Manipal Academy of Higher Education
Department of Sciences
Department of Physics, MIT-Manipal
M.Sc. (Physics)
Choice Based Credit System (CBCS-2020)

L - Lecture Hours, **T** - Tutorial Hours, **P** - Practical Hours, **C** - Credits

I Semester

Subject Code	Subject	L	T	P	C
PHY 5151	Mathematical Methods of Physics	4	0	0	4
PHY 5152	Classical Mechanics	4	0	0	4
PHY 5153	Quantum Mechanics – I	4	0	0	4
PHY 5154	Fundamentals of Electronics	4	0	0	4
PHY 5155	Physics Lab – I	0	0	4	2
PHY 5156	Physics Lab – II	0	0	4	2
	TOTAL CREDITS				**20**

II SEMESTER

Subject Code	Subject	L	T	P	C
PHY 5251	Basic Condensed Matter Physics	4	0	0	4
PHY 5252	Numerical Methods and Computational Physics	4	0	0	4
PHY 5253	Quantum Mechanics – II	4	0	0	4
PHY 5254	Nuclear and Particle Physics	4	0	0	4
PHY 5255	Physics Lab – III	0	0	4	2
PHY 5256	Computational Physics Lab	0	0	4	2

PHY 5257	Research Methodology and Technical Communication	3	0	0	3
	TOTAL CREDITS				**23**

III SEMESTER

<table>
<tr><th colspan="2">Subject code</th><th>Subject</th><th>L</th><th>T</th><th>P</th><th>C</th></tr>
<tr><td colspan="2">PHY 6101</td><td>Atomic and Molecular Spectroscopy</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="2">PHY 6102</td><td>Electromagnetic Theory</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="2">PHY 6103</td><td>Experimental Methods in Physics</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="2">PHY 6051</td><td>Open Elective</td><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td rowspan="5">ELECTIVE 1</td><td>PHY 6001</td><td>Condensed Matter Physics-I</td><td>3</td><td>0</td><td>2</td><td rowspan="5">4</td></tr>
<tr><td>PHY 6002</td><td>Optoelectronics - I</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6003</td><td>Nuclear Physics - I</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6004</td><td>Electronics - I</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6005</td><td>Theoretical Physics - I</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td colspan="2"></td><td colspan="4">TOTAL CREDITS</td><td>19</td></tr>
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Open Elective: Offered by the Departments of Chemistry, Geology and Mathematics

IV SEMESTER

<table>
<tr><th colspan="2">Subject code</th><th>Subject</th><th>L</th><th>T</th><th>P</th><th>C</th></tr>
<tr><td colspan="2">PHY 6201</td><td>Statistical Mechanics</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="2">PHY 6202</td><td>General Relativity and Cosmology</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td rowspan="5">ELECTIVE 2</td><td>PHY 6011</td><td>Condensed Matter Physics-II</td><td>3</td><td>0</td><td>2</td><td rowspan="5">4</td></tr>
<tr><td>PHY 6012</td><td>Optoelectronics - II</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6013</td><td>Nuclear Physics - II</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6014</td><td>Electronics - II</td><td>3</td><td>0</td><td>2</td></tr>
<tr><td>PHY 6015</td><td>Theoretical Physics - II</td><td>4</td><td>0</td><td>0</td></tr>
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PHY 6206	Project	-	-	-	6
	TOTAL CREDITS				**18**

Total Credits for M.Sc. = 80

PHY 5151: MATHEMATICAL METHODS OF PHYSICS **[4 0 0 4]**

Course Outcomes:

1. Understand the applications of special functions and functions of complex variables in solving specific problems in physics.
2. Understand the concepts of curvilinear coordinates and matrices, their applications in quantum mechanics.
3. Understand the applications of integral transforms and group theory in wave mechanical problems, relativity and crystallography.

Functions of Complex Variable: Review of functions of a complex variable: Cauchy Riemann conditions (without proof), Analytic functions. Contour integrals. Cauchy integral theorem, Cauchy integral formula. Laurent's series. Singular points, simple pole, m^{TH} order pole. Evaluation of residues. The Cauchy's residue theorem. Evaluation of definite integrals using residues. **10 hours**

Special Functions: Bessel functions of the first kind-derivation of the series form- Recurrence relations, differential equation, Fraunhofer diffraction at a circular aperture. Legendre and Associated Legendre functions - Recurrence relations and differential equations, potential due to a dipole. Laguerre functions – differential equations. Hermite functions - Recurrence relations – differential equation, simple harmonic oscillator. **10 hours**

