doppler effect.
Big-Bang and the Physics of the early Universe. Entropy and Thermodynamics of the early Universe. Particle and the Nucleo-synthesis in the early Universe. Various phase transitions and time-line of the Universe. Saha's ionization equation.
Inflationary cosmology and generation of density perturbations. Alternative cosmologies: Quasi-Steady State Theory of the Universe.

Suggested Readings

1. S. Weinberg: General Relativity, Gravitation and Cosmology, Wiley (2013).
2. Meissner, Kip Thorn and John Wheeler, Gravitation and Cosmology, Benjamin Feeman (1973).
3. James Hartle, Gravity: An Introduction to Einstein's General Relativity, Pearson (2003).
4. Peacock J. A.: Cosmological Physics, Cambridge University Press (1998).
5. J. V. Narlikar: Introduction to Cosmology, Cambridge University Press (2002).
6. Pankaj S. Joshi, Global Aspects in Gravitation and Cosmology, Oxford Science Publications (1993).

MPH-404A2: Astrophysics Credit(s): 4

Unit-I: Overview of Astrophysics

The structure, origin, and evolution of the major components of the Universe: planets, stars, and galaxies. Formation of the Sun and planets.

Luminosity and magnitudes of stars. Saha's ionization equation.

Unit-II: Astrophysical Processes

Astrophysical processes. Basics of electromagnetic radiations; Statistical mechanics of Astrophysical phenomena; Radiative processes; Spectra; Neutral fields and plasma in Astrophysics.

Stellar evolution; X-ray sources, Binary stars, Pulsars, Quasars and other compact stars. The origin and search for life in the Universe.

Unit-III: Structure Formation

Structure formation in the early Universe. Galaxy formation. Elliptical and spiral galaxies. Rotational curves of galaxies and signatures of Dark matter. Physics of the inter-stellar and inter-gallactic media.

Unit-IV: Stellar Structure

Star formation. Radiative transfer and stellar mechanics. Chandrashekhar limit and life-cycles of stars: Supernovae-Adult stars-Red Giants-Black Holes/White Dwarfs. The idea of White holes and Brown Dwarfs.

Unit-V: Evolution of the Universe

Big-Bang. First Three Minutes. Physics of the Early Universe. Dark Matter. Dark Energy.

Suggested Readings

1. Arnab Rai Chaudhary: Astrophysics for Physicists, Cambridge University Press (1998).
2. T. Padmanabhan: Theoretical Astrophysics-I, Cambridge University Press (2001).
3. T. Padmanabhan: Theoretical Astrophysics-II, Cambridge University Press (2001).
4. T. Padmanabhan: Theoretical Astrophysics-III, Cambridge University Press (2002).
5. Peacock J. A.: Cosmological Physics, Cambridge University Press (1998).

MPH-304B1: Particle Physics- I Credit(s): 4

Unit-I

Elementary particles and the fundamental forces. Quarks and leptons. The mediators of the electromagnetic, weak and strong interactions. Interaction of particles with matter; particle acceleration, and detection techniques. Symmetries and conservation laws.

Bound states. Discoveries and observations in experimental particle physics and relation to theoretical developments. Symmetries, group theory, SU(2) group, Finite Symmetry Group: P and C, SU(2) of Isospin, SU(3) groups.

Unit-II

Quark and Antiquark states: Mesons, Three quark states: Baryon, color factors, Asymptotic freedom. Charged and neutral weak interactions. Electroweak unification.

Unit-III

Decay rates and Cross sections: Feynman diagrams Introduction to Feynman integrals. The Dirac equation. Feynman rules for quantum electrodynamics (no derivation). Moller scattering, trace theorems and properties of gamma matrices, helicity representation at high energies., the electron propagator, the photon propagator.

Unit-IV
Structure of Hadrons: form factors, e-p scattering, inelastic e-p scattering, Bjorken scaling, Partons, gluons, deep inelastic scattering, evolution equations for Parton densities.

QCD: Electron positron annihilation into hadrons, heavy quark production, three jet events, QCD corrections, Perturbative QCD, Drell-Yan process.

Unit-V

Weak Interactions: Parity violation, V-A form of weak interaction, Nuclear beta decay, muon decay, pion decay, charged current neutrino electron scattering, neutrino quark scattering, weak neutral currents, the Cabibo angle, weak mixing angles, CP invariance.

***Suggested Readings*:**

1. Francis Halzen and Allan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley (2008).
2. B.R. Martin and G. Shaw, Particle Physics, 2nd edition, J. Wiley and Sons (1997).
3. David Griffiths: Introduction to Elementary Particles, Wiley (2008).
4. Donald Perkin: Introduction to high energy physics, Cambridge University Press (2000).
5. Byron Roe: Solutions Manual for Particle Physics at the New Millennium, Springer (2013).
6. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/

MPH-404B2: Particle Physics- II Credit(s): 4

Unit-I

Gauge Symmetries: U(1) Local gauge invariance and QED, Non-abelian gauge invariance and QCD, massive gauge bosons, spontaneous breakdown of symmetry, the Higgs mechanism.

Unit-II

Local gauge invariance and Yang-Mills fields: Lagrangian of the Spontaneous symmetry breaking and the Higgs mechanism, The Weinberg-Salam model and beyond.

Unit-III

Standard Model of Particle Physics: Unified models of weak and electromagnetic interactions, flavor group, flavor-changing neutral currents. Weak isospin.

Unit-IV

Quark and lepton mixing: CP violation. Neutrino oscillations. CKM quark mixing matrix, GIM mechanism, rare processes, neutrino masses, seesaw mechanism.

Unit-V

QCD confinement and chiral symmetry breaking, instantons, strong CP problem.

***Suggested Readings*:**

1. Francis Halzen and Allan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley (2008).
2. B.R. Martin and G. Shaw, Particle Physics, 2nd edition, J. Wiley and Sons (1997).
3. David Griffiths: Introduction to Elementary Particles, Wiley (2008).
4. Donald Perkin: Introduction to high energy physics, Cambridge University Press (2000).
5. Byron Roe: Solutions Manual for Particle Physics at the New Millennium, Springer (2013).
6. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/

MPH-304C1: Digital Electronics Credit(s): 4

Unit-I

Analog Circuits: Integrated Circuits (Qualitative Treatment only): Active and Passive components. Discrete Circuit Component. Wafer. Chip. Advantages and Drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (Basic Idea and Definitions Only). Classification of ICs. Fabrication of Components on Monolithic ICs. Examples of Linear and Digital ICs.

Operational Amplifiers (Use Black Box approach): Basic Characteristics of Op-Amps. Characteristics of an Ideal Op-Amp. Feedback in Amplifiers. Open-loop and Closed-loop Gain. Frequency Response. CMRR. Virtual ground.

Unit-II

Applications of Op-Amps: (1) Inverting and Non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Unity follower, (5) Differentiator, (6) Integrator, (7) Zero Crossing Detector.

Timers (Use Black Box approach): 555 Timer and its Applications: Astable and Monostable Multivibrator.

Digital Circuits: Difference Between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND AND NOR Gates. Exclusive OR and Exclusive NOR Gates.

