National Education Policy – 2020

H.N.B. Garhwal University

Revised Syllabus

M.Sc. (Physics)

w.e.f. 2025-2026

P.G. First Year (for Two-year P.G. program)
M.Sc. (Physics)

M.Sc. (Physics) First Year - First Semester

Entry requirement	3-year bachelor's degree (120 credits), and candidates who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations.				
Semester	**Course category**	**Course title**	**Credits**		**Total Credit**
			T	**P**	
I	**Discipline Specific Core**	**DSC-1: Classical Mechanics**	5	-	**5**
		DSC-2: Mathematical Physics	5		**5**
		DSC-3: Electrodynamics	5	-	**5**
		DSC Practical	-	3	**3**
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	**DSE – I:** 1. **Electronics – A** 2. **Laser Physics - A**	4	-	**4**
		DSE Practical	-	2	**2**
Total			19	5	**24**

M.Sc. (Physics) First Year - Second Semester

Semester	**Course category**	**Course title**	**Credits**		**Total Credit**
			T	**P**	
II	**Discipline Specific Core**	**DSC-1: Atomic and Molecular Physics**	5	-	**5**
		DSC-2: Solid State Physics	5		**5**
		DSC-3: Astrophysics	5	-	**5**
		DSC Practical	-	3	**3**
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	**DSE – I** 1. **Electronics – B** 2. **Laser Physics - B**	4	-	**4**
		DSE Practical	-	2	**2**
Total			19	5	**24**

M.Sc. (Physics) Second Year – Third Semester

Semester	Course category	Course title	Credits T	Credits P	Total Credit
III	Discipline Specific Core	DSC-1: Quantum Mechanics	5	-	5
		DSC-2: Nuclear Physics	5		5
		DSC-3: Statistical Mechanics	5	-	5
		DSC Practical	-	3	3
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	DSE-II: 1. Condensed Matter Physics – A 2. High Energy Physics – A 3. Astrophysics – A	4	-	4
		DSE Practical	-	2	2
Total			19	5	24

M.Sc. (Physics) Second Year – Fourth Semester

Semester	Course category	Course title	Credits T	Credits P	Total Credit
IV	Discipline Specific Core	DSC-1: Advanced Quantum Mechanics	5	-	5
		DSC-2: Particle Physics	5		5
		DSC-3: Computational and Numerical Methods in Physics	5	-	5
		Core Practical	-	3	3
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	DSE-II: 1. Condensed Matter Physics – A 2. High Energy Physics – A 3. Astrophysics – A	4	-	4
		DSE (Project Work)	-	2	2
Total			19	5	24

Note: ***In lieu of Elective Practical (2 credits) the departments may offer 2 credit additional course (Field work/Project).***

Course Structure for One-Year PG Program

M.Sc. (Physics) First Year – First Semester

Entry requirement	4-year bachelor's degree (160 credits), and candidates who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations.				
Semester	**Course category**	**Course title**	**Credits**		**Total Credit**
			T	**P**	
I	**Discipline Specific Core**	**DSC-1: Quantum Mechanics**	5	-	**5**
		DSC-2: Nuclear Physics	5		**5**
		DSC-3: Statistical Mechanics	5	-	**5**
		DSC Practical	-	3	**3**
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	**DSE-II:** **4. Condensed Matter Physics – A** **5. High Energy Physics – A** **6. Astrophysics – A**	4	-	**4**
		DSE Practical	-	2	**2**
Total			19	5	**24**

M.Sc. (Physics) First Year – Second Semester

Semester	**Course category**	**Course title**	**Credits**		**Total Credit**
			T	**P**	
II	**Discipline Specific Core**	**DSC-1: Advanced Quantum Mechanics**	5	-	**5**
		DSC-2: Particle Physics	5		**5**
		DSC-3: Computational and Numerical Methods in Physics	5	-	**5**
		Core Practical	-	3	**3**
	Discipline Specific Elective (Any 1 out of Minimum 2 electives)	**DSE-II:** **1. Condensed Matter Physics – A** **2. High Energy Physics – A** **3. Astrophysics – A**	4	-	**4**
		DSE (Project Work)	-	2	**2**
Total			19	5	**24**

Note: ***In lieu of Elective Practical (2 credits) the departments may offer 2 credit additional course (Field work/Project).***

M.Sc. (Physics)
Semester - I
DSC - 1
Classical Mechanics
(Credits: Theory – 05)

Lagrangian Formulation: Mechanics of system of particles, conservation theorems for a system of particles, generalized coordinates, degree of freedom, constraints, principle of virtual work, D'Alembert's principle, Lagrange's equations of motion, Lagrange's equations in polar and cylindrical coordinates, applications of Lagrange's equations.

Hamiltonian Formulation and Variational Principle: Hamiltonian function and its physical significance, cyclic coordinates, Hamilton's equations of motion, Hamilton's equations in different co-ordinates, applications of Hamilton's equations, Hamilton's principle, Euler- Lagrange's equations, modified Hamilton's principle, derivation of Lagrange's equations from Hamilton's principle, derivation of Hamiton's equations of motion from Hamilton's principle (Variational Principle), principle of least action.

Canonical Transformations and Brackets: Legendre transformation, Canonical transformations, generating functions, conditions for the transformations to be canonical, use of canonical transformations, Poisson and Legendre Brackets, properties of Poisson brackets, invariance of Poisson and Legendre brackets under canonical transformations, angular momentum and Poisson bracket, applications of Poisson bracket.

Dynamics of Rigid bodies and Small oscillations: Generalized coordinates of a rigid body, Euler's angles, angular velocity, angular momentum and inertia tensor, principal axes and principle moment of inertia, rotational kinetic energy, Euler's equation of motion of a rigid body, torque-free motion, Force-free motion of symmetrical top, one -dimensional harmonic oscillator, normal coordinates and normal modes, small oscillations, secular equation and eigen value equation, two coupled oscillations, double pendulum, vibration of linear triatomic molecule.

Reference Books:

1. S. Leonard, G. Hrabovsky: Classical Mechanics, Penguin UK
2. N.C. Rana and P.S. Joag: Classical Mechanics, McGraw-Hill
3. H. Goldstein, C.P. Poole & J. Safko: Classical Mechanics, Pearson Education
4. J.C. Upadhyay: Classical Mechanics, Himalaya Publishing House
5. S.L. Gupta, V. Kumar & H.V. Sharma: Classical mechanics. Pragati Prakashan

M.Sc. (Physics)
Semester - I
DSC - 2
Mathematical Physics
(Credits: Theory – 05)

Special Functions and Partial Differential Equations in Physics: Series Solution of Legendre's, Bessel's, Hermite's and Laguerre's Differential equation; Legendre's, Bessel's, Hermite's and Laguerre's Polynomials; Generating function, Orthogonality condition, Rodrigue's formula, Recurrence relations for Legendre's, Bessel's, Hermite's and Laguerre's Polynomials; Dirac delta and Green's function; Laplace's equation and it's solution in Cartesian, Cylindrical and Spherical Coordinates; Circular, Cylindrical and Spherical Harmonics; Heat flow in two and three Dimensions; Heat flow in Circular Plate; Potential of a ring and spherical surface; Wave equation in two and three dimensions; Vibration of Rectangular and Circular membrane.

Group Theory: Definition; Classification of groups; Subgroup; Cyclic group; Multiplication table, The group of symmetry of an Equilateral Triangle and a Square; Isomorphism and Homomorphism; Classes; Product of classes; Representation theory of finite groups; Reducible and Ir-reducible representations; Schur's Lemma; Orthogonality theorem; Characters of representations; The Unitary groups.

Complex Variables: Function of complex variable; Analytic functions; Cauchy's Riemann equations; Taylor and Laurent's series; Cauchy's integral formula; Singularities of an analytical function; Residues and their evaluation; Cauchy's integral theorem; Contour integration; Evaluation of definite integrals; Integration round the unit circle; Improper real integral; Evaluation of integrals when integrand has poles on real axis; Jordan Lemma and evaluation of integrals by Jordan Lemma.

Matrices and Tensors: Inverse and Trace of a Matrix; Hermitian, Orthogonal and Unitary Matrices; Similarity transformations; Solutions of linear differential equations; Eigen values-Eigen vectors; Cayley-Hamilton theorem; Diagonalisation of matrices; Tensors; Coordinate transformations; Covariant and contravariant Tensors; Raising and lowering of indices; Addition, Multiplication and Contraction of tensors; Metric tensors; Christoffel symbols; Transformation laws of Christoffel symbols; Geodesic.

