FOUR YEAR UNDERGRADUATE (FYUG) PROGRAMME

UNDER

NEW EDUCATION POLICY, 2020

PHYSICS

Date of approval in Academic Council -30th May and 21st June 2024

Preface

This syllabus outlines the curriculum for the Four-Year Undergraduate Programme (FYUG) in Physics, designed as per the guidelines of the National Education Policy 2020 (NEP-2020). Following NEP's recommendations, the programme offers students multiple exit and entry options while allowing them to pursue the following:

(i) A certificate upon completing one year of study;
(ii) A diploma upon completing two years of study;
(iii) A 3-year UG degree after completion of three years of study; and
(iv) A UG Honours or UG Honours with Research after completion of a 4-year programme.

The programme aims to foster academic excellence, research proficiency, and professional development within students. The carefully designed curriculum aims to cultivate a deep interest in Physics, equipping students with the tools to explore the Universe and develop innovative technologies that will shape the future. Students will gain a strong foundation in fundamental concepts, principles, and theories that underlie the field of physics.

The programme also incorporates laboratory work, enabling students to bridge the gap between theoretical knowledge and experimental observations and practical exercises with real-world applications of the theoretical concepts learned, which enhances their scientific skills.

Considering the latest advancements in Physics, the programme encompasses various branches/sub-disciplines of Physics. These include Mechanics, Electricity & Magnetism, Heat & Thermodynamics, Acoustics, Classical Mechanics, Quantum Mechanics, Special Theory of Relativity, Optics, Electronics, Thermal & Statistical Physics, Solid State Physics, Atomic & Molecular Physics, Nuclear & Particle Physics, Computational Physics, and Experimental Physics. At the end of the programme, students are expected to possess a solid foundation in core Physics principles, preparing them for the future in research, teaching or technical endeavours.

Programme Outcomes

Upon successful completion of this program, the students would be able to:

- Understand different branches of physics and other related allied Physics subjects.
- Develop critical thinking ability using basic physics knowledge and concepts to explain some natural phenomena.
- Apply appropriate theories to solve problems of a physical nature.
- Identify, formulate, and solve physics problems by intelligent guessing, formulating appropriate models and theories, and at the same time, holding an element of doubt and thereby hoping to modify it in terms of future experience and practising a pragmatic outlook.
- Understand the basic principles of instruments used in the physics laboratory, design and conduct experiments, analyse results and interpret data.
- Use the techniques, skills, and sophisticated instruments in real-world applications.
- Recognise the importance of mathematical modelling, simulation, and computational methods, as well as the role of approximation and mathematical approaches in describing the physical world and beyond.
- Conduct physics experiments, record, analyse and interpret experimental data through quantitative and qualitative methods.
- Communicate scientific findings effectively through written reports, presentations, and discussions.
- Use appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of physics.
- Have competence in the methods and techniques of theoretical, experimental, and computational physics to achieve an overall understanding of the subject for holistic development.

Structure of the Syllabus (Physics)

1st Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-100	Mathematical Physics I, Properties of Matter and Waves (Major)	3	1	4	75
PHY-100	Mathematical Physics I, Properties of Matter and Waves (Minor)	3	1	4	75
MDC-110. ... 119	Any one of the available courses as notified by the University from time to time.	3	-	3	45
AEC-120….129	Any one of the available courses as notified by the University from time to time.	3	-	3	45
SEC-130… .. 139	Any one of the available courses as notified by the University from time to time.			3	45-90
VAC-140	Available courses as notified by the University from time to time	3	-	3	45
				20	

2nd Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-150	Electricity & Magnetism, Optics I and Electronics I (Major)	3	1	4	75
PHY-150	Electricity & Magnetism, Optics I and Electronics I (Minor)	3	1	4	75
MDC-160…..169	Any one of the available courses as notified by the University from time to time.	3	-	3	45
AEC-170…..179	Any one of the available courses as notified by the University from time to time.	3	-	3	45
SEC-180……189	Any one of the available courses as notified by the University from time to time.			3	45-90
VAC-190… .. 199	Any one of the available courses as notified by the University from time to time.	3	-	3	45
				20	

3rd Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-200	Mathematical Physics II and Experimental Physics III	3	1	4	75
PHY-201	Heat & Thermodynamics and Experimental Physics IV	3	1	4	75
MDC-210…..219	Physics Around Us	3	3	3	45
AEC-220…..229	Any one of the available courses as notified by the University from time to time.	2	-	2	30
SEC-230……239	Any one of the available courses as notified by the University from time to time.			3	45-90
VTC -240…..249	Any one of the available courses as notified by the University from time to time.	1	3	4	105
				20	

4th Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-250	Optics II and Acoustics	4	-	4	60
PHY-251	Classical Mechanics I and Special Theory of Relativity	4	-	4	60
PHY-252	Quantum Mechanics I	4	-	4	60
PHY-253	Experimental Physics V		4	4	120
VTC-260….269	Any one of the available courses as notified by the University from time to time	1	3	4	105
				20	

5th Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-300	Electromagnetic Theory	4	-	4	60
PHY-301	Electronics II and Computational Physics I	4	-	4	60
PHY-302	Thermal and Statistical Physics	4	-	4	60
PHY-302	Modern Physics I (Minor)	4	-	4	60
PHY-303	Internship/Apprenticeship/Community engagement and service/ field-based learning or minor project	-	4	4	120
				20	

6th Semester

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
PHY-350	Solid State Physics (Major)	4	-	4	60
PHY-351	Atomic and Molecular Physics	4	-	4	60
PHY-352	Nuclear and Particle Physics	4	-	4	60
PHY-353	Experimental Physics VI	-	4	4	120
VTC-360…369	Any one of the available courses as notified by the University from time to time	1	3	4	105
				20	

*Multidisciplinary Course (MDC) is an introductory course for students who have not studied physics in Class XI and XII.

** In the 5th Semester, there is no practical in physics as all students will undergo four internship credits.

Instructions for 3rd Semester

The theory examination for 3rd Semester will be 75 each, whereas the practical examination will be 25 marks each. Each student has to perform one experiment for 4 hours. Internal assessment in (a) Theory will be based on sessional tests and assignments, (b) Practical will be based on performance in the laboratory work and the number of practicals completed during class hours.

I. **Course Code: PHY – 200**
Course Title: MATHEMATICAL PHYSICS II AND EXPERIMENTAL PHYSICS III
Total Contact Hours: 75 (45 (T) + 30 (P))

Course Objectives: Mathematical Physics will enable the learners to understand advanced mathematical concepts required to solve various problems in different branches of physics. Practicals will help learners to understand the fundamentals of electronics, electricity, and magnetism.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the curvilinear coordinates and apply them to solve problems with cylindrical and spherical symmetry.
- Apply the complex analysis method to solve problems involving complicated differentiations and integrations in various physics branches.
- Use series methods to solve the Legendre and Hermite differential equations.
- Solve partial differential equations that arise in various fields of physics.
- Learn about different types of matrices and apply them to solve simple problems in physics.
- Learn and utilise gamma and beta functions to solve categories of integrals.
- Gain practical experience to help them understand the basic operation of some electronic devices.
- To verify basic laws of electricity and magnetism.

