University of Gour Banga

POST GRADUATE PROGRAMMES IN PHYSICS

MASTER OF SCIENCE (Physics)

NEP 2020: Post Graduate Curricular Framework (PGCF) 2026

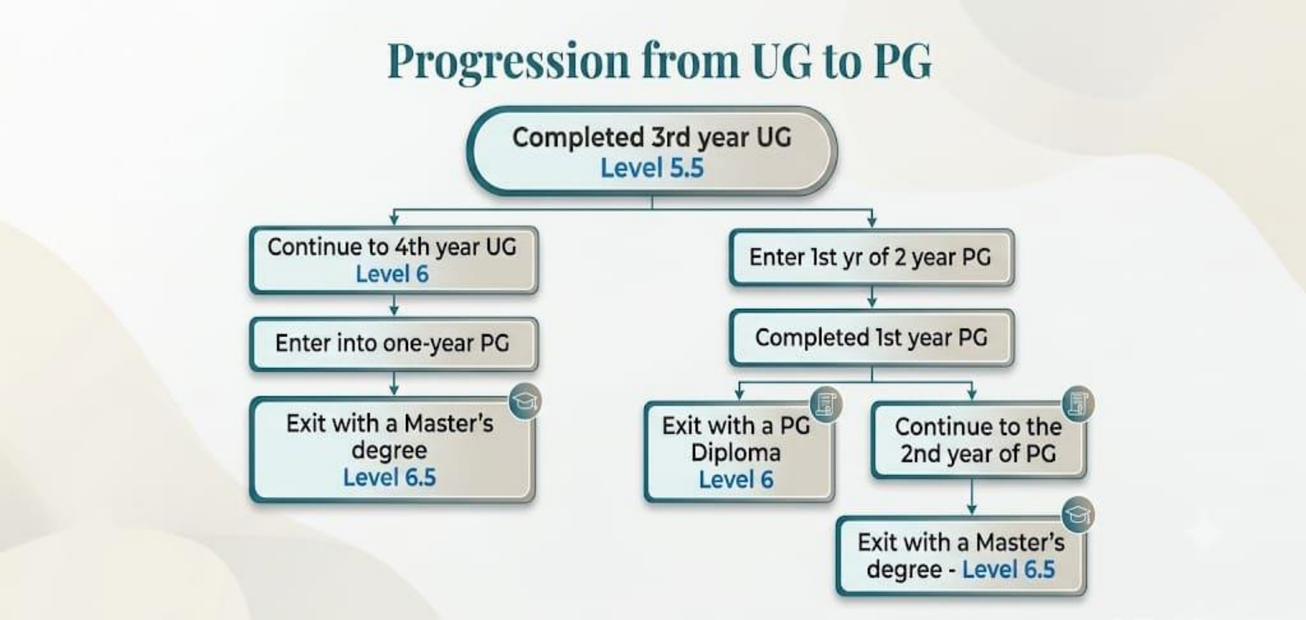
TWO YEARS PG PROGRAMME AFTER COMPLETION OF THREE-YEAR UG PROGRAMME (3+2)

ONE YEAR PG PROGRAMME AFTER COMPLETION OF FOUR-YEAR UG PROGRAMME (4+1)

DEPARTMENT OF PHYSICS

UNDER FACULTY OF SCIENCE

UNIVERSITY OF GOUR BANGA



PROGRAMMES OF STUDY WITH EQUIVALENT QUALIFICATION LEVELS

Entry Qualification	PG Duration	Exit Qualification	Academic Level
Three year UG	Exit after one year	PG Diploma	6.0
	Two years	PG Degree	6.5
Four year UG	One year	PG Degree	6.5

In accordance with the NHEQF, the levels for the PG Programme

Two-Year PG Programme After Completion of Three-Year UG Programme (3+2)
Academic Year - First

Semester	Subject Type	Paper Type	Paper Name	Credit	Paper Code	Page Number
I	Core	Theory	Mathematical Methods	4	PHYS 101	7
		Theory	Classical Mechanics	4	PHYS 102	9
		Theory	Classical Electrodynamics	4	PHYS 103	12
		Practical	General Practical	4	PHYS 104	14
	DSE (Any one from the options A, B & C)	Theory	(A)Atomic and Molecular Physics	4	PHYS 105 (A)	15
			(B) Astronomy and Astrophysics		PHYS 105 (B)	17
			(C) Swayam Course as Offered by the Department		PHYS 105 (C)	-
	SEC	Theory + Practical	Numerical Methods and Programming	2+2=4	PHYS 106	20
II	Core	Theory	Statistical Mechanics	4	PHYS 201	23
		Theory	Electronics	4	PHYS 202	26
		Theory	Quantum Mechanics-I	4	PHYS 203	29
		Practical	Optics Practical	4	PHYS 204	31
	DSE (Any one from the options A, B & C)	Theory	(A) Laser Physics and Optoelectronics	4	PHYS205 (A)	32
			(B) Advanced Mathematical Methods		PHYS 205 (B)	34
			(C) Swayam Course as Offered by the Department		PHYS 205 (C)	-
	SEC	Practical	Analog and Digital Circuit Design and Analysis	4	PHYS 206	36

Two-Year PG Programme After Completion of Three-Year UG Programme (3+2)
Academic Year - Second

Semester	Subject Types	Paper Type	Paper Name	Credit	Paper code
III	Core	Theory	Quantum Mechanics-II	4	PHYS 301
	DSE (Any one from the options A, B & C)	Theory	(A) Condensed Matter Physics	4	PHYS302 (A)
			(B) Coherent Spectroscopy of Atoms		PHYS 302 (B)
			(C) Swayam Course as offered by the Department		PHYS 302 (C)
		Theory	(A) Plasma Physics	4	PHYS 303 (A)
			(B) High Energy Physics		PHYS 303 (B)
			(C) Swayam Course as offered by the Department		PHYS 303 (C)
	DRP	Research	Advanced Research Methodology	4	PHYS 304
		Research	Dissertation / Research	8	PHYS 305
IV	Core	Theory	Nuclear Physics	4	PHYS 401
	DSE (Any one from the options A, B & C)	Theory	(A) Computational Physics	4	PHYS 402 (A)
			(B) Gravitation and Cosmology & General Theory of Relativity (GTR)		PHYS 402 (B)
			(C) Swayam Course as offered by the Department		PHYS 402 (C)
	DSE (Any one from the options A, B & C)	Theory	(A) Non Linear Dynamics	4	PHYS 403 (A)
			(B) Advanced Condensed Matter Physics		PHYS 403 (B)
			(C) Swayam Course as offered by Department		PHYS 403 (C)
	DRP	Research	Dissertation/Research Project/Entrepreneurship	12	PHYS 404

One-Year PG Programme After Completion of Four-Year UG Programme (4+1)
Academic Year - First