Unit-III

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Minterms and Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

Data processing circuits: Basic Idea of Multiplexers, De-multiplexers, Decoders, Encoders, Parity Checkers.

Memories: Read-only memories (ROM), PROM, EPROM.

Unit-IV

Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement Method).

Half Adders and Full Adders and Subtractors (only up to Eight Bits).

Sequential Circuits: RS, D, and JK Flip-Flops. Level Clocked and Edge Triggered Flip-Flops.

Preset and Clear Operations. Race-around Conditions in JK Flip-Flops. Master-Slave JK Flip-Flop (As Building Block of Sequential Circuits).

Unit-V

Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out, and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

Counters: Asynchronous and Synchronous Counters. Ring Counters. Decade Counter. D/A and A/D conversion: D/A converter – Resistive network. Accuracy and Resolution.

***Suggested Books*:**

1. D. P. Leach and A. P. Malvino: Digital Principles and Applications, Glencoe (1995).

2. Thomas L. Floyd: Digital Fundamentals, 3rd Edition, Universal Book Stall, India (1998).

3. Robert F Coughlin and Frederick F Driscoll: Operational Amplifiers and Linear Integrated Circuits, 4th Edition, PHI (1992).

4. T. L. Floyd, Digital Fundamentals, Pearson International Publications, Ninth Edition (2000).

5. Malvino and Leach, Electronics Principles, Mc. Graw Hill, Third edition (2000).

6. R. L. Tokheim, Digital Electronics: Principles and Applications, Tata McGraw-Hill Education (2013).

7. R P Jain, Modern Digital Electronics, Tata McGraw-Hill Education (2003).

(Digital Communication Systems)

8. Bernard Sklar, 'Digital Communications: Fundamentals and Applications', Prentice Hall (2001).

9. B. P. Lathi, "Modern Digital and Analog Communication Systems", Oxford University Press (2000) (3rd Ed., Oxford Series in Electrical and Computer Engineering).

10. Simon Haykin, "Communication Systems", 4th Ed., John Wiley, (2006).

MPH-404C2: Microwave Electronics and Communication Credits: 4

Unit-I

Microwave Wave Guides: Rectangular wave guides: TE, TM and TEM modes in wave guides, power transmission in wave guide, power losses in wave guide, excitation modes in wave guide, Characteristics of standard wave guides.

Unit-II

Microwave Components: microwave cavities, microwave attenuators, Scattering parameters, E-H tunner, directional coupler, circulators and isolators, Phase shifter.

Microwave Tubes: Linear beam: klystrons, reflex klystrons, TWTs. Microwave Crossed Field Tubes: Magnetrons, forward wave crossed field amplifier (FWCFA), high power gyrotrons. (Operating principle, construction & analytical treatment of above mentioned microwave tubes.)

Unit-III

Microwave Solid State Devices: Microwave tunnel diodes, microwave FETs, gunn effect diodes, RWH Theory, LSA diodes, Impatt diodes, PIN diodes, ruby laser, MESFETs and HEMT. (Operating principle, construction and analytical treatment of above mentioned microwave devices.)

Unit-IV

Microwave Measurements: Detection of microwave power: measurement of microwave low and high power, thermister parameters, thermister mounts, barreters, direct reading barreters bridges, Measurement of wavelengths: single line cavity coupling system, Transmission cavity-wave meter and reaction wavemeter, measurement of VSWR, measurements of attenuation, input impedance.

Unit-V

Microwave Antennas: Different types of antennas.

Modulation and Demodulation: Types of Modulation. Amplitude Modulation. Modulation Index. Analysis of Amplitude Modulated Wave. Sideband Frequencies in AM Wave. CE Amplitude Modulator. Demodulation of AM Wave using Diode Detector. Idea of Frequency, Phase, and Digital Modulation.

Suggested Readings

1. R. E. Collin: Foundation of Microwave Engg, McGraw Hill (1992).

2. Samul Liao: Microwave Devices and Circuit, PHI (2003).

3. David M. Pozar, Microwave Engineering, John Wiley& Sons, Inc. (2013).

4. Roddy. D., “Microwave Technology” Reston Publications (1986).

5. Chatterjee R., “Microwave Engineering “East West Press (1988).

6. Rizzi. P. ”Microwave Engineering Passive circuits”. Prentice Hall (1987).

7. Clock, P.N., “Microwave Principles and Systems” Prentice Hall (1986).

MPH-304D1: Ionospheric Physics Credit(s): 4

Unit-I

Sun: Structure of Sun. Thermonuclear Reactions in the core of the Sun. Convection and radiative transfer. Photosphere, Chromosphere and Corona. Nanoflares. Sun Spots and Solar Cycle. Solar Cycle and Weather on the Earth.

Unit-II

Ionosphere: Production of Ionosphere. Different layers of the Ionosphere. Photochemical reactions in the Ionosphere. Loss reactions. Equation of continuity. Air Glow and Aurora.

Unit-III

Morphology of the Ionosphere: Morphology of the D, E, F1 and F2 regions.

Unit-IV

Passage of the Electromagnetic waves through Ionosphere: Dispersion. A wave in the continuous medium of specific dielectric constant. Polarization of E-M waves. Curves of ***R(X)***. Quasi-Longitudinal (QL) and Quasi-Transverse (QT) approximations.

The Role of Ionosphere in the communication of Radio waves. The *Skip* distance.

Unit-V

Magnetosphere: Formation of the Earth’s Magnetosphere. Its role in controlling the Solar wind, plasma particles and protecting life on the Earth. Physics of the Magnetosphere associated phenomena.

Suggested Readings

1. B.N. Dwivedi and E.N. Parker, Dynamic, Cambridge University Press (2003).
2. M.C. Kelly, The Earth's Ionosphere: Plasma Physics and Electrodynamics: Volume 96, Academic Press, 2nd edition (2009).
3. V. Bychkov, G. Golubkov and A. Nikitin, The Atmosphere and Ionosphere, Springer (2013).
4. Robert Schunk and Andrew Nagy, Ionospheres, Cambridge University Press (2009).
5. C. Donald Ahrens, Essentials of Meteorology (3rd Edition), S. Chand and Co. (2000).
6. James R. Holton: Introduction to Dynamic Meteorology (4th Edition), Elsevier- Academic Press (2004).

MPH-404D2: Atmospheric Physics and Weather Science Credit(s): 4

Unit-I

Atmosphere and its constituents: Synoptic observations- surface and upper air. Preparation of weather charts and their analysis, Diurnal variation of temperature, pressure, relative humidity, clouds etc.

Tropical meteorology: Easterly Waves, ET-ITCZ, Inversion.

Unit-II

Extratropical Meteorology: Air mass, Fronts- Frontogenesis and Frontolysis, Extratropical Cyclones and Anticyclones, Jet Streams.

Synoptic systems: Winter -Western disturbance, Rossby Waves,

Unit-III

Westerly Jet Stream, Fog, Cold Wave etc. Summer - Thunderstorms, Dust storms, Heat wave, Cyclonic disturbances. Monsoon - Onset, Activity, Withdrawal, Breaks,

Depressions, Easterly Jet Stream. Post Monsoon - Cyclones in the Indian Seas, N.E. Monsoon.