Part A (Theory: 75 Marks; Internal: 19, End Term: 56)

Unit I **(17 hours)**

Orthogonal curvilinear coordinates: Cylindrical and spherical polar coordinates, Introduction to gradient, divergence, curl, and Laplacian in terms of curvilinear coordinates.

Complex Variables: Basic idea of complex numbers, Functions of complex variables, Analytic functions, Cauchy-Riemann conditions, Cauchy's theorem (with proof), Cauchy's integral formula (with proof), Simply and multiply connected regions, Taylor series and Laurent series (without proof), Poles and residues, Cauchy residue theorem (with proof), Applications of residue theorem in integrals of functions having simple poles.

Unit II **(14 hours)**

Second order linear differential equations: Singular points, Importance of second order linear differential equations, Frobenius method and its applications to differential equations:

(a) Legendre Polynomial- Solutions of Legendre differential equation in terms of Legendre polynomial $P_n(x)$, Generating function of $P_n(x)$, Recurrence relation for $P_n(x)$, Rodrigue's formula for $P_n(x)$, Orthogonality of $P_n(x)$;

(b) Hermite Polynomial- Solutions of Hermite differential equation in terms of Hermite Polynomials $H_n(x)$, Generating function of $H_n(x)$, Recurrence relations for $H_n(x)$, Rodrigue's formula for $H_n(x)$, Orthogonality of $H_n(x)$.

Partial differential Equations: Solutions of partial differential equations by separating variables and their application to the solution of the heat flow equation in one dimension.

Unit III

(14 hours) Matrices: Different types of matrices, Properties of symmetric, skew-symmetric, Hermitian, and skew-Hermitian matrices, Characteristic equation, Eigen values and eigen vectors of a matrix and matrix diagonalisation (only for 2 x 2 matrices).

Jacobian, Properties of Jacobian, Jacobian of Implicit functions.

Gamma and beta functions: Definition of gamma and beta functions as definite integrals, Recursion formula of gamma functions, Euler's reflection formula: $\Gamma(x)\,\Gamma(1 - x) = \pi / \sin(\pi x)$ (without proof), Legendre duplication formula, Evaluation of $\Gamma(1/2)$, Evaluation of gamma functions for rational and negative numbers using recursion, Euler reflection, and Legendre duplication formulae, Relationship between gamma and beta functions, Evaluation of definite integrals using beta and gamma functions.

Part B (Practical: 25 Marks; Internal: 6, End Term: 19)

Unit IV: Experimental Physics III **(30 hours)**

1. To design OR, AND, and NOT gates using NAND/NOR gates.
2. To determine the energy gap of a semiconductor diode.
3. To draw the characteristics of an LDR
4. To draw the characteristics of a photodiode.
5. To study the characteristics of a diode clipper.
6. To determine the electrochemical equivalent of copper using a copper voltameter.
7. To determine the magnetic moment of a bar magnet (M) and the value of the horizontal component of the earth's magnetic field (H) using deflection and vibration magnetometers.
8. To study Biot Savart's law.

Suggested readings: (All latest editions)

1. Mathematical Physics, H.K. Dass and Rama Verma, S. Chand and Company.
2. Mathematical Methods for Physicist, G. Arfken, Academic Press Inc, Prism Book Pvt. Ltd.
3. Mathematical Physics, B. D. Gupta, Vikash Publishing House.
4. Introduction to Mathematical Physics, C. Harper, Prentice Hall of India Pvt. Ltd.
5. Matrices and Tensors, A.W. Joshi, Wiley Eastern.
6. B.Sc. Practical Physics, C.L. Arora, S. Chand and Co.
7. A Textbook of Practical Physics, K.G. Majumdar, Syndicate Press.
8. Mathematical Methods in the Physical Sciences, Mary L. Boas, Wiley.

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II. **Course Code**: **PHY – 201**
Course Title: HEAT & THERMODYNAMICS AND EXPERIMENTAL PHYSICS IV
Total Contact Hours: 75 (45 (T) + 30 (P))

Course Objectives: The theory of this course will help the learners to understand various concepts and phenomena of Heat and Thermodynamics & the related applications. Practicals will help learners determine various constants /coefficients related to Mechanics, radiation, Heat and Thermodynamics.

Learning Outcomes:

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

- Understand the limitation of the kinetic theory of gases and apply the Van der Waals equation to account for the behaviour of real gas and evaluate critical constants.
- Learn about various physical quantities related to transport phenomena and the concept of Brownian motion.
- Understand the concept of entropy and apply the laws of thermodynamics to solve related problems.
- Learn about different methods of liquefaction of gases.
- Understand the various laws governing black body radiation.
- Gain practical experience and determination of various physical quantities related to heat transfer, mechanics, and radiation.

Part A (Theory: 75 Marks; Internal: 19, End Term: 56)

Unit I **(15 hours)**

Review of kinetic theory of gases, Limitations of the ideal gas equation P.V. = nRT, Van der Waals equation and evaluation of critical constants of a real gas, Degrees of freedom, Law of equipartition of energy and it's application to obtain γ (= C_P/C_V) of monatomic and polyatomic gases.

Transport phenomena: Calculation of mean free path, Clausius mean free path and estimation of molecular diameter, Viscosity, Thermal conductivity, and Diffusion of a gas, Einstein's theory of Brownian motion, Langevin's Theory of Brownian motion.

Unit II **(15 hours)**

Laws of thermodynamics**:** Thermodynamic variables - Extensive and Intensive variables, Zeroth Law: Example and applications, Indicator diagram, Work done, First Law, Internal energy, Application of the First Law: Calculation of C_p - C_v for an ideal gas, Reversible and irreversible process, Carnot cycle and efficiency of Carnot engine, Carnot theorem, Carnot cycle as refrigerator, Second Law, Entropy as a thermodynamic variable, Entropy change in reversible and irreversible processes, Principle of increase of entropy, Entropy of an ideal gas, Entropy and unavailable energy, Thermodynamic scale of temperature and its identity with perfect gas scale, Impossibility of attaining absolute zero, Third Law and it's applications.

Unit III **(15 hours)**

Liquefaction: Cooling by Adiabatic expansion, Principle of Regenerative cooling, Linde's air liquefier, Principle of Cascaded cooling, Liquefaction of Oxygen and Hydrogen, Adiabatic Demagnetization.

Radiation: Black body radiation and its spectral energy distribution, Kirchhoff's Law (derivation and applications), Pressure of diffuse radiation, Stefan's law and Stefan-Boltzmann law, Wien's displacement law, Rayleigh-Jeans law (statements), Ultraviolet Catastrophe, Planck's Law (derivation), Wien's Law and Rayleigh-Jeans law from Planck's Law.

Part B (Practical: 25 Marks; Internal: 6, End Term: 19)

Unit IV: EXPERIMENTAL PHYSICS IV **(30 hours)**

1. Determination of the coefficient of linear expansion of a solid using Pullinger's apparatus and optical lever.
2. Determination of the specific heat of a liquid by the method of cooling.
3. Determination of the mechanical equivalent of heat by Joule's calorimeter.
4. Determination of the coefficient of thermal conductivity of a good conductor by Searle's method.
5. Measurement of temperature (e.g., melting point/boiling point of a substance) using a Thermocouple.
6. Determination of the coefficient of thermal conductivity of a bad conductor by Lee's method.
7. Determination of Planck's constant by a photocell or by heating method.
8. Determination of Young's modulus and Poisson's ratio of glass by Cornu's method.