Reference Books:

1. G.B. Arfken & H.J. Weber: Mathematical Methods for Physicists: A Comprehensive Guide, Elsevier (Academic Press)
2. L.A. Pipes and L.R. Harvil: Mathematical Methods for Engineers and Physicists, McGraw-Hill
3. C. Harper: Introduction to Mathematical Physics, Prentice Hall of India
4. B.D. Gupta: Mathematical Physics, S Chand & Company Ltd
5. H.K. Das and Rama Verma, Mathematical Physics, S Chand & Company Ltd.
6. A.W. Joshi: Elements of Group Theory for Physicists, New Age International Publishers

M.Sc. (Physics)
Semester - I
DSC - 3
Electrodynamics
(Credits: Theory – 05)

Maxwell's Equations and Special Relativity: Maxwell's equations and their physical significance; Equation of continuity; Four-vectors; Vector and scalar potentials; Lorentz Transformations; Lorentz and Coulomb gauge: Gauge transformations; Gauge invariance; Electromagnetic energy; Poynting vector; Poynting's theorem.

Electromagnetic Waves: Electromagnetic waves and the wave equation; Electromagnetic waves in vacuum; Electromagnetic waves in matter; Absorption and dispersion; Guided Electromagnetic waves; Plane wave solutions of Electromagnetic waves; Fourier Solution.

Electromagnetic Field and Potentials: Fields from the random distribution of charges; Fields from a charged particle at random motion; Multipole expansion of electromagnetic fields; Hertz Potential; Retarded potential; Lienard-Wiechert potential; Electromagnetic field tensor; Covariance of electromagnetic fields.

Electromagnetic Radiations from Moving Charges: Fields produced by moving charges; Radiations from an accelerated charged particle at low velocities; Radiations from charged particles with co-linear velocity and acceleration; Radiations from an accelerated charged particle at low velocities in circular orbits-Larmor formula; Radiations from an accelerated charged particle at relativistic velocities in circular orbits; Relativistic generalization of Larmor's Formula; Bremsstrahlung; Cerenkov radiation.

Reference Books:

1. D.J. Griffiths: Introduction to Electrodynamics, Pearson Education India
2. J.R. Reitz, F.J. Milford & R.W. Christy: Foundation of E.M. Theory, Pearson
3. J.D. Jackson: Classical Electrodynamics, John Wiley & Sons Inc
4. S.P. Puri: Classical Electrodynamics, Tata McGraw-Hill Publishing Co. Ltd.
5. M.A. Heald & J.B. Marion: Classical Electromagnetic Radiation, Dover Publications Inc.
6. L.D. Landau & E.M. Lifshitz: The Classical Theory of Fields, Pergamon Press
7. W.K.H. Panofsky & M. Philips: Classical Electricity and Magnetism, Dover Publications
8. R.N. Singh: Electromagnetic Waves and Fields, Tata McGraw-Hill
9. E.C. Jordan & K.G. Balman: Electromagnetic Waves and Radiating Systems, Pearson Education

M.Sc. (Physics)
Semester - I
DSC Practical
Credits: 03

List of experiments: At least **six** experiments are to be performed

1. Determine the Expansion of periodic functions in a series of sine by the Fourier coefficients.
2. Verification of Fresnel Law
3. Determine the velocity of ultrasonic waves
4. Measurement of resistivity by using the four-probe technique
5. To plot the magnetic hysteresis loop of a ferromagnetic rod
6. Determination of magnetic susceptibility
7. Lecher wire experiment
8. Determination of the elastic constant of crystals by optical methods
9. Determination of the absorption coefficient of iodine vapour
10. Study of regulated power supply

M.Sc. (Physics)
Semester - I
DSE – 1
Electronics – A
(Credits: Theory – 04)

Amplifiers and Oscillators: Power Amplifiers, Class A, B, AB, C and D amplifiers, Push Pull Circuits, Principles of feedback amplifiers, General characteristics of negative feedback amplifier, Effect of Feedback on Gain, Stability, Nonlinear Distortion, Bandwidth, Input, and Output Impedance, Different Types of Feedback, Criteria for Oscillation, Phase Shift, Wein Bridge, Crystal oscillator, Astable, Monostable and Bistable Multivibrators, Schmitt Trigger, Bootstrap-sweep Circuits. Differential amplifiers. Operational amplifiers, Mathematical Operations, Active Filters, Analog Computations, Comparators, S and H Circuits.

Number Systems and Logic Gates: Binary, Octal, Decimal & Hexadecimal Numbers and their interconversions, AND, OR, NOT, NAND, NOR, XOR, Universal Gates, DTL, TTL, and CMOS Logic Families, comparison of various logic families, Adders, Subtractors, Comparators, Multiplexers, Demultiplexers, Encoders, Decoders.

Sequential Circuits and Memory Devices: Basic Architectural Distinctions between Combinational and Sequential circuits, SR Latch, SR, JK, JK Master Slave, D and T Type Flip Flops, Excitation Table of all Flip Flops, Timing and Triggering Consideration, Shift Registers, Universal shift register, Applications of Shift Registers, Asynchronous/ Ripple counters, Synchronous counters, Modulo–n Counters, Shift counters, Ring counters. Classification of memories, ROM, PROM, EPROM, EEPROM, RAM, Write operation, Read operation, Static RAM, Programmable Logic Array (PLA), Programmable Array Logic, Implementation of Combinational Logic circuits using ROM, PLA, PAL.

Optoelectronics: Light propagation through optical fiber, Total Internal Reflection (Critical angle and its expression), step index and Graded index fibres, Attenuation, absorption, scattering losses, bending loss, dispersion, point-to-point communication using Optical Fibers. Light Emitting Diodes (LED), Injection Laser Diode (ILD), comparison of LED and ILD. PIN Photodetector, Avalanche Photodiodes, Detector response time, Temperature effect on Avalanche gain, Comparison of Photo detectors.

Reference Books:

1. Robert L. Boylestad and Louis Nashelsky: Electronic Devices and Circuit Theory, Pearson Education India.
2. Ashish Bagwari and G.S. Tomar: Fundamentals of Electronic Devices and Circuits, Springer Verlag, Singapore.
3. S.M. Sze: Semiconductor Devices - Physics and Technology, Wiley, New York
4. A.P. Melvino & D.P. Leach: Digital Principles and Applications, McGraw-Hill
5. Morris Mano: Digital Design, Pearson Education
6. J. Millman & C.C. Halkias: Integrated Electronics, McGraw-Hill
7. Pallab Bhattacharya: Semiconductor Optoelectronic Devices, Prentice-Hall
8. Gerd Keiser: Optical Fiber Communications, Tata McGraw-Hill

M.Sc. (Physics)
Semester - I
DSE – 1
Laser Physics – A
(Credits: Theory – 04)

Basic principles: Basic principles and theory of absorption and emission of radiation, Einstein's coefficients, line-broadening mechanisms, rate equations for three and four level laser systems, population inversion, theory of optical resonators, laser modes, spatial and temporal coherence,

Types of lasers: Gas lasers, He-Ne, argon ion, N2, CO2 lasers; dye lasers, solid state, Semiconductor lasers: Ruby, Nd:YAG and Nd:glass lasers, Fabrication technology of lasers, diode lasers, colour centre and spin flip lasers, laser spikes, mode locking Q-switching, CW and pulsed lasers.

Nonlinear optics: Theory of nonlinear phenomena, second and third harmonic generation, phase matching, parametric generation, self-focusing,

Laser spectroscopy: Laser fluorescence spectroscopy using CW and pulsed lasers, Single photon counting, Laser Raman spectroscopy, multiphoton processes, photo acoustic and photon electron spectroscopy, stimulated Raman spectroscopy, Coherent anti-Stokes Raman spectroscopy.

Reference Books:

1. A. Ghatak and K. Thyagarajan: Lasers: Fundamentals and Applications, Laxmi Publications
2. O. Svelto: Principles of Lasers, Kluwer Academic
3. W.T. Silfvast: Lasers Fundamentals, Cambridge University Press
4. B.B. Laud: Lasers and Non-Linear Optics, New Age International Pvt Ltd.