<table>
<tr><th>Semester</th><th>Subject Types</th><th>Paper Type</th><th>Paper Name</th><th>Credit</th><th>Paper Code</th></tr>
<tr><td rowspan="10">I</td><td>Core</td><td>Theory</td><td>Quantum Mechanics-II</td><td>4</td><td>PHYS 101</td></tr>
<tr><td rowspan="6">DSE
(Any one from the options A, B & C)</td><td rowspan="3">Theory</td><td>(A) Condensed Matter Physics</td><td rowspan="3">4</td><td>PHYS102 (A)</td></tr>
<tr><td>(B) Coherent Spectroscopy of Atoms</td><td>PHYS 102 (B)</td></tr>
<tr><td>(C) Swayam Course as offered by the Department</td><td>PHYS 102 (C)</td></tr>
<tr><td rowspan="3">Theory</td><td>(A) Plasma Physics</td><td rowspan="3">4</td><td>PHYS 103 (A)</td></tr>
<tr><td>(B) High Energy Physics</td><td>PHYS 103 (B)</td></tr>
<tr><td>(C) Swayam Course as offered by the Department</td><td>PHYS 103 (C)</td></tr>
<tr><td rowspan="2">DRP</td><td>Research</td><td>Advanced Research Methodology</td><td>4</td><td>PHYS 104</td></tr>
<tr><td>Research</td><td>Dissertation / Research</td><td>8</td><td>PHYS 105</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">II</td><td>Core</td><td>Theory</td><td>Nuclear Physics</td><td>4</td><td>PHYS 201</td></tr>
<tr><td rowspan="3">DSE
(Any one from the options A, B & C)</td><td rowspan="3">Theory</td><td>(A) Computational Physics</td><td rowspan="3">4</td><td>PHYS 202 (A)</td></tr>
<tr><td>(B) Gravitation and Cosmology & General Theory of Relativity (GTR)</td><td>PHYS 202 (B)</td></tr>
<tr><td>(C) Swayam Course as offered by the Department</td><td>PHYS 202 (C)</td></tr>
<tr><td rowspan="3">DSE
(Any one from the options A, B & C)</td><td rowspan="3">Theory</td><td>(A) Non Linear Dynamics</td><td rowspan="3">4</td><td>PHYS 203 (A)</td></tr>
<tr><td>(B) Advanced Condensed Matter Physics</td><td>PHYS 203 (B)</td></tr>
<tr><td>(C) Swayam Course as offered by Department</td><td>PHYS 203 (C)</td></tr>
<tr><td>DRP</td><td>Research</td><td>Dissertation/Research Project/Entrepreneurship</td><td>12</td><td>PHYS 204</td></tr>
</table>

Note on SWAYAM Course Substitution:

Students may, with the recommendation of the concerned Department, opt for an appropriate SWAYAM course in place of a prescribed course in a semester, provided that the SWAYAM course is considered academically equivalent and carries the required credits. The substitution shall be made in accordance with NEP 2020, the UGC Credit Framework, and the applicable rules and guidelines of the University. Prior approval of the Department and the Controller of Examinations (CoE) shall be obtained wherever required. The credit earned through the approved SWAYAM course may be transferred and counted towards the corresponding programme requirements, subject to the University's prevailing regulations.

SEMESTER-I

Course Code: PHYS 101
Course Name: Mathematical Methods

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop mathematical techniques used in theoretical physics.
- Solve ordinary and partial differential equations.
- Apply vector and tensor analysis to electrodynamics and continuum mechanics.
- Use complex analysis in quantum mechanics and condensed matter physics.
- Employ special functions and integral transforms in solving physical problems.
- Gain familiarity with Green's functions and variational methods.

Course Content:

Module I – Linear Algebra, Vector Spaces, Matrices and Tensors (15 Lectures)

Vector spaces and subspaces; linear dependence and independence; basis and dimension; inner product and norm; orthogonal and orthonormal bases; Gram–Schmidt orthogonalization; Hilbert spaces; linear transformations and linear operators; matrix representation of linear operators; eigenvalues and eigenvectors; characteristic equation; diagonalization of matrices; Hermitian, unitary, projection and normal operators; properties of eigenvalues and eigenvectors; spectral representation of operators; functions of matrices; applications of matrix methods in quantum mechanics and mathematical physics.

Introduction to tensors; coordinate transformations; scalars, vectors and tensors; covariant and contravariant tensors; tensor notation and algebra; addition, multiplication and contraction of tensors; Kronecker delta and Levi-Civita symbol; metric tensor; basic applications in physics.

Module II – Ordinary Differential Equations and Special Functions (15 Lectures)

First- and second-order ordinary differential equations; linear and nonlinear differential equations; homogeneous and non-homogeneous equations; initial- and boundary-value problems; power-series solutions; ordinary and regular singular points; Frobenius method.

Special functions and their differential equations; Legendre polynomials and functions; generating functions, recurrence relations and orthogonality properties; Bessel and spherical Bessel functions;

Hermite and Laguerre polynomials; Chebyshev polynomials; properties and applications of special functions in mathematical physics.
Sturm–Liouville theory; eigenvalue problems; orthogonal functions and completeness; applications of special functions and Sturm–Liouville systems to problems in quantum mechanics, electromagnetism and wave physics.

Module III – Complex Analysis (15 Lectures)

Functions of a complex variable; limits and continuity; differentiability and analyticity; Cauchy–Riemann equations; harmonic functions and their relation to analytic functions; elementary complex functions; multiple-valued functions; branch points and branch cuts; Riemann surfaces.
Complex integration and contour integrals; Cauchy's theorem; Cauchy's integral formula; Liouville's theorem; Morera's theorem; maximum modulus principle; Taylor and Laurent series; singular points and their classification; poles, essential singularities and isolated singularities; residue theorem; Jordan's lemma.
Applications of contour integration and residue calculus to the evaluation of definite and improper integrals; integrals involving trigonometric and exponential functions; evaluation of integrals with branch-point singularities; summation of infinite series using complex-variable techniques.

Module IV – Integral Transforms, Green's Functions and Integral Equations (15 Lectures)

Fourier transforms and Fourier inverse transforms; properties of Fourier transforms; convolution theorem; Fourier transforms of derivatives; multidimensional Fourier transforms and their applications.
Laplace transforms and inverse Laplace transforms; properties and operational rules; convolution theorem; applications of Laplace transforms to ordinary and partial differential equations and initial-value problems.
Dirac delta function and its properties; representations of the delta function; Green's functions for ordinary and partial differential equations; construction and properties of Green's functions; applications to electrostatics, quantum mechanics and boundary-value problems; response functions and propagators.
Integral equations; classification of integral equations; Fredholm and Volterra integral equations; integral equations of the first and second kind; relation between differential and integral equations; applications to physical boundary-value and initial-value problem

Recommended Books:

1. M. R. Spiegel: *Theory and Problems of Complex Variables*, Schaum's Outline Series, (McGraw-Hill).
2. G. B. Arfken, H. J. Weber and F. E. Harris: *Mathematical Methods for Physicists*, (Academic Press/Elsevier).
3. J. Mathews and R. L. Walker: *Mathematical Methods of Physics*, 2nd ed., (W. A. Benjamin).
4. P. Dennery and A. Krzywicki: *Mathematics for Physicists*, (Harper & Row).
5. L. C. Andrews and B. K. Shivamoggi: *Integral Transforms for Engineers*, (Prentice Hall of India).
6. E. A. Coddington and N. Levinson: *Theory of Ordinary Differential Equations*, (McGraw-Hill).

Course Code: PHYS 102
Course Name: Classical Mechanics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

Develop an advanced understanding of Lagrangian and Hamiltonian formulations of classical mechanics.

- Study the canonical transformations, Poisson brackets, and Hamilton–Jacobi theory for dynamical systems.
- Understand the mathematical and physical aspects of rigid-body motion, rotational dynamics, and stability.
- Analyze small oscillations, coupled systems, normal modes, and resonance phenomena.
- Develop advanced understanding of central-force dynamics, orbital motion, and scattering processes.
- Apply analytical and mathematical techniques of classical mechanics to a range of physical systems.

Course Content:

Module I: Lagrangian and Hamiltonian Dynamics(15 Lectures)

Lagrangian formulation for constrained dynamical systems, generalized forces and velocity-dependent interactions, cyclic variables and conservation laws, dissipative systems, Lagrangian formulation of various systems, symmetries and conservation laws, Noether's theorem and its applications.

Legendre transformation and Hamiltonian formulation, phase space and phase trajectories, canonical variables, Hamiltonian dynamics of continuous and relativistic systems, conserved quantities and constants of motion, Liouville theorem and phase-space flow.

Calculus of variations and functional derivatives, Euler–Lagrange equations from variational principles, stationary-action formulation, variational formulation of classical and relativistic systems.

