MSc Physics Restructured Syllabus 2021
(Semester I & II)

16 Papers, 1600 Marks, 16×6=96 Credits
24 Credits per semester. 4×24=96 Credits
Each paper of 100 marks has 6 credits; 6 classes per week
Each module is of 36 lectures

Semester-1

Paper-01

Group A: Mathematical Physics–I (Tensor and Complex Analysis)

Tensor Analysis

Tensors: Tensor equations as transformational invariants, mathematical operation with tensors (addition, subtraction & multiplication and contraction), metric tensors, raising and lowering of indices, covariant differentiation, Christoffel symbol, Geodesic Equation.

[12 lectures]

References:

(1) Vector analysis and an introduction to Tensor Analysis (Murray R. Spiegel);

(2) Introduction to Tensor Calculus and Continuum Mechanics (J.H. Heinbockel)

Complex Analysis: [Recapitulation of essential notions: Complex Plane, Analytic functions: elementary classification of singularities, Cauchy Riemann Equations, Cauchy Integral theorem and Integral formula] Complex Taylor Series. Laurent Series and the calculus of Residues: evaluation of integrals. [10 Lectures]

Application to the evaluation of Green's function for Inhomogeneous Differential Equations. [8 Lectures]

Analytic Continuation. Mittag-Leffler Expansions [Conformal Transformations].

[6 Lectures]

[24 Lectures]

References:

1. Murray Spiegel et al, Schaum's Outline of Complex Variables, 2ed ; McGraw Hill Education
2. Churchill and Brown, Complex Variables and Applications; McGraw Hill Higher Education
3. Tristan Needham, Visual Complex Analysis; Oxford
4. Zill & Shanahan, A First Course in Complex Analysis with Applications
5. Harold Cohen, Complex Analysis with Applications in Science and Engineering; Springer

Group B: Quantum Mechanics–I

Vector space and inner product space: Axiomatic definition, completeness, linear independence, basis and dimension, inner product, norm, orthogonality, Gram-Schmidt orthogonalization. Dual space. Linear Operators, Eigenvalues and eigenvectors, Diagonalisation, Hermitian and Unitary operators. Tensor product space.

[12 lectures]

Formulation of quantum mechanics: Postulates and their interpretation, Quantisation scheme: Simple illustrative examples

[4 lectures]

Aspects of time evolution: Solution of the Schrodinger equation and the time evolution operator for conservative systems, time evolution of expectation values, Ehrenfest's theorem. Constants of motion. Heisenberg and interaction pictures of time evolution.

[6 lectures]

One dimensional harmonic oscillator by operator method. Three dimensional harmonic oscillator.

[3 lectures]

Symmetries: Momentum as translation generator, Angular momentum: Connection with rotational symmetry. Symmetry and invariance. **[3 lectures]**

Angular momentum algebra and generalised angular momentum. Solution of the eigenvalue problem using ladder operators. Spin angular momentum, matrix representations for s = ½ and s = 1.

[4 lectures]

Addition of angular momenta: Clebsch-Gordan coefficients.

[4 lectures]

References:

(1). Introduction to Quantum Mechanics; D. J. Griffiths; Pearson Education.

(2). Quantum Mechanics Vol 1 & 2; C. Cohen Tannoudji, B.Diu, F. Laloe; Wiley.

(3). Primer of Quantum Mechanics; Marvin Chester; John Wiley & Sons.

(4). Principles of Quantum Mechanics; R. Shankar; Springer

(5). Modern Quantum Mechanics: J. J. Sakurai (Addison-Wesley Publ. Co. Ltd.)

(6). Feynman Lectures Vol. III: R. P. Feynman, R. B. Leighton and M. Sands (Addison-Wesley)

Paper-02

Group A: Classical Mechanics–I

Revision of Canonical formalism: Lagrangian and Hamiltonians, P.B formalism. Rotations, Rigid bodies and Classical Scattering Theory; An overview of the Lagrangian formalism; Some specific applications of Lagarange's equation; small oscillations, normal modes and frequencies.

[6 lectures]

Hamilton's principle; Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle;

Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action.

[6 lectures]

Canonical transformations; Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations;

Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum and Poisson bracket relations.

[8 lectures]

Action angle variables, Hamilton-Jacobi theory, The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function;

[6 lectures]

Rigid bodies; Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal);

Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations;

Heavy symmetrical top with precession and nutation.