Unit-IV

Global Climatology: Global distribution of pressure and temperature in winter and summer, distribution of annual rainfall and its variability, distribution of moisture and clouds. Vertical distribution of temperature. General circulation of atmosphere.

Development of monsoons. Major categories of world climates.

Unit-V

Indian Climatology - Different seasons, Distribution of Means Sea level

Pressure/temperature in different seasons, Wind circulation and temperature distribution over India in lower, middle and upper troposphere in different seasons. Indian rainfall in different seasons. Indian summer monsoon, onset, withdrawal, rainfall distribution, inter annual variability of monsoon. Main synoptic pressure systems causing weather over India in different seasons.

Suggested Readings

1. R.J. Barry and R.G. Chorley, Atmosphere, Routledge (2009).
2. R.J. Barry and R.G. Chorley, Atmosphere, Weather and Climate, Routledge (2009).
3. V. Bychkov, G. Golubkov and A. Nikitin, The Atmosphere and Ionosphere, Springer (2013).
4. Robert Schunk and Andrew Nagy, Ionospheres, Cambridge University Press (2009).
5. C. Donald Ahrens, Essentials of Meteorology (3rd Edition), S. Chand and Co. (2000).
6. James R. Holton: Introduction to Dynamic Meteorology (4th Edition), Elsevier- Academic Press (2004).
7. S. Pettersen, An Introduction to Meteorology, McGraw-Hill Book Co. (2008).
8. Y.P. Rao, South West Monsoon" IMD Publication (1976).
9. T.N. Krishnamurthy, Tropical Meteorology, Springer (2013).
10. Lydia Stefanova, T. N. Krishnamurti, and Vasubandhu Misra, Tropical Meteorology, Springer (2013).

MPH-451: Project **Credit(s): 4**

Work with any University/ Academic Institution/ Research Lab/Eminent Professor

MPH-252: Dissertation + Seminar (Presentation of Project Work)

Credit(s): 4(2+2)

Syllabi

One Year M.Sc. (Physics) Programme

One Year M.Sc. (Physics)

Semester-I

NMPH-101T: Nuclear and Particle Physics Credit(s): 4

Unit-I: Interaction of radiation and charged particle with matter (No derivation)

Law of absorption and attenuation coefficient; Photoelectric effect, Compton scattering, pair production; Klem-Nishina cross sections for polarized and unpolarized radiation, angular distribution of scattered photon and electrons, Energy loss of charged particles due to ionization, Bremstrahlung; energy target and projectile dependence of all three processes, Range-energy curves; Straggling.

Unit-II: Nuclear Models

(i) Nuclear Shell Model: Single particle and collective motions in nuclei: Assumptions and justification of the shell model, average shell potential, spin orbit coupling; single particle wave functions and level sequence; magic numbers; shell model predictions for ground state parity; angular momentum, magnetic dipole and electric-quadrupole moments; and their comparison with experimental data; configuration mixing; single particle transition probability according to the shell model; selection rules; approximate estimates for the transition probability and Weisskopf units: Nuclear isomerism.

(ii) Unified (Collective) Nuclear Model: Collective variable to describe the cooperative modes of nuclear motion; Parametrization of nuclear surface; A brief description of the collective model Hamiltonian (in the quadratic approximation); Vibrational modes of a spherical nucleus, Collective modes of a deformed even-even nucleus and moments of, inertia; Collective spectra and electromagnetic transition in even nuclei and comparison with experimental data; Nilsson model for the single particle states in deformed nuclei.

Unit-III: Nuclear gamma and Beta decay: Electric and magnetic multipole moments and gamma decay probabilities in nuclear system (no derivations), Reduced transition probability, Selection rules; zero- zero transition. General characteristics of weak interaction; nuclear beta decay and lepton capture; electron energy spectrum and Fermi- Kurie plot; Fermi theory of beta decay (parity conserved selection rules Fermi and Gamow-Teller) for allowed transitions; ft-values; General interaction Hamiltonian for beta decay with parity conserving and non-conserving terms; Forbidden transitions, Experimental verification of parity violation; The V-A interaction and experimental evidence.

Unit-IV: Experimental Techniques: Gas filled counters; Scintillation counter, Cerenkov counters; Solid state detectors; Surface barrier detectors; Electronic circuits used with typical nuclear detectors; Multiwire proportion chambers; Nuclear emulsions, techniques of measurement and analysis of tracks; Proton synchrotron; Linear accelerations; Acceleration of heavy ions.

Introduction to Particle Accelerators: Pelletron. Lenear Accelerators. Cyclotrons. Large Particle Colliders.

Unit-V

Fundamental Particles: Relativistic energy and momentum of particles. Scalar particles. Mesons.
Particle Classification: Fermions and Bosons. Fundamental and Composite Particles.
Types of Particle Interactions (Introduction only): Quantum Electrodynamics (QED). Strong Interactions or Quantum Chromodynamics (QCD). Weak Interactions.

Symmetries and Quantum Numbers: Parity (P), Time-reversal (T), Charge Conjugation (C), and CP and CPT operations and symmetries. CPT Theorem.

Suggested Readings:

1. J. M Blatt and V. F. Weisskopf: Theoretical Nuclear Physics Springer-Verlag(1979).
2. R. D. Evans: The Atomic Nucleus, McGraw-Hills (1955).
3. H. Enge: Introduction to Nuclear Physics, Addition-Wesley (1970).
4. E. Segre: Nuclei and Particles, Benjamin (1977).
5. W. E. Burcham: Elements of Nuclear Physics, ELBS, Longman (1988).
6. B. L. Cohen: Concept of Nuclear Physics, Tata Mc-Graw Hills (1988).
7. I. Kaplan: Nuclear Physics, Addison Wesley (1963).
8. R. M. Singru, Introductory Experimental Nuclear Physics (1972).
9. M. K. Pal: Nuclear Structure: Affiliated East-West Press (1982).
10. R. R. Roy and B. P. Nigam: Nuclear Physics, Willey-Eastern (1979).
11. David Griffiths: Introduction to Elementary Particles, Wiley (2008).
12. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/
13. W.E. Burcham & M. Jobes, Nuclear and Particle Physics, Addison Wesley, Longman (1995).

Course Outcome (CO) of Nuclear Physics

Upon completion of this course, students would be able to:

CO-1: Understand basic Nuclear Physics properties.

CO-2: Understand basic properties of nucleus and develop nuclear models.

CO-3: Understand Nuclear reaction dynamics and apply wherever applicable.

CO-4: Analyse the properties of nuclear structure and apply it in nuclear research.

CO-5: Understand nuclear reactions and apply it in the nuclear power generation.

NMPH-102T: Quantum Mechanics- II Credit(s): 4

Unit-I

Density Matrices: Basic definition and properties. Pure and Mixed states.

Quantum Entanglement. Quantum Teleportation (Introduction).

Quantum Computing: Basic Idea of Quantum Computation and Quantum Information Theory. Quantum Logic Gates. Single and Multi-qubit Operations.