M.Sc. (Physics)
Semester – I
DSE Practical

Electronics – A
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Design and study of FET amplifier
2. Design and study of MOSFET amplifier
3. Study of Class-B power amplifier
4. Design and study of a phase shift oscillator
5. Astable/Monostable/Bistable Multivibrators
6. Design and study of the Wien-Bridge oscillator
7. Measurement of Op-Amp parameters.
8. Analog to Digital and Digital to Analog converter
9. Study Multiplexer/Demultiplexer
10. Study of pin connection and biasing of various linear IC's and their timers 555

Or

Laser Physics – A
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Study of the vibrational levels of Iodine.
2. Measurement of the fluorescence spectra of Uranyl Nitrate Hexahydrate.
3. Determination of the intrinsic lifetime for a dye molecule.
4. Determination of change in dipole moment in the excited state using the Solvatochromic shift method.
5. Measurement of the wavelength of the He-Ne laser using interference and diffraction patterns
6. Measurement of the thickness of a thin wire using a laser
7. Determination of the wavelength of laser light using semiconductor laser diffraction.
8. Analyse the characteristics of a stabilized diode laser

M.Sc. (Physics)
Semester - II
DSC - 1
Atomic and Molecular Physics
(Credits: Theory – 05)

Atomic Spectroscopy:

Fine structure of Hydrogen lines, alkali atom Spectra, penetrating and non-penetrating orbits, Hund's rule Spectra of two valence electron atoms (Helium, Magnesium), selection rules for atomic transitions, multielectron spectra, Central field approximation, Hartree self-consistent field theory, Thomas Fermi statistical model.

Pauli's exclusion principle and determination of ground state, electron spin-orbit interaction, L-S and J-J coupling schemes, Zeeman Effect, Paschen-Back Effect, Hyperfine structure, Stark effect, width of spectral lines, Lamb shift.

Molecular Spectroscopy:

Rotational spectra of diatomic molecules, nonrigid rotator, vibrational spectra enharmonic oscillator explanation of rotational, vibrational spectra in infrared, molecular dissociation and calculation of dissociation energy, Raman effect and intensity alternation of the rotational bands, Applications of infrared and Raman spectroscopy.

Born Oppenheimer approximation, Molecular orbital theory, Heitler-Loudon treatment of Hydrogen molecule ion and Hydrogen molecule, Electronic spectra of molecules, Fortrat Parabola, Deslandres table, vibrational structure of electronic bands, Intensities of electronic transitions, Franck-Condon principle, Condon parabola.

Reference Books:

1. H.E. white: Atomic Spectra, Cambridge University Press, New York
2. B.W. Shore and H.D. Menzel: Principles of Atomic Spectra, John Wiley & Sons
3. G. Herzberg: Spectra of Diatomic Molecules, Krieger Publishing Company
4. Fundamentals of Molecular Spectroscopy: C.N. Banwell and E.M. McCash, Tata McGraw-Hill, New Delhi
5. Molecular Structure and Spectroscopy: G. Aruldhas, Prentice Hall India

M.Sc. (Physics)
Semester - II
DSC - 2
Solid State Physics
(Credits: Theory – 05)

Crystal Structure and Diffraction: Crystal translational vectors, basis, and lattice**,** Unit cell, Wigner–Seitz cell**,** Two- and three-dimensional Bravais lattices, Miller indices and lattice planes, Symmetry operations: rotation, reflection, inversion, Point groups and space groups (basic idea only), Common crystal structures: Simple cubic (**sc**), **bcc, fcc, hcp**, diamond, NaCl, CsCl, ZnS, Crystal density, coordination number, and atomic packing fraction, X-ray diffraction, Bragg's Law and Laue equations, Reciprocal lattice, Bragg's diffraction in terms of reciprocal lattice, First Brillouin zone and its significance, Atomic scattering factor, structure factor, and atomic form factor.

Crystal Binding and Elastic Constants: Types of crystal binding - ionic, covalent, metallic, van der Waals, and hydrogen bonds, Cohesive energy and potential energy curves, Elastic properties of solids: stress and strain, Work done by elastic forces and energy density, Stress–strain relationships and Hooke's law, Elastic stiffness and compliance tensors, Propagation of elastic waves in solids, Wave velocities in cubic crystals, Elastic waves in (**100**), (**110**), and (**111**) directions, Experimental determination of elastic constants (e.g., ultrasonic methods).

Phonons and Lattice Vibrations: Lattice vibrations in 1D monatomic and diatomic chains, Dispersion relations and acoustic/optical branches, Brillouin zones and phonon dispersion curves, Group velocity and long-wavelength limit, Quantization of lattice vibrations: Phonons, Phonon momentum and inelastic scattering, Interaction of phonons with photons and electrons (qualitative), Infrared absorption and optical properties of ionic crystals.

Thermal Properties of Solids: Classical theory of heat capacity (Dulong and Petit)**,** Einstein model of specific heat, Debye theory and Debye approximation, Density of states for phonons, Lattice thermal conductivity: phonon scattering mechanisms, electronic contribution to heat capacity, Thermal expansion and Grüneisen parameter.

Reference Books:

1. C. Kittel, Introduction to Solid State Physics, Wiley India
2. J.M. Ziman: Principles of the Theory of Solids, Cambridge University Press
3. A.J. Dekker. Solid State Physics, Laxmi Publications
4. N.W. Ashcroft & N. David Mermin: Solid State Physics, Brooks/Cole
5. R.K. Puri & V.K. Babbar: Solid State Physics, S Chand Publishing
6. Ajay Kumar Saxena: Solid State Physics, Laxmi Publications
7. B.S. Saxena, R.C. Gupta, P.N. Saxena, J.N. Mandal, Solid State Physics, Pragati Prakashan
8. R.L. Singhal: Solid State Physics, Kedar Nath Ram Nath
9. S.O. Pillai: Solid state physics, NEW AGE International Pvt Ltd

M.Sc. (Physics)
Semester - II
DSC - 3
Astrophysics
(Credits: Theory – 05)

The Solar System: Aspects of the sky: Concept of Celestial Coordinates and spherical astronomy. Astronomical telescopes. The early years of solar system, the solar system today. Study of Planets: Classification of the Planets, Orbits, Laws of planetary motion, Physical features, surface features, Internal Structure, Atmosphere, Satellites and Rings.

Minor Bodies in Solar System: Asteroids, Meteors and Meteorites**,** Discovery of minor planets (Asteroids), their orbits and physical nature, Origin of the minor planets, Meteors and Meteorites, Observation of meteor showers and sporadic meteors, Orbits of sporadic meteoroids and meteor showers, Meteorites, its types and composition, Meteorite craters, Comets- Discovery and designation, Periodic comets, Physical nature, Spectra, Brightness variation, Gas production rates, dust and ion tails, Nature of dust particles and origin of comets.

Stellar System: Sun as a Star, History of Sun, Sun's interior, the photosphere, the solar atmosphere (chromosphere & corona). Salient features of sunspots, sun's rotation & solar magnetic field, explanation for observed features of sunspots, Distances of stars from the trigonometric, Secular and moving cluster parallaxes, Stellar motions. Magnitude scale and magnitude systems, Atmospheric extinction, Absolute magnitudes and distance modulus, Colour index, The Hertzberg- Russell Diagram, The colour, Brightness or luminosity, the population of star, Elementary idea of Binary & Variable Stars, Nuclear fission, Nuclear Fusion, condition for nuclear reaction in stars.

Galaxy & Cosmology: Basic structure and properties of different types of Galaxies, Structure and features of the Milky Way Galaxy, Rotation curve of the Galaxy and the dark matter, Virial theorem Standard Candles (Cepheids and SNe Type1a), Cosmic distance ladder, Expansion of the Universe, Cosmological Principle, Newtonian Cosmology and Friedmann Models, Cosmic distance ladder.

