INDRASHIL UNIVERSITY

(Established by an Act under the Gujarat Private Universities Act, 2009)

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Sustained Excellence with Relevance

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DEPARTMENT OF PHYSICS (PHY)

PROGRAM STRUCTURE

M. Sc. (Physics) 2022–2024

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SEMESTER - I			
Course code	**Course Name**	**L-T-P**	**Credits**
PHY M101	Mathematical Methods in Physics – I	3-1-0	4
PHY M102	Classical Mechanics	3-1-0	4
PHY M103	Quantum Mechanics – I	3-1-0	4
PHY M104	Electronic Devices and Digital Electronics	3-1-0	4
PHY M105	Introduction to Computing (C and Python)	2-0-2	3
PHY M106	Physics Laboratory – I	0-0-8	4
	Total	14L-4T-10P	**23**
SEMESTER –II			
Course code	**Course Name**	**L-T-P**	**Credits**
PHY M201	Mathematical Methods in Physics – II	3-1-0	4
PHY M202	Electrodynamics and Plasma Physics	3-1-0	4
PHY M203	Condensed Matter Physics	3-1-0	4
PHY M204	Quantum Mechanics – II	3-1-0	4
PHY M205	Computational Methods in Physics	2-0-2	3
PHY M206	Physics Laboratory – II	0-0-8	4
IUM 000	Basic Communication and Soft Skills	1-0-0	0
	Total	15L-4T-10P	**23**

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SEMESTER -III			
Course code	**Course Name**	**L-T-P**	**Credits**
PHY M301	Statistical Mechanics	3-1-0	4
PHY M302	Atomic & Molecular Spectroscopy	3-1-0	4
PHY M303	Nuclear and Particle Physics	3-1-0	4
PHY M304	Advanced Condensed Matter Physics	3-1-0	4
PHY M305	*Elective – I	3-0-0	3
PHY M306	Physics Laboratory – III	0-0-8	4
	Total	15L-4T-8P	**23**
SEMESTER -IV			
Course code	**Course Name**	**L-T-P**	**Credits**
PHY M401	**Elective – II	3-0-0	3
PHY M402	***MOOCs	---	3
PHY M403	Research or Industrial Project	0-0-34	17
	TOTAL	3L-0T-34P	**23**

***Elective – I (PHY M305)**

(A) Physics of Nanosciences and Nanotechnology – I
(B) Laser Physics and Applied Optics – I
(C) Physics of Disordered Systems and Polymers – I
(D) Biophysics – I

****Elective – II (PHY M401)**

(A) Physics of Nanosciences and Nanotechnology – II
(B) Laser Physics and Applied Optics – II
(C) Physics of Disordered Systems and Polymers – II
(D) Biophysics – II

*****MOOCs (PHY M402)**

As per the courses available on the NPTEL, Swayam portals

Credit to Hours calculation:

Lecture: 1h = 1C
Practical: 2h = 1C

Total credits: 92

SEMESTER - I

PHY M101 Mathematical Methods in Physics – I (L-T-P-C: 3-1-0-4)

UNIT – I: Linear Vector Spaces

Linear vector spaces, dual space, inner product spaces, Linear operators, matrices for linear operators, Eigenvalues and eigenvectors, Similarity transformation, (matrix) diagonalization, Special matrices: Normal, Hermitian and Unitary matrices, Hilbert space.

UNIT – II: Complex Analysis

Complex numbers and variables, Complex analyticity, Cauchy-Riemann conditions, Classification of singularities, Cauchy's theorem, Residues, Evaluation of definite integrals, Taylor and Laurent expansions, Analytic continuation, Gamma function, zeta function.

UNIT – III: Fourier and Laplace Transforms:

Fourier transform, Sine, Cosine and Complex transforms with examples, Definition, Properties and Representations of Dirac Delta Function, Properties of Fourier Transforms, Laplace transform, Properties and examples of Laplace Transform, Convolution theorem and its applications, Laplace transform method of solving differential equations.

UNIT – IV: Ordinary Differential Equations and Special Functions

Regular Points, Simple Pole, Series Solution-indicial equation, Convergence of the series, Existence and evaluation of the Second order solution, Legendre, Hermite, Lagurre Bessel's Functions, Generating Functions, Recurrence Relations, Spherical Bessels Functions, Associated Legendre Functions, Spherical Harmonics

Text Books:

1. B. S. Rajput, *Mathematical Physics*
2. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley
3. H. K. Das, *Mathematical Physics*
4. P. Dennery and A. Krzywicki, *Mathematics for Physicists*, Dover
5. Gerald, *Applied Numerical Analysis*.
6. M.R. Spiegel, *Complex Variables,* McGraw-Hill