Module II: Canonical Transformations and Hamilton–Jacobi Theory (15 Lectures)

Canonical transformations and their geometrical significance, generating functions and transformation theory, infinitesimal canonical transformations, Poisson brackets and canonical invariants, equations of motion in Poisson-bracket form, algebra of dynamical variables.

Hamilton–Jacobi equation and complete integrals, Hamilton's principal and characteristic functions, separation of variables, applications to integrable dynamical systems, Hamilton–Jacobi treatment of the harmonic oscillator, central-force problems and Kepler motion, action-angle variables for one dimensional system.

Module III: Advanced Rigid Body Dynamics (15 Lectures)

Inertia tensor and principal axes, ellipsoid of inertia, rotational kinematics, Euler angles, body-fixed and space-fixed descriptions, Euler equations of motion, angular momentum and rotational energy.

Torque-free rotation, stability of rotational motion, geometrical interpretation of rigid-body motion, body and space cones, symmetric and asymmetric tops, motion of a heavy symmetric top, regular precession, spin and nutation, fast and sleeping top, qualitative aspects of rotational stability and applications.

Module IV: Small Oscillations and Central-Force Dynamics (15 Lectures)

Small oscillations about equilibrium configurations, quadratic approximation, matrix formulation of coupled oscillations, eigenvalue problem, normal modes and normal coordinates, principal-axis transformation, orthogonality and normalization of modes, degeneracy, forced and damped oscillations, resonance, continuum limit and oscillations of a stretched string.

Two-body dynamics in central-force fields, effective potential and qualitative analysis, orbit equation and classification of trajectories, bound and unbound motion, scattering and differential cross-section, virial theorem, power-law potentials and conditions for closed orbits, Bertrand's theorem, Kepler problem, artificial satellite dynamics, Rutherford scattering and advanced applications of central-force theory.

Recommended Books:

1. H. Goldstein, C. Poole and J. Safko: *Classical Mechanics*, (Pearson).
2. V. Barger and M. Olsson: *Classical Mechanics: A Modern Perspective*, (McGraw-Hill).
3. N. C. Rana and P. S. Joag: *Classical Mechanics*, (Tata McGraw-Hill).
4. J. V. Jose and E. J. Saletan: *Classical Dynamics: A Contemporary Approach*, (Cambridge University Press).
5. L. D. Landau and E. M. Lifshitz: *Mechanics*, (Elsevier).

Course Code: PHYS 103
Course Name: Classical Electrodynamics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop an advanced understanding of classical electromagnetic theory and Maxwell's equations.
- Apply Green's functions, boundary conditions, and multipole expansion techniques to electromagnetic problems.
- Understand electromagnetic wave propagation, waveguides, and cavity resonators.
- Study electromagnetic potentials, radiation, and radiation from moving charges.
- Develop a covariant and relativistic formulation of electrodynamics.
- Understand electromagnetic scattering, absorption, and dispersion in matter.
- Develop analytical skills for solving advanced problems in electrodynamics.

Course Content:

Module I: Electrostatics, Magnetostatics and Electromagnetic Waves (15 Lectures)

Review of electrostatics and magnetostatics; electrostatic and magnetostatic boundary conditions; boundary-value problems and Green's function method for Poisson's and Laplace's equations; multipole expansion of fields and potentials; electrostatics and magnetostatics of macroscopic media; scalar and vector potentials; electromagnetic induction; Maxwell's equations in differential and integral forms; continuity equation; electromagnetic energy and momentum; Poynting theorem and Poynting vector; electromagnetic waves in conducting and non-conducting media; absorption and dispersion of electromagnetic waves; reflection at conducting surfaces; frequency dependence of permittivity and refractive index; rectangular waveguides, TE and TM modes, cut-off frequencies, and cavity resonators.

Module II: Electromagnetic Potentials and Radiation (20 Lectures)

Gauge transformations; Lorenz and Coulomb gauges; inhomogeneous wave equations; retarded and advanced potentials; fields and radiation from localized oscillating sources; multipole expansion of scalar and vector potentials; near-field and far-field components; radiation fields and radiation zone; electric dipole radiation; Liénard–Wiechert potentials; electromagnetic fields of a uniformly moving charge; radiation from an accelerated charge; Larmor formula and its relativistic generalization; radiation from acceleration parallel and perpendicular to velocity; bremsstrahlung; Cherenkov radiation; radiation reaction.

Module III: Relativistic Electrodynamics (15 Lectures)

Four-vectors and tensors in Minkowski space; Lorentz transformations; electromagnetic four-potential; electromagnetic field tensor; transformation of electric and magnetic fields; Lorentz invariants of the electromagnetic field; covariance of Maxwell's equations; relativistic equation of motion of a charged particle; relativistic Lagrangian and Hamiltonian formulation of a charged particle in an electromagnetic field; Lagrangian formulation of the electromagnetic field; canonical momentum; electromagnetic stress-energy tensor; conservation of energy, momentum and angular momentum.

Module IV: Electromagnetic Scattering, Absorption and Dispersion (10 Lectures)

Scattering of electromagnetic radiation by free and bound electrons; Thomson scattering; Rayleigh scattering; classical theory of scattering; absorption of radiation by bound electrons; oscillator model of the bound electron; Lorentz electromagnetic theory of dispersion; normal and anomalous dispersion; complex refractive index; absorption coefficient; frequency-dependent dielectric response; relation between dispersion and absorption.

Recommended Books:

1. W. Panofsky and M. Phillips: *Classical Electricity and Magnetism*, (Addison-Wesley).
2. D. Griffiths: *Introduction to Electrodynamics*, (Prentice Hall India).
3. J. D. Jackson: *Classical Electrodynamics*, (Wiley).
4. J. Marion: *Classical Electromagnetic Radiation*, (Academic Press).
5. J. Schwinger: *Classical Electrodynamics*.
6. A. K. Das: *Classical Electrodynamics*.
7. L. D. Landau and E. M. Lifshitz: *The Classical Theory of Fields*, (Elsevier).
8. E. M. Purcell and D. J. Morin: *Electricity and Magnetism*, (Cambridge University Press).
9. W. Greiner: *Classical Electrodynamics*, (Springer).

Course Code: PHYS 104
Course Name: General Practical

Credit: 4
Total Contact Hours: 120

List of Experiments:

1. **Determination of Energy Band Gap of a Semiconductor by Four-Probe Method**
Study the temperature dependence of the electrical resistivity of a semiconductor using the four-probe method and determine its energy band gap from the resistivity–temperature characteristics.

2. **Study of Ferromagnetic Hysteresis**
Study the hysteresis characteristics of a ferromagnetic material using a hysteresis loop tracer and determine its saturation magnetization, retentivity, and coercivity.

3. **Study of Hall Effect in a Semiconductor**
Study the Hall effect in an extrinsic semiconductor and determine the Hall coefficient, carrier concentration, and type of charge carriers. Investigate their temperature dependence.

4. **Determination of Velocity of Ultrasonic Waves in a Liquid**
Determine the velocity of ultrasonic waves in a liquid using a multi frequency ultrasonic interferometer and/or ultrasonic grating method.

5. **Study of Quantized Energy Levels by Franck–Hertz Experiment**
Demonstrate the existence of discrete atomic energy levels and determine the excitation potential of the gas using the Franck–Hertz experiment.

6. **Determination of Landé g-Factor by Electron Spin Resonance**
Study electron spin resonance (ESR) of DPPH and determine the spectroscopic splitting factor (Landé g-factor) from the resonance condition.

7. **Study of Ferroelectric Phase Transition**
Study the temperature dependence of the dielectric constant of a ferroelectric material and determine its Curie temperature from the dielectric anomaly.