[10 lectures]

Group B: Non-Linear Dynamics

Theory:

Physics of nonlinear systems, dynamical equations and constants of motion, phase space, fixed points, stability analysis, bifurcations and their classifications, Poincarè section and iterative maps.

[8 lectures]

One dimensional non-invertible maps, period doubling and universality, intermittency, invariant measure, Lyapunov exponents. Two dimensional systems, Henon map, idea of attractors, Lorenz equations.

[8 lectures]

Fractal geometry and concept of dimensions.

[4 lectures]

Introduction to Hamiltonian systems and integrability. **[4 lectures]**

Computation Lab:

Discrete time problems: Time-series analysis, Iterative maps and Cobweb diagrams, The logistic map, Bifurcation, State space methods: orbits, Chaos and sensitivity to initial conditions.

Continuous systems: The damped driven pendulum: Expected features, approach to chaos through the period doubling route, other non-linear oscillators.

[12 lectures]

References:

(1) Chaos and Fractals - An Elementary Introduction, D.P. Feldman, OUP
(2) Non Linear Dynamics, S. H. Strogatz, Perseus Books
(3) Chaotic Dynamics - an introduction, G. L. Baker and J. P. Gollub, CUP
(4) Non Linear Workbook, Willi - Hans Steeb, World Scientific (3rd edition)
(5) Non Linear Physics with Mathematica for Scientists and Engineers, R. Enns and G. C. McGuire, Berkhauser publications.

Paper-03

Group A: Electronics

Semiconductor Physics:
Direct and indirect semiconductors; intrinsic and extrinsic semiconductors; energy band diagram; carrier concentration in both cases; non degenerate and degenerate semiconductors.

[4 lectures]

Carrier transport phenomena: Mobility; Hall effect; diffusivity; generation and recombination; direct and indirect recombination; surface and Auger recombination.

Continuity equation: Utilised for steady state injection from one-side.

[6 lectures]

P-N Junction diode: Equilibrium Fermi level constant; built in potential, depletion layer width, depletion layer width and energy band diagram of a p-n junction diode under various biasing conditions (a) Thermal equilibrium condition (b) forward biasing conditions (c) reverse bias conditions.
Depletion capacitance, capacitance voltage characteristics.
Avalanche and Zener breakdown, Zener diode
Varactor diode

[6 lectures]

Metal semiconductor junction, Schottky barrier. Bipolar junction transistor equation for Ebers Moll model.
Tunnel diode: order of the width of the depletion region; reverse and forward bias is showing positions of Fermi levels. Explanation of I-V characteristics using the diagrams; Tunnel diode as oscillator, other applications.

[6 lectures]

Unijunction transistor (UJT) applications as a relaxation oscillator. MOSFET: MOS diode and drain current drain voltage characteristics.
JFET: Structure, Operation, Principle I-V characteristics.
Logic families: DTL, TTL, TTL Schottky, Low Power Schottky, CMOS
ADC and DAC

[14 lectures]

References:

1. S M Sze(2nd edition)

2. J. Millman and C. Halkias: Integrated Electronics

3. J. Kennedy: Electronic Communication Systems

5. J. Millman and A. Grabel: Microelectronics

6. B.G. Streetman, S. Banerjee: Solid State Electronic Devices

9. Digital Circuits (Vol I and II), D. Roy Choudhury, Platinum Publishers

Group B: Statistical Mechanics I

Introduction: Objective of statistical mechanics, specification of the state of a many particle system, phase space, counting the number of microstates in phase space, phase points, statistical ensemble, Density of phase points, postulate of equal a priori probability, Liouville's theorem, ergodic hypothesis, H-theorem, probability calculation, thermal, mechanical and general interaction.

[8 lectures]

Microcanonical ensemble: Thermal interaction between systems in equilibrium, temperature, heat reservoirs, sharpness of the probability distribution, applications.

[6 lectures]

Canonical ensemble: System in contact with a heat reservoir, Boltzmann distribution, canonical partition function, calculation of mean values in canonical ensemble, connection with thermodynamics, entropy of an ideal gas, Gibbs' paradox, applications.

[8 lectures]

Grand canonical ensemble: System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number, chemical potential of an ideal gas, applications.

[8 lectures]

Fluctuation in energy and particles. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature.

[6 lectures]

References:

1. F. Reif, Fundamentals of Statistical and Thermal Physics.
2. K. Huang, Introduction to Statistical Mechanics
3. R. K. Pathria, Statistical Mechanics
4. David Chandler, Introduction to Modern Statistical Mechanics
5. R. Kubo, Statistical Mechanics (Collection of problems).