Reference Books:

1. G.B. Arfken, *Mathematical Methods for Physicists*, Elsevier
2. S.D. Joglekar, *Mathematical Physics: Basics (Vol. I) and Advanced (Vol. II),* Universities Press
3. R.V. Churchill and J.W. Brown, *Complex Variables and Applications,* McGraw-Hill
4. P.M. Morse and H. Feshbach, *Methods of Theoretical Physics (Vol. I & II),* Feshbach Publishing

PHY M102 Classical Mechanics (L-T-P-C: 3-1-0-4)

UNIT – I: Lagrangian Mechanics

Calculus of variations, Hamilton's principle of least action, Lagrange's equations of motion, Symmetries and conservation laws, Noether's theorem,

UNIT – II: Two-Body Central Force Problem

Equation of motion and first integrals, Kepler's problem, Classification of orbits, Satellites and inter-planetary orbits, Scattering in central force field, CM vs Lab frame, classical scattering (Rutherford Scattering)

UNIT – III: Small Oscillations and Rigid body dynamics

Small Oscillations: Linearization of equations of motion, Normal coordinates, Damped and forced oscillations. Anharmonic terms, perturbation theory.

Rigid Body Dynamics: Rotational motion, moments of inertia, torque. Euler's theorem, Euler angles, Symmetric top, Gyroscopes and their applications.

UNIT – IV: Hamiltonian Mechanics

Hamilton's equations of motion, Phase plots, fixed points and their stabilities, Canonical transformations, Poisson brackets, Hamilton-Jacobi theory, action-angle variables.

Suggested Books:

1. J. C. Upadhyay, *Classical Mechanics*, Himalaya Publishing House
2. H. Goldstein, C.P. Poole and J.F. Safko, *Classical Mechanics,* Addison-Wesley
3. N.C. Rana and P.S. Joag, *Classical Mechanics*, Tata McGraw-Hill
4. L.D. Landau and E.M. Lifshitz, *Mechanics,* Butterworth-Heinemann

PHY M103 Quantum Mechanics – I (L-T-P-C: 3-1-0-4)

UNIT – I: Linear Vector and Representation Theory

Linear vector space, Dirac notations of Bra - Ket notation, Matrix representation of Observables and states, Determination of eigenvalues and eigenstate for observables using matrix representations, Change of representation and unitary transformations, Coordinate and momentum representations.

UNIT – II: Structure of Quantum Mechanics

Operators and observables, operators as matrices, significance of eigenvalues and eigenfunctions, Commutation relations, Uncertainty principle.

UNIT – III: Schrödinger Equation and One – dimensional problems

Time-dependent Schrödinger equation, Stationary states and their significance, Time-independent Schrödinger equation.

Free-particle, periodic boundary condition, Wave packets, Symmetric and Asymmetric Square well potential, Transmission through a potential barrier, Gamow theory of alpha-decay, Simple harmonic oscillator: solution by wave equation and operator method.

UNIT – IV: Spherically Symmetric Potentials

Separation of variables in spherical polar coordinates, Orbital angular momentum, parity, Spherical harmonics, Free particle in spherical polar coordinates, Spherical well, Hydrogen atom, Numerical solution of the radial equation in arbitrary potential.

Suggested Books:

1. C. Cohen-Tannoudji, B. Diu and F. Laloe, *Quantum Mechanics (Vol. I),* Wiley
2. L.I. Schiff, *Quantum Mechanics,* McGraw-Hill
3. R. Shankar, *Principles of Quantum Mechanics,* Springer
4. A. Das, *Lectures on Quantum Mechanics,* Hindustan Book Agency

PHY M104 Electronic Devices and Digital Electronics (L-T-P-C: 3-1-0-4)

UNIT – I: Introduction
Survey of network theorems and network analysis, AC and DC bridges, transistors at low and high frequencies, FET.

UNIT – II: Electronic Devices
General properties of semiconductors. Schottky diode, p-n junction, Diodes, light-emitting diodes, photo-diodes, negative-resistance devices, p-n-p-n characteristics, transistors (FET, MoSFET, bipolar). Basic differential amplifier circuit, operational amplifier -characteristics and applications, simple analog computer, analog integrated circuits.

UNIT – III: Analog and Digital circuits
Analog Circuits: Active filters and equalizers with feedback, Phase shift and delay.
Digital Circuits: Gates, combinational and sequential digital systems, flip-flops, counters, multi-channel analyzer. A/D and D/A converters. Basics of micro-processor and micro-controller.

UNIT – IV: Communication Systems
Amplitude, Angle and Pulse-analog modulation: Generation and detection. Model of communication system, classification of signals, representation of signals.