Reference Books:

1. Marc L. Kutner: Astronomy: A Physical Perspective, Cambridge Univ Press
2. F.H. Shu: The Physical Universe: An Introduction to Astronomy, University Science Books
3. Robert H. Baker: Astronomy. Van Nostrand Reinhold
4. L. Motz & A. Duveen: The Essentials of Astronomy, Columbia University Press
5. Willian K. Hartmann: Moons & Planets, Brooks/Cole
6. I. Morison: Introduction to Astronomy and Cosmology, John Wiley & Sons Inc
7. A.W. Joshi & N.C. Rana: Our solar system, New Age International Pvt Ltd
8. Jayant V. Narlikar: The Structure of the Universe, Oxford Paperbacks
9. K.D. Abhyankar: Astrophysics: Stars & Galaxies, Universities Press
10. K.S. Krishnaswamy: Physics of Comets, World Scientific Publishing Co Pvt Ltd
11. McCusky: Introduction to Celestial Mechanics, Addison-Wesley Educational Publishers Inc

M.Sc. (Physics)
Semester - II
DSC Practical
(Credits: 03)

List of experiments: At least **six** experiments are to be performed

1. Absorption spectroscopy by a spectrophotometer
2. e/m by Zeeman Effect
3. Michelson Interferometer
4. Measurement of the energy band gap of a semiconductor by using the four-probe technique
5. To plot the magnetic hysteresis loop of a ferromagnetic rod
6. Measurement of Dielectric Constant
7. Determination of magnetic susceptibility
8. Lecher wire experiment
9. Determination of the elastic constant of crystals by optical methods
10. Study of fluorescence spectra of a given compound
11. Determination of the Hall coefficient using the Hall effect

M.Sc. (Physics)
Semester - II
DSE – 1
Electronics – B
(Credits: Theory – 04)

Modulation and Demodulation: Amplitude Modulation - Theory, Plate Modulated Class C Amplifier, Balanced Modulator, Single Side Band Modulation (Phase Shift Method). Frequency Modulation - Theory, Reactance Tube Modulator, Transistor Reactance Modulator, FET Reactance Modulator. Demodulation - Envelope Diode Detector, Super Regenerative Detection, Foster-Seely Phase Discriminator, Ratio Detector, A.M. Transmitter, F.M. Transmitter, TRF Receiver, Super Heterodyne Receiver, Amplitude Limiting.

Transmission Lines and Antennas: TL Equations and Their Solutions, Characteristic Impedance, Lossless Open and Short-Circuited Lines, Standing Wave Ratio and Reflection Coefficient, Stub Matching, Quarter and Half Wavelength Lines. Antenna - Radioactive Field Strength, Power & Radiation Patterns of an Elementary Electric Doublet and Linear Antenna, Effects of Ground Reflection. Hertz Antenna, Marconi Antenna, Yagi Antenna, Loop Antenna, Direction Finding, Resonant & Non-Resonant Antenna, Antenna array (Broadside & End fire arrays), T.V. aerials. Horn Antenna, Parabolic reflectors, Lens Antenna.

Propagation of Radio Waves: Eccles-Larmor Theory, Appleton–Hartree Theory of Sky Wave Propagation, Skip Distance and Maximum Usable Frequency, Chapman's Theory of Layer Formation. Pulse Method for Measuring the Height of the Ionospheric Region.

Television and Radar Systems: General Principles of Image Transmission and Reception of Signals, pick-up Instruments (Iconoscope, Image Orthicon, and Videocon), Image Scanning Sequence, Scanning Synchronization, Composite Video Signal, Colour Television. Radar Systems - Principle of Radar, Basic Arrangement of Radar System, Azimuth and Range Measurement, Operating Characteristics of Systems, Radar Transmitters and Receivers, Duplexers, Indicator Unit, Maximum Range of a Radar Set.

References Books:

1. F.E. Terman: Electronics and Radio Engineering, McGraw-Hill
2. G. Kennedy: B. Davis & SRM Prasanna, Electronic Communication Systems, McGraw-Hill
3. G.K. Mithal: Radio Engineering Vol. II, Khanna Publishers
4. S.L. Gupta & V. Kumar: Handbook of Electronics, Pragati Prakashan
5. Frenzel, Communication Electronics: Principles and Applications, McGraw-Hill
6. D. Rody & J. Coolen: Electronics Communication Systems, Pearson India
7. W. Tomasi: Electronic Communications System, Pearson Education

M.Sc. (Physics)
Semester - II
DSE – 1
Laser Physics – B
(Credits: Theory – 04)

Optical Modulation Techniques: Electro-optic effect, longitudinal and transverse phase modulation, consideration of modulator designs and circuit aspects, acousto-optic effect, Raman-Nath and Bragg regimes, acousto-optic modulators, magneto-optic effect, integrated optics, optical directional couplers and optical switches, phase modulators.

Optical sources and detectors: Laser devices, radiation pattern and modulation, LED structures, light source materials, liquid crystal diodes, photoelectric, photovoltaic and photconductive methods of detection of light, photodiodes: structure, materials and working, PIN photodiodes, avalanche photodiodes, microchannel plates, photodetector noise responsivity and efficiency, photomultipliers, image intensifier tubes, Videocon and CCD.

Fibre optics: Basic characteristics of optical fibres, fibre structure and fundamentals of waveguides, step and graded index fibres, signal degradation in optical fibres, absorption scattering, radiation and core cladding losses, Design considerations of a fibre optical communication system, analogue and digital modulation, optical fibre amplifiers.

Holography: Basic principles, construction and reconstruction of holograms, applications of holography, laser interferometry, laser applications in industry and medicine

Reference Books:

1. A. Ghatak and K. Thyagarajan: Optical Electronics, Cambridge India
2. J. Wilson and J. Hawkes: Optoelectronics, Pearson Education
3. G. Keiser: Optical Fibre Communications, McGraw-Hill Education
4. A. Ghatak and K. Thyagarajan: Introduction to fibre optics, Cambridge University Press
5. I.P. Csorba: Image tubes, Longman Higher Education
6. Eds. L.M. Biberman and S. Nudelman: Photoelectronic Imaging Devices, Kluwer Academic/Plenum Publishers

M.Sc. (Physics)
Semester - II
DSE Practical

Electronics – B
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Study of Amplitude Modulation and Demodulation
2. Study of Frequency Modulation and Demodulation
3. Study of Transmission Lines
4. Study of Digital combinational and sequential circuits
5. Study of different flip-flop circuits (RS, JK, D-type, T-type, Master slave).
6. Shift Registers
7. Microwave experiment
8. Fiber Optics communication
9. Measurement of propagation loss in the optical fiber cable

Or

Laser Physics – B
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Measurement of the non-radiative decay rate for a known sample.
2. Determination of the quantum yield of known samples using steady-state spectroscopy.
3. To measure the static and dynamic characteristics of an LED.
4. Study of V-I characteristics of different optical sources LASER.
5. To measure the output current or voltage of photodiodes under different light intensities.
6. Study of electro-optic effect
7. Study of the Acousto-optic effect
8. Observe the effect of fiber bending on the transmitted signal.

M.Sc. (Physics)
Semester - III
DSC - 1
Quantum Mechanics
(Credits: Theory – 05)

Introduction: A brief review of the foundations of quantum mechanics, basic postulates of quantum mechanics, uncertainty relations, Schrodinger wave equation, expectation value and Ehrenfest theorem. Relationship between space and momentum representation. **Applications:** One dimensional potential step, tunnelling, particle in a three dimensional box.

Matrix Formulation of Quantum Mechanics: Vector representation of states, transformation of Hamiltonian with unitary matrix, representation of an operator, Hilbert space. Dirac bra and ket notation, projection operators, Schrodinger, Heisenberg and interaction pictures. Relationship between Poisson brackets and commutation relations. Matrix theory of Harmonic oscillator.

Symmetry in Quantum Mechanics: Unitary operators for space and time translations. Symmetry and degeneracy. Rotation and angular momentum; Commutation relations, eigenvalue spectrum, angular momentum matrices of J_+, J_-, J_z, J_2. Concept of spin, Pauli spin matrices, their eigenvalues and eigenvectors, Pauli vectors and spinors, Addition of angular momenta, Clebsch-Gordon coefficients and their properties, Recursion relations. The Hydrogen atom. **Applications**: C. G. coefficients of addition for j =1/2, 1/2; 1/2, 1; 1, 1.

Approximation Methods for Bound States: Time independent perturbation theory for non-degenerate systems up to second order perturbation. Application to a harmonic oscillator, first order Stark effect in hydrogen atom. Time independent perturbation theory for degenerate systems, Variation principle, application to ground state of harmonic oscillator, hydrogen atom, helium atom. WKB approximation: energy levels of a potential well, Quantization rules. application to Coulomb potential, spin-less particle in 1D box, Time dependent perturbation theory; transition probability (Fermi Golden Rule).