Suggested readings: (All latest editions)

1. Heat and Thermodynamics, Brij Lal and N. Subrahmanyam, and P.S. Hemne, S. Chand, New Delhi.
2. Heat and Thermodynamics, Jeremy Tatum, University of Victoria (e-book).
3. Heat and Thermodynamics, M.W. Zemansky and R.H. Dittman, McGraw Hill, Singapore.
4. Thermal Physics, S.C. Garg, R.M. Bansal and C.K. Ghosh, Tata McGraw Hill Publications.
5. B. Sc. Practical Physics, C.L. Arora, S. Chand and Co.
6. A Textbook of Practical Physics, K.G. Majumdar, Syndicate Press.

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III. **Course Code**: **MDC-**
Course Title: PHYSICS AROUND US
Total Contact Hours: 45
Full-marks: 75

Course Objectives: The course aims to provide knowledge of the basic laws of physics governing familiar phenomena and different physical activities in our daily lives.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the fundamental units and compare the scale of objects in the Universe, ranging from the smallest particles to the largest structures.
- Explain motion with the help of Newton's laws.
- Explain the concept of gravity using Newton's Law of Gravitation and it's application in launching a satellite.
- Utilise the laws of reflection to predict image formation by spherical mirrors and the laws of Refraction to predict image formation by spherical lenses and bending of objects in water.
- Understand the basic idea of waves and their properties.
- Understand the basic concepts of static electricity and magnetism and some of their applications.
- Learn about electromagnetic waves and their Importance in communication systems.

Unit I **(17 hours)**

Basic idea of fundamental units and their dimensions, Scale of objects in the Universe from the smallest to the biggest, Scalar and Vector quantities with examples.

Concept of motion, Understanding of Speed, Velocity, and Acceleration, Idea of inertia, Idea of momentum as a measure of motion, Force as the cause of motion, Newton's laws of motion and their applications in daily life, Newton's Law of Gravitation, Acceleration due to gravity, Mass and weight, Apparent weight, Weightlessness, Escape velocity, Rotational motion, Torque, Introductory idea of Centripetal and Centrifugal forces, Kepler's Law of Planetary motion, Natural and Artificial satellites.

Concept of Work, Energy, and Power, Potential and Kinetic energies. Law of conservation of energy and its applications in everyday activities, Thermal energy, Temperature, Different temperature scales – degrees Celsius, Fahrenheit, and Kelvin. Density, Pressure, Statement of Archimedes principle and Bernoulli's theorem and their applications.

Unit II **(15 hours)**

Elementary ideas of Reflection, Refraction, Refractive index, Total internal reflection, Interference, Diffraction, Scattering, and their examples in daily life: Apparent depth, Blue colour of the sky, Twinkling of stars, Mirages, Sparkling of diamonds, Primary and Secondary rainbows, Optical fibres.

Spherical mirrors (Concave and convex mirrors) and their applications, Lenses: Focal length, Power of a lens, Defects in the human eye – Myopia, Hypermetropia, Presbyopia, and Astigmatism and their corrections by the lens.

Wave motion, Properties, and illustrations of longitudinal and transverse waves, Basic idea of Frequency, Wavelength, and Amplitude.

Sound waves and their propagations, Echo, Doppler Effect (qualitative idea).

Unit III **(13 hours)**

Elementary idea of electric Charge, Voltage, and Current (D.C. and A.C.), Ohm's law and simple electrical circuits containing active and passive elements, Electrical Power, Commercial unit of electrical energy, Power rating of household appliances, BEE star rating.

Elementary idea of Magnetism, Different types of magnetism, Earth's magnetic field and magnetic compass, Basic idea of Faraday's law of electromagnetic induction and its applications, Induction cooker and transformer.

Electromagnetic (E.M.) waves: Speed of E.M. waves, Characterisation of E.M. waves based on frequency, wavelength, and energy. Electromagnetic wave spectrum, Use of electromagnetic waves in communications, e.g., T.V., Mobile Phones, FM Radio.

Suggested readings: (All latest editions)

1. Physics Around Us: How & Why Thinks Work, Ernest M Hanley and J Gregory Dash, World Scientific.
2. The World Around Us: A Modern Guide to Physics, Paul Karlson, Kessinger Publishing.
3. Physics of Everyday Phenomena, W. Thomas Griffith, McGraw Hill.
4. Feynman lectures in Physics Vol. I, II, III, R. P. Feynman, R. B. Leighton, and M. Sands, Pearson Education.
5. Concept of Physics, H. C. Verma, Bharati Bhawan.
6. Fundamentals of Physics with Applications, Arthur Beiser, McGraw Hill Education.

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Instructions for 4th Semester

The theory and practical examinations for the 4th Semester will be 100 Marks. Each student has to perform one experiment for 6 hours. Internal assessment in (a) Theory will be based on sessional tests and assignments, (b) Practical will be based on performance in the laboratory work and the number of practicals completed during class hours.

I. **Course Code: PHY-250**
Course Title: OPTICS II AND ACOUSTICS
Total Contact Hours: 60
Full-marks: 100

Course Objectives: This course offers knowledge and understanding of the various concepts of Optics and Acoustics.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the basics of geometrical optics and related optical instruments and their applications.
- Learn about various optical instruments and phenomena involving interference and diffraction of light.
- Analyse the periodic functions in terms of the Fourier series.
- Learn about various applications of ultrasonic waves and analyse the reverberation and acoustics of buildings.

Unit I **(10 hours)**

Aberration in images: Chromatic aberration, Achromatic combination of lenses in contact and separation, Monochromatic aberrations and their reductions, Aplanatic points of a sphere (with proof), Oil-immersion objectives.

Optical instruments: Ramsden eye-piece and Huygens eye-piece and their relative merits and demerits.

Unit II **(15 hours)**

Interference of light: Phase change on reflection (Stokes' treatment), Temporal and spatial coherence, Fringes produced by wedge-shaped thin films (reflected and transmitted light), Fringes of equal thickness, equal inclination, and Haidinger fringes. Theory of Newton's rings and it's applications in the determination of wavelength of monochromatic light.

Interferometers: Michelson interferometer- Construction and production of fringes (qualitative ideas), it's applications for determining the wavelength and wavelength difference, Intensity distribution in multiple beam interference, Fabry-Perot interferometer- Construction and production of fringes.

Unit III **(20 hours)**

Diffraction of light: Fresnel diffraction- half-period zones, zone plates, straight edge, and rectilinear propagation. Fraunhofer diffraction- single slit, double slit, N-slits, theory of plane diffraction grating, Resolution of images, Resolving Power of Fabry-Perot interferometer and plane gratings.

Polarisation: Different production and detection methods of polarised light (linear and circular), Quarter wave-plate and half wave-plate, Double refraction in uniaxial crystals (it's electromagnetic theory), Rotation of plane of polarisation, Brewster's Law, Fresnel's theory of optical rotation.

Dispersion and scattering: Theory of dispersion of light, Absorption bands, Normal and anomalous dispersion, Rayleigh scattering (qualitative).

Unit IV **(15 hours)**

Fourier Analysis: Fourier series and Fourier coefficients, Simple examples - Square wave, theory of struck string.

Ultrasonics: Piezoelectric effect and it's application for producing and detecting ultrasonic waves, Application of ultrasonic waves, Principle of ultrasonography.