6. An Introductory Course of Statistical Mechanics, Palash B. Pal, Alpha Sciences.

7. Statistical Physics, J. K. Bhattacharjee

8. Statistical Mechanics: An elementary outline, Abhijit Lahiri

9. Equilibrium and Non-Equilibrium Statistical Thermodynamics, Michel Le Bellac, Maurice Le Bellac, Fabrice Mortessagne, G. George Batrouni, George Batrouni, CUP.

Paper-04

Group A: Core Lab-I (Electronics)

1. Design of Passive Filters: Symmetric T- and Π- filters (LPF and HPF) designed using inductances and capacitances
2. Design of Active Filters: LPF, BPF, HPF and Notch filters designed using OPAMP IC –741C.
3. Design of oscillators: Astable multivibrator designed using BJT as a square wave generator as well as VCO. Relaxation oscillator designed using UJT (2N 2646)
4. Design of A/D and D/A converters using discrete components
5. Experiment with MOS device: Drain and Transfer characteristic of MOSFET (Depletion and Enhancement mode)
6. Programming a micro-processor (8085) and interfacing using a 7 – segment display (Counting of pulses).
7. Programming a micro-controller (80851)

References:

1**.** Foundation of solid state devices by Streetman and Banerjee, Pearson

2. Digital Electronics by Malvino and Leach, Tata McGraw Hill

3. Electronic Communication by Roddy and Coolen , Pearson

4. P. B. Zbar and A. P. Malvino – Basic Electronics: A text-lab manual (Tata-McGraw Hill Publ. Co.)

[36 lectures]

Group B: (Lab) (Computational Technique)

Brief Introduction to ELN

Matlab/Scilab: Matrix computing, Matrix vs. Array operations, Storage, Constants (e,pi, Inf,NaN etc) and Test matrices (Hadamard, Pascal, Magic etc). Simple applications using signals and images. Data Visualization: 2D/3D/Interactive plotting, Curve fitting, Interpolation and root finding (tools and algorithms).

Scientific Report writing: The LaTeX ecosystem, Document structure, Commands and Environments, Typesetting Mathematics, Including graphics and generating bibliographies.

[36 lectures]

Semester-2

Paper-05

Group A: Mathematical Physics–II (Group Theory and Differential Equations)

Ordinary differential equations, second order homogeneous and inhomogeneous equations: Wronskian, general solutions (recap), basic idea of singularities, particular integral using the method of variation of parameters.

[4 lectures]

Sturm Liouville (SL) problem, SL operators, expansions in orthogonal functions, Rodrigues formula, Special functions, Recurrence relations and generating functions.

[5 lectures]

Idea of Integral Transforms: Kernel, applications.

[4 Lectures]

Partial Differential Equations: Partial differential equations in Physics: Laplace, Poisson and Helmholtz equations; diffusion and wave equations. Applications.

[5 lectures]

[18 lectures]

References:

(1) G. Arfken and H. J. Weber, Mathematical Methods for Physicists, Academic Press, 6th Edition, Indian Edition, (2005).

(2) P. Dennerey and A. Kryzwicki, Mathematics for Physicists, Dover (Indian Edition), (2005).

(3) K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press (Cambridge Low-priced Edition) (1999).

(4) Special Functions for Scientists and Engineers: W. W. Bell (D. Van Nostrand Co. Ltd.)

(5) The Mathematics of Physics and Chemistry: H. Margenau and G. M. Murphy (Affiliated East-West Press Pvt. Ltd.)

Group Theory: Recapitulation of basic concepts: Sets, maps, equivalent relations and classes, homomorphism and isomorphism. **[2 lectures]**

Groups: Definition of group, cyclic groups and its generators, permutation groups, alternating groups, Cayley's theorem, Conjugate elements and associated equivalence classes.

[4 lectures]

Group representations: faithful and unfaithful representations, equivalent representations. Reducible and irreducible representations. Character of a representation. Schur's lemmas, orthogonality theorems, Character tables and applications

[6 lectures]

Lie groups and Lie algebras: SU(2) and SU(3) Groups and their corresponding Lie algebras. Introduction to Lorentz and Poincare groups.