Suggested Books:

1. P. Horowitz and W. Hill, *The Art of Electronics,* Cambridge University Press
2. J. Millman and A. Grabel, *Microelectronics,* McGraw-Hill
3. J.J. Cathey, *Schaum's Outline of Electronic Devices and Circuits,* McGraw-Hill
4. M. Forrest, *Electronic Sensor Circuits and Projects,* Master Publishing Inc
5. W. Kleitz, *Digital Electronics: A Practical Approach,* Prentice Hall
6. J.H. Moore, C.C. Davis and M.A. Coplan, *Building Scientific Apparatus,* Cambridge University Press
7. B.G. Streetman, Solid State Electronic Devices, (7th Ed., Pearson, 2015)
8. M. S. Tyagi, Introduction to Semiconductor Materials and Devices, (1st Ed., Wiley, 2012)

PHY M105 Introduction to Computing (C and Python) (L-T-P-C: 2-0-2-3)

Unit – I: Introduction to C

Introduction to "C" language, Standard I/O functions and data types
Operators: Arithmetic, Logical and Relational, Type conversion and combination of operands
Functions: printf(), scanf() and return values
Conditional statements: If and Else, Nested If and Else

Unit – II: Character and Functions

Iteration and loops in "C", Use of "While", "Do" and "For" loops, Multiple loop variables
Arrays: Syntax and representation, Character and String Arrays, Multidimensional Array
Functions: User defined functions, Calling of function, Return values, Nesting of functions
Pointer: Concept, Declaration, Operation on pointers, Array of pointers

UNIT – III: Introduction to Python Program

Introduction to python, Standard I/O functions and data types

Problems related to the numerical analysis will be conducted in the Laboratory as per the mentioned syllabus.

Suggested Books:

1. Yashwant Kanetkar, Let Us C: Authentic Guide To C Programming Language
2. Herbert Schildt, C: The Complete Reference, Mc Graw Hill
3. Brian W. Kernighan and Dennis Ritchie, The C Programming Language, Pearson

PHY M106 Physics Laboratory – I (L-T-P-C: 0-0-8-4)

1. Logic Gates using circuit diagram
2. Transistors (p-n-p and n-p-n) and its characteristics
3. Characteristics of FET
4. 555 timer
5. Planck's Constant
6. Prism Spectrometer (Diffraction Grating)
7. Malus Law
8. Optical Fibre
9. Michelson Interferometer
10. Ultrasonic

SEMESTER II

PHY M201 Mathematical Methods in Physics – II (L-T-P-C: 3-1-0-4)

UNIT – I: Tensor Analysis

Introduction, definitions, contraction, direct product, summation convention, quotient rule, pseudotensors, Levi-Civita symbol, Irreducible tensors, Metric tensor

UNIT – II: Non-homogeneous Ordinary Differential Equations and Partial Differential Equations – Green's Functions technique

Introduction to non-homogeneous ordinary differential equations and their solutions, Review of expressions for gradient, divergence, curl and Laplacian operators in generalized coordinates, Boundary conditions, Laplace's equation, Heat diffusion equation and wave equation in Physics, Separation of variable technique to solve them, Green's function technique in general and especially for Poisson's equation

UNIT – III: Group Theory

Concept of a group (additive and multiplicative), Discrete and continuous groups, Matrix representation of a group, Reducible and irreducible representation of a group, Applications to physics: Crystallographic Symmetry, Rotation (SO(3)) and Spin-SU(2)

UNIT – IV: Numerical Methods of Analysis:

Solution of algebraic and transcendental equations: Iterative, bisection and Newton-Raphson methods, Solution of simultaneous linear equations: Matrix inversion method, Interpolation: Newton and Lagrange formulas, Numerical differentiation, Numerical Integration, Simpson methods, Numerical solution of ordinary differential equations: Euler and Runge-Kutta methods.

Suggested Books:

1. F. A. Cotton, *Chemical Applications of Group Theory*, Wiley
2. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley
3. P. Dennery and A. Krzywicki, *Mathematics for Physicists*, Dover
4. Gerald, Applied Numerical Analysis.
5. M.R. Spiegel, *Complex Variables,* McGraw-Hill
6. G.B. Arfken, *Mathematical Methods for Physicists*, Elsevier
7. S.D. Joglekar, *Mathematical Physics: Basics (Vol. I) and Advanced (Vol. II),* Universities Press
8. R.V. Churchill and J.W. Brown, *Complex Variables and Applications,* McGraw-Hill
9. P.M. Morse and H. Feshbach, *Methods of Theoretical Physics (Vol. I & II),* Feshbach Publishing

PHY M202 Electrodynamics and Plasma Physics (L-T-P-C: 3-1-0-4)

UNIT – I: Review of Electrostatics and Magnetostatics

Coulomb's law, action-at-a distance vs. concept of fields, Poisson and Laplace equations, formal solution for potential with Green's functions, boundary value problems; multipole expansion; Dielectrics, polarization of a medium; Biot-Savart law, differential equation for static magnetic field, vector potential, magnetic field from localized current distributions; Faraday's law of induction; energy densities of electric and magnetic fields.