Course Code: PHYS 105 (A)
Course Name: Atomic and Molecular Spectroscopy

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Understand the fundamental principles of atomic and molecular spectra and their origin.
- Study atomic structure, fine and hyperfine interactions, angular momentum coupling, and magnetic-field effects.
- Understand molecular rotational, vibrational, electronic, infrared, microwave, and Raman spectra.
- Develop knowledge of spectral broadening, selection rules, molecular symmetry, and spectroscopic techniques.
- Gain familiarity with modern spectroscopic methods and their applications in atomic, molecular, and materials science.

Course Content:

Module I: Atomic Spectroscopy and Atomic Structure (15 Lectures)

Hydrogenic spectra and Bohr model, energy levels of hydrogen atom, fine structure of hydrogen spectra, relativistic correction, spin–orbit interaction, Lamb shift, electron spin and angular momentum, Landé g-factor, Zeeman effect and Paschen–Back effect, spectra of alkali atoms, quantum defect, penetrating and non-penetrating orbits, hyperfine structure of monovalent atoms, magnetic dipole and electric quadrupole interactions, spectra of divalent atoms, singlet and triplet states, LS and jj coupling schemes, magnetic-field effects on atomic spectra.

Module II: Many-Electron Atoms, X-Ray Spectra and Spectral Broadening (15 Lectures)

Pauli exclusion principle, periodic classification of elements, equivalent and non-equivalent electrons, spectral terms of equivalent and non-equivalent electrons, ground and excited electronic configurations, angular momentum coupling in many-electron atoms, origin of X-ray spectra, characteristic and continuous X-ray spectra, screening constants, X-ray energy levels and fine structure, spin–orbit interaction and screening doublet laws, diagram and non-diagram lines, Auger effect, natural broadening, Doppler broadening, collision and pressure broadening, lifetime broadening, qualitative treatment of line shapes and spectral resolution.

Module III: Molecular Structure and Rotational–Vibrational Spectroscopy (15 Lectures)

Born–Oppenheimer approximation and separation of electronic and nuclear motion, molecular orbitals, hydrogen molecular ion and hydrogen molecule, valence-bond approach, Coulomb and exchange integrals, chemical bonding and hybridization, molecular energy levels, microwave and far-infrared spectroscopy, rigid and non-rigid rotator models, rotational energy levels and selection rules, determination of molecular structure, isotope effect, rotational spectra of polyatomic molecules, infrared spectroscopy, harmonic and anharmonic oscillator models, Morse potential, vibrational energy levels, selection rules, dissociation energy, rotational–vibrational coupling, symmetry of molecular wave functions and nuclear-spin effects.

Module IV: Raman and Electronic Molecular Spectroscopy (15 Lectures)

Raman spectroscopy and molecular polarizability, rotational Raman spectra, vibrational Raman spectra, rotational–vibrational Raman spectra, Stokes and anti-Stokes lines, Raman selection rules, nuclear-spin effects in Raman spectra, vibrational spectra of polyatomic molecules, normal modes of vibration, infrared and Raman activity, normal modes of CO_2 and other simple triatomic molecules, electronic spectra of diatomic molecules, vibrational band structure, progressions and sequences, isotope shifts, Franck–Condon principle, intensity distribution in vibrational structure, rotational structure of electronic spectra, P-, Q- and R-branches, band-head formation, Hund's coupling cases, predissociation, inversion spectrum of ammonia, applications of atomic and molecular spectroscopy.

Recommended Books:

1. H. E. White: *Introduction to Atomic Spectra*, (McGraw-Hill).
2. B. H. Bransden and C. J. Joachain: *Physics of Atoms and Molecules*, Pearson/Longman).
3. S. N. Ghoshal: *Atomic and Nuclear Physics, Vol. I,* (S. Chand).
4. C. N. Banwell and E. M. McCash: *Fundamentals of Molecular Spectroscopy*, (McGraw-Hill).
5. M. Weissbluth: *Atoms and Molecules*, (Academic Press).
6. G. Herzberg: *Molecular Spectra and Molecular Structure: I. Spectra of Diatomic Molecules*, (D. Van Nostrand Company).
7. G. M. Barrow: *Introduction to Molecular Spectroscopy*, (McGraw-Hill).
8. J. M. Hollas: *Modern Spectroscopy*, (Wiley).
9. G. Aruldhas: *Molecular Structure and Spectroscopy*, (Prentice-Hall of India).

Course Code: PHYS 105 (B)
Course Name: Astronomy and Astrophysics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop a systematic understanding of the historical development, fundamental concepts, and observational foundations of astronomy and astrophysics, including contributions from the Indian astronomical tradition.
- Understand the physical principles governing radiation, gravitation, stellar atmospheres, the Sun, and other astrophysical systems.
- Develop knowledge of stellar structure, stellar evolution, compact objects, galaxies, and the physical processes governing their formation and evolution.
- Introduce the observational and quantitative techniques used to determine astronomical distances, stellar properties, galactic dynamics, and cosmological parameters.
- Provide a foundation in modern cosmology, including the expanding universe, dark matter, dark energy, cosmic microwave background, and large-scale structure of the universe.

Course Content:

Module I: Historical Foundations, Astronomical Scales and Observational Astronomy (15 Lectures)

Development of astronomy from ancient civilizations, with emphasis on the Indian astronomical tradition and contributions of **VedāṅgaJyotiṣa, Āryabhaṭa, Varāhamihira, Brahmagupta and Bhāskara II** to calendrical science, time measurement, planetary motions, eclipses and astronomical calculations. Development of Greek, Islamic and European astronomy and the transition from classical astronomy to modern astrophysics through telescopes and physical theories.

Astronomical units and scales of length, mass, time and brightness; astronomical unit, parsec and light-year; radiant flux, luminosity and inverse-square law; apparent and absolute magnitude, distance modulus and basic stellar parameters. Celestial sphere and spherical astronomy: horizon, equatorial and ecliptic coordinate systems, spherical triangles, coordinate transformations, diurnal and annual motions, sidereal and solar time, equation of time and astronomical timekeeping. Geometric parallax and astronomical distance determination.

Astronomical Techniques and Observational Methods: Optical telescopes; refracting and reflecting telescopes, Newtonian configuration, angular resolution, light-gathering power, magnification and focal ratio; telescope mountings and tracking. Photographic plates, photomultiplier tubes, CCD and CMOS detectors; sensitivity, signal-to-noise ratio and detection limits. Atmospheric effects, observational constraints, space-based observatories and introduction to multi-wavelength astronomy.

Module II: Physical Processes, Radiation and the Solar System (15 Lectures)

Thermal physics of astronomical systems; thermodynamic equilibrium and equations of state. The Sun as a typical star: solar parameters and internal structure—core, radiative and convective zones, photosphere, chromosphere and corona; solar energy generation and transport. Solar magnetic activity, sunspots, flares, prominences, solar cycle and basic magnetohydrodynamics. Solar System: planets, satellites, asteroids, comets and dwarf planets; Keplerian motion and orbital dynamics. Origin and evolution of the Solar System; nebular model and observational evidence

Module III: Stellar Structure, Classification and Evolution (15 Lectures)

Atomic and molecular spectra in astrophysical environments; stellar spectra and spectral classification (OBAFGKM), luminosity classes and Hertzsprung–Russell diagram. Stellar luminosity, effective temperature, radius and mass; mass–luminosity relation. Stellar structure**:** mass conservation, hydrostatic equilibrium, energy generation and transport, radiative and convective equilibrium, equations of state and opacity. Stellar nucleosynthesis and energy generation: proton–proton chain, CNO cycle and triple-alpha process; stellar timescales. Stellar evolution: formation and pre-main-sequence evolution, main-sequence evolution and mass dependence; evolution of low- and intermediate-mass stars through red giants, helium burning, asymptotic giant branch and planetary nebulae; evolution of massive stars, advanced nuclear burning and supernovae. Compact objects: degenerate matter, white dwarfs, Chandrasekhar limit, neutron stars, degeneracy pressure and basic physics of black holes *(qualitative treatment only)*.