Unit-II: Time Independent Approximation Methods

Variational Methods, WKB method, tunneling.

Perturbation Theory: Non-degenerate perturbation theory, degenerate case, Stark effect, Zeeman effect and other examples.

Unit-III

Time-dependent Perturbation Theory: Interaction Picture; Constant and harmonic perturbations; Fermi Golden rule; Sudden and adiabatic approximations. Beta decay as an example.

Unit-IV

Scattering Theory: Differential cross-section, scattering of a wave packet, integral equation for the scattering amplitude, Born approximation, method of partial waves, low energy scattering and bound states, resonance scattering.

Unit-V

Symmetries in Quantum Mechanics: Symmetry Operations and Unitary Transformations, conservation principles, space and time translation, rotation, space inversion and time reversal, symmetry and degeneracy.

Identical Particles: Meaning of identity and consequences; Symmetric and anti-symmetric wavefunction; incorporation of spin, symmetric and antisymmetric spin wave function of two identical particles, Slater's determinant, Pauli exclusion principle.

Suggested Readings

1. P.A.M. Dirac, Principles of Quantum Mechanics, Oxford Science Publications (1981).
2. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics (Vol. I), Wiley (2020).
3. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics (Vol. II), Wiley (2020).
4. Albert Messiah, Quantum Mechanics, Dover Publications (2014).
5. L. I. Schiff, Quantum Mechanics, Mc-Graw Hill (1969).
6. J. J. Sakurai, Modern Quantum Mechanics, Pearson Education (1980).
7. E. Merzbecher, Quantum Mechanics, John Wiley (1958).
8. J. Powel and B. Craseman, Quantum Mechanics, Springer (1972).
9. Thomas F. Jordan, Linear Operators in Quantum Mechanics, John Wiley & Sons, Inc. (1968).
10. Ashok Das and A.C. Melissinos, Quantum Mechanics, Adisson-Wesley (1986) (Reprinted CRC Press).
11. V. K. Thankappan, Quantum Mechanics, New Age International Pub. (2012) (3rd Edition).
12. Quantum Mechanics, Schaum's (Series) Outlines, McGraw Hill (2014).

Course Outcome (CO) of Quantum Mechanics-II

Upon completion of this course, students would be able to:

CO-1: Understand the idea of 'Quantum Computers', 'Quantum Entanglements' and contribute to in the development of 'Quantum Information Theory'.

CO-2: Understand various 'Time Independent Approximation Methods in Physics' such as 'WKB Approximation', 'Variational Method', and ''.

CO-3: Understand 'Time Dependent Perturbation Methods' and further explore the transitions.

CO-4: Understand nitty-gritty of 'scattering theory' and apply it in the properties of matter.

CO-5: Understand 'symmetries in Quantum Mechanics' and apply it in the advanced research.

CO-6: Understand- 'Theory of Angular Momentum in Quantum Mechanics' and apply it to 'Hydrogen-like Atom' and 'Spectroscopic Techniques'.

CO-7: Understand and apply the mathematical techniques of 'Total Angular Momentum' including 'selection rules' and 'Chlebsch-Gordon Coefficients'.

NMPH-103T: Condensed Matter Physics-I Credit(s): 4

Unit-I

Structure Factor: Static structure factor and its relation with the pair correlation function. Determination of structure factor by X-ray and neutron scattering. Inelastic neutron scattering and dynamic structure factor, space time correlation function and its relation with dynamic structure factor, properties of space time correlation function. Langevin's equation for Brownian Motion and its modifications. Velocity auto-co-relation function, mean square displacement, Relation between velocity auto-correlation function and diffusion coefficient.

Unit-II

Liquid Metals: Metallic interactions: Kinetic energy, electrostatic exchange and correlation, Pseudopotential formalism, diffraction model, structure factor, form factor for local and nonlocal potentials, energy eigen states, dielectric screening. Energy wave number characteristics, calculation of phonon dispersion of liquid metals. Band structure energy in momentum and direct space. Ziman's resistivity formula, Green function method for energy bands in liquid metals.

Unit-III

Quantum Liquids: Distinction between classical and quantum liquids, criteria for freezing, phase diagram of He4, He I and He II Tisaza's two fluid model, entropy filter, Fountain effect, superfluid film vehicle, Viscosity and specific heat of He4, first sound, second sound, third sound and fourth sound, Landau theory: Rotons and Phonis, t-matrix theory of superfluid He. Basic differences in superfluidity in He3 and He4.

Unit-IV

Exotic Solids: Structure and symmetries of liquids, liquid crystals and amorphous solids. Aperiodic solids and quasicrystals; Fibonacci sequency, Penrose lattices and their extension to 3-dimensions, Special carbon solids. Fullerenes and tubules; formation and characterization of fullerenes and tubules. Single wall and multi-wall carbon tubules. Electronic properties of tubules. Carbon nanotubule based electronic based devices Definition and properties of nano-structured materials. Methods of synthesis of nanostructured materials. Special experimental techniques for characterization of nano-structured materials. Quantum size effect and its applications.

Unit-V

Quantum Dots. Introduction to quantum dots as semi-conductor nanocrystals. Their structure and properties. Colloidal synthesis. Fabrication and Electro-chemical assembly.

Suggested Readings

1. P.A. Egelstaff, An Introduction to the Liquid State (Chapters 2, 3, 5, 6, 7 & 8), Clarendon Press (1994).
2. Jean P. Hansen and I.R. McDonald, Theory of Simple Liquids (Ch. 3, 5, 7 & 9) Academic Press (2013).
3. D. Pines and P. Nozier, The Theory of Quantum Liquid, West View Press Inc. (1989).
4. W.A. Harison: Pseudopotentials in the Theory of Metals Benjamin, W.A. Benjamin Inc. (1966).
5. N.H. March, W.H. Young and S. Sampanthar, Many Body Problems in Quantum Mechanics, Cambridge University Press (1967).
6. N.H. March and M.P. Tosi, Atomic Dynamics in Liquids, Springer (1976).
7. March, Tosi and Street: Amorphous Solids and the Liquid State, Plenum (1985).
8. Kittel, C., Introduction to Solid State Physics, John Willey (2007).
9. Omar, M.A., Elementary Solid-State Physics, Pearson Education (1999).
10. Srivastava, J.P., Elements of Solid-State Physics, Prentice Hall of India (2008).
11. Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Cengage Learning (2008).
12. Dekker, A.J., Solid State Physics, Macmillan (2003).

NMPH-104T: Elective-1 — Credit(s): 4

NMPH-111P: Nuclear Physics Lab — Credit(s): 2

Students have to perform any eight experiments from the following:

1. To study G.M. detector characteristics and determine operating voltage of a G.M. tube.
2. To study random nature of radioactive decay using G.M. counter.
3. To determine the resolving time of G.M. counting set up (single and double source methods).
4. To study the absorption of β- particles and determine end point energy using G.M. counter.
5. To determine absorption coefficient of γ- rays.
6. Study of secular equilibrium in radioactive decay.
7. To determine end point energy of β- particles using Scintillation counter.
8. To study Compton scattering of γ- rays using Scintillation counter.
9. Study of absorption curve of α- particles using semiconductor detectors.
10. Study of specific energy loss and straggling of α- particles using semiconductor detectors.