UNIT – II: Maxwell's Equations

Maxwell's equations in vacuum. Vector and Scalar potentials in electrodynamics, gauge invariance and gauge fixing, Coulomb and Lorenz gauges. inhomogeneous wave equation, retarded and advance Green function , retarded potentials

UNIT – III: Electromagnetic waves

Displacement current, Energy and momentum of Electromagnetic waves, Poynting theorem, Maxwell stress tensor**,** Inhomogeneous wave equation and its solutions using Green's function method, Electromagnetic waves in free space and dielectric materials and conductors, Covariant formulation of Maxwell's equations (brief discussion)

UNIT – IV: Plasma Physics:

Elementary Concepts: Plasma Oscillations, Debye Shielding, Plasma Parameters, Magnetoplasma, Plasma Confinement, Firt, Second, and Third Adiabatic Invariants (Pinch Effect, Magnetic Mirrors), Formation of Van Allen Belt.

Suggested Books:

1. D.J. Griffiths, *Introduction to Electrodynamics*, Prentice Hall
2. J.D. Jackson, *Classical Electrodynamics*, Wiley
3. W. Greiner, Classical Electrodynamics, (Springer-Verlag, New York, 1998) - Indian reprint
4. A. Das, *Lectures on Electromagnetism*, Hindustan Book Agency
5. J.R. Reitz, F.J. Milford and R.W. Christy, *Foundations of Electromagnetic Theory*, Addison-Wesley
6. W.K.H. Panofsky and M. Phillips, *Classical Electricity and Magnetism*, Dover
7. A. Zangwill, *Modern Electrodynamics*, Cambridge Univ Press
8. Basudev Ghosh, *Basic Plasma Physics*,
9. J. A. Bittencourt, *Fundamentals of Plasma Physics*, Springer

PHY M203 Quantum Mechanics – II (L-T-P-C: 3-1-0-4)

UNIT – I: Symmetries in Quantum Mechanics

(a) Rotation and Angular Momentum: Rotation operator, generators of infinitesimal rotation, angular momentum algebra, eigenvalues of J^2 and J_z.

(b) Spin and its mathematical description: Pauli matrices and spinors, Addition of angular momenta, Clebsch–Gordan coefficients

(c) Identical particles: Indistinguishability, symmetric and antisymmetric wave functions, incorporation of spin, Slater determinants, Pauli exclusion principle.

UNIT – II: Approximate methods - I

Variation method, WKB approximation, Time independent perturbation theory - Non-degenerate and degenerate perturbation theory. Stark effect, Zeeman effect and other examples, Variational methods. WKB approximation, Tunnelling, Numerical perturbation theory, comparison with analytical results.

UNIT – III: Approximate methods – II (Time dependent Perturbation theory)

Schrödinger and Heisenberg pictures, Interaction picture, Time-dependent perturbation theory. Transition probability calculations, Fermi's golden rule. Adiabatic and sudden approximations. Beta decay. Interaction of radiation with matter. Einstein A and B coefficients, introduction to the quantization of electromagnetic fields.

UNIT – IV: Scattering Theory

Differential scattering 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.

Suggested Books:

1. C. Cohen-Tannoudji, B. Diu and F. Laloe, *Quantum Mechanics* (*Vol. II*), Wiley
2. A. Messiah, *Quantum Mechanics* (*Vol.II*), Dover
3. S. Flügge, *Practical Quantum Mechanics*, Springer
4. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson
5. K. Gottfried and T.-M. Yan, *Quantum Mechanics: Fundamentals,* Springer
6. C. Cohen-Tannoudji, B. Diu and F. Laloe, *Quantum Mechanics (Vol. I),* Wiley
7. L.I. Schiff, *Quantum Mechanics,* McGraw-Hill
8. R. Shankar, *Principles of Quantum Mechanics,* Springer
9. A. Das, *Lectures on Quantum Mechanics,* Hindustan Book Agency

PHY M204 Condensed Matter Physics (L-T-P-C: 3-1-0-4)

UNIT – I: Review and Crystal Lattices

Drude theory, DC conductivity, Hall effect and magneto-resistance, AC conductivity, thermal conductivity, thermo-electric effects, Fermi-Dirac distribution, thermal properties of an electron gas, Wiedemann-Franz law, critique of free-electron model.