Sound and Noise: Intensity of sound, bel and decibel, Limit of human audibility, Noise and noise reduction (qualitative discussions only).

Acoustics of buildings: Requirements of a good auditorium, Reverberation and optimum reverberation, Derivation of Sabine's formula for reverberation time, live and dead room.

Suggested readings: (All latest editions)

1. Optics, Ajoy Ghatak, McGraw Hill.
2. Modern Optics, A. B. Gupta, Books and Allied (P) Ltd.
3. A Textbook of Optics, N. Subrahmanyam, Brij Lal, M. N. Avadhanlu, S. Chand & Company Ltd.
4. Vibrations, Waves & Aoustics, D. Chattopadhyay, P. C. Rakshit, Books & Allied (P) Ltd.
5. Fundamentals of Optics, Devraj Singh, PHI Learning.
6. Acoustics, Waves and Oscillations, S. N. Sen, New Academic Science.

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II. **Course Code: PHY-251**
Course Title: CLASSICAL MECHANICS I AND SPECIAL THEORY OF RELATIVITY
Total Contact Hours: 60
Full-marks: 100

Course Objectives: This course introduces the Lagrangian and Hamiltonian formulations of classical mechanics and the ability to analyse simple, dynamical systems. The course also introduces the special theory of relativity and the paradigm-changing implications of Newtonian mechanics.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the concepts of constraints, degrees of freedom and virtual work.
- Utilise Lagrangian and Hamiltonian formulations to derive equations of motion for simple systems.
- Utilise symmetries in a system to identify conserved quantities like energy and momentum.
- Understand the limitation of Galilean transformations in the inertial and non-inertial frames.
- Apply Lorentz transformations to analyse relativistic effects like length contraction and time dilation.
- Understand space-time as a four-dimensional construct and concept of proper time.
- Understand the concept of mass-energy equivalence arising from special relativity.

Unit I **(15 hours)**

Limitations of Newtonian formulation, Lagrangian formulation: Degrees of freedom, Constraints (holonomic and non-holonomic with examples), Generalised coordinates, Transformation equations, Generalised notations for displacement, velocity, acceleration, momentum, and force. Virtual work, Principle of virtual work, d'Alembert's principle, Lagrangian, Lagrange's equation of motion, Applications of Lagrange's equation: Motion of single particle (Cartesian and polar coordinates) and simple pendulum.

Unit II **(15 hours)**

Legendre transformation, Hamilton's formulation: Phase space, Derivation of Hamilton's Principle from Lagranges's equations and vice-versa, Generalised momentum, Hamiltonian and it's significance, Hamilton's equations of motions in different coordinates (Cartesian, polar, cylindrical, and spherical coordinates), Applications of Hamilton's equations (Harmonic oscillator, Particle moving in a central force field in space), Advantages of Hamiltonian formulation over Lagrangian formulation.

Unit III **(15 hours)**

Special Theory of Relativity: Galilean transformation (G.T.), Invariance of Newton's laws of motion under G.T. and non-invariance of electromagnetism under G.T. (qualitative), Absolute frame and ether, Michelson-Morley experiment and it's results, Postulates of Special Theory of Relativity, Lorentz Transformations (L.T.), Inverse Lorentz Transformation, G.T. as a limiting case of L.T., Relativistic velocity addition.

Unit IV **(15 hours)**

Application of the special theory of relativity: Length contraction, Time-dilation, Variation of mass with velocity, Mass-energy equivalence, Relation between momentum and energy, Relativistic Doppler's shift and Muon lifetime.

Four-dimensional space-time (Minkowski space), World points and world lines, Proper time, Four-vectors: Position four-vector, Velocity four-vector, Momentum four-vector, Acceleration four-vector, and Force four-vector.

Suggested readings: (All latest editions)

1. Classical Mechanics, Herbert Goldstein, Charles P. Poole, John Safko, Pearson.
2. Foundations of Classical Mechanics, P. C. Deshmukh, Cambridge University Press.
3. Classical Mechanics, J. C. Upadhyaya, Himalaya Publishing House.
4. Fundamentals of Classical Mechanics, A. B. Gupta, Books & Allied (P) Ltd.
5. Introduction to Special Relativity, Robert Resnick, Wiley.
6. Special Theory of Relativity, S. P. Puri, Pearson.
7. The Special Theory of Relativity, V. Devanathan, Alpha Science.

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III. **Course Code: PHY-252**
Course Title: QUANTUM MECHANICS I
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides basic concepts of Quantum mechanics and its applications to understanding microscopic phenomena that classical theory cannot explain.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the limitations of classical physics in describing the microscopic world.
- Understand the concept of wave-particle duality, de-Broglie matter wave, wave-packet, phase, and group velocities.
- Analyse the behaviour of microscopic particles by applying the Heisenberg uncertainty principle.
- Interpret wave function to understand the probabilistic nature of quantum systems.
- Apply the Schrödinger equation for solving simple one-dimensional systems.
- Learn about Hilbert space and operator representation of various physical quantities and their commutation relations.
- Understand the concept of spin and it's representation by Pauli matrices.

Unit I **(15 hours)**

Inadequacy of classical physics and origin of quantum theory (with examples), Wave-particle duality, Concept of the matter wave, de-Broglie wavelength, Particle as a wave packet, Phase velocity and group velocity, Demonstration of probabilistic nature of quantum mechanics by the double slit experiment, Heisenberg uncertainty principle and it's experimental demonstration using single-slit electron diffraction, Application of uncertainty principle: non-existence of electrons in the nucleus, Binding energy of an electron in a hydrogen atom.

Unit II **(15 hours)**

Concept of the wave function and it's physical interpretation, Normalisation of a wave function, Physically acceptable wave functions with examples, Probability density, Postulates of quantum mechanics, Time-dependent and time-independent Schrodinger equations, Ehrenfest's theorem, Stationary states, Probability current density, Conservation of probability density, Concept of free and bound states, Applications of time-independent Schrodinger equations to one-dimensional systems: infinite square well, finite square well, quantum tunnelling through a potential barrier, and the linear harmonic oscillator.

Unit III **(15 hours)**

Linear vector space, Hilbert space, Dirac Bra-Ket notation, Operators, Hermitian and skew-Hermitian operators, Eigen values and eigen vectors of a Hermitian operator, Momentum operator, Energy operator, Matrix representation of an operator, Expectation values of an operator with examples, Commutation relations, Derivation of Heisenberg's uncertainty relation by operator method.

Unit IV **(15 hours)**

Angular momentum: Orbital angular momentum operators in Cartesian and spherical polar coordinates and their commutation relations, Eigenvalues and eigenvectors of L_z and L^2 , Spin operators and their eigenvalues and eigenvectors, Pauli matrices: Properties and commutation relations, Total angular momentum operator and commutation relation.

Suggested readings: (All latest editions)

1. Introduction to Quantum Mechanics, David J. Griffiths and Darrell F. Schroeter, Cambridge University Press.
2. Quantum Mechanics, H.C. Verma, Surya publication.
3. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley.
4. Quantum Mechanics, G. Aruldhas, Prentice Hall of India.
5. Quantum Mechanics: Theory and Applications, Ajoy K. Ghatak and S. Lokanathan, New Delhi Trinity Press.
6. A Textbook of Quantum Mechanics: P.M. Mathews and K. Venkatesan, Tata McGraw-Hills, New Delhi.