Reference Books:

1. L.I. Schiff: Quantum Mechanics, McGraw Hill.
2. V.K. Thankappan: Quantum Mechanics, Wiley Eastern.
3. P.M. Mathews and K. Venkatesan: A Text-Book of Quantum Mechanics, TMH
4. Claude Cohen-Tannoudji, Bernard Diu, Franck Laloë: Quantum Mechanics Vols. I & II, Wiley VCH.
5. J.J. Sakurai: Modern Quantum Mechanics, Addison-Wesley.
6. A.K. Ghatakh and S. Lokanathan: Quantum Mechanics, 3rd ed., MacMillan.
7. N. Zettili: Quantum Mechanics: Concepts and Applications, Wiley

M.Sc. (Physics)
Semester - III
DSC - 2
Nuclear Physics
(Credits: Theory – 05)

General Properties & Nuclear Models: Nuclear size, nuclear angular momentum (Spin), Nuclear magnetic moments, statistics, Binding energy, Semi-Empirical Mass Formula, Liquid drop model, Magic Numbers, Shell model, Predictions of Shell model, Collective model.

Nuclear Forces & Interaction of Radiation with Matter – Ground state of deuteron, Low energy neutron-proton scattering, scattering length, phase shift, spin dependence, proton-proton scattering, non-central forces, Exchange and tensor forces, Interaction of charged particles with matter, Energy loss of heavy ions, stopping power, Range and Straggling, Absorption of gamma rays.

Radioactive decay: Radioactive decay equation, equilibrium, units, Gamow's theory of alpha decay and Geiger-Nuttal law, Fermi's theory of beta decay, parity violation in beta decay, electromagnetic decays, Ionization Chamber, G.M. Counter, Scintillation Counter, Cerenkov Counter, Semiconductor Detectors, Nuclear Emulsions.

Nuclear Reactions and Particle Accelerators: Q-value of nuclear reaction, Bohr's Theory of compound nucleus, Scattering cross section of nuclear reaction (phase shift method), Breit-Wigner single-level resonance formula for scattering cross section, Nuclear Fission, Nuclear fusion, Van de Graaff, Tandem Van de Graaff accelerators, Cyclotron, Betatron, Linear accelerator, Proton and Neutron Synchrotron.

References Books:

1. I. Kaplan: Nuclear Physics, Narosa Publishing House
2. A.H. Enge: Introduction to Nuclear Physics, Addison-Wesley Publishing Company
3. R.R. Roy & B.P. Nigam: Nuclear Physics: Theory and Experiments, New Age International Pvt Ltd
4. R.D. Evans: The Atomic Nucleus, Krieger Pub Co
5. W.E. Bucham & M. Jobes: Nuclear and Particle Physics, Prentice Hall
6. D. Halliday: Introductory Nuclear Physics, John Wiley & Sons Inc
7. B.R. Martin & G. Shaw: Nuclear and Particle Physics, Wiley
8. B.L. Cohen: Concepts of Nuclear Physics, McGraw-Hill
9. S.S.M. Wong: Introductory Nuclear Physics, Wiley India Pvt Ltd
10. S.B. Patel: Nuclear Physics: An Introduction, Anshan Ltd
11. S.N. Ghoshal: Nuclear Physics, S Chand Publishing

M.Sc. (Physics)
Semester - III
DSC - 3
Statistical Mechanics
(Credits: Theory – 05)

Basic Postulates- Phase space, relation between eigen states and phase space volume, Liouville's theorem, ensembles, microcanonical, canonical and grand canonical ensembles, Maxwell-Boltzmann's distribution and Gibbs' formulation for canonical and grand canonical ensembles, partition function, their thermodynamic properties, laws of thermodynamics.

Ideal and Imperfect gases: Degrees of freedom, translational motion, Helmholtz free energy, Gibbs' free energy, entropy and thermodynamic properties, Gibbs' paradox, Sakur-Tetrode equation. Difference between ideal and real gas, imperfect gases, Van der Waals' equation, virial coefficients, condensation of gases, general properties of liquids, Fermi theory, liquid Helium, phase rule.

Quantum Statistics: Drawbacks of M B distribution, Bose-Einstein's and Fermi-Dirac distribution, symmetric and antisymmetric particles, partition functions, non-degenerate, weakly degenerate and strongly degenerate cases, B.E. condensation, application to He, pressure-energy relationship, electronic specific heat of solids and paramagnetism.

Black Body Radiation: Planck's distribution, pressure and energy relationship of photons, black body radiation, Rayleigh-Jeans' formula, Wein's law, Wein's displacement formula, absorption and emission of radiation, Stefan's law, high temperature measurements.

Reference Books:

1. E.S. Raj Gopal: Statistical Mechanics and Properties of Matter, John Wiley & Sons
2. E. Mayer & G. Mayer: Statistical Mechanics, John Wiley & Sons Inc.
3. S. Glasstone: Theoretical Chemistry, Van Nostrand Reinhold Inc.
4. L.D. Landau & E M Lifshitz: Statistical Physics, Butterworth-Heinemann Ltd
5. A.J. Pointon: Introduction to Statistical Physics, Prentice Hall Press
6. K. Huang: Statistical Mechanics, Wiley & Sons
7. G.H. Wannier: Statistical Physics, Dover Publications
8. E. Guha: Statistical Mechanics, Narosa Publishing House
9. Satya Prakash: Statistical Mechanics, Kedar Nath Ram Nath Publications

M.Sc. (Physics)
Semester - III
DSC Practical
(Credits: 03)

List of experiments: At least **six** experiments are to be performed

1. To determine Planck's constant and work function using the photoelectric effect.
2. To determine the wavelength of light using Fabry Fabry-Perot interferometer
3. Study of IC-Based Power Supply
4. Study of optoelectronic devices
5. Millikan Oil Drop Experiment
6. Verify the inverse square law for γ-ray using a Geiger-Müller counter.
7. To determine the dead time of the Geiger-Müller counter using the single-source method
8. To perform energy calibration of the NaI detector and determine the energy resolution of a known decay transition.
9. Study of Silicon Controlled Rectifier
10. Logicom, AND/OR/NAND/NOR/NOT gates

M.Sc. (Physics)
Semester - III
DSE - 2
Astrophysics - A
(Credits: Theory – 04)

Physics of the Stars: Apparent and Mean Position of Stars. Effects of atmospheric refraction, aberration, precession, nutation, and proper motion on the coordinates of stars. Types of Parallaxes, Reduction from apparent to mean places and vice versa. Spectra of Stars. Distribution of stars in space. Local standard of rest. Solar motion and its determination. Comparison with the solar neighbourhood. Bottlinger diagram.

HR diagram, HD, and MK spectral classification of stellar spectra. Radiation laws and basic ideas on spectral line formation. Explanation of stellar spectra in terms of the Boltzmann and Saha equations.

Fundamental Equations: Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources. Stellar models: The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of the mass-luminosity law.

Stellar Evolution: Abundance of elements in the sun by the method of fine analysis-Stromgren's method, use of weight functions, abundances of elements in normal stars. Composition of differences in population I and II stars. Anomalous abundances in cool stars. Peculiar A stars and metallic line stars. Magnetic field in stars. Pre-main-sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of the isothermal core and subsequent development. Ages of galactic and globular clusters.

Superdense Objects: Mechanism of Mass Transfer in Binary Stars. Mass-radius relation. Non-degenerate upper layers and abundance of Hydrogen. Stability of white dwarfs. Final cooling of white dwarfs. Accretion by white dwarfs and its consequences. Pressure ionisation and mass-radius relation for cold bodies. Formation, features, and properties of Neutron stars, Pulsars, and black holes

Recommended Books:

1. Baidyanath Basu: An introduction to astrophysics, Prentice Hall India Learning Private Limited
2. Erika Böhm-Vitense: Introduction to Stellar Astrophysics: Volume 2, Cambridge University Press
3. K.D. Abhyankar: Astrophysics of Stars and Galaxies, Univ. Press India Limited
4. Bradley W Carroll and Dale A Ostlie: An Introduction to Modern Astrophysics, Cambridge University Press
5. Donald D. Clayton: Principles of Stellar Evolution and Nucleosynthesis, The University of Chicago Press
6. Stuart L. Shapiro and Saul A. Teukolsky: Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects, Wiley-Interscience Pub, New York
7. Carl J. Hansen, Steven D. Kawaler: Stellar Interiors: Physical Principles, Structure, and Evolution, Virginia Trimble, New York, Springer-Verlag

M.Sc. (Physics)
Semester - III
DSE - 2
Condensed Matter Physics – A
(Credits: Theory – 04)

Defects in Crystals: Point Defects: Vacancies (intrinsic and extrinsic), Interstitials, Substitutional impurities, Ionic Defects: Schottky and Frenkel defects — definitions and concentration expressions, Impurity Defects: Doping and extrinsic conductivity, Line Defects (Dislocations): Edge and Screw dislocations, Burgers vector, Strain fields around dislocations, Planar and Volume Defects: Grain boundaries, Twin boundaries, Stacking faults, Voids, Diffusion in Solids: Fick's laws, Diffusion mechanisms, Colour Centres: F-centres, V-centres, Other types (e.g., M-centres, R-centres).