Bravais lattice, symmetry operations and classification of Bravais lattices, common crystal structures, reciprocal lattice, Brillouin zone, X-ray diffraction, Bragg's law, Von Laue's formulation, diffraction from non-crystalline systems.

UNIT – II: Classification and Defects in Solids

Band classifications, covalent, molecular and ionic crystals, nature of bonding, cohesive energies, hydrogen bonding,

DEFECTS: Point defects: general thermodynamic features, color centers and optical properties of ionic crystals; linear defects, planar defects, volume defects.

UNIT – III: Electronic States in Crystals and Electron Dynamics

Electron Dynamics: Periodic potential and Bloch's theorem, weak potential approximation, energy gaps, Fermi surface and Brillouin zones

Wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, theory of holes.

UNIT – IV: Lattice Dynamics

Failure of the static lattice model, harmonic approximation, vibrations of a one-dimensional lattice, one-dimensional lattice with basis, models of three-dimensional lattices, quantization of vibrations, Einstein and Debye theories of specific heat, phonon density of states.

Suggested Books:

1. C. Kittel, *Introduction to Solid State Physics,* Wiley
2. N.W. Ashcroft and N.D. Mermin, *Solid State Physics,* Brooks/Cole
3. J.M. Ziman, *Principles of the Theory of Solids,* Cambridge University Press
4. A.J. Dekker, *Solid State Physics,* Macmillan
5. G. Burns, *Solid State Physics,* Academic Press
6. M.P. Marder, *Condensed Matter Physics,* Wiley

PHY M205 Computational methods in Physics (L-T-P-C: 2-0-2-3)

UNIT – I: Introduction to Fortran

Fortran 90 programming language: Conditional statements; Looping; Logical expression and case statement; Arrays; Modular programming using functions and subroutines; Format specifications and processing strings and characters; Processing files in Fortran 90 ; Dynamic memory allocation and pointers.

UNIT – II: Numerical Methods

Numerical methods: Statistical description of data: Mean, Variance and Skewness. Solution of algebraic and transcendental equation : bisection method, the method of false position, Newton Raphson method. Interpolation. Integration of functions : Trapezoidal rule, Simpson`s 1/3 method; Least squares fit; Sorting; Matrices : Matrix inversion and evaluation of determinant by elimination method. Solution of ordinary differential equation: Runge-Kutta method

The students have to perform the execution of the programs studied in the classroom. Generally the problems will be of -

1. Newton Rapson
2. Simpson's 1/3rd Rule
3. Numerical Analysis
4. Matrix formulation
5. Random number selection

Suggested Books:

1. V. Rajaraman, *Computer Programming in FORTRAN 90 and 95*, PHI
2. S. J. Chapman, *Fortran 90/95 for Science and Engineering*, McGraw Hill Education

PHY M206 Physics Laboratory – II (L-T-P-C: 0-0-8-4)

1. Hall Effect
2. Four Probe
3. Zeeman Effect
4. Microprocessor
5. Operational Amplifier
6. Adder and Substractor
7. MOSFET
8. Rectifier (Half and Full)
9. GM Counter,
10. Thermoelectric effect

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IUM 000 Basic Communication and Soft Skills (L-T-P-C: 1-0-0-0)

Unit 1: Fundamentals of Communication

- Importance of Communication
- Importance of Interpersonal Communication
- Process of Communication
- Flows and Types of Communication

Unit 2: Barriers to Communication

- Definition
- Types of Barriers

Unit 3: Listening

- Hearing & Listening
- Types of Listening
- Do's and Don'ts of Effective Listening

Unit 4: Effective Presentation

- Patterns & Methods of Presentation, Oral Presentation
- How to prepare presentation
- Effective ways to deliver the presentation
- How to prepare multi-media presentation
- Difference between C.V & Resume, types of resume

Unit 5: Corporate Etiquettes

- Non-verbal Communication
- E-mail etiquette, telephone etiquette, dining etiquette
- Office meeting etiquettes, dress etiquette

Text Books:

1. Soft Skills for Everyone by Jeff Butterfield, Cengage publication
2. Technical Communication; Principles and Practice" by Meenakshi Raman & Sangita Sharma (Oxford University Press)
3. "Communication Skills" by Dr. Sanjay Kumar and Dr. Pushp Lata, Oxford University Press

Reference Books:

1. Personality Development and Soft Skills by Barun K Mitra
2. Business Correspondence and Report writing"- R C Sharma and Krishna Mohan, Tata McGraw Hill, 8th Ed.2015

SEMESTER - III

PHY M301 Statistical Physics (L-T-P-C: 3-1-0-4)

UNIT – I: Review of thermodynamics and topics in probability theory

Quasistatic and nonquasistatic processes, laws of thermodynamics, entropy of a probability distribution, random walks.