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IV. **Course Code: PHY-253**
Course Title: EXPERIMENTAL PHYSICS V
Total Contact Hours: 120
Full Marks: 100

Course Objective: This course will help students gain practical skills in optics and acoustics.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Verify various phenomena in optics, such as refraction, interference, diffraction, and polarisation,
- Apply experimental techniques in optics to measure physical properties like wavelength, slit width, and resolving power.
- Determine the specific charge of an electron.
- Develop skills to estimate and reduce errors and take required precautions during sound and optics experiments.

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List of experiments

1. To draw the I-D curve of a prism using a spectrometer and find out the minimum deviation and refractive index of the prism material.
2. To determine the refractive index of the material of a convex lens by measuring it's focal length (displacement method) and radii of curvature (using a spherometer).
3. To determine the wavelength of sodium light using Bi-prism.
4. To find the wavelength of LASER using diffraction grating.
5. To measure the width of a single slit from the study of it's Fraunhofer diffraction.
6. To determine the resolving power of a plane transmission diffraction grating.
7. To determine the wavelength of the spectral lines of mercury or hydrogen by using a plane diffraction grating and a spectrometer.
8. To determine the specific rotation of sugar solution using a polarimeter.
9. To determine the wavelength of a monochromatic light using Michelson's interferometer.
10. To determine the radius of curvature of the convex surface of a plano convex lens by Newton's ring method.
11. To determine the velocity of ultrasonic waves in liquid.
12. To determine the frequency of A.C. mains using a sonometer.
13. To determine the specific charge (e/m) of an electron using Magnetron/Thomson's method,

Suggested readings: (All latest editions)

1. B.Sc. Practical Physics, C. L. Arora, S Chand and Co.
2. A Text Book of Practical Physics, S. Ghosh, New Central Book Agency, Kolkata.
3. A Text Book on Practical Physics, K.G. Mazumdar, Syndicate Press.
4. Practical Physics, K. K. Dey and B. N. Dutta, Kalyani Publishers.

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Instructions for 5th Semester

The theory examinations for the 5th Semester will be 100 Marks. Internal assessment in Theory will be based on sessional tests and assignments.

I. **Course Code: PHY-300**
Course Title: ELECTROMAGNETIC THEORY
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides fundamental concepts of electromagnetic theory and it's applications for understanding the production method of electromagnetic waves and their propagations in various media.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Apply vector calculus to solve problems involving electric and magnetic fields, including Poisson's and Laplace's equations.
- Analyse the electric field inside a dielectric medium.
- Understand the Maxwell's equations and gauge transformations.
- Utilise vector and scalar potentials to solve problems involving electromagnetic fields.
- Obtain electromagnetic wave equations and their propagations in various media.
- Understand various optical phenomena in terms of electromagnetic waves.
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Unit I **(17 hours)**
Poisson and Laplace's equations, Uniqueness theorem (with proof), Method of electrical images, Electric field near the surface of a grounded conducting plane using the method of electrical images.
Electric field inside matter: Polarisation and polarisation vector, Relation between polarisation vector and bound charge density, Potential and field due to polarised matter applied to the sphere, Displacement field, Electric susceptibility and dielectric constant, Boundary conditions satisfied by **E** and **D** at the interface between two homogeneous dielectrics, Dielectric sphere in a uniform field, Capacitor filled with dielectrics, Polar and non-polar molecules, Induced dipoles, Clausius-Mossoti relation.

Unit II **(18 hours)**
Maxwell Equations: Derivation of Maxwell's equations (in free space and dielectric medium) and their physical significances, Displacement Current, Vector and Scalar Potentials, Calculation of vector potential for an infinitely long solenoid.
Gauge Transformations: Coulomb and Lorentz Gauges, Poynting's Theorem, Electromagnetic (E.M.) Energy Density, Physical Concept of Electromagnetic Field Energy Density.

Unit III **(10 hours)**

E.M. Wave Propagation in Unbounded Media**:** Electromagnetic wave equation and it's plane wave solution, Waves through vacuum and isotropic dielectric medium and it's transverse nature, Polarisation of electromagnetic waves, Refractive index, Dielectric constant, Wave impedance, Plane EM waves through conducting medium, Relaxation time, Skin depth, Attenuation constant.

Unit IV **(15 hours)**

E.M. Wave Propagation in Bounded Media: Boundary conditions at a plane interface between two

media, Reflection and refraction of plane E.M. waves at a plane interface between two dielectrics

media, Laws of Reflection and Refraction. Reflection and Transmission coefficients, Total internal reflection, Fresnel's formulae for perpendicular and parallel polarisation, Brewster's Law.

Wave Guides and optical fibres: Propagation wave guides between conducting planes, Light propagation in optical fibre using ray theory, Acceptance angle; Numerical aperture, Step and Graded Indices (Definitions Only), Single and Multiple Mode Fibers (Definition and Applications).

Suggested readings: (All latest editions)

1. Introduction to Electrodynamics, D.J. Griffiths, Cambridge University Press.
2. Foundations of Electromagnetic Theory, J. R. Reitz, F.Z. Milford, and R. W. Christy, Narosa Publication.
3. Electromagnetic, B. B. Laud, New Age International (P) Limited.
4. Electromagnetic Theory and Electrodynamics, Satya Prakash, Kedar Nath Ram Nath and Co.
5. Introduction to Electromagnetic Theory, T. L. Chow, Jones & Bartlett Learning.
6. Fundamentals of Electromagnetics, M. A.W. Miah, Tata McGraw Hill.

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II. **Course Code: PHY-301**
Course Title: ELECTRONICS II AND COMPUTATIONAL PHYSICS
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides concepts of basic semiconductor devices and their applications in amplifiers, oscillators, and multivibrators. This course also includes designing computational programmes using FORTRAN.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand amplifiers' basic construction, biasing, classification, coupling, and feedback mechanism.
- Understand the working of OP-AMPs and their practical use in electronic circuits.
- Understand the basic operation of oscillators, flip-flops, and multivibrators.
- Learn FORTRAN 77 as a programming language and be able to solve simple problems.
- Learn basic numerical techniques to solve algebraic and differential equations.

Unit I **(20 hours)**

Network Theorem: Superposition theorem, Thevenin's theorem, and Norton's theorem.
Amplifiers: Transistor as 2-port Network, h-parameters, Equivalent Circuit, Input and Output Impedance, Current, Voltage and Power Gains, Transistor as an amplifier: Class A, B, & C Amplifiers.
Coupled Amplifier: Two-stage RC-coupled amplifier and its frequency response.
FET: Similarities and dissimilarities of FET and BJT.
JFET: Static and transfer characteristics of JFET, Pinch off voltage, Idea of MOSFET.
Oscillators: Positive feedback and Barkhausen criterion, Colpitt, and Wein Bridge oscillators.

Unit II **(15 hours)**

Operational Amplifiers: Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop and Closed-loop Gain, Frequency Response.
Applications of Op-Amps: Inverting and non-inverting amplifiers, Adder, Subtractor, Differentiator, Integrator.
Arithmetic Circuits: Half and Full Adders, Half & Full Subtractors, 4-bit binary Adder/Subtractor.
Sequential Circuits: Flip-Flops (S.R., J.K., D, and T).
Multivibrators: Astable, Monostable, and Bistable multivibrators.