Suggested Readings:

1. G.F. Knoll, Radiation Detections and Measurement, Wiley India (2010).
2. S.S. Kapoor and Ramamurthy; Experimental Nuclear Physics: Tata McGraw Hill (2010).
3. J. Varma, Experiments in Nuclear Physics, New Age Publishers, New Delhi (2000).
4. R. M. Singru, Introductory Experimental Nuclear Physics (1972).

NMPH-112P: Advanced Electronics and Instrumentation Lab Credit(s): 4

1. To study OP-AMP as inverting and non-inverting amplifier.
2. To study IC7805 and its applications.
3. To study IC740 and its applications.
4. To study IC741 and its applications.
5. To study IC555 and its applications.
6. To study microprocessors 8085 and 8086 and their applications.
7. To record observations on **Atomic Absorption Spectrometer** and analyze it.
8. To record observations on **Fluorescent Spectrometer** and analyze it.
9. To record observations on **Ultra Violet/Visible Spectrometer** and analyze it.
10. To record observations on **FTIR** and analyze it.
11. To record observations on **X-Ray Diffraction (XRD) Spectrometer** and analyze it.

Semester II

NMPH-201T: Relativistic Quantum Mechanics and Quantum Field Theory

(Quantum Mechanics-III) Credit(s): 4

Unit-I: Relativistic formulation of Quantum Mechanics

Klein-Gordon equation. Covariance and solution of Klein-Gordon equation. Dirac's equation. Covariance and solution of Dirac's equation. Symmetries of Dirac's equation. Bilinear covariants.

Unit-II: Quantum Fields

Classical Lagrangian field theory, 'Euler-Lagrange's equation, Lagrangian density for electromagnetic field. Occupation number representation for simple harmonic oscillator, linear array of coupled oscillators. Quantization of identical bosons. Second quantization of the real and complex Klein Gordan field. The meson propagator.

Unit-III

The occupation number representation for fermions. Second quantization of the Dirac filed. The fermion propagator. The electromagnetic interaction and gauge invariance. Covariant quantization of the free electromagnetic field. The photon propagator.

Unit-IV

S-matrix formulation: *S*-matrix expansion. Wick's theorem. Diagrammatic representation in configuration space, the momentum representation, Feynman diagrams of basic processes, Feynman rules of QED.

Path Integral Formalism: Applications

Unit-V

Specific Processes: Applications of *S* matrix formalism: Coulomb scattering, Bhabha scattering, Moller scattering, Compton scattering and Pair Production. Weak interaction by means of V-A theory.

Suggested Readings:

1. J. D. Bjorken and Sidney Drell, Relativistic Quantum Mechanics, Tata McGraw Hill (2013).
2. F. Mandal & G. Shaw, Quantum Field Theory, John Wiley (1986).
3. S. Weinberg, Quantum Theory of Fields-I, Cambridge University Press (2013).
4. S. Weinberg, Quantum Theory of Fields-II, Cambridge University Press (2013).
5. S. Weinberg, Quantum Theory of Fields-III, Cambridge University Press (2013).
6. M.E. Peskin and D.V. Shröder, Introduction to Quantum Field Theory, Addisson-Wesley (2021). (Now Republished by CRC Press)
7. J. M. Ziman: Elements of Advance Quantum Theory, Cambridge University Press (1975).
8. A. Zee, Quantum Field Theory in Nut-Shell, Princeton University Press (2010).
9. Bilenky, S.M., Introduction to Feynmann Diagrams, Elsevier (2013).
10. Chang, S.M., Introduction to Quantum Field Theory, World Scientific (2010).

Course Outcome (CO) Electrodynamics-II

Upon completion of this course, students would be able to:

CO1: Explain classical electrodynamics based on Maxwell's equations including its formulation in covariant form.

CO2: Solve the electromagnetic problems with the help of electrodynamic potentials and super-potentials, and make a detailed account for gauge transformations and their use

CO3: Formulate and solve electrodynamic problems in relativistically covariant form in four-dimensional spacetime.

CO4: Calculate the electromagnetic radiation from localized charges which move arbitrarily in time and space, taking into account retardation effects.

CO5: Calculate the electromagnetic radiation from radiating systems, like oscillating electric and magnetic dipoles (aerials, localized charge and current distributions)

NMPH-202T: Classical Electrodynamics-II Credit(s): 4

(Classical Electrodynamics in Matter and Medium)

Unit-I

Special techniques for calculating potentials

Laplace's Equation: Laplace's equation in one dimension. Solution of Laplace's equation in two dimensions. Laplace's equation in three dimensions. Boundary conditions and Uniqueness theorems. Conductors and second uniqueness theorem.

Unit-II

The Method of Images: The classic image problem. The induced surface charge. Other image problems

Multi-pole Expansion: Approximate potentials at large distances. The monopole and dipole terms. Origin of coordinates in multi-pole expansion. The electric field of an electric charge.

Unit-III

Electro-magnetic waves in conducting and non-conducting media

Electro-magnetic waves in non-conducting media: Monochromatic plane waves in vacuum. Energy and momentum of electro-dynamic waves. Propagation through linear media. Reflection and transmission at normal and oblique incidence

Unit-IV

Electromagnetic Waves in Conductors: The modified wave equation. Monochromatic plane waves in conducting media. Reflection and transmission at conducting surface.

Dispersion: The frequency dependence of ε, μ and σ . Dispersion in non-conductors. Free electrons in conductors and plasma.

Guided Waves and Transmission Lines: Wave guides. TE waves in rectangular wave-guides. The coaxial transmission lines.

Unit-V

Magneto-Hydrodynamics and Plasma Physics

Introduction and definitions. MHD equations. Magnetic Diffusion: Viscosity and Pressure. Pinch effect: instabilities in pinched plasma column. Magneto-hydrodynamics waves. Plasma Oscillations: Short wave length limit of plasma oscillations and Debye shielding distance.

Suggested Readings

1. L. D. Landau & Lifshitz: Classical Theory of Electrodynamics; Pergamon Press (1984).
2. J. D. Jackson: Classical Electro-dynamics; John Wiley (1998).
3. David J. Griffiths, Introduction to Electro-dynamics, Prentice Hall (2015).
4. Panofsky & Phillip, Classical Electrodynamics and Magnetism, (2012).
5. Sadiku, N.O., Principles of Electromagnetics, Oxford University Press (2015).
6. William, Hyatt and John A. Buck, Engineering Electromagnetics, McGraw Hill (2010).