[6 lectures]

References:

1. Group Theory in Physics Vol 1 & 2, J. F. Cornwell, Academic Press

2. Group Theory and its Application to Physical Problems, M. Hamermesh, Dover Publications

3. Lie Group for Pedestrians, H. J. Lipkin (Dover Publications, Inc.)

4. Elements of Group Theory for Physicists, A. W. Joshi (New Age International Publ.)

Group B: Quantum Mechanics-II

Approximation methods: Time-independent perturbation theory, first and second order corrections to the energy eigenvalues, first order correction to the eigenvectors, one dimensional harmonic oscillator perturbed by linear, quadratic and cubic potentials. Degenerate perturbation theory, application to the one-electron system – relativistic mass correction, spin- orbit coupling (L-S and J-J), Zeeman effect and Stark effect. Variational method: He atom as an example, first order perturbation, exchange degeneracy, Ritz principle for excited states for He atoms.

[10 lectures]

The WKB approximation, Time-dependent perturbation theory: Interaction picture, constant and harmonic perturbation – Fermi's Golden rule, sudden and adiabatic approximation.

[8 lectures]

Symmetries in quantum mechanics: Conservation laws and degeneracy associated with symmetries. Continuous symmetries – space and time translations, rotations. Discrete symmetries – parity and time reversal.

[9 lectures]

Identical Particles: Meaning and consequences, symmetric and antisymmetric wavefunctions, Slater determinant, symmetric and antisymmetric spin wavefunctions of two identical particles, Many-electron atoms: central field approximation.

[9 lectures]

References:

1. Quantum Mechanics: Vol 2; C. Cohen-Tannoudji, B. Diu, F. Laloe; Wiley.

2. Modern Quantum Mechanics: Vol 2; J. J. Sakurai; Pearson.

3. Quantum Mechanics: Vol 2; A. Messiah; Dover.

Paper-06

Group A: Classical Electrodynamics

Vector and scalar potentials, Gauge transformations: Lorentz and Coulomb gauge, Helmholtz theorem (with proof); Inhomogeneous wave equation; Green function for the inhomogeneous wave equation.

[8 lectures]

Simple radiating systems: Fields and radiation of a localized oscillating source, electric dipole fields and radiation, angular distribution of radiation due to an oscillating dipole. Center-fed linear antenna.

[9 lectures]

Radiation by moving charges: Lienard-Wiechert potentials and fields for a point charge, charges moving with uniform velocity, accelerated charges, radiation from accelerated charges moving (i) with low velocities and (ii) with relativistic velocities, bremsstrahlung, synchrotron radiation; Cherenkov radiation. Rayleigh's scattering and the colour of sky.

[13 lectures]

Total power radiated by an accelerated charge – Larmor's formula, angular distribution of radiation, radiation reaction – Abraham Lorentz formula

[6 lectures]

References:

1. Classical Electrodynamics (3rd edition, Wiley) – J.D. Jackson

2. Classical Electricity and Magnetism (2nd edition, Dover Publications) – Panofsky and Phillips

3. Introduction to Electrodynamics (4th edition, Pearson)– D. J. Griffiths

4. Foundations of Electromagnetic Theory (4th edition, Pearson) – Reitz, Milford and Christy

5. Feynman Lectures Vol. II - R. P. Feynman, R. B. Leighton and M. Sands (Addison-Wesley)

Group B: Classical Mechanics–II (Continuum Mechanics)

Canonical formalism for continuous media: Lagrangian and Hamiltonian densities, Noether's theorem, Energy momentum Tensor; applications to sound wave equation and Maxwell equation.

[18 lectures]

Fluid Systems: Stress and Strain Tensors, Lagrangian and Eulerian coordinates, Conservation equations, The Navier-Stokes-Duhem Equations for Fluid Motion. Applications.

[18 lectures]

References:

1. Bachelor, An introduction to fluid Mechanics; CUP
2. Faber, Fluid Dynamics for Physicists; CUP
3. Falkovich, Fluid Mechanics, a short course for Physicists; CUP
4. White, Fluid Mechanics; WCB McGraw Hill
5. Kundu & Cohen, Fluid Mechanics, Academic Press
6. Classical Mechanics, Goldstein
7. Classical Mechanics, K. C. Gupta

Paper-07

Group A: Statistical Mechanics II

Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Quantum Liouville's theorem, density matrices for microcanonical, canonical, grand canonical

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

[12 lectures]

Systems of indistinguishable particles – BE and FD distributions, Ideal Bose and Fermi gas, statistics of occupation number, equation of state, BE condensation, Thermodynamic behaviour of an ideal Bose gas, blackbody radiation, thermodynamic behaviour of ideal Fermi gas, the electron gas in metals, statistical equilibrium of white dwarf stars.