UNIT – II: Classical ensemble theory

Phase space, microstates and macrostates; Liouville's equation, Postulates of statistical mechanics, Microcanonical ensemble, Boltzmann relation for entropy, Definition of temperature, derivation of the laws of thermodynamics for macroscopic systems, Sackur-Tetrode equation, Canonical ensemble; partition function; Helmholtz free energy, Grand-canonical ensemble, Equivalence of the various ensembles, Application to various classical systems.

UNIT – III: Quantum statistical mechanics

Indistinguishable particles in quantum mechanics. Bosons and Fermions. Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. Density operator, Quantum Liouville equation. Pure and mixed states.

UNIT – IV: Mean Field Theory

Ising model, mean-field theory, exact solution in one dimension, renormalization in one dimension.

Suggested Books:

1. F. Reif, *Fundamentals of Statistical and Thermal Physics,* Levant
2. K. Huang, *Statistical Mechanics,* Wiley
3. R.K. Pathria, *Statistical Mechanics,* Elsevier
4. D.A. McQuarrie, *Statistical Mechanics,* University Science Books
5. S.K. Ma, *Statistical Mechanics,* World Scientific
6. R.P. Feynman, *Statistical Mechanics,* Levant
7. D. Choudhury and D. Stauffer, *Principles of Equilibrium Statistical Mechanics,* Wiley-VCH
8. M. Kardar, Statistical Physics of Particles, (Cambridge University Press, 2007).
9. R. Kubo, Statistical Mechanics:An Advanced course with problems and solutions, (North-Holland, 1965).
10. Statistical Thermodynamics, M.C. Gupta, New Age Int. Ed. (1998)
11. An Introduction to Statistical Thermodynamics, T. L. Hill, Dover Publication (1986)

PHY M302 Atomic and Molecular Spectroscopy (L-T-P-C: 3-1-0-4)

UNIT – I: Atomic Physics

Fine structure of hydrogenic atoms, Mass correction, spin-orbit term, Darwin term. Intensity of fine structure lines. Zeeman, Paschen-Bach and Stark effects. The ground state of two-electron atoms – perturbation theory and variational methods. Many-electron atoms – Central Field Approximation-LS and jj coupling schemes, Lande interval rule. Selection rules for electric and magnetic multipole radiation.

UNIT – II: Molecular Structure

Born-Oppenheimer approximation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules.

UNIT – III: Molecular Spectra

Rotational spectra of diatomic molecules-rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules- harmonic and anharmonic vibrators, Intensity of spectral lines, dissociation energy, vibration-rotation spectra, Electronic spectra of diatomic molecules- vibrational structure of electronic transitions (coarse structure)-progressions and sequences. Rotational structure of electronic bands (Fine structure)-P,Q,R branches. Intensities in electronic bands-The Franck-Condon principle. The electron spin and Hund's cases. Raman Effect. Electron Spin Resonance. Nuclear Magnetic Resonance.

UNIT – IV: Lasers

Masers versus lasers, components of a laser system, amplification by population inversion, oscillation condition, types of lasers.

Suggested Books:

1. B. H. Bransden and C. J. Jochain, Physics of Atoms and Molecules, (2nd Ed., Pearson Education, 2003)
2. G. Herzberg, Atomic Spectra and Atomic Structure, (Dover Publications, 2003)
3. G. Herzberg, Molecular Spectra and Molecular Structure, (Van Nostrand, 1950)
4. W. Demtroder, Atoms, Molecules and Photons, (Springer, 2006)
5. C. N. Banwell, Fundamentals of Molecular Spectroscopy, (McGraw Hill, 1983)
6. J. M. Hollas, Basic atomic & Molecular Spectroscopy, (Royal Society of Chemistry, 2002)
7. O. Svelto, Principles of Lasers, (5th Ed., Springer, 2010)
8. I. N. Levine, Quantum Chemistry, (7th Ed., Pearson, 2016)

PHY M303 Nuclear and Particle Physics (L-T-P-C: 3-1-0-4)

UNIT – I: Nuclear Physics

Discovery of the nucleus, Rutherford scattering. Scattering cross-section, form factors. Kinematics of (non-)relativistic scattering. Properties of nuclei: size, mass, charge, angular momentum, magnetic moment, parity, quadrupole moment. Charge and mass distribution.

Mass defect, binding-energy statistics, Bethe-Weiszacker mass formula. Magic numbers, shell model, parity and magnetic moment.