General Curvilinear Coordinates: Elements of curvilinear coordinates - transformation of coordinates - orthogonal curvilinear coordinates – expression for arc length, elemental area, and volume element. Special cases. The gradient, Laplacian, divergence and curl in orthogonal curvilinear coordinates: special cases – spherical polar coordinates, cylindrical coordinates. **8 hours**

Matrices: Matrices as operators. Simultaneous equations – Solving simultaneous equations using matrices, Cramer's rule. Symmetric, orthogonal, Hermitian and unitary matrices. Eigen values and eigen vectors of a matrix - examples. Similarity, orthogonal, unitary and congruence transformations. Diagonalization of a matrix using similarity and congruence transformation, examples. **6 hours**

Group theory: Basic concepts of Group Theory - multiplication tables - subgroups - direct product. Properties of groups. Representations of finite group - reducible and irreducible representations and example of $C4_v$, SU(2), O(3) groups. **5 hours**

Integral Transform: Fourier series – Review. Mean convergence of Fourier series, Fourier integral and Fourier transform, applications. Laplace transforms and applications in physics, z-transforms, wavelet transforms (qualitative discussion)

9 hours

References:

[1] G. Arfken, *Mathematical Methods for Physicists*, 7th Edition, United States: Academic Press, 2012.

[2] Charlie Harper, *Introduction to Mathematical Physics*, 1st Edition, India: Prentice Hall India Learning Private Limited,1978.

[3] I.N. Sneddon, *Special Functions of Mathematical Physics and Chemistry*, 1st Edition, United States: Addison-Wesley Longman Ltd, 1980.

[4] P.K. Chattopadhyay, *Mathematical Physics*, 3rd Revised Edition, United Kingdom: New Academic Science Ltd, 2008.

[5] E. Kreyszig, *Advanced Engineering Mathematics*, 9th Edition, New York: Wiley, 2011

[6] M.R. Spiegel, *Complex Variables* : *Schaum's outline series*, 2nd Edition, New York: McGraw Hill Education, 2017.

[7] H.Cohen*, Mathematics for Scientists and Engineers*, 1st Edition, United States: Prentice Hall, 1992.

[8] A.W. Joshi, *Matrices and Tensors in Physics*, 3rd Edition, India: New Age International,1995

[9] Mathews J and Walker R L, *Mathematical Methods of Physics*, 2nd Edition, United States: W A Benjamin Inc.,1979.

[10] Sokolnikoff and Redheffer, *Mathematics of Physics and Modern Engineering*, 2nd Edition, New York: McGraw Hill,1966

[11] A W Joshi, *Elements of Group Theory for Physicists*, 5th Edition, India: New Age International, 2018.

PHY 5152: CLASSICAL MECHANICS **[4 0 0 4]**

Course Outcomes:

1. Explain the conservation principles (conservation of energy, linear and angular momentum) and Describe the motion of particles under central forces
2. Understand the mechanics of rigid bodies
3. Apply the appropriate law (Newton's laws) / principles (variation principle, Lagrangian principle, Hamiltonian principle) to the problems in Nature, to get solutions
4. Explain the Poisson brackets and Canonical transformations
5. Understand the small oscillations and relative motion between particles through Lorentz equations.

Mechanics of a System of Particles: Center of mass. Conservation of linear and angular momentum in the absence of (net) external forces and torques. The energy equation and the total potential energy of a system of particles. **4 hours**

Central Forces: Definition and characteristics. Motion of a particle in central force field and arbitrary potential field. Inverse square field. Two body problem – closure and stability of circular orbits, general analysis of orbits. Satellite motion. Stability of orbits. Kepler's laws of planetary motion. Newton's law of gravitation. **7 hours**

Scattering in Central Force Field: general description of scattering, cross-section, impact parameter, Rutherford scattering, centre of mass and laboratory co-ordinate systems. **4 hours**

Mechanics of rigid bodies: Displacements of a rigid body - kinematics of rotation - Eulerian angles - Euler's equations of motion. Motion of a rigid body with one point fixed - force free motion - Motion in non-inertial reference frames - Foucault's pendulum. **6 hours**

Small Oscillations: Types of equilibriums, Quadratics forms for kinetic and Potential energies of a system in equilibrium, Lagrange's equations of motion, Normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, tri-atomic molecule. **4 hours**

Lagrangian Equations: Types of constraints. Generalized coordinates. D'Alemberts principle and Lagrangian equations of the first and second kind. Examples of (i) single particle in three dimensions in Cartesian, spherical polar and cylindrical polar coordinates, (ii) the Atwood machine and (iii) a bead sliding on a rotating wire in a force-free space. Velocity dependent potential; the Lagrangian for a charged particle in an external electromagnetic field. Derivation of Lagrange equation from Hamilton principle. **10 hours**