NMPH-203: Condensed Matter Physics-II Credit(s): 4

Unit-I

Phase Transformation and Alloys: Equilibrium transformation of first and second order. Equilibrium diagrams. Phase rule. Interpretation of phase diagrams. Substitutional solid solutions. Vegard's law, intermediate phases, Hume-Rothery rules. Interstitial phases (carbides, nitrides, hydrides, borides). Martensitic transitions. structure factor of liquid metal alloys, behaviour of s(q), radial distribution function g(r) and relationship between s(q) and g(r)

Unit-II

Disordered Systems: Disorder in condensed Matter, Substitutional, positional and topographical disorder. Short and long-range order. Spinning, sputtering and ion-implantation techniques, glass Transition, glass formation ability, nucleation and growth processes. Anderson model for random system and electron localization, mobility edge, qualitative application of the idea of amorphous semiconductors and hopping conduction. Metal glasses, Models for structure of metal glasses. Structure factor of binary metallic glasses and it relationship with the radial distribution functions. Discussion of electric, magnetic and mechanical properties of glassy system.

Unit-III

Structure determination/characterization: Basic theory of X-ray diffraction. Indexing of Debye-Scherer patterns powder samples, examples from some cubic and non-cubic symmetries. Neutron diffraction-basic interactions, cross section, scattering length and structure factor. Mossbauer effect, hyperfine parameters-Isomer shift, quadrupole splitting and Zeeman splitting. Application 0Valence and coordination, site symmetry magnetic behaviour. Discussion in context of Fe57.

Unit-IV

Electronic Structure Determination: Basic principles of X-ray, photo-emission and positron annihilation techniques. qualitative discussion of experimental arrangement and typical results for both simple as well as transition metals.

Unit-V

Semiconductor: Lattice properties of 4^{th} group elements; structure, physical constants, influence of impurities, diffusion of impurities, influence of lattice defects, Fermi level and electron-hole distribution in energy band, simplified and improved models for isolators and intrinsic semiconductor. Models of an impurity semiconductor, Intrinsic and extrinsic semiconductors, Hydrogenic model of impurity levels, temperature dependence of Fermi level in extrinsic semiconductor, conductivity in semiconductor, carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors Band-gap. Direct and indirect gap semiconductors. Effect of temperatures and impurities in semiconductor, introduction to amorphous semiconductor. Quantum Hall Effect.

Suggested Readings:

1. P.A. Egelstaff, An Introduction to the Liquid State (Chapters 2, 3, 5, 6, 7 & 8), Clarendon Press (1994).

2. Jean P. Hansen and I.R. McDonald, Theory of Simple Liquids (Ch. 3, 5, 7 & 9) Academic Press (2013).

3. D. Pines and P. Nozier, The Theory of Quantum Liquid, WestView Press Inc. (1989).

4. W.A. Harison: Pseudopotentials in the Theory of Metals Benjamin, W.A. Benjamin Inc. (1966).

5. N.H. March, W.H. Young and S. Sampanthar, Many Body Problems in Quantum Mechanics, Cambridge University Press (1967).

6. N.H. March and M.P. Tosi, Atomic Dynamics in Liquids, Springer (1976).

7. March, Tosi and Street: Amorphous Solids and the Liquid State, Plenum (1985).

8. 1. Kittel, C., Introduction to Solid State Physics, John Willey (2007).

9. Omar, M.A., Elementary Solid State Physics, Pearson Education (1999).

13. Srivastava, J.P., Elements of Solid State Physics, Prentice Hall of India (2008).

14. Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Cengage Learning (2008).

15. Dekker, A.J., Solid State Physics, Macmillan (2003).

NMPH-204T: Elective-2 **Credit(s): 4**

Syllabi of Special Elective Courses

NMPH-104A1: General Relativity and Cosmology **Credit(s): 4**

Unit-I

Principle of equivalence. Metric formulation and tensor nature of gravitational field. Gradient, divergence, curl, and Laplace in . Christoffel symbols of the first and second kind. Covariant differentiation. Bianchi identity. Curvature and torsion in Riemannian Geometry.

Unit-II

Geodesics and equation of motion in the curved space. Riemann curvature tensor. Weyl tensor, Conformal curvature tensor. Ricci tensor. Energy Momentum tensors. Energy Momentum tensors for Electro-magnetic field. Energy-Momentum tensor for perfect fluid; and Energy-Momentum tensor for dust-like case.

Unit-III

Einstein's field equation and gravitation. Schwarzchild metric and solutions of Einstein's equation. Three crucial tests of Einstein's theory of gravitation: Advance of the perihelion of Mercury; Bending of the light beam in the presence of gravitating object; and, Gravitational Red-shift. Gravitational lensing. Killing vectors.

Unit-IV

Singularities of Schwarzchild metric. Krüskal-Szekere's coordinates and Penrose diagrams.
Einstein's equation from Action principal. Theory of gravitational waves. Ray-Chaudhary equation. Vaidya metric.

Unit-V: Cosmology

Einstein's model of Universe. De-Sitter Universe. Pressure, density, and energy tensors in the Einstein and de Sitter Universes.
Friedman-Robertson-Walker-Lemaitre model of the Universe. Particle horizon. Event horizon. Luminosity distance. Doppler effect.
Big-Bang and the Physics of the early Universe. Entropy and Thermodynamics of the early Universe. Particle and the Nucleo-synthesis in the early Universe. Various phase transitions and time-line of the Universe. Saha's ionization equation.
Inflationary cosmology and generation of density perturbations. Alternative cosmologies: Quasi-Steady State Theory of the Universe.

Suggested Readings

1. S. Weinberg: General Relativity, Gravitation and Cosmology, Wiley (2013).
2. Meissner, Kip Thorn and John Wheeler, Gravitation and Cosmology, Benjamin Feeman (1973).
3. James Hartle, Gravity: An Introduction to Einstein's General Relativity, Pearson (2003).
4. Peacock J. A.: Cosmological Physics, Cambridge University Press (1998).
5. J. V. Narlikar: Introduction to Cosmology, Cambridge University Press (2002).
6. Pankaj S. Joshi, Global Aspects in Gravitation and Cosmology, Oxford Science Publications (1993).

NMPH-204A2: Astrophysics Credit(s): 4

Unit-I: Overview of Astrophysics

The structure, origin, and evolution of the major components of the Universe: planets, stars, and galaxies. Formation of the Sun and planets.

Luminosity and magnitudes of stars. Saha's ionization equation.

Unit-II: Astrophysical Processes

Astrophysical processes. Basics of electromagnetic radiations; Statistical mechanics of Astrophysical phenomena; Radiative processes; Spectra; Neutral fields and plasma in Astrophysics.

Stellar evolution; X-ray sources, Binary stars, Pulsars, Quasars and other compact stars. The origin and search for life in the Universe.

Unit-III: Structure Formation

Structure formation in the early Universe. Galaxy formation. Elliptical and spiral galaxies. Rotational curves of galaxies and signatures of Dark matter. Physics of the inter-stellar and inter-gallactic media.

Unit-IV: Stellar Structure

Star formation. Radiative transfer and stellar mechanics. Chandrashekhar limit and life-cycles of stars: Supernovae-Adult stars-Red Giants-Black Holes/White Dwarfs. The idea of White holes and Brown Dwarfs.

Unit-V: Evolution of the Universe

Big-Bang. First Three Minutes. Physics of the Early Universe. Dark Matter. Dark Energy.