Nuclear stability: alpha, beta and gamma decay. Tunnelling theory of alpha decay, Fermi theory of beta decay. Parity violation. Fission and fusion. Nuclear reaction. Nuclear force. Nuclear reaction. Deuteron, properties of nuclear potentials. Yukawa's hypothesis.

UNIT – II: Particle Physics

Fundamental forces and fundamental particles, Symmetries and conservation laws, Space time symmetries, Space inversion, Charge conjugate and time reversal symmetries,CPT theorem and its consequences,Lepton numbers and baryon numbers, Isospin,Strangeness and Charm,Gell-Mann and Nishima relation, Hadronic spectrum and Quark model, Concept of colour and gluons

Discovery of elementary particles in cosmic rays. Muon, meson and strange particles. Isospin and strangeness.

Accelerators and detectors.

Quark hypothesis, flavour and colour. Meson and Baryon octets. Gellmann-Nishijima formula. Discovery of J/psi, charm quark. Families of leptons and quarks. Bottom and top quarks.

Gauge symmetry and fundamental forces. Weak interaction, W and Z bosons, Higgs mechanism and spontaneous symmetry breaking. Higgs particle. Gluons and strong interaction.

Neutrino oscillations, CP violation.

Suggested Books:

1. B.L. Cohen, *Concepts of Nuclear Physics,* Tata McGraw Hill
2. W.N. Cottingham and D.A. Greenwood, *An introduction to Nuclear Physics,* Cambridge University Press
3. I. Kaplan, *Nuclear Physics,* Addison-Wesley
4. B.R. Martin, *Nuclear and Particle Physics*, Wiley
5. A. Das and T. Ferbel, *Introduction to Nuclear and Particle Physics,* World Scientific
6. B. Povh, K. Rith, C. Scholtz and F. Zetsche, *Particles and Nuclei,* Springer
7. G.D. Coughlan and J.E. Dodd, *The Ideas of Particle Physics,* Cambridge University Press
8. D. Griffiths, *Introduction to Elementary Particles,* Wiley
9. D.H. Perkins, *Introduction to High Energy Physics,* Cambridge University Press

PHY M304 Advanced Condensed Matter Physics (L-T-P-C: 3-1-0-4)

UNIT – I: Semiconductors

General properties and band structure, carrier statistics, impurities, intrinsic and extrinsic semiconductors, equilibrium fields and densities in junctions, drift and diffusion currents.

UNIT – II: Dielectric Properties of Solids

Dielectric constant of metal and insulator using phenomenological theory (Maxwell's equations), polarization and ferroelectrics, inter-band transitions, Kramers-Kronig relations, optical properties of metals and insulators.

UNIT – III: Transport Properties of Solids

Boltzmann transport equation, resistivity of metals and semiconductors, thermoelectric phenomena, Quantum Hall Effect.

UNIT – IV: Magnetism

Diamagnetism, paramagnetism of insulators and metals, ferromagnetism, Curie-Weiss law, introduction to other types of magnetic order. Magnetic interactions, Heitler-London method, exchange and super exchange, magnetic moments and crystal-field effects, ferromagnetism, spin-wave excitations and thermodynamics, anti-ferromagnetism.

UNIT – V: Superconductivity

Superconductors, review of basic properties, thermodynamics of superconductors, London's equation and Meissner effect, Type-I and Type-II superconductor. Superconductivity, London equations, Cooper pairs, coherence, Ginzburg-Landau theory, BCS theory, Josephson effect, SQUID, excitations and energy gap, magnetic properties of type-I and type-II superconductors, flux lattice, introduction to high-temperature superconductors.

Suggested Readings:

1. N.W. Ashcroft and N.D. Mermin, *Solid State Physics,* Brooks/Cole
2. D. Pines, *Elementary Excitations in Solids,* Addison-Wesley
3. S. Raimes, *The Wave Mechanics of Electrons in Metals,* Elsevier
4. P. Fazekas, *Lecture Notes on Electron Correlation & Magnetism,* World Scientific
5. M. Tinkham, *Introduction to Superconductivity,* CBS
6. M. Marder, *Condensed Matter Physics,* Wiley
7. P.M. Chaikin and T.C. Lubensky, *Principles of Condensed Matter Physics,* Cambridge University Press

PHY M305 Elective – I

1) Physics of Nanoscience and NanoTechnology – I (L-T-P-C: 3-0-0-3)

UNIT – I: Nanoparticles – Synthesis and Properties

Method of Synthesis: RF Plasma Chemical Methods, Thermolysis, Pulsed Laser Methods, Biological Methods: Synthesis using micro-organisms, Synthesis using Plant Extract, Metal Nanoclusters, Magic Numbers, Modeling of Nanoparticles, Bulk to Nano Transitions.