Hamilton's equations: Generalized momenta. Hamilton's equations. Examples of (i) the Hamiltonian for simple harmonic oscillator. (ii) Hamiltonian for a free particle in different coordinates. Cyclic coordinates. Derivation of Hamilton's equations from a variational principle. **Canonical transformations:** examples. Poisson brackets; angular momentum and Poisson bracket relations. The Hamilton-Jacobi equation; Poission theorems, angular momentum PBs, small oscillations, normal modes and coordinates. Canonical equations in PB notations. **10 hours**

Special relativity in classical mechanics: Newtonian Relativity, Michelson-Morley experiment, Special theory of relativity, Lorentz transformation, Time dilation, Variation of mass with velocity, relativistic kinematics, mass-energy equivalence. **3 hours**

References:

[1] H. Goldstein, Classical Mechanics, 2nd Edition. Wiley Eastern, 1985.
[2] R.G. Takwale and P S.Puranik, Introduction to Classical Mechanics, Tata McGraw Hill, 1979.
[3] A. Sommerfeld, Mechanics, Academic Press, 1964.
[4] N. C. Rana and P S. Joag, Classical Mechanics. Tata McGraw Hill, 1991.

PHY 5153: QUANTUM MECHANICS – I **[4 0 0 4]**

Course Outcomes:

At the end of this course students will be able to:

1. Understand the origin and the need for new quantum theory
2. Describe the mathematical formalism of Hilbert space, operators, eigenvalues, eigenstates, commutators and their physical implications
3. Explain the basic postulates of quantum mechanics, different pictures of quantum mechanics and use the superposition principle to predict experimental outcomes for measurement of observables on simple quantum systems
4. Apply time independent Schrodinger equation to various one dimensional problems and Solve three dimensional Schrodinger equation for some simple potentials including the hydrogen atom and describe the structure of the hydrogen atom.
5. Describe the quantisation of angular momentum and spin, and combine spin and angular momenta

Introduction: Brief review of Old Quantum Theory; Need for a new Quantum theory; Wave function; Probabilistic interpretation; Schrodinger equation **3 Hours**

Mathematical Formalism: Basic probability theory; Linear vector space; Inner product; Hilbert Space; Dimension and Basis; Orthogonality; Orthonormality; Completeness; Dirac notation; Operators; Hermitian adjoint; Hermitian operators; Commutator algebra; Uncertainty relation between two operators; Inverse and Unitary operators; Eigenvalues and eigenvectors of an operator; Representation in discrete bases; Matrix representation of kets, bras, and operators; Matrix representation of the eigenvalue problem; Representation in continuous bases; Position and momentum representation; Connecting the position and momentum representations; Matrix and wave mechanics **15 Hours**

Postulates of Quantum Mechanics and the Schrodinger Equation: The basic postulates of Quantum Mechanics; State of a system; Probability density; Superposition Principle; Observables and operators; Measurement and the Uncertainty relations; Expectation values; Schrodinger equation for Time-independent potentials; Stationary states; Conservation of probability; Pictures of quantum mechanics; Ehrenfest Theorem **9 Hours**

Problems in One, two and three Dimensions: Infinite square well potential; Harmonic oscillator; Free particle; Wave packets; Potential barrier; Tunneling; Finite square well potential; Some two dimensional examples; Three Dimensional Problems; Schrodinger equation in spherical coordinates; Central potentials; Separation of variables; Angular and radial equations; Rigid rotor; Hydrogen atom **11 Hours**

Angular Momentum: Orbital angular momentum; Matrix representation of angular momentum; Spin angular momentum and Pauli spin matrices; Eigen functions of orbital angular momentum; Eigen functions and eigenvalues L_z and L^2; Properties of the spherical harmonics; Addition of two angular momenta; Clebsch-Gordan coefficients; Calculation of the Clebsch - Gordan coefficients **10 Hours**

References:

[1] Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, 2nd Edition, New Delhi: Wiley, 2016.

[2] D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*, 3rd Edition, Cambridge: Cambridge University Press, 2018.

[3] R. Shankar, *Principles of Quantum Mechanics*, 2nd Edition, New York: Springer, 1994.

[4] J. J. Sakurai and Jim J. Napolitano, *Modern Quantum Mechanics*, 2nd Edition, Cambridge: Cambridge University Press, 2017.