Suggested Readings

1. Arnab Rai Chaudhary: Astrophysics for Physicists, Cambridge University Press (1998).
2. T. Padmanabhan: Theoretical Astrophysics-I, Cambridge University Press (2001).
3. T. Padmanabhan: Theoretical Astrophysics-II, Cambridge University Press (2001).
4. T. Padmanabhan: Theoretical Astrophysics-III, Cambridge University Press (2002).
5. Peacock J. A.: Cosmological Physics, Cambridge University Press (1998).

NMPH-104B1: Particle Physics- I Credit(s): 4

Unit-I

Elementary particles and the fundamental forces. Quarks and leptons. The mediators of the electromagnetic, weak and strong interactions. Interaction of particles with matter; particle acceleration, and detection techniques. Symmetries and conservation laws.

Bound states. Discoveries and observations in experimental particle physics and relation to theoretical developments. Symmetries, group theory, SU(2) group, Finite Symmetry Group: P and C, SU(2) of Isospin, SU(3) groups.

Unit-II

Quark and Antiquark states: Mesons, Three quark states: Baryon, color factors, Asymptotic freedom. Charged and neutral weak interactions. Electroweak unification.

Unit-III

Decay rates and Cross sections: Feynman diagrams Introduction to Feynman integrals. The Dirac equation. Feynman rules for quantum electrodynamics (no derivation). Moller scattering, trace theorems and properties of gamma matrices, helicity representation at high energies., the electron propagator, the photon propagator.

Unit-IV

Structure of Hadrons: form factors, e-p scattering, inelastic e-p scattering, Bjorken scaling, Partons, gluons, deep inelastic scattering, evolution equations for parton densities.

QCD: Electron positron annihilation into hadrons, heavy quark production, three jet events, QCD corrections, Perturbative QCD, Drell-Yan process.

Unit-V

Weak Interactions: Parity violation, V-A form of weak interaction, Nuclear beta decay, muon decay, pion decay, charged current neutrino electron scattering, neutrino quark scattering, weak neutral currents, the Cabibo angle, weak mixing angles, CP invariance.

Suggested Readings:

1. Francis Halzen and Allan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley (2008).
2. B.R. Martin and G. Shaw, Particle Physics, 2nd edition, J. Wiley and Sons (1997).
3. David Griffiths: Introduction to Elementary Particles, Wiley (2008).
4. Donald Perkin: Introduction to high energy physics, Cambridge University Press (2000).
5. Byron Roe: Solutions Manual for Particle Physics at the New Millennium, Springer (2013).
6. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/

NMPH-204B2: Particle Physics- II Credit(s): 4

Unit-I

Gauge Symmetries: U(1) Local gauge invariance and QED, Non-abelian gauge invariance and QCD, massive gauge bosons, spontaneous breakdown of symmetry, the Higgs mechanism.

Unit-II

Local gauge invariance and Yang-Mills fields: Lagrangian of the Spontaneous symmetry breaking and the Higgs mechanism, The Weinberg-Salam model and beyond.

Unit-III

Standard Model of Particle Physics: Unified models of weak and electromagnetic interactions, flavor group, flavor-changing neutral currents. Weak isospin.

Unit-IV

Quark and lepton mixing: CP violation. Neutrino oscillations. CKM quark mixing matrix, GIM mechanism, rare processes, neutrino masses, seesaw mechanism.

Unit-V

QCD confinement and chiral symmetry breaking, instantons, strong CP problem.

Suggested Readings:

1. Francis Halzen and Allan D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley (2008).
2. B.R. Martin and G. Shaw, Particle Physics, 2nd edition, J. Wiley and Sons (1997).
3. David Griffiths: Introduction to Elementary Particles, Wiley (2008).

4. Donald Perkin: Introduction to high energy physics, Cambridge University Press (2000).

5. Byron Roe: Solutions Manual for Particle Physics at the New Millennium, Springer (2013).

6. Review of Particle Physics, (Particle Data Group, 2020); https://pdg.lbl.gov/2020/

NMPH-104C1: Digital Electronics Credit(s): 4

Unit-I

Analog Circuits: Integrated Circuits (Qualitative Treatment only): Active and Passive components. Discrete Circuit Component. Wafer. Chip. Advantages and Drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (Basic Idea and Definitions Only). Classification of ICs. Fabrication of Components on Monolithic ICs. Examples of Linear and Digital ICs.

Operational Amplifiers (Use Black Box approach): Basic Characteristics of Op-Amps. Characteristics of an Ideal Op-Amp. Feedback in Amplifiers. Open-loop and Closed-loop Gain. Frequency Response. CMRR. Virtual ground.

Unit-II

Applications of Op-Amps: (1) Inverting and Non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Unity follower, (5) Differentiator, (6) Integrator, (7) Zero Crossing Detector.

Timers (Use Black Box approach): 555 Timer and its Applications: Astable and Monostable Multivibrator.

Digital Circuits: Difference Between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND AND NOR Gates. Exclusive OR and Exclusive NOR Gates.

Unit-III

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Minterms and Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

Data processing circuits: Basic Idea of Multiplexers, De-multiplexers, Decoders, Encoders, Parity Checkers.

Memories: Read-only memories (ROM), PROM, EPROM.

Unit-IV

Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement Method).

Half Adders and Full Adders and Subtractors (only up to Eight Bits).

Sequential Circuits: RS, D, and JK Flip-Flops. Level Clocked and Edge Triggered Flip-Flops.

Preset and Clear Operations. Race-around Conditions in JK Flip-Flops. Master-Slave JK Flip-

Flop (As Building Block of Sequential Circuits).

Unit-V

Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out, and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

Counters: Asynchronous and Synchronous Counters. Ring Counters. Decade Counter. D/A and A/D conversion: D/A converter – Resistive network. Accuracy and Resolution.

Suggested Books:

1. D. P. Leach and A. P. Malvino: Digital Principles and Applications, Glencoe (1995).

2. Thomas L. Floyd: Digital Fundamentals, 3rd Edition, Universal Book Stall, India (1998).

3. Robert F Coughlin and Frederick F Driscoll: Operational Amplifiers and Linear Integrated Circuits, 4th Edition, PHI (1992).

4. T. L. Floyd, Digital Fundamentals, Pearson International Publications, Ninth Edition (2000).

5. Malvino and Leach, Electronics Principles, Mc. Graw Hill, Third edition (2000).

6. R. L. Tokheim, Digital Electronics: Principles and Applications, Tata McGraw-Hill Education (2013).

7. R P Jain, Modern Digital Electronics, Tata McGraw-Hill Education (2003).

(Digital Communication Systems)

8. Bernard Sklar, 'Digital Communications: Fundamentals and Applications', Prentice Hall (2001).

9. B. P. Lathi, "Modern Digital and Analog Communication Systems", Oxford University Press (2000) (3rd Ed., Oxford Series in Electrical and Computer Engineering).

10. Simon Haykin, "Communication Systems", 4th Ed., John Wiley, (2006).

NMPH-204C2: Microwave Electronics and Communication — Credits: 4

Unit-I

Microwave Wave Guides: Rectangular wave guides: TE, TM and TEM modes in wave guides, power transmission in wave guide, power losses in wave guide, excitation modes in wave guide, Characteristics of standard wave guides.

Unit-II

Microwave Components: microwave cavities, microwave attenuators, Scattering parameters, E-H tunner, directional coupler, circulators and isolators, Phase shifter.

Microwave Tubes: Linear beam: klystrons, reflex klystrons, TWTs. Microwave Crossed Field Tubes: Magnetrons, forward wave crossed field amplifier (FWCFA), high power gyrotrons. (Operating principle, construction & analytical treatment of above mentioned microwave tubes.)

Unit-III

Microwave Solid State Devices: Microwave tunnel diodes, microwave FETs, gunn effect diodes, RWH Theory, LSA diodes, Impatt diodes, PIN diodes, ruby laser, MESFETs and HEMT. (Operating principle, construction and analytical treatment of above mentioned microwave devices.)

Unit-IV

Microwave Measurements: Detection of microwave power: measurement of microwave low and high power, thermister parameters, thermister mounts, barreters, direct reading barreters bridges, Measurement of wavelengths: single line cavity coupling system, Transmission cavity-wave meter and reaction wavemeter, measurement of VSWR, measurements of attenuation, input impedance.

Unit-V

Microwave Antennas: Different types of antennas.

Modulation and Demodulation: Types of Modulation. Amplitude Modulation. Modulation Index. Analysis of Amplitude Modulated Wave. Sideband Frequencies in AM Wave. CE Amplitude Modulator. Demodulation of AM Wave using Diode Detector. Idea of Frequency, Phase, and Digital Modulation.

Suggested Readings

1. R. E. Collin: Foundation of Microwave Engg, McGraw Hill (1992).

2. Samul Liao: Microwave Devices and Circuit, PHI (2003).

3. David M. Pozar, Microwave Engineering, John Wiley& Sons, Inc. (2013).

4. Roddy. D., "Microwave Technology" Reston Publications (1986).

5. Chatterjee R., "Microwave Engineering "East West Press (1988).

6. Rizzi. P. "Microwave Engineering Passive circuits". Prentice Hall (1987).

7. Clock, P.N., "Microwave Principles and Systems" Prentice Hall (1986).

NMPH-104D1: Ionospheric Physics　　　　Credit(s): 4

Unit-I

Sun: Structure of Sun. Thermonuclear Reactions in the core of the Sun. Convection and radiative transfer. Photosphere, Chromosphere and Corona. Nanoflares. Sun Spots and Solar Cycle. Solar Cycle and Weather on the Earth.

Unit-II

Ionosphere: Production of Ionosphere. Different layers of the Ionosphere. Photochemical reactions in the Ionosphere. Loss reactions. Equation of continuity. Air Glow and Aurora.

Unit-III

Morphology of the Ionosphere: Morphology of the D, E, F1 and F2 regions.

Unit-IV

Passage of the Electromagnetic waves through Ionosphere: Dispersion. A wave in the continuous medium of specific dielectric constant. Polarization of E-M waves. Curves of ***R(X)***. Quasi-Longitudinal (QL) and Quasi-Transverse (QT) approximations.

The Role of Ionosphere in the communication of Radio waves. The *Skip* distance.

Unit-V

Magnetosphere: Formation of the Earth's Magnetosphere. Its role in controlling the Solar wind, plasma particles and protecting life on the Earth. Physics of the Magnetosphere associated phenomena.

Suggested Readings

1. B.N. Dwivedi and E.N. Parker, Dynamic, Cambridge University Press (2003).
2. M.C. Kelly, The Earth's Ionosphere: Plasma Physics and Electrodynamics: Volume 96, Academic Press, 2nd edition (2009).
3. V. Bychkov, G. Golubkov and A. Nikitin, The Atmosphere and Ionosphere, Springer (2013).
4. Robert Schunk and Andrew Nagy, Ionospheres, Cambridge University Press (2009).
5. C. Donald Ahrens, Essentials of Meteorology (3rd Edition), S. Chand and Co. (2000).
6. James R. Holton: Introduction to Dynamic Meteorology (4th Edition), Elsevier- Academic Press (2004).

NMPH-204D2: Atmospheric Physics and Weather Science   Credit(s): 4

Unit-I

Atmosphere and its constituents: Synoptic observations- surface and upper air. Preparation of weather charts and their analysis, Diurnal variation of temperature, pressure, relative humidity, clouds etc.

Tropical meteorology: Easterly Waves, ET-ITCZ, Inversion.

Unit-II

Extratropical Meteorology: Air mass, Fronts- Frontogenesis and Frontolysis, Extratropical Cyclones and Anticyclones, Jet Streams.

Synoptic systems: Winter -Western disturbance, Rossby Waves,

Unit-III

Westerly Jet Stream, Fog, Cold Wave etc. Summer - Thunderstorms, Dust storms, Heat wave, Cyclonic disturbances. Monsoon - Onset, Activity, Withdrawal, Breaks,

Depressions, Easterly Jet Stream. Post Monsoon - Cyclones in the Indian Seas, N.E. Monsoon.

Unit-IV

Global Climatology: Global distribution of pressure and temperature in winter and summer, distribution of annual rainfall and its variability, distribution of moisture and clouds. Vertical distribution of temperature. General circulation of atmosphere.

Development of monsoons. Major categories of world climates.

Unit-V

Indian Climatology - Different seasons, Distribution of Means Sea level

Pressure/temperature in different seasons, Wind circulation and temperature distribution over India in lower, middle and upper troposphere in different seasons. Indian rainfall in different seasons. Indian summer monsoon, onset, withdrawal, rainfall distribution, inter annual variability of monsoon. Main synoptic pressure systems causing weather over India in different seasons.

Suggested Readings

1. R.J. Barry and R.G. Chorley, Atmosphere, Routledge (2009).
2. R.J. Barry and R.G. Chorley, Atmosphere, Weather and Climate, Routledge (2009).
3. V. Bychkov, G. Golubkov and A. Nikitin, The Atmosphere and Ionosphere, Springer (2013).
4. Robert Schunk and Andrew Nagy, Ionospheres, Cambridge University Press (2009).
5. C. Donald Ahrens, Essentials of Meteorology (3rd Edition), S. Chand and Co. (2000).
6. James R. Holton: Introduction to Dynamic Meteorology (4th Edition), Elsevier- Academic Press (2004).
7. S. Pettersen, An Introduction to Meteorology, McGraw-Hill Book Co. (2008).
8. Y.P. Rao, South West Monsoon" IMD Publication (1976).
9. T.N. Krishnamurthy, Tropical Meteorology, Springer (2013).
10. Lydia Stefanova, T. N. Krishnamurti, and Vasubandhu Misra, Tropical Meteorology, Springer (2013).
11. G.C. Asnani, Tropical Meteorology, Vol 1, 2, 3 (2016).

NMPH-251: Project Credit(s): 4

Work with any University/ Academic Institution/ Research Lab/Eminent Professor

MPH-252: Dissertation + Seminar (Presentation of Project Work)

Credit(s): 4(2+2)