UNIT – II: Quantum Wells, Wires and Dots

Preparation of Quantum Nanostructures, Size Effects, Conduction Electrons and Dimensionality, Properties Dependent on Density of States.

UNIT – III: Characterization Techniques

Scanning Probe Microscopes (SPM), Diffraction Techniques, Spectroscopic Techniques, Magnetic Measurements, FT – IR, RAMAN, UV – Visible, NMR, XRD, SEM, TEM

Suggested Books:

1. Poole and Owners, Introduction to Nanotechnology
2. Jacak, Hawrylak and Wojs, Quantum Dots
3. Nalva (editor), Handbook of Nanostructured Materials and Nanotechnology
4. S.K. Kulkarni, Nano Technology/ Principles and Practices
5. Silvana Fiorito, Carbon Nanotubes
6. Richard Booker and Earl Boysen, Nanotechnology

2) Laser Physics and Applied Optics – I (L-T-P-C: 3-0-0-3)

UNIT – I: Coherence

Concepts of coherence and correlation functions, coherent states of the electromagnetic field, minimum uncertainty states, unit degree of coherence, Poisson photon statistics.

UNIT – II: Optical Resonators and Pulsed Operation

Closed versus open cavities, modes of a symmetric confocal optical resonator, stability, quality factor.

Q-switching, electro-optic and acousto-optic modulation, saturable absorbers, mode-locking.

UNIT – III: Applications of Lasers

Introduction to atom optics, Doppler cooling of atoms, introduction to nonlinear optics: self-(de) focusing, second-harmonic generation (phase-matching conditions). Industrial and medical applications.

Suggested Books:

1. K. Thyagarajan and A.K. Ghatak, *Lasers: Theory and Applications,* Springer
2. A.K. Ghatak and K. Thyagarajan, *Optical Electronics,* Cambridge University Press
3. W. Demtroeder, *Laser Spectroscopy,* Springer
4. B.B. Laud, *Lasers and Nonlinear Optics,* Wiley-Blackwell
5. M. Sargent, M.O. Scully and W.E. Lamb, Jr., *Laser Physics,* Perseus Books
6. M.O. Scully and M.S. Zubairy, *Quantum Optics,* Cambridge University Press
7. P. Meystre and M. Sargent, *Elements of Quantum Optics,* Springer
8. L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics,* Cambridge University Press

3) **Physics of Disordered Systems and Polymers – I (L-T-P-C: 3-0-0-3)**
4) **Biophysics – I (L-T-P-C: 3-0-0-3)**

PHY M306 Physics Laboratory – III (L-T-P-C: 0-0-8-4)

1. Microprocessor
2. Zeeman Effect
3. Absorption Spectroscopy of Iodine
4. Experiment with Raman spectrometer
5. Study of Rutherford Scattering
6. Gamma - Ray Spectroscopy Using NaI (Tl) detector
7. Alpha Spectroscopy with Surface Barrier Detector
8. Mössbauer effect
9. Spectroscopy of Biomolecules

SEMESTER - IV

PHY M401 Elective – II

1) Physics of Nanoscience and NanoTechnology – II (L-T-P-C: 3-0-0-3)

Suggested Books:

7. Poole and Owners, Introduction to Nanotechnology
8. Jacak, Hawrylak and Wojs, Quantum Dots
9. Nalva (editor), Handbook of Nanostructured Materials and Nanotechnology
10. S.K. Kulkarni, Nano Technology/ Principles and Practices
11. Silvana Fiorito, Carbon Nanotubes
12. Richard Booker and Earl Boysen, Nanotechnology

2) Laser Physics and Applied Optics – II (L-T-P-C: 3-0-0-3)

Suggested Books:

9. K. Thyagarajan and A.K. Ghatak, *Lasers: Theory and Applications,* Springer
10. A.K. Ghatak and K. Thyagarajan, *Optical Electronics,* Cambridge University Press
11. W. Demtroeder, *Laser Spectroscopy,* Springer
12. B.B. Laud, *Lasers and Nonlinear Optics,* Wiley-Blackwell
13. M. Sargent, M.O. Scully and W.E. Lamb, Jr., *Laser Physics,* Perseus Books
14. M.O. Scully and M.S. Zubairy, *Quantum Optics,* Cambridge University Press
15. P. Meystre and M. Sargent, *Elements of Quantum Optics,* Springer
16. L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics,* Cambridge University Press

3) Physics of Disordered Systems and Polymers – I (L-T-P-C: 3-0-0-3)

4) Biophysics – I (L-T-P-C: 3-0-0-3)

PHY M402 MOOCs (3)

Available online courses (NPTEL, Swayam portals)

PHY M403 Research or Industrial Project / Viva (L-T-P-C: 0-0-34-17)