Module IV: Galaxies, Cosmology and Large-Scale Structure (15 Lectures)

Galaxies and classification: elliptical, spiral, lenticular and irregular galaxies; Hubble classification and physical properties. Star clusters and Milky Way**:** open and globular clusters; structure and dynamics of the Milky Way—disk, bulge, halo and stellar populations. Active galaxies**:** radio galaxies, quasars and supermassive black holes. Cosmic distances and expansion: distance ladder, parallax, standard candles, Cepheids and Type-Ia supernovae; redshift, Doppler effect and Hubble–Lemaître law; evidence for cosmic expansion. Large-scale structure**:** galaxy groups and clusters, cosmic structure and gravitational lensing. Dark matter and dark energy: observational evidence and basic models. Cosmology: cosmological principle, homogeneous and isotropic universe, Friedmann model, Big Bang, thermal history and cosmic microwave background; Olbers' paradox, evidence for cosmic evolution and current challenges in cosmology.

Recommended Books:

1. B. W. Carroll and D. A. Ostlie: *An Introduction to Modern Astrophysics*, 2nd ed., (Pearson).
2. M. Zeilik and S. A. Gregory: *Introductory Astronomy & Astrophysics*, (Cengage Learning).
3. A. K. Kembhavi and J. V. Narlikar: *Basics of Astronomy*, (Universities Press).
4. J. B. Kaler: *Stars and Their Spectra: An Introduction to the Spectral Sequence*, (Cambridge University Press).
5. S. Chandrasekhar: *An Introduction to the Study of Stellar Structure*, (Dover Publications).

Course Code: PHYS 106

Course Name: Numerical Methods and Programming

Credit: 2 (Theory)+2 (Practical)
Lectures: 30, Tutorials: 10, Practical: 60
Total Contact Hours: 100 (30+10+60)

Course Objectives:

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

- Understand the basic concepts of numerical computation and the use of computational tools for solving scientific problems.
- Apply numerical methods to solve algebraic and transcendental equations, interpolate and fit numerical data, and perform numerical differentiation and integration.
- Implement numerical methods for solving ordinary differential equations, including initial-value problems.
- Assess the accuracy, convergence, stability and numerical errors associated with computational methods.
- Develop and execute computer programs for numerical methods and apply them to relevant physical problems.
- Interpret and compare numerical results with analytical or exact solutions wherever available.

Course Content:

<u>Module I: Numerical Methods for Algebra and Calculus (15 Lectures)</u>

Brief introduction to computational tools and programming for scientific computation; basic programming constructs including variables, data types, operators, input/output, conditional and looping statements, arrays and functions; basic concepts of algorithms, compilation, execution and debugging of scientific programs. Representation of integers and real numbers in computers; floating-point representation; numerical range, precision, overflow and underflow; accuracy and precision; truncation and round-off errors; basic error propagation and numerical stability.

Solution of algebraic and transcendental equations using bisection and Newton–Raphson methods; interpolation using Lagrange's and Newton's interpolation formulae; least-square fitting and analysis of numerical data; matrix addition, multiplication and basic matrix operations; numerical differentiation; numerical integration using trapezoidal and Simpson's rules and Gaussian Quadrature; comparison of accuracy and convergence of numerical methods.

Module II: Numerical Solution of Differential Equations (15 Lectures)

Numerical solution of ordinary differential equations and initial-value problems; Euler and modified Euler methods; Runge–Kutta methods of different orders; accuracy, stability and convergence of numerical solutions; truncation and round-off errors in numerical solutions; comparison of numerical and analytical solutions.
Applications of numerical methods to physical problems such as particle motion, radioactive decay, RC and RL circuits, oscillations and other dynamical systems; comparison of numerical methods based on accuracy, convergence, stability and computational efficiency; numerical solution of second-order differential equations by reduction to a system of first-order equations.

Module III: Practical — Numerical Methods for Algebra and Calculus (Contact Hours: 30)

Students shall develop and implement computer programs corresponding to the numerical methods and computational techniques covered in **Module I.**

Suggested Programs:

1. Program to solve an algebraic equation using the Bisection Method.
2. Program to solve an algebraic or transcendental equation using the Newton–Raphson Method.
3. Program to perform Lagrange's interpolation for a given set of data.
4. Program to perform Newton's interpolation for a given set of data.
5. Program for least-square fitting of numerical data and determination of relevant parameters.
6. Program for matrix addition, multiplication and basic matrix operations, including a suitable physical application.
7. Program for numerical differentiation to determine velocity and/or acceleration from given position-time data.
8. Program to evaluate a suitable physical integral using the Trapezoidal Rule.
9. Program to evaluate a suitable physical integral using Simpson's One-Third Rule.
10. Program to evaluate a suitable physical integral using Gaussian Quadrature.
11. Program to study the accuracy and convergence of a numerical method by varying the step size, number of intervals or number of data points, and estimating the corresponding numerical error.

Module IV: Practical — Numerical Solution of Differential Equations(Contact Hours: 30)

Students shall develop and implement computer programs corresponding to the numerical methods and physical applications covered in **Module II.**

Suggested Programs:

1. Program to solve a first-order ordinary differential equation using the Euler Method.
2. Program to solve a first-order ordinary differential equation using the Modified Euler Method.
3. Program to solve a first-order ordinary differential equation using the Second-Order Runge–Kutta Method.
4. Program to solve a first-order ordinary differential equation using the Fourth-Order Runge–Kutta Method.
5. Program to solve a suitable physical first-order differential equation using a numerical method. Applications may include particle motion, radioactive decay, RC circuits and RL circuits.
6. Program to solve a second-order differential equation by reducing it to a system of first-order differential equations and applying a suitable numerical method, with simple harmonic motion as an application.

Practical Requirement

Modules 3 and 4 are the practical components corresponding respectively to Modules 1 and 2 of the theory course. Students shall develop and implement their own computer programs for the numerical methods covered in the corresponding theory modules.

During the practical examination, each student shall execute and demonstrate one or two programs selected from the prescribed practical exercises of Modules 3 and 4.

Recommended Books:

1. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI Learning.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International.
3. V. Rajaraman, Computer Oriented Numerical Methods, Prentice-Hall of India.
4. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, McGraw Hill.
5. R. L. Burden, J. D. Faires and A. M. Burden, Numerical Analysis, Cengage.
6. N. J. Giordano and H. Nakanishi, Computational Physics, Pearson.

SEMESTER -II

Course Code: PHYS 201

Course Name: Statistical Mechanics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop a systematic understanding of the statistical foundations of thermodynamics and the microscopic origin of macroscopic properties.
- Introduce the microcanonical, canonical, and grand canonical ensembles and their application to equilibrium systems.
- Develop the formalism of classical and quantum statistics, with applications to ideal gases, electrons, photons, and phonons.
- Introduce the statistical description of interacting systems, phase transitions, and critical phenomena, including the Ising model and Landau theory.
- Establish the application of statistical-mechanical concepts to condensed matter systems, magnetism, and nanoscale materials.

Course Content:

Module I – Foundations of Classical Statistical Mechanics (15 Lectures)

Review of probability theory and statistical distributions; probability distributions and distribution functions; binomial, Gaussian and Poisson distributions; mean values, moments and fluctuations; random variables and statistical averages.

Classical statistical mechanics and phase-space description; microscopic and macroscopic states; phase space; Liouville theorem and its physical significance; statistical ensembles and ensemble averages; microcanonical, canonical and grand canonical ensembles; thermodynamic probability and entropy; Boltzmann distribution; partition function and its relation to thermodynamic quantities; Gibbs free energy and other thermodynamic potentials; equipartition theorem; classical ideal gas; Gibbs paradox and its resolution; two-level systems and their thermodynamic properties.