Unit III **(13 hours)**

Programming in Fortran 77
Importance of computers in solving physics problems, algorithms, and flowcharts, Examples: Roots of quadratic equation, Sum of two matrices, Sum of a finite series.

Introduction to FORTRAN, Basic elements of FORTRAN: Character Set, Constants and their types, Variables and their types, Keywords, Variable declaration and concept of instruction and programme.
Operators: Arithmetic, Relational, Logical and Assignment Operators.
Expressions: Arithmetic, Relational, Logical, Character and Assignment Expressions, Fortran Statements: Executable and Non-Executable Statements, I/O Statements (unformatted/formatted), Layout of Fortran Program, Format of writing program and concept of coding.

Control Statements: Types of Logic (Sequential, Selection, and Repetition), Branching Statements (Logical IF, Arithmetic IF, Block IF, Nested Block IF, SELECT CASE, and ELSE IF, Ladder statements), Looping Statements (DO-CONTINUE, DO-ENDDO, DO WHILE, Implied and Nested D.O. Loops), Jumping Statements (Unconditional GOTO, Computed GOTO, and Assigned GOTO), Subscripted Variables (Arrays: Types of Arrays, DIMENSION Statement, Reading and Writing Arrays), Functions and Subroutines (Arithmetic Statement Function, Function Subprogram, and Subroutine), RETURN, CALL, COMMON and EQUIVALENCE Statements, Structure, Disk I/O Statements, Open a file, Writing in a file, Reading from a file.

Unit IV **(12 hours)**

Numerical Analysis: Solution of algebraic equations- Iterative, bisection, and Newton Raphson methods.
Interpolation: Numerical differentiation, Numerical Integration, Trapezoidal, Simpson, and Gaussian quadrature methods.
Numerical Solution of Ordinary Differential Equation: Euler and Runge -Kutta Methods.

Suggested readings: (All latest editions)

1. Electronics: Fundamentals and Applications, J.D. Ryder, Prentice Hall.
2. Basic Electronics, B. L. Theraja, S. Chand Publication.
3. Digital Principles and Applications, A.P. Malvino, D.P. Leach, and Goutam Saha, Tata McGraw.
4. Basic Electronics, D.C. Tayal, Himalaya Publication.
5. Handbook of Electronics, Gupta and Kumar, Pragati Prakashan.
6. Fortran 77 and Numerical Analysis, C. Xavier, New Age International.
7. Computer Programming in Fortran 77, V. Rajaraman, PHI.
8. Numerical Methods, E. Balagurusamy, Tata McGraw-Hill.
9. Numerical Analysis, G. Sankara Rao, Newage Publishers.
10. Numerical Methods for Scientists and Engineering Computations, M. K. Jain, S. R. K. Iyenger and R. K. Jain, New Age International.

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III. **Course Code**: **PHY-302**
Course Title: THERMAL AND STATISTICAL PHYSICS
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides an understanding of the relationship between various thermodynamical quantities, phase space, probability theory, and different types of distributions, which help interpret various statistical phenomena.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand various thermodynamic equations in terms of Maxwell's equations.
- Understand different types of phase transition and the concept of triple point.
- Understand the fundamentals of probability laws and their applications to study different types of distributions.
- Understand the concept of phase space and ensembles theory and their applications in analysing different physical systems.
- Understand different distributions in classical and quantum statistics and apply them to various physical systems.

Unit I **(13 hours)**

Thermodynamic Relations: Maxwell's thermodynamical relations and their applications, Heat capacity equations, TdS equations, Internal energy equations, Joule – Thomson effect, Temperature of inversion, Clausius – Clapeyron equation, Thermodynamic potentials, Equilibrium between liquid and it's vapour, First and second order phase transitions, Co-existence of phases, Triple point, Ehrenfest's Theorem.

Unit II **(10 hours)**

Elementary Probability Theory: Fundamental probability laws, Binomial and Poisson distributions: Calculation of mean and variance, Stirling approximation (up to second order), Normal (Gaussian) distribution: Calculation of mean and variance.

Unit III **(20 hours)**

Statistical Physics and Applications: State of a system (microscopic and macroscopic), Phase space, Density distribution in phase space and application to the one-dimensional harmonic oscillator and free particles, Principle of equal a Priori Probability, Ergodic hypothesis, Liouville theorem (with proof).

Postulates of Statistical Mechanics, Thermal equilibrium between two systems, β parameter and it's identity with probability and entropy, and their relations.

Ensemble theory, Probability distribution in Microcanonical, Canonical, and Grand–Canonical ensembles, Application to a classical ideal gas, Harmonic oscillator, Energy fluctuation in Canonical distribution, and particle fluctuations in a grand canonical ensemble.
Statistical interpretation of the second law of thermodynamics, Partition function and it's relation with thermodynamic quantities like free energy, entropy, and specific heat, Law of equipartition of energy and its applications.

Unit IV **(17 hours)**

Derivation of Maxwell-Boltzmann distribution function and it's application to a perfect gas, Derivation of Maxwell's distribution of molecular speeds with the calculation of mean velocity, rms velocity, and most probable velocity.

Indistinguishability of particles, Bose-Einstein (B.E.) and Fermi-Dirac (F.D.) Statistics, Maxwell-Boltzmann Statistics as a classical limit of quantum statistics, Application of B.E. statistics to a photon gas and derivation of Planck's formula, F.D. statistics to a free electron in metals, Calculation of Fermi energy.

Suggested readings: (All latest editions)

1. Fundamentals of Statistical and Thermal Physics, Frederick Reif, McGraw Hill.
2. Fundamental of Statistical Mechanics, B. B. Laud, New Age International Publishers.
3. Statistical Mechanics, R.K. Pathria and Paul D. Beale, Elsevier.
4. Statistical Mechanics, G. Sanon, Alpha Science.
5. Statistical Mechanics, B. K. Agarwal, New Age Publication.
6. Heat and Thermodynamics, M.W. Zeemansky and R. H. Dittmann, McGraw Hill Education, India.
7. Heat Thermodynamics and Statistical Physics, Brij Lal, N Subrahmanyam, and P S Hemne, S. Chand Publication.

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IV. **Course Code: PHY-303**
Course Title: MODERN PHYSICS I
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides an overview of quantum mechanics, solid state, atomic and nuclear physics

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the basics of Quantum theory, de Broglie's concept of wave and wave-particle duality, and Heisenberg's uncertainty principle.
- Learn about some important properties of solid materials.
- Get introduced to the basics of Atomic Physics.
- Understand the basic properties of a nucleus and it's stability.
- Learn the basics of radioactivity and the different radioactive emissions.
- Know about Nuclear reactions, particularly fission and fusion reactions, and their Importance for mankind.

Unit I **(12 hours)**

Quantum Mechanics: Planck's theory, Planck's constant and light as a collection of photons, Photoelectric effect and Compton effect (no derivation), de Broglie concept of matter wave and wave-particle duality, Heisenberg uncertainty principle, Estimation of minimum energy of a confined particle using uncertainty principle, Energy-time uncertainty principle.