Magnetism: Classification of magnetic materials: Dia, Para, and Ferromagnetism**,** Langevin's theory of Para magnetism, Weiss molecular field theory of Ferromagnetism, Concept of Ferromagnetic domains and hysteresis, Antiferromagnetism: Basic concepts and characteristics, Neel's theory of Antiferromagnetism, Two-sublattice model for Antiferromagnetic and Ferrimagnetic materials, Introduction to Ferrites: Structure, properties, and applications.

Free Electron, Nearly Free Electron Model and Band Theory: Free Electron Model, Nearly Free Electron Model: Weak periodic potential, Formation of energy gaps, Brillouin zone boundaries and effective mass, Bloch Theorem and Bloch Functions, Kronig-Penney Model: Analytical solution for a periodic potential, Formation of allowed and forbidden bands, Brillouin Zones and Reciprocal Space, Tight Binding Approximation: Energy bands from atomic orbitals, Overlap and hopping integrals, Advanced Band Structure Methods: Orthogonalized Plane Wave (OPW) method, Pseudopotential method.

Dielectric and Electrical Properties of Insulators: Polarization Mechanisms: Electronic, Ionic, Orientation, and Space-charge polarization, Dielectric Parameters: Macroscopic dielectric constant, Internal/Lorentz field, Clausius–Mossotti relation, Complex dielectric constant and dielectric loss, Relaxation and Dispersion: Dielectric relaxation time, Frequency dependence, Optical Properties: Optical absorption, Refractive index, Absorption edge.

Reference Books:

1. S.O. Pillai: Solid State Physics, New Age International
2. R.K. Puri & V.K. Babbar: Solid State Physics and Electronics, S. Chand
3. J.P. Srivastava: Elements of Solid-State Physics, PHI
4. C.M. Kachhava: Solid State Physics, TMH
5. C. Kittel: Introduction to Solid State Physics, Wiley
6. J.M. Ziman: Principles of the Theory of Solids, Cambridge University Press
7. J. Callaway: Quantum Theory of Solids, Academic Press Inc
8. A.J. Dekker: Solid State Physics, Laxmi Publications
9. N.D. Mermin and N.W. Ashcroft: Solid State Physics, Brooks/Cole
10. Ajay Kumar Saxena: Solid State Physics, Laxmi Publications
11. A N Tripathi: Condensed Matter Physics, New Age International

M.Sc. (Physics)
Semester - III
DSE - 2
High Energy Physics - A
(Credits: Theory – 04)

Classical and Quantum Field Equations: Coordinates of the Field, Classical Lagrangian Equation, Classical Hamiltonian Equations, Quantum Equations for the Field, Canonical coordinates for the fields, Real scalar field, Complex Field, Schrodinger's field, Dirac fields, Maxwell's field.

Relativistic Kinematics: Minkowski Space, Lorentz Transformations, Four Vectors, Matrix Tensor, Relativistic Energy-Momentum, Einstein Summation Convection, Lorentz Rotation and Boost Matrices, Weyl Spinors, Lorentz Invariance, Scalar Fields, Vector Fields, Tensor Fields. The Klein-Gordon Equation; its Plane Wave Solutions, Probability Density, The Dirac Equation and its Solutions, Dirac Hamiltonian Operator, Dirac Spinors.

Quantization of Fields: Fock Space, Second quantization, Quantization of Neutral and Complex Scalar Fields, Quantization of Dirac Field, Quantization of Electromagnetic Field. Interaction between fields, Polarisation States of Massless and Massive Spin-1 Particles, Photon propagator, Unequal time commutators, Normal and time ordered (chronological) product.

Scattering Matrix and Feynman Rules: The S-Matrix, Reduction of S-Matrix, Chronological Product, Wicks Theorem, Feynman Diagrams and Feynman Rules for QED, and Calculation of Scattering Matrix for Bhabha scattering, Compton scattering, Moller Scattering, Coulomb scattering, Electron-positron annihilation.

Reference Books:

1. J.M. Jauch and E. Rohrlich: Theory of Photons and Electrons, Springer-Verlag
2. J.D. Bjorken and S. D. Drell: Relativistic Quantum Fields, McGraw-Hill
3. A.I. Akhiezer and V.B. Berestetski, Quantum Electrodynamics, John Wiley & Sons Inc
4. Walter Greiner & Joachim Reinhardt: Quantum Electrodynamics, Springer
5. Amitabha Lahiri, Palash B. Pal: A First Book of Quantum Field Theory, Narosa
6. Ashok Das: Lectures on Quantum Field Theory, World Scientific
7. Matthew D. Schwartz: Quantum Field Theory and the Standard Model, Cambridge University Press
8. Fayyazuddin and Riazuddin: A Modern Introduction to Particle Physics, World Scientific Publishing Co. Pvt. Ltd.
9. M.E. Peskin and D.V. Schroeder: An Introduction to Quantum Field Theory, CRC Press

M.Sc. (Physics)
Semester - III
DSE Practical

Condensed Matter Physics
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Determination of the elastic constant of crystals by optical methods
2. Study of fluorescence spectra of a given compound
3. Study of colour centers
4. Determination of lattice parameters using the powder method.
5. Determination of the Hall coefficient using the Hall effect
6. Determination of the Energy gay of a semiconductor by the four-probe method
7. Electron Spin Resonance
8. Dielectric constant

High Energy Physics
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Measurement of the non-radiative decay rate for a known sample.
2. Characteristic curve of a GM Detector and Absorption coefficient of aluminium using GM Detector.
3. Absorption coefficient of aluminium using gamma-ray spectrometer.
4. Characteristics of Scintillation Detector.
5. Study of gamma-gamma unperturbed angular correlations.
6. Study of particle tracks using a Nuclear Emulsion Detector.
7. Classification of tracks in interaction with Nuclear Emulsion and determination of excitation energy.
8. Mossbauer spectrometer

Astrophysics
(Credits: 02)

List of experiments: At least **five** experiments are to be performed

1. Study of Hubble's law (from given data)
2. Study of a constant-density neutron star
3. Study of the static parameters of a Neutron Star model with inverse square density distribution
4. Study of a star cluster from a given dataset
5. Study of Extinction coefficients
6. Study of the variability of stars

M.Sc. (Physics)
Semester - IV
DSC - 1
Advanced Quantum Mechanics
(Credits: Theory – 05)

Scattering Theory: General considerations; kinematics, wave mechanical picture, scattering amplitude, differential and total cross-section. Green's function for scattering. Partial wave analysis: asymptotic behaviour of partial waves, phase shifts, scattering amplitude in terms of phase shifts, cross-sections, Optical theorem. Phase shifts and its relation to potential, effective range theory. Application to low energy scattering; resonant scattering, Breit-Wigner formula for one level and two levels, non-resonant scattering. s-wave and p-wave resonances. Exactly soluble problems; Square-well, Hard sphere, coulomb potential. Born approximation; its validity, Born series.

Identical Particles: The Schrodinger equation for a system consisting of identical particles, symmetric and antisymmetric wave functions, elementary theory of the ground state of two electron atoms; ortho- and Para-helium. Spin and statistics connection, permutation symmetry and Young tableaux. Scattering of identical particles.

Relativistic and Non-Relativistic Quantum Mechanics: Generalization of the Schrodinger equation; Klein-Gordon equation, plane wave solutions, charge and current densities, interaction with electromagnetic fields, Hydrogen-like atom (to show it does not yield physical spectrum), non-relativistic limit. Extension of Klein-Gordon equation to spin 1 particles.