Module II – Quantum Statistical Mechanics and Quantum Ideal Gases (15 Lectures)

Quantum statistical distributions; indistinguishability of identical particles; Bose–Einstein and Fermi–Dirac statistics; Maxwell–Boltzmann limit; chemical potential and occupation numbers; density of states and thermodynamic properties of ideal quantum gases.

Ideal Bose gas; Bose–Einstein condensation; critical temperature and condensate fraction; thermodynamic properties of Bose gases; black-body radiation as a Bose gas; phonon statistics and the concept of Bose condensation.

Ideal Fermi gas; Fermi energy, Fermi momentum and Fermi temperature; temperature dependence of the chemical potential; degenerate Fermi gas; electronic contribution to the heat capacity of metals; Fermi pressure; applications to astrophysical systems; white dwarf stars and Chandrasekhar limit.

Pauli paramagnetism and Landau diamagnetism of an electron gas; comparison of classical and quantum magnetic responses.

Module III – Density Matrix and Interacting Statistical Systems (15 Lectures)

Pure and mixed quantum states; statistical operator and density matrix; properties of the density matrix; density matrix for stationary ensembles; expectation values and thermodynamic averages; time evolution of the density operator.

Applications of the density matrix to a free particle in a box and an electron in a magnetic field; density matrix for an ensemble of spin half particles; construction of density matrices for pure states and statistical mixtures; polarization vector and spin expectation values; reduced density matrix and the concept of subsystems.

Interacting many-particle systems; exchange interaction and Heisenberg Hamiltonian; Ising model and its physical significance; Ising Hamiltonian as a simplified form of the Heisenberg model; one-dimensional Ising model; exact solution using the transfer-matrix method; thermodynamic properties and correlation functions; introduction to mean-field approximations.

Module IV – Phase Transitions, Critical Phenomena and Fluctuations (15 Lectures)

First-order and second-order phase transitions; thermodynamic criteria for phase transitions; order parameter and symmetry breaking; Landau theory of phase transitions; Landau free-energy expansion; equilibrium conditions and spontaneous symmetry breaking; critical temperature and susceptibility; elementary theory of critical phenomena.

Mean-field theory and Bragg–Williams approximation; Bethe–Peierls approximation; comparison of different approximations; limitations of mean-field theories; critical phenomena and universality; critical exponents and scaling concepts; susceptibility, correlation length and fluctuations near the critical point.
Thermodynamic fluctuations; fluctuations in energy and particle number; fluctuation–dissipation concepts; Boltzmann's H-theorem and approach to equilibrium; statistical interpretation of entropy and irreversibility; elementary discussion of critical fluctuations and their role near phase transitions.

Recommended Books:

1. R. K. Pathria and Paul D. Beale: *Statistical Mechanics*, 3rd ed., (Elsevier).
2. Kerson Huang: *Introduction to Statistical Physics*, 2nd ed., (CRC Press).
3. S. R. A. Salinas: *Introduction to Statistical Physics*, (Springer).
4. Frederick Reif: *Fundamentals of Statistical and Thermal Physics*, (McGraw-Hill).
5. Ryogo Kubo, Sadao Yokota and Sadao Nakajima: *Statistical Physics I: Equilibrium Statistical Mechanics*, (Springer).

Course Code: PHYS 202

Course Name: Electronics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Understand the fundamental concepts of electrical networks, filters, and transmission lines.
- Study semiconductor physics, carrier transport, and semiconductor devices.
- Understand the principles and applications of analog and digital communication systems.
- Develop knowledge of digital logic circuits, memory devices, and data conversion techniques.
- Introduce microprocessors, microcontrollers, programmable devices, and embedded systems.

Course Content:

Module I- Network Theory, Filter Circuit and Transmission Lines (15 Lectures)

Linear and bilateral networks, Active and passive networks, Independent and dependent sources, Mesh and nodal analysis, Source transformation, Network Theorems and their applications, Driving-point impedance and admittance, Transfer impedance and transfer admittance, Foster's reactance theorem, T and π networks, Equivalent transformation between T and π networks, Examples of transformation of a complicated network to its equivalent simple network, Symmetrical T and π networks

Concept and classification of passive and active filters, Frequency response and attenuation characteristics, Constant-k filter concept, Constant-k prototype low-pass filter, Constant-k prototype high-pass filter, Band-pass and band-reject filters — basic treatment

Distributed-parameter networks; primary and secondary transmission line constants; telegrapher's equations; characteristic impedance; reflection coefficient, VSWR, and input impedance of a lossless transmission line; impedance matching(quarter-wave transformer—qualitative);distortion of electromagnetic waves in practical transmission lines; Smith chart and its applications.

Module II: Semiconductor Physics and Devices (15 Lectures)

Energy-band theory of solids: Conductors, insulators and semiconductors, Intrinsic and extrinsic semiconductors, Carrier concentration in semiconductors, Fermi level and its temperature dependence, Degenerate and non-degenerate semiconductors, Fermi level in degenerate semiconductors, Variation of Fermi level with doping concentration and temperature, Direct and indirect band-gap semiconductors, Formation of p–n junction, Depletion region, Built-in potential

Carrier transport in semiconductors, Mobility and conductivity, Drift and Diffusion currents, Einstein relation, Generation and recombination of charge carriers, Carrier lifetime, Continuity equation — basic treatment

Light-emitting diode (LED), Semiconductor Laser, Homo and Heterojunction laser, Concept of carrier confinement, Photodetectors, Solar cell, Tunnel diode, Quantum tunneling and negative differential resistance, Semiconductor Controlled Rectifier (SCR), Unijunction Transistor (UJT), Gunn diode, IMPATT diode,

Module III: Digital Logic and Communication Fundamentals (15 Lectures)

Number systems and binary codes (BCD, Gray, ASCII), Boolean algebra and logic simplification using Karnaugh maps and the Quine–McCluskey method, logic gates and combinational circuits, arithmetic circuits, basics of sequential logic—latches and flip-flops (RS, JK, D, Master–Slave JK), multivibrators, registers and shift registers, introduction to communication systems, basic concepts of modulation, AM and FM—principles, generation and demodulation (qualitative), sampling theorem and pulse modulation, introduction to digital communication.

Module IV: Advanced Digital Electronics and Digital Communication (15 Lectures)

Analysis and design of synchronous and asynchronous counters, modulo-N, ring, and Johnson counters, memory devices (RAM and ROM), ADC and DAC, basics of microprocessors, microcontrollers, and embedded systems, memory and I/O interfacing, serial communication protocols—UART, SPI, and I^2C, digital communication systems—PCM, quantization and encoding, pulse code modulation, ASK, FSK, PSK, basic transmitter–receiver concepts, bandwidth and noise considerations and applications of digital communication.

Recommended Books:

1. J. D. Ryder: *Networks, Lines and Fields*, (Prentice Hall of India).
2. Frazier: *Telecommunications*, (Prentice Hall).

3. J. Millman and C. C. Halkias: *Integrated Electronics*, (Tata McGraw-Hill).
4. B. G. Streetman and S. K. Banerjee: *Solid State Electronic Devices*, (Pearson).
5. P. Bhattacharya: *Semiconductor Optoelectronic Devices*, (Prentice Hall of India).
6. A. Chattopadhyay and P. C. Rakshit: *Electronic Circuit Analysis*, (New Age International).
7. A. P. Malvino and D. J. Bates: *Electronic Principles*, (McGraw-Hill).
8. Anand Kumar: *Fundamentals of Digital Circuits*, (Prentice Hall of India).
9. A. P. Malvino and J. A. Brown: *Digital Computer Electronics*, (McGraw-Hill).