Unit II **(15 hours)**

Solid State Physics: Amorphous and Crystalline materials, Basic idea of energy bands in crystals: Metals, insulators, and semiconductors, Electrical and thermal properties of crystals and their applications (qualitative)- Carrier concentration, Electrical conductivity, Thermal conductivity, Specific heat, Magnetic properties of materials (qualitative): Magnetic susceptibility, Magnetization, Paramagnets, Diamagnets, Ferromagnets, Antiferromagnets, and Ferrimagnets. Temperature-dependent behaviour of ferromagnetic materials: Bloch $T^{3/2}$ law and Curie-Weiss law. Basic idea of superconductors: characteristic features (Zero resistance, Critical temperature, Meissner effects, Critical magnetic field, Flux quantisation), Type-1 and Type-2 superconductors, Applications of superconductors and current challenges.

Unit III **(13 hours)**

Atomic Physics: Review of atomic models, Space quantisation, Electron spin, Magnetic moment of an atom, Quantisation of magnetic moment, Pauli's exclusion Principle.
Lasers: Absorption, Spontaneous, and Stimulated emissions, Condition for laser action: Population inversion, Metastable states, Resonators. Properties and applications of the laser, He-Ne laser.

Unit IV **(20 hours)**

Nuclear Physics: Composition and properties of the nucleus, Nuclear stability, Binding Energy of a nucleus, Introduction to Liquid- drop model and Shell model (without derivations). Radioactivity: Different types of radioactive emissions, their properties, and applications, Types of nuclear reactions, Conservation laws obeyed in nuclear reactions, Nuclear fission, Nuclear reactors: Construction, Working principle and applications.
Nuclear fusion, Nuclear fusion as a source of energy generation (basic introduction).

Suggested readings: (All latest editions)

1. Concepts of Modern Physics, Arthur Beiser, McGraw Hill, India
2. Introduction to Modern Physics, F. K. Richtmyer, and E. H. Kennard, Tata McGraw Hill.
3. Elements of Modern Physics, R. Murugeshan and Kiruthiga Sivaprasath, S. Chand Publications.
4. Modern Physics, B. L. Theraja, S. Chand Publications.

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Instructions for 6th Semester

The theory and practical examinations for the 6th Semester will be 100 Marks. Each student has to perform one experiment for 6 hours. Internal assessment in (a) Theory will be based on sessional tests and assignments, (b) Practical will be based on performance in the laboratory work and the number of practicals completed during class hours.

I. **Course Code: PHY-350**
Course Title: SOLID STATE PHYSICS
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course aims to explain the structure of crystalline solids and provide an understanding of their thermal, electrical, magnetic, and superconducting properties.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the basic concepts in crystalline solids.
- Analyse the structure of crystals by methods of diffraction.
- Understand lattice vibrations and their roles in governing the thermal properties of solids.
- Understand the free electron gas model of solids using classical and quantum theories.
- Understand the band theory of solids using the nearly free electron model, Bloch theorem, and concept of effective mass.
- Learn the mean-field theories of magnetism and different types of magnetic materials.
- Understand the basic knowledge of superconductors, their properties, and their explanations using BCS theory.

Unit I **(10 hours)**

Crystal structure: Translational vectors, Lattice and basis, Crystalline symmetries, Concepts of point and space groups, Primitive unit cell and conventional unit cell, Two-dimensional and three-dimensional Bravais lattices, Coordination number, Crystal planes and Miller indices, Packing fraction of sc, bcc, fcc, hcp structures. Structure of diamond and CsCl.

Unit II **(17 hours)**

Diffraction: Bragg's law, Laue's treatment of diffraction, Concept of the reciprocal lattice, Reciprocal lattice of sc, bcc, and fcc lattices. Wigner-Seitz cell, Atomic form factor, Structure factor of bcc and fcc lattices. Experimental techniques: Laue method, Rotating crystal method, Powder method, and Neutron diffraction method.

Lattice vibration: Quantisation of lattice vibration (phonon), Lattice vibration of one-dimensional monatomic and diatomic lattice, Acoustic and optical phonons, Lattice heat capacity, Planck distribution, Einstein theory, Phonon density of states, Debye theory, Thermal expansion, Thermal conductivity.

Unit III **(18 hours)**

Drude model of metals: Electrical and thermal conductivity of an electron gas, Wiedemann-Franz law, Sommerfeld model of metals: Concept of Fermi level, Density of states, Heat capacity of electron gas, Experimental heat capacity of metals, Electrical conductivity and resistivity of metals, Matthiessen's rule. Band Theory: Nearly free electron model, Bloch theorem, Origin of band and band gaps, Metals, Semiconductor, and Insulator, Effective mass, Intrinsic carrier concentration, Intrinsic mobility, Impurity conductivity, Hall effect and it's applications.

Unit IV **(15 hours)**

Magnetism: Magnetic susceptibility, Classification of materials, Langevin theory of diamagnetism and paramagnetism, Domains and spontaneous magnetisation in ferromagnetic materials, Mean field theory of ferromagnetism, anti-ferromagnetism, and ferri-magnetism.

Superconductivity: Introduction, Persistent current, Meissner's effect, Critical fields, Flux quantisation, London penetration depth, Type-I and Type-II superconductors, Josephson effects, Elementary idea of BCS theory.

Suggested readings: (All latest editions)

1. Solid State Physics, Neil Ashcroft and N. Mermin, Brooks/Cole.
2. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons.
3. Elementary Solid State Physics, M. Ali Omar, Pearson Education, Inc.
4. Solid State Physics, A. J. Dekker, Mc Milan.
5. Fundamentals of Solid State Physics, J. R. Chrisman, John Wiley.
6. Solid StatePphysics, M. A. Wahab, Narosa Publishing House.

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II. **Course Code: PHY-351**
Course Title: ATOMIC AND MOLECULAR PHYSICS
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides an understanding of the origin of atomic and molecular spectra and their analysis using different techniques.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the origin of fine and hyperfine spectra of hydrogen-like atoms with the help of different models.
- Understand the spectra of multi-electron atoms.
- Understand the Production and properties of X-rays.
- Understand the electronic, vibrational and rotational spectra of molecules.
- Study the properties of different molecules using various spectroscopic techniques.
- Study the basic concept of NMR, ESR and LASER and their applications.

Unit I **(15 hours)**

One-electron atoms: Space quantisation; Electron spin, Stern-Gerlach experiment, Vector atom model and their physical significances, Term symbols, Spin-orbit interaction and it's explanation of fine structures, Magnetic moment due to orbital motion and spin, Bohr's magneton, Lande-g factor, Larmour theorems, Gyromagnetic ratio.

Interaction of one-electron atoms with external electric and magnetic fields: linear stark effect, Classical and quantum theory of normal Zeeman effect, Quantum theory of Anomalous Zeeman effect, Paschen-Back effect.

Unit II **(15 hours)**

Multi-electron atoms: Coupling scheme- L.S. Coupling and jj Coupling, Hund's rule, Spectra of Alkali atoms, Effect of screening, Fine structure in sodium spectrum. Spectra of Helium atom and alkaline earth atoms, Singlet and triplet fine structure, Selection rules, Metastable states, Width of spectral lines.

X-rays: Production, Duane-Hunt law, Continuous X-ray, Characteristic X-rays and it's fine structure, Derivation of Moseley's law from Bohr's theory, Absorption of X-rays, Exponential law, Auger effect, Compton scattering and expression for the wavelength change.