[5] B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, 2nd Edition, New Delhi: Pearson Education, 2000.
[6] V. K. Thankappan, *Quantum Mechanics*, 2nd Edition, New Delhi: New Age International, 2003.
[7] P. M. Mathews and K. Venkatesan, *A text book of Quantum Mechanics*, 2nd edition, New Delhi: Mc Graw Hill India, 2010.
[8] Stephen Gasiorowicz, *Quantum Physics*, 3rd Edition, New Delhi: Wiley, 2005.
[9] Ajoy Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, 5th Edition, Chennai: Macmillan, 2004.
[10] L. D. Landau and E. M. Lifshitz, Quantum Mechanics: Non-Relativistic Theory, 3rd Edition, Oxford: Butterworth-Heinemann, 2005.
[11] Eugen Merzbacher, *Quantum Mechanics*, 3rd Edition, New Delhi: Wiley India, 2011.
[12] Leonard I. Schiff, *Quantum Mechanics*, 4th Edition, New Delhi: McGraw Hill India, 2014.
[13] G. Aruldhas, *Quantum Mechanics*, 2nd Edition, Delhi: Prentice Hall India, 2018.
[14] H. C. Verma, *Quantum Physics*, 2nd Edition, Ghaziabad: Surya Publications, 2009.

PHY 5154: FUNDAMENTALS OF ELECTRONICS **[4 0 0 4]**

Course outcomes:

1. In this course it is expected that student should be able to understand the design and functional performance of electronic circuits using various semiconductor devices.
2. In addition, the student will understand the functional properties and characteristics of semiconductor devices in analog & digital circuits using analog and digital signals.

Semiconductor Devices and Circuits: Characteristics of a pn junction. Clipping and clamping circuits. BJT, JFET and MOSFET devices. Voltage divider bias. BJT ac analysis – transistor modelling – r_e model, hybrid equivalent model and hybrid π model. Small signal analysis of BJT and FET amplifiers in CE/CS configuration. Comparison of CE/CS configuration with CB/CG and CC/CD configurations. Frequency response of BJT amplifier. UJT characteristics and its use in a relaxation oscillator. SCR characteristics and its use in ac power control. **12 hours**

Operational Amplifiers and Circuits: BJT differential amplifier. Operational amplifier - voltage/current feedback concepts (series & parallel). Inverting and noninverting configurations. Basic applications of opamps - comparator and Schmitt trigger, differentiator, integrator, Wein bridge oscillator, active filters- first order low pass and high pass butter worth filters. IC555 timer - monostable and astable multivibrators. Crystal oscillator using opamp. Instrument amplifier **12 hours**

Digital Electronics: Logic gates, latches and flip-flops - overview. Simplification of logic functions by Karnaugh maps. Tristate devices. Decoders and encoders. Multiplexers and demultiplexers with applications. Parallel and series shift registers, Synchronous and asynchronous counter design. Digital to analog conversion with R/2R network. Analog to digital conversion using flash technique. **12 hours**

Microprocessors: Introduction to CPU architecture and interfacing the devices. Instruction data format and storage. 8085 architecture - register organization – Memory, input and output devices, Example of microcomputer system. 8085 instruction set – classification. Instruction cycle, machine cycle, timing diagram. **12 hours**

References:

[1] Boylestad R L & Nashelsky L, Electronic Devices & Circuit Theory, Tenth edition, India, Prentice Hall of India Pvt. Ltd, 2009.
[2] Floyd T L, Electronic Devices, Ninth edition, India, Pearson Education Asia, 2015.
[3] Millman J, Halkias C and Parikh C D, Integrated Electronics, Second edition, India, TaTa McGraw Hill Education, 2009.
[4] Gayakwad R A, Opamps and Linear Integrated Circuits, Fourth edition, India, Prentice Hall of India Pvt. Ltd, 2012.
[5] Floyd T L, Digital Fundamentals, Tenth edition, India, Pearson Education Asia, 2011.
[6] Tocci, Widemer, Digital Systems, Principles and Applications, Tenth edition, India, Prentice Hall International, 2009.
[7] Gaonkar Ramesh S, Microprocessor architecture programming and applications with 8085, Sixth edition, India, Penram International Publishing Pvt. Ltd, 2012.

PHY 5155: PHYSICS LAB - I

[0 0 4 2]

Course Outcomes (COs):
At the end of this course, the student should be able to

1. Understand the concepts of interference, diffraction and polarization.
2. Analyze the elastic and thermal properties of solids.
3. Evaluate the electrical properties of semiconductors.
4. Understand the concepts of modern physics namely radioactive decay, atomic excitation energy, photoelectric effect.