Course Code: PHYS 203

Course Name: Quantum Mechanics-I

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop a rigorous understanding of the mathematical formalism and fundamental postulates of quantum mechanics.
- Formulate and solve quantum-mechanical problems involving one-dimensional and three-dimensional systems.
- Develop proficiency in the mathematical formalism of quantum mechanics using vector spaces, Hilbert spaces, Dirac notation, operators, eigenvalues and eigenvectors.
- Understand observables, quantum measurements, Hermitian operators, commutation relations, uncertainty principles and complete sets of commuting observables.

Course Content

Module I: Foundations and One-Dimensional Quantum Mechanics (15 Lectures)

Review of basic concepts: wave function, probabilistic interpretation, time-independent Schrödinger equation and stationary states. One-dimensional Schrödinger equation: free particle, infinite square well, finite square well, bound and scattering states, transmission and reflection coefficients, rectangular barrier and quantum tunnelling. Linear harmonic oscillator and operator method.

Module II: Mathematical Formalism of Quantum Mechanics (15 Lectures)

Vector spaces, linear independence, basis, dimensionality and inner product; eigenvalues and eigenvectors, orthonormality and Hilbert space. Kets, bras and operators, basis kets and matrix representation, eigenkets as basis kets. Superposition and completeness of eigenstates, observables and measurement, Hermitian operators, statistical interpretation, expectation values, generalized uncertainty relation, commutators and operator algebra, non-commuting observables, complete sets of commuting observables and change of basis.

Module III: Quantum Mechanics in Three Dimensions and Hydrogen Atom (15 Lectures)

Schrödinger equation in three dimensions; three-dimensional box and harmonic oscillator; symmetry and degeneracy. Schrödinger equation in spherical coordinates; orbital angular momentum, commutation relations and ladder operators; eigenvalues and eigen functions of angular momentum; spherical harmonics and parity. Quantum mechanics of a particle in a central potential; separation of radial and angular equations; Coulomb potential and hydrogen atom; radial wave functions, probability distributions, quantum numbers, energy spectrum and degeneracy of hydrogenic states; orbital angular momentum, spherical harmonics and parity of hydrogen-atom states.

Module IV: Approximation Methods in Quantum Mechanics (15 Lectures)

Time-independent perturbation theory for non-degenerate and degenerate states, with applications to the anharmonic oscillator and Stark effect in hydrogen. Variational method and applications to the delta-function potential, the ground state of helium atom; WKB approximation: general formulation, connection formulas and application to alpha decay.

Recommended Books:

1. D. J. Griffiths and D. F. Schroeter: *Introduction to Quantum Mechanics*, (Cambridge University Press).
2. P. A. M. Dirac: *The Principles of Quantum Mechanics*, (Oxford University Press).
3. A. Messiah: *Quantum Mechanics*, (Dover Publications).
4. C. Cohen-Tannoudji, B. Diu and F. Laloë: *Quantum Mechanics*, (Wiley).
5. L. I. Schiff: *Quantum Mechanics*, (McGraw-Hill).

Course Code: PHYS 204

Course Name: Optics Practical

Credit: 4
Total Contact Hours: 120

List of Experiments:

1. **Study of Iodine Vapour Spectrum**
   Study the absorption spectrum of iodine vapour using an optical spectrometer and determine the dissociation energy and anharmonicity constant from the observed spectral bands.
2. **Wavelength Measurement Using Michelson Interferometer**
   Determine the wavelength of a monochromatic light source using a Michelson interferometer by measuring the displacement of interference fringes.
3. **Study of Zeeman Effect**
   Study the normal Zeeman effect and determine the Landé g-factor from the observed spectral line splitting in a magnetic field.
4. **Verification of Malus' Law**
   Study the polarization properties of laser light and verify Malus' law by measuring the transmitted intensity as a function of analyzer angle.
5. **Study of Photoconductivity of a Semiconductor**
   Study the variation of photoconductivity with illumination and applied voltage, and determine relevant photoelectric parameters such as dark current, photocurrent, and sensitivity.
6. **Study of Electron Spin Resonance (ESR)**
   Study the ESR spectrum of a suitable paramagnetic sample and determine the resonance condition and spectroscopic g-factor.
7. **Determination of Specific Charge of Electron**
   Determine the specific charge (e/m) of the electron using Thomson's method by studying the deflection of an electron beam in electric and magnetic fields.
8. **Study of Optical Fibre Characteristics**
   Study the transmission characteristics of an optical fibre and determine its acceptance angle, numerical aperture, attenuation, and bending losses.

Course Code: PHYS 205 (A)

Course Name: Laser Physics and Optoelectronics

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

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

- Develop an advanced understanding of laser amplification, gain mechanisms, line broadening, and threshold conditions.
- Analyze population and photon rate equations governing different laser systems and their dynamics.
- Understand laser resonators, longitudinal and transverse modes, mode selection, and frequency control.
- Study continuous-wave and pulsed laser operation, including Q-switching and mode-locking techniques.
- Familiarize students with important gas, solid-state, dye, and semiconductor laser systems and their applications.
- Develop knowledge of optical fibres and optoelectronic devices, including propagation, dispersion, attenuation, splicing.

Course Content:

Module I: Fundamentals of Laser Physics and Optical Amplification(15 Lectures)

Laser oscillation and amplification, interaction of radiation with an active medium, gain and loss mechanisms, line-shape functions and spectral profiles, homogeneous and inhomogeneous broadening, natural, collision and Doppler broadening, Lorentzian and Gaussian line shapes, complex line profiles and spectral linewidth, gain coefficient and small-signal amplification, population inversion and its relation to optical gain, threshold condition and threshold population inversion, pumping mechanisms, gain saturation and saturation intensity, amplification and propagation of radiation through an active medium, gain–loss balance and laser threshold.

Module II: Population Rate Equations and Laser Dynamics(10 Lectures)

Population rate equations for two-level, three-level and four-level laser systems, steady-state population distribution, conditions for population inversion, threshold pumping rate, photon rate equation, variation of photon number near and above threshold, laser turn-on and transient behaviour, relaxation oscillations, continuous-wave laser operation, pulsed laser operation, laser efficiency, output characteristics and stability of laser oscillation.

Module III: Laser Modes and Different Laser Systems(20 Lectures)

Optical resonators and feedback, resonator stability, longitudinal and transverse modes, mode frequencies and mode spacing, methods of reducing the number of oscillating modes, open resonator cavity, mode selection and frequency stabilization, continuous-wave and pulsed laser systems, Q-switching and giant-pulse generation, active and passive Q-switching, mode locking and ultrashort pulse generation, pulse duration and repetition rate, comparison of Q-switched and mode-locked lasers, important laser systems including gas, solid-state, dye and semiconductor lasers.

Module IV: Fibre Optics and Optoelectronic Systems(15 Lectures)

Dielectric waveguides and optical fibre principles, numerical aperture and acceptance angle, normalized frequency (V-number) and waveguide parameters, step-index and graded-index fibres, single-mode and multimode fibres, propagation modes, cutoff condition, material and waveguide dispersion, pulse broadening and intermodal dispersion, attenuation mechanisms, fibre coupling, splicing and splice loss, connectors and couplers, fibre-optic communication link

Recommended Books:

1. K. Thyagarajan and A. Ghatak: *Lasers: Fundamentals and Applications*, (Macmillan).
2. A. Ghatak and K. Thyagarajan: *Introduction to Fibre Optics*, (Cambridge University Press).
3. O. Svelto: *Principles of Lasers*, (Springer).
4. P. Milonni and J. Eberly: *Laser Physics*, (John Wiley & Sons).
5. A. E. Siegman: *Lasers*, (University Science Books).
6. B. E. A. Saleh and M. C. Teich: *Fundamentals of Photonics*, (John Wiley & Sons).
7. J. Wilson and J. F. B. Hawkes: *Optoelectronics: An Introduction*, (Prentice Hall).
8. R. W. Boyd: *Nonlinear Optics*, (Academic Press).