Dirac Equation and Its Implications in Quantum Mechanics: Dirac Equation; relativistic Hamiltonian, probability density, expectation values, Dirac gamma matrices, and their properties, non-relativistic limit of Dirac equation. Covariance of Dirac equation and bilinear covariance, plane wave solution, energy spectrum of hydrogen atom, electron spin and magnetic moment, negative energy sea, hole interpretation and the concept of positron. Spin-orbit coupling, hyperfine structure of hydrogen atom.

Reference Books:

1. P.M. Mathews and K. Venkatesan: A Text book of Quantum Mechanics (TMH)
2. A.S. Davydov: Quantum Mechanics (Pergamon).
3. L.I. Schiff: Quantum Mechanics (McGraw Hill).
4. J.D. Bjorken and S. D. Drell: Relativistic Quantum Mechanics (McGraw Hill).
5. J.J. Sakurai: Advanced Quantum Mechanics (Addison Wesley).
6. V.K. Thankappan: Quantum Mechanics (Wiley Eastern).
7. R.P. Feynman and A.R.Hibbs; Quantum Mechanics and Path Integrals.
8. L.H. Ryder: Quantum Field Theory (Academic Press).

M.Sc. (Physics)
Semester - IV
DSC - 2
Particle Physics
(Credits: Theory – 05)

Classification and Properties of Elementary Particles: Elementary Particles and their Classification based on their mass and spins, Fermions and Bosons, Leptons, Mesons, Baryons, and field quanta, General Properties (mass, spins, lifetime, production and decay modes) of Elementary Particles, Antiparticles, Strange Particles.

Conservation Laws and Gauge Invariances: Conservation of Energy, Linear and Angular momentum, Spin, Charge, Lepton Number, Baryon Number, Isospin, Hypercharge, Parity, Strangeness, τ-θ puzzle, Charge conjugation (C), Parity (P), Time Reversal (T), CP Violation, CPT theorem, Gauge Symmetries, Global and Local gauge invariances, U(1), SU(2) and SU(3) local gauge invariance.

Fundamental Interaction: Basic Idea of Different Fundamental Interactions with Suitable Examples, Qualitative Ideas (Relative strengths, Ranges, Characteristic times and Mediators) of Gravitational, Electromagnetic, Strong and Weak Nuclear interactions, The Quest to Unify Strong, Weak, and Electromagnetic Forces, General Idea of Electroweak and Grand Unification.

Quark Model: The Eightfold Way, Six Quarks (up, down, strange, charm, top, and bottom), Antiquarks, General Properties (Charge, Mass, Colour, Isospin) of Quarks, Quark flavours and their Quantum Numbers, Quarks as Constituents of Hadrons, Qualitative idea of Quark Confinement and Asymptotic Freedom, Evidences for Quarks (Lepton scattering, Hadron Spectroscopy, Jet production), Necessity of Introducing the Colour Quantum Number, Quark Compositions of Mesons and Baryons. General Idea of the Standard Model, Idea of the Higgs Boson.

Reference Books:

1. D. Griffiths: Introduction to Elementary Particle Physics, John Wiley & sons
2. V.K. Mittal, R.C. Verma & S.C. Gupta, Introduction to Nuclear & Particle Physics, Prentice Hall of India Pvt. Ltd.
3. D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press
4. Francis Halzen & A D. Martin: Quarks and Leptons - An Introductory course in Modern Particle Physics, John Wiley & Sons, Inc.
5. M.P. Khanna: Introduction to Particle Physics, Prentice Hall of India
6. Fayazuddin & Riyazuddin: A Modern Introduction to Particle Physics, World Scientific Publishing Co Pvt Ltd
7. M. Leon, Particle Physics: An Introduction, Academic Press

M.Sc. (Physics)
Semester - IV
DSC – 3
Computational and Numerical Methods in Physics
(Credits: Theory – 05)

Numerical Methods and Curve Fitting: Roots of equations - Bisection method, Newton-Raphson method, Secant method, Interpolation and extrapolation - Lagrange and Newton's interpolation, Numerical integration - Trapezoidal and Simpson's rules, Runge-Kutta methods (up to 4th order), Least squares curve fitting method.

Matrix Computations and Linear Systems: Eigenvalues and eigenvectors - Power method and Jacobi method, Solution of simultaneous linear equations - Gaussian elimination, partial and complete pivoting, Iterative methods - Gauss-Seidel and Jacobi iterative method, Matrix inversion techniques

Computational Techniques in Physics: Hartree-Fock theory - Basic computational approach, Monte Carlo simulations: Random number generation and applications, Network analysis techniques in physics, Fourier Transform and Fast Fourier Transform (FFT), Solution of second-order differential equations (hyperbolic, parabolic, elliptic PDEs) using numerical methods

Programming and Application Software in Physics: Introduction to scientific programming - Python, C++, and Fortran 90/95, Use of symbolic and numerical libraries - SymPy (Python), NumPy, SciPy, Application software in computational physics - Ab initio software: Quantum ESPRESSO, VASP, ABINIT, GPAW, SIESTA, Symbolic & numerical software - MATHEMATICA, MATLAB, GAP, Writing basic scripts for simulations and analysis.

Recommended Textbooks:

1. S.S. Sastry: *Introductory Methods of Numerical Analysis*, PHI Learning
2. M.K. Jain, S.R.K. Iyengar, R.K. Jain: *Numerical Methods for Scientific and Engineering Computation*, New Age International
3. V Rajaraman: *Computer Programming in C* and *Fortran 90/95*, PHI
4. Suresh Chandra: *Computational Physics*, Narosa Publishing
5. Steven E. Koonin and Dawn C. Meredith: *Computational Physics*, Add-Wesley.
6. Mark Newman: *Computational Physics*, CreateSpace Independent Publishing.
7. W.H. Press, S.A. Teukolsky, W.T. Vetterling, B.P. Flannery: *Numerical Recipes in C: The Art of Scientific Computing*, Cambridge University Press.
8. Rubin H. Landau, Manuel Paez, and Cristian Bordeianu: *A Survey of Computational Physics*, Princeton University Press.
9. E. Kreyszig: *Advanced Engineering Mathematics*, John Wiley & Sons
10. Nicholas J. Giordano and Hisao Nakanishi: *Computational Physics*, Pearson
11. Tao Pang: *An Introduction to Computational Physics*, Cambridge Univ. Press

M.Sc. (Physics)
Semester - IV
DSC Practical
(Credits: 03)

List of experiments: At least **ten** experiments are to be performed

1. Quantum Mechanics: Particle in a 1D/2D Potential Well - Solve time-independent Schrödinger equation via finite difference method.
2. Eigenvalue Problems in Quantum Wells: Discretize and solve matrix eigenvalue problems.
3. Phonon Dispersion in 1D/3D Lattices: Construct and diagonalize the dynamical matrix.
4. Density of States (Numerical Integration/Histogram Method): Use tight-binding or free-electron approximation.
5. Matrix Diagonalization (Jacobi / QR Method): For eigenvalue problems in lattice or QM systems.
6. Numerical Integration (Trapezoidal/Simpson’s Rule): Evaluate definite integrals of physical functions.
7. Solving ODEs (Euler/Runge-Kutta Methods)
8. Planetary Motion (N-Body Problem): Gravitational interaction between multiple masses.
9. To measure the distance to the moon using the parallax method
10. Powder X-ray Diffraction (XRD): Determination of lattice parameters and identification of crystal structure.
11. Raman Spectroscopy: Study of phonon modes and lattice vibrations.
12. Infrared (IR) Spectroscopy: Molecular and lattice vibration analysis.

M.Sc. (Physics)
Semester - IV
Elective - 2
Astrophysics - B
(Credits: Theory – 04)

Detectors Photometry and Spectroscopy: Detectors for optical and infrared regions. Application of CCD's to stellar imaging, photometry, and spectroscopy. Techniques of observations of astronomical sources from space in different regions of the electromagnetic spectrum.

Astronomical photometry. Simple design of an astronomical photometer. Observing technique with a photometer. Correction for atmospheric extinction. Astronomical spectroscopy. Simple design of an astronomical spectrograph. Radial velocity measurements. Radio Astronomy Techniques. Radio window. Design and construction of a simple Radio Telescope.