Unit III **(15 hours)**

Molecular Spectra: Introduction, Types of molecular spectra, Spectra of a diatomic rigid body rotator and quantum mechanical derivation of it's energy levels, frequency of the spectral lines, selection rules, and spectrum. Vibrating diatomic molecule as a harmonic oscillator-energy level, frequency, selection rules, spectrum. Vibrational-Rotational spectra, energy levels. Electronic spectra, Frequency of electronic spectra, Franck- Condon principle.

Raman effect, Characteristics of Raman lines, Quantum theory of Raman effect, Fundamental ideas of U.V. and I.R. spectroscopy, Comparison of Raman and I.R. spectra.

Unit IV **(15 hours)**

Basic concepts of NMR and ESR and their applications.

Laser: Absorption, Spontaneous, and Stimulated emissions. Einstein coefficients, Condition for laser action, Population inversion, Metastable states, Resonators, Properties and applications of laser, He-Ne laser, Semiconductor laser.

Suggested readings: (All latest editions)

1. Physics of Atoms and Molecules, B. H. Bransden and C.J Joachain, Pearson Education Ltd.
2. Molecular Structure and Spectroscopy, G. Aruldhas, PHI.
3. Introduction to Atomic Spectra, H.E. White, McGraw Hill.
4. Introduction to Molecular Spectroscopy, G. M. Barrow, Creative Media Partners.
5. Element of Spectroscopy: Atomic, Molecular and Laser Physics, S. L. Gupta, Pragati Prakashan.
6. Molecular Spectroscopy, J.D. Graybeal, Mc Graw Hills International Edition.

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III. **Course Code: PHY-352**
Course Title: NUCLEAR AND PARTICLE PHYSICS
Total Contact Hours: 60
Full Marks: 100

Course Objectives: This course provides a basic understanding of nuclear structure, decay, and reactions. Also, it gives an idea about elementary particles and cosmic rays.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Understand the basic properties of the nucleus and nuclear models.
- Understand nuclear radiation with the help of different theories and their detections.
- Understand nuclear fission and fusion using different models and their applications.
- Understand the elementary particles and their conservation laws, the building block of matter.
- Learn about cosmic rays and their characteristics.

Unit I **(15 hours)**

Basic properties of a nucleus: Composition, Size and estimation of nuclear radius by mirror nuclei method, Spin and magnetic moment, Electric quadruple moment, Binding energy, Binding energy per nucleon and it's variation with mass number, Stability curve, Semi-empirical mass formula.
Nuclear models: Liquid drop model, Shell model, Schmidt lines.

Unit II **(15 hours)**

Radioactivity: Energy spectrum of α-, β- and γ-decay, Range of α- and β –particles, Geiger-Nuttal law, Gamow's theory of α-decay (qualitative), Neutrino hypothesis, Fermi's theory of β-decay (qualitative), γ-ray emission, Interaction of γ-rays with matter, Absorption coefficient.

Nuclear radiation detectors: Ionisation chamber, Proportional counter, and Geiger-Muller counter. Biological effect of nuclear radiation, Maximum permissible level for safety, Precautions against radiation hazards.

Unit III **(15 hours)**

Nuclear Reactions: Rutherford's experiments on artificial transmutations, Conservation theorems, Q-value, Threshold energy, and Cross-section of nuclear reactions.
Nuclear Fission: Spontaneous fission and it's condition, Bohr - Wheeler's theory (qualitative), Nuclear chain reaction (controlled and uncontrolled), Four-factor formula for a nuclear multiplication factor, Criticality, Moderators, Types of reactors- Power breeder reactor.
Nuclear Fusion: Fusion reaction in plasma, Condition for maintaining fusion reaction, Tokamak experiment in fusion systems.

Unit IV **(15 hours)**

Elementary particles: Classification of elementary particles, Fundamental interactions, Conservation laws, Quark model.

Cosmic rays: General characteristics, Soft and Hard components of cosmic rays, Primary and Secondary cosmic rays, Altitude effect, Effect of Earth's magnetic field on cosmic rays: Latitude effect and East-West effect, Origin of cosmic rays.

Suggested readings: (All latest editions)

1. Nuclear Physics, R. R. Roy and B. P. Nigam, Wiley.
2. Concept of Nuclear Physics, Bernard L. Cohen, McGraw Hill Education, India.
3. Nuclear Physics Experimental and Theoretical, H. S. Hans, New Age International Publishers.
4. Nuclear Physics, D. C. Tayal, Himalaya Publishing House.
5. Introduction to Elementary Particles, David J. Griffith, Wiley-VCH.
6. Nuclear Physics, S. N. Ghoshal, S. Chand and Company Ltd.
7. Introduction to Nuclear Physics, Kenneth S. Krane, Wiley.
8. Introductory Nuclear Physics, Samuel S. M. Wong, Prentice-Hall of India.

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IV. **Course Code: PHY-353**
Course Title: EXPERIMENTAL PHYSICS VI
Total Contact Hours: 120
Full Marks: 100

Course Objectives: This course will help the students to verify various physical laws and determine various physical quantities related to electronics and semiconductor physics. Students will also acquire knowledge of solving non-linear equations using computational methods.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Gain practical experience in handling and determining the characteristics of a Field Effect Transistor, an OP-AMP, etc.
- Determine the semiconducting properties of a solid by the Four-probe method and the Hall effect.
- Perform computational evaluation of integration functions by Trapezoidal and Simpson's 1/3 rule.
- Solve non-linear equations by numerical methods.

List of experiments:

1. To determine the electrical conductivity of solid electrolytes by Kohlrausch method.
2. To trace the B-H curve for a ferromagnetic material using CRO and to find the magnetic parameters from the B-H hysteresis loop.
3. To study the voltage gain and frequency response of a two-stage R-C coupled amplifier.
4. To study the characteristics of a given Field Effect Transistor (JFET) and determine the amplification factor (μ), dynamic drain resistance, and transconductance.
5. To determine the CMRR of an OP-AMP and study it's working as an adder and subtractor.
6. To study the characteristic curve of a G.M. counter and find the half-life of the radioactive source.
7. To study Lissajous figures using CRO and determine the frequency of the unknown source.
8. To verify the addition and multiplication of two 3×3 matrices using Fortran programming.
9. To find the solution to a cubic equation using the Newton-Raphson method,
10. To evaluate (a) $\int_0^1 x^2$ dx and (b) $\int_0^\pi sin^2x$ dx by Trapezoidal rule with $n = 6$.
11. To evaluate $\int_0^1 e^x\ dx$ by Simpson's one-third rule.
12. To study the temperature dependence of resistivity of a semiconductor (Four probe method) and determine the band gap of the semiconductor.
13. To find the Hall-Coefficient of a semiconductor and determine the type and concentration of charge carriers.

Suggested readings: (All latest editions)

1. B.Sc. Practical Physics, C. L. Arora, S. Chand and Co.
2. A Text Book of Practical Physics, S. Ghosh, New Central Book Agency, Kolkata.
3. A Text Book on Practical Physics, K. G. Mazumdar, Syndicate Press.
4. Fortran 77 and Numerical Analysis, C. Xavier, New Age International.
5. Computer Programming in Fortran 77, V. Rajaraman, PHI.
6. Numerical Methods, E. Balagurusamy, Tata McGraw-Hill.

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