Course Code: PHYS 205(B)

Course Name: Advanced Mathematical Methods

Credit: 4
Lectures: 60, Tutorials: 20
Total Contact Hours: 80

Course Objectives:

After successful completion of the course students will be able to

- Provide systematic knowledge of group theory and its applications to symmetry, transformations, and physical systems.
- Develop the ability to formulate and solve first-order partial differential equations using analytical methods such as Lagrange's, Charpit's, Cauchy's, and Jacobi's methods.
- Introduce tensor analysis and develop proficiency in tensor algebra, coordinate transformations, metric tensors, and related mathematical structures used in theoretical physics.
- Develop an understanding of asymptotic methods and perturbation techniques for obtaining approximate solutions to complex physical problems.
- Familiarize students with regular and singular perturbation methods, multiple-scale analysis, boundary-layer theory, WKB approximation, and asymptotic evaluation of integrals.

Course Content:

Module I: Group Theory (20 Lectures)

Groups: Definition and examples; order of a group; multiplication table; rearrangement theorem; generators of a finite group; conjugate elements and conjugacy classes; subgroups; Cayley's theorem; cosets; Lagrange's theorem; direct product of groups; invariant subgroups; factor groups; isomorphism and homomorphism; permutation groups; distinct groups of a given order; cyclic and non-cyclic groups.

Group representations: definition of representation; faithful and unfaithful representations; equivalent representations; invariant subspaces; reducible and irreducible representations; Schur's lemmas; orthogonality theorem; construction of selected groups such asC_2v, C_3v, and $D_{2h.}$

Discrete, continuous, and mixed continuous groups; topological and Lie groups; axial rotation group SO(2); rotation group SO(3); special unitary groups SU(2) and SU(3), with applications in physics.

Module II: Partial Differential Equations (10 Lectures)

First-order partial differential equations: formation and classification; linear and quasi-linear equations; Lagrange's auxiliary equations and Lagrange's method; geometrical interpretation of first-order PDEs and characteristic curves; nonlinear first-order PDEs; complete, general, and singular integrals; Charpit's method; Cauchy's method of characteristics; Jacobi's method; initial and boundary-value problems; applications of first-order PDEs in mathematical physics.

Module III: Tensor Analysis (15 Lectures)

Review of basic Tensor analysis. Tensor fields and mixed tensors; quotient theorem and reciprocal tensors; Euclidean and Riemannian spaces; metric tensor and raising/lowering of tensor indices; Christoffel symbols and covariant differentiation; covariant forms of gradient, divergence and curl; geodesics and equations of geodesic motion; curvature tensor, Ricci tensor and scalar curvature; basic applications of tensor analysis in General Relativity and mathematical physics.

Module IV: Asymptotic Methods and Perturbation Theory (15 Lectures)

Asymptotic expansions; asymptotic sequences and series; Poincaré asymptotic expansions; dominant balance; regular and singular perturbation methods; method of multiple scales; boundary-layer theory; matched asymptotic expansions; WKB approximation; stationary-phase and steepest-descent methods; applications of perturbation and asymptotic methods to wave propagation, quantum mechanics, differential equations, and nonlinear physical systems.

Recommended Books:

1. J. Mathews and R. L. Walker, Mathematical Methods of Physics (W. A. Benjamin).
2. M. R. Spiegel, Theory and Problems of Advanced Mathematics for Engineers and Scientists (Schaum's Outline Series).
3. P. Dennery and A. Krzywicki, Mathematics for Physicists (Harper & Row).
4. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for Physics and Engineering (Cambridge University Press).
5. J. F. Cornwell, Group Theory in Physics: An Introduction (Academic Press).
6. J. M. Simmonds and J. E. Mann, Jr., A First Look at Tensor Analysis: With Applications to Mechanics and Physics (Dover Publications).
7. C. M. Bender and S. A. Orszag, Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory (Springer).
8. G. Arfken, H. J. Weber and F. E. Harris, Mathematical Methods for Physicists (Academic Press).

Course Code: PHYS 206

Course Name: Digital and Analog Circuit Design and Analysis

Credit: 4
Total Contact Hours: 120

List of Practical Experiments

1. Design and Study of Operational Amplifier Circuits

To design and study inverting, non-inverting, summing, differential, integrator, differentiator, precision rectifier, and Schmitt trigger circuits using standard op-amp ICs and determine relevant circuit parameters.

2. Design and Study of Active/Passive Filters

To design and study first- and/or second-order active/passive low-pass, high-pass, band-pass, and band-stop filters and determine cut off frequency, bandwidth, gain, and frequency response.

3. Study and Characterization of Semiconductor Devices

To study the characteristics of LED, solar cell, MOSFET, and tunnel diode (where available) and determine relevant device parameters from experimental characteristics.

4. Generation and Study of AM Modulation and Demodulation

To generate an amplitude-modulated (AM) signal, determine its modulation index, study AM demodulation, and observe the carrier, modulating, and modulated waveforms using an oscilloscope.

5.Generation and Study of Frequency Modulation

To generate a frequency-modulated (FM) signal and determine carrier frequency, frequency deviation, and modulation index. Study the variation of frequency deviation and observe the FM waveform and spectrum.

6.Design and Verification of Combinational Logic Circuits

To design and implement half/full adders,subtractors, comparators, and code converters using standard logic ICs. Formulate truth tables, simplify Boolean expressions using Karnaugh maps, and verify the circuit outputs

7. Study of Multivibrators

To design and study astable, monostable, and bistable multivibrators, VCOs using IC 555 and/or logic gates.

8. Study of Registers and Counters

To study shift registers, ring counters, Johnson counters, and synchronous/asynchronous counters and observe their timing waveforms.

9. Design, Interfacing and Calibration of Sensors

To design and interface temperature, light, or pressure sensors (e.g., LM35/DS18B20, LDR, or pressure sensor) with suitable signal-conditioning circuits; calibrate the sensor against known standards and determine sensitivity, linearity, response, and measurement accuracy.

10. Basic Programming of 8085/8086 Microprocessor

Development and execution of simple 8085/8086 programs for: (a) average of a set of numbers, (b) testing even/odd numbers, (c) addition of two-byte numbers, and (d) multiplication of two 8-bit numbers.

11. Power Supply and Voltage Regulation

Study of half-wave/full-wave/bridge rectifiers, capacitor filtering, and regulated power supplies. Determination of ripple factor, regulation, and load characteristics.

Recommended Books:

1. A. P. Malvino and D. J. Bates, *Electronic Principles* (McGraw-Hill).
2. Robert L. Boylestad and Louis Nashelsky, *Electronic Devices and Circuit Theory* (Pearson).
3. J. Millman and C. C. Halkias, *Integrated Electronics: Analog and Digital Circuits and Systems* (McGraw-Hill).
4. R. P. Jain, *Modern Digital Electronics* (McGraw-Hill).
5. P. B. Zbar, A. P. Malvino and M. A. Miller, *Basic Electronics: A Text-Lab Manual* (McGraw-Hill).

6. David A. Bell, *Electronic Devices and Circuits* (Oxford University Press).
7. Ramakanth A. Gayakwad, *Op-Amps and Linear Integrated Circuits* (Pearson).
8. M. Morris Mano and Michael D. Ciletti, *Digital Design* (Pearson).
9. Adel S. Sedra and Kenneth C. Smith, *Microelectronic Circuits* (Oxford University Press).
10. Paul Horowitz and Winfield Hill, *The Art of Electronics* (Cambridge University Press).

Note: The syllabus, including its course contents, modules (theoretical and laboratory components), may be revised, modified, or updated from time to time, as deemed necessary, on the recommendation of the Post Graduate Board of Studies (PGBOS) and with the approval of the competent authority.