Galactic System: Interstellar Matter: Composition and properties of interstellar matter. Oort limit. Interstellar extinction. Estimate of colour excess. Visual absorption. Interstellar reddening law and magnetic fields. Stromgren's theory of H II regions. Galactic Structure: General galactic rotational law. Oort's theory of galactic rotation. Determination of Oort's constants. Size and mass of our galaxy. Spiral structure of our Galaxy from optical and radio Observations.

Extragalactic Systems: Classification of galaxies and clusters of galaxies. Hubble sequence. Galaxy interactions. Determination of the extragalactic masses and distances. Active galactic nuclei (AGNs), Radio galaxies, and Quasars. Energy problem in active galaxies and accretion discs. Flat rotation curves of galaxies and Dark Matter.

Gravitation and Cosmology: Conceptual foundations of GR and curved spacetime: Principle of equivalence. Connection between gravity and geometry. Metric tensor and its properties. Form of metric in Newtonian limit. Einstein's field equations, Cosmological Constant, Observational tests of general relativity. Hubble's law. Models of the universe: Steady State Models. Standard Model: The expanding universe model. Microwave background radiation (CMBR). Friedmann-Lemaitre-Robertson-Walker (FLRW) model. The early universe. Thermodynamics of the early universe. Primordial Black Holes (PBHs). Implications of the Dark Energy in modern cosmology.

Recommended Books:

1. T. Padmanabhan: Theoretical Astrophysics: Stars and Stellar Systems, Cambridge University Press
2. Linda S. Sparke and John S. Gallagher: Galaxies in the Universe: An Introduction, Cambridge University Press
3. J. B. Hartle: Gravity: An Introduction to Einstein's General Relativity, Pearson
4. Robert M. Wald: General Relativity, University of Chicago Press
5. Bradley W Carroll and Dale A Ostlie: An Introduction to Modern Astrophysics, Cambridge University Press
6. C.R. Kitchin: Astrophysical Techniques, CRC Press
7. Barbara Ryden: Introduction to Cosmology, Cambridge University Press

M.Sc. (Physics)
Semester - IV
Elective - 2
Condensed Matter Physics – B
(Credits: Theory – 04)

Electronic Properties and Band Applications: Effective mass of electrons and holes, Crystal momentum and charge carrier dynamics, Concept of holes and hole band construction, Constant energy surfaces, Fermi energy and Fermi level in metals and semiconductors, Classification of Solids: Metals, insulators, and semiconductors based on band filling and band gaps, Band Gap Engineering: Direct and indirect band gaps, Tuning band gaps through doping, strain, and confinement, Applications in semiconductor and optoelectronic devices.

Piezoelectric and Ferroelectrics: Definition and origin of piezoelectricity, Direct and inverse piezoelectric effects, Crystal symmetry requirements for piezoelectric behaviour, Piezoelectric coefficients and tensor notation, Natural piezoelectric crystals (e.g., quartz, tourmaline), Synthetic materials, Structure-property correlations, Applications of Piezoelectric Materials. Ferroelectric crystals, classification of ferroelectric crystals, displacive transition, soft optical phonons, Landau theory of phase transition, Second and first order transition, antiferroelectricity, ferroelectric domains, Ferroelasticity, optical ceramics, Applications of Ferroelectric materials

Superconductivity: Experimental Survey, Occurrence of superconductivity, destruction of superconductivity by magnetic field and temperature, Meissner effects, Type-I and Type-II superconductors, Isotope effect, Thermodynamics of Superconducting transition, London Equations, Coherence length, BCS Theory, Cooper pairs, Josephson superconductor tunnelling, AC & DC Josephson effect, High temperature superconductors, critical fields and critical currents.

Nano Material Science and Technology: History, Origin, Quantum dots, Synthesis, Applications and advantages, Quantum wires, Quantum well & application, Fullerenes, Carbon nanobuds, carbon nanotubes as quantum wires, Areas of Nanotechnology, nanomaterials, nanoelectronics, nanobiotechnology, nanofabrication, microelectromechanical systems (MEMS)

Reference books:

1. S.O. Pillai: Solid State Physics, New Age International.
2. R.K. Puri & V.K. Babbar: Solid State Physics and Electronics, S. Chand.
3. J.P. Srivastava: Elements of Solid-State Physics, PHI
4. C.M. Kachhava: Solid State Physics, TMH
5. B.S. Saxena, R.C.Gupta, P.N.Saxena, Mandal: Solid State Physics, Pragati Prakashan
6. R.L. Singhal: Solid State Physics, Kedar Nath Ram Nath.
7. P.M. Chaikin & T.C. Lubensky: Principles of Cond. Matter Physics, Camb. Univ. Press
8. R. Kubo: Solid State Physics. McGraw-Hill Inc
9. O. Madelung: Introduction to Solid State Theory, Springer-Verlag Berlin
10. J. Patterson and B. Bailey: Introduction to Solid State Physics, Springer-Verlag Berlin
11. C. Kittel: Introduction to Solid State Physics, Wiley
12. N.D. Mermin and N.W. Ashcroft: Solid State Physics, Brooks/Cole
13. Ajay Kumar Saxena: Solid State Physics, Laxmi Publications
14. A N Tripathi, Condensed Matter Physics, New Age International

M.Sc. (Physics)
Semester - IV
Elective - 2
High Energy Physics - B
(Credits: Theory – 04)

General idea of groups and their properties: Lie groups and their generators, Lie algebra, Basic idea of Unitary, Special unitary, Orthogonal and Special orthogonal groups. Noether's theorem, Concept of gauge fields, Principal of gauge invariance, Global and Local gauge invariance, Abelian and non-Abelian gauge invariance, U(1) gauge invariance of quantum electrodynamics, Yang–Mills gauge field, non-Abelian gauge field theory SU(2), Spontaneous symmetry breaking, Goldstone bosons, Higgs mechanism.

Weak Interactions: Purely Leptonic, Semi-leptonic, and Non-leptonic Interactions, Parity, Helicity, Chirality, Charge Conjugation, Two Component Theory of Neutrinos, Relativistic Fermi Theory of Beta Decay: The V-A Interaction, The Chiral Structure of Weak Interactions, Universality of Weak Interactions, Intermediate Vector Boson, W-Boson Propagator, Cabibbo Theory, Weak Decay of Quarks: GIM model and CKM Matrix, CP violation, Neutral Weak Interactions.

Electroweak Unification and Gauge Symmetry: SU(2) Global and Local Gauge Invariance, Yang Mills Field, Weinberg-Salam Theory of Electroweak Unification, Weak Isospin and Hypercharge, The Matter Fields, The Gauge Fields, The Gauging of SU(2)×U(1), Fermion Assignments in the Electroweak Model, Spontaneous Symmetry Breaking and Choice of Higgs Field, Lepton and Quark Masses, Gauge Boson Masses

QCD and Standard Model: Colour Gauge Invariance and QCD, Basic Idea of Standard Model of Fundamental Interaction, General Mass Terms, Experimental Evidence of the Standard Model: QED, Weak Interactions, Colours.

References Books:

1. Syed Afsar Abbas: Group Theory in Particle, Nuclear and Hadron Physics, CRC Press
2. Fayyazuddin and Riazuddin: A Modern Introduction to Particle Physics, World Scientific Publishing
3. G.L. Kane: Modern Elementary Particle Physics, Addison-Wesley
4. Graham Ross: Grand Unified Theories, Benjamin-Cummings Pub. Co.
5. D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press
6. C. Quigg: Gauge Theories of Strong, Weak, and Electromagnetic Interactions, Addison–Wesley
7. T.D. Cheng and Ling Fong Li: Gauge Theory of Elementary Particle Physics, Clarendon Oxford
8. D. C. Joshi: Introduction to Quantum Electrodynamics and Particle Physics, Tech Sar Pvt. Ltd.

M.Sc. (Physics)
Semester - IV
DSE - Project Work
(Credits: 02)

Project work for all specializations:

This course will be based on preliminary research-oriented topics, both in theory and experiment. The teachers who will act as supervisors for the projects will float projects, and any one of them will be allocated to the students. At the completion of the project by the semester end, the student will submit a Project Report in the form of a dissertation, which will be examined by the examiners. The examinations shall consist of a presentation and a comprehensive viva voce.

Project Evaluation:

Evaluation by External and Internal – Project (40) + Viva (20) – Total 60 Marks
Internal assessment (Test, Seminars, etc) = 40 Marks