The students are expected to perform at least TEN of the following experiments*

1. Cornu's fringes
2. Michelson Interferometer
3. Thermal conductivity of a metal bar
4. Geiger-Muller tube characteristics and dead time
5. Study of p-n junction
6. Half-life of radioactive isotope K-40 using GM Counter
7. Determination of Planck's constant by photoelectric effect and verification of inverse square law.
8. Verification of Fresnel's laws
9. Frank Hertz Experiment
10. Babinet compensator
11. Dispersion relation and cutoff frequency in the case of a monoatomic lattice using lattice dynamics kit
12. Diffraction from powder particles

* *Additional experiments may be included.*

PHY 5156: PHYSICS LAB – II

[0 0 4 2]

Course Outcomes (COs):

At the end of this course, the student should be able to

1. Construct electronic circuits using active & passive components, Analog ICs namely Clipping, Clamping, Integrator, Differentiator, Amplifiers, Oscillators and to understand its working principle.
2. Analyze the working principle of digital electronic circuits namely Flip-flops and Counters.

The students are expected to perform at least TEN of the following experiments*

1. Tracing the characteristic curves of RC circuit and diodes using Cathode Ray Oscilloscope (CRO)
2. Clipping and clamping circuits using diodes.
3. UJT characteristics and Relaxation Oscillator.
4. Integrator and Differentiator using OP-AMP (IC 741).
5. RC-coupled amplifier & phase shift oscillator.
6. Square wave and triangular wave generator using OP-AMP (IC 741).
7. Monostable and astable multivibrator using IC555 Timer.
8. Wien-Bridge oscillator using OP-AMP (IC 741).
9. Active filters – high pass, low pass and band pass using OP-AMP (IC 741).
10. JFET Characteristics.
11. SCR Characteristics.
12. Two stage CE amplifier
13. Flip-flops: RS, JK, D Latch, Toggle
14. Counters: Binary, Ring, Johnson, Counting down

* *Additional experiments may be included.*

PHY 5251: BASIC CONDENSED MATTER PHYSICS **[4 0 0 4]**

Course outcomes:

At the end of this course, the student should be able to

1. Understand the concepts of crystal structure and various experimental techniques to quantify the structure.
2. Analyze the elastic and thermal properties of solids.
3. Evaluate the electrical properties of solids.
4. Understand the basics of semiconductor and superconductors.

Crystal structure: Bonding in Solids, Lattice energy of ionic crystals, Madelung constant. Crystal Structure: Symmetry, Space lattice, Unit cell, Crystal systems, Bravais lattices, Close packing of spheres, Miller indices, Indices of a direction, Crystal projections, Point groups and crystal classes, Glide plane, Screw axes, Space groups, Reciprocal lattice, Ewald sphere, Brillouin zone, Wigner Seitz cell, Bragg-Laue formulation of X-ray diffraction by a crystal, Atomic scattering factor, geometric structure factor, Experimental methods of X-ray diffraction, Electron and neutron diffraction by crystals. **16 hours**

Elastic and thermal properties of solids: Analysis of stress and strain, Dilation, Elastic compliance and stiffness constants, Elastic stiffness constants of cubic crystals, Experimental determination of elastic constants. Elastic vibrations of one dimensional homogeneous line, Normal modes of vibration in a finite length of the lattice, Linear diatomic lattice – dispersion relation, optical and acoustical mode, normal modes, Phonons, Phonon momentum. Specific heat: Classical theory, Einstein theory, Debye theory, Thermal conductivity, Phonon-phonon scattering, Normal and Umklapp processes, Thermal expansion. **14 hours**

Electrical properties of metals: Classical free electron theory - Drude model, Drawbacks of classical theory, Sommerfeld theory of electrical conductivity, Fermi-Dirac statistics and electron distribution in solids, Density of energy states and Fermi energy, Heat capacity of the electron gas, Variation of resistivity with temperature – Matthiessen's rule, Thermal conductivity in metals, Wiedemann-Franz law, Thermoelectric effects, Failure of Sommerfeld's free electron theory, Band theory of solids, Electron in a periodic field of a crystal – Kronig Penney model, Brillouin zones, Effective mass, Distinction between metals, semiconductors and insulators. **10 hours**

Semiconductors and Superconductors: Energy band gap, Equations of motion, Effective masses in semiconductors, Intrinsic carrier concentration, Intrinsic mobility, Impurity conductivity, Donor and acceptor states, Intrinsic and extrinsic semiconductors and their Fermi level, Hall Effect in metals and semiconductors. Superconductivity: Zero resistance, Critical temperature, Critical field, Meissner effect, Type I and type II superconductors, Cooper pairs, BCS theory (elementary ideas only), Josephson effects, London equation, applications of superconductors. Super fluidity. Basics of crystal defects and dislocations. Overview of optical, dielectric and magnetic properties of solids. **8 hours**

References:

[1] A. R. Verma and O. N. Srivastava, *