[12 lectures]

Interacting systems: Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian. Equivalence of the Ising model to other models: Lattice Gas and Binary alloy. Spontaneous Magnetization. Exact solution of one-dimensional Ising system (Matrix methods).

[12 lectures]

References:

1. K. Huang, Introduction to Statistical Mechanics

2. R. K. Pathria, Statistical Mechanics

3. David Chandler, Introduction to Modern Statistical Mechanics

4. Kadanoff, Statistical Mechanics. World Scientific.

5. R. Kubo, Statistical Mechanics. (Collection of problems)

6. M. Plischke and B. Bergersen, Equilibrium Statistical Physics, World-Scientific.

Group B: Relativity & Relativistic Electrodynamics

Relativity & Relativistic Electrodynamics:

Postulates of the special theory of relativity. Galilean & Lorentz transformation. Applications of Lorentz transformation: Length contraction, time dilation, simultaneity, transformation equations for velocity and acceleration. Thomas Precession. Space-like, time-like and light-like intervals. Lorentz invariance of space-time intervals. Relativistic mass & energy. Conservation of momentum and energy. Geometric representation of space-time: Minkowski diagrams and applications. Twin paradox.

[10 lectures]

Four-vectors: Definitions and components, transformation properties. Time derivative of a four-vector. Scalar product of four-vectors and its invariance under Lorentz transformation. Orthogonality. Lorentz invariance of four-dimensional differential volume element. Interaction of particles: conservation of momentum four-vector.

Tensors: contravariant & covariant, rank of a tensor, transformation properties, contraction, symmetric and anti-symmetric tensors, metric tensor. Four-gradient, four-divergence. Four-dimensional Laplacian operator. Wave number four-vector and Doppler effect. Relativistic Lagrangian and Hamiltonian.

[10 lectures]

Relativistic electrodynamics: Maxwell's equations, scalar and vector potentials, four-vector representation of electromagnetic potentials. Transformation of charge density. Current four-vector. Continuity equation: covariant form. Maxwell's equations in terms of potential four-vector and current four-vector. Electromagnetic field tensor and its transformation properties. Lorentz force law in terms of field tensor and its covariance. Covariance of Maxwell's equations. Dual field strength tensor and its application. Electromagnetic field invariants. Transformation laws for the components of electric field and magnetic field. Fields due to a point charge in uniform motion.

Electric & magnetic fields produced by an accelerated charge.

[16 lectures]

Books:

1) Relativity, Gravitation and Cosmology by, Robert J. A. Lambourne (Cambridge University Press, 2010).

2) The Special Theory of Relativity by Dennis Morris (Mercury Learning and Information)

3) Classical Theory of Fields by Landau and Lifshitz (Butterworth-Heinemann; 4th edition, 1987)

4) Introduction to Electrodynamics by, D J Griffiths (Prentice Hall, 1999.)

5) The Special Theory of Relativity by Banerji & Banerjee (Prentice Hall of India, 2006)

6) Electricity and Magnetism by, Nayfeh & Brussel (John Wiley & Sons, 1985)

7) Classical Electrodynamics by J D Jackson (John Wiley, 2007)

8) Classical Electricity and Magnetism by Panofsky & Phillips (Dover Publications, 2005)

Paper-08

Group A: Core Lab-II (Non-Electronics)

1. Determination of Numerical aperture of optical fibers and related experiments

2. To study Iodine absorption spectrum

3. To study Acousto-optical effect using piezo-electric crystal and determination of the velocity of ultrasonic wave in liquids.

4. Interferometry with Michelson's / Jamin's interferometer.

5. Spectrophotometry : Absorption of biomolecules / study of melting.

6. Experiments with Laser: Characteristics of a Diode Laser

7. Experiments with Laser: Thickness of a wire

8. To Study Ferromagnetic to Paramagnetic Phase Transition.

9. Energy band gap of semiconductor by studying the luminescence spectra.

10. Determination of Curie temperature using ferroelectric material

[36 lectures]

Group B: (Lab) (Computational Physics)

Numerical Computing using Matlab / Scilab:

Solution of Nonlinear ODEs and System of ODES: tools and algorithms (Euler, Modified Euler, RK, Stiff Integrators). Solution of PDES using FD / FEM scheme: Elementary examples. Modelling of Physical Systems: (a) Nonlinear Oscillations,
(b) Stochastic Computation.

[36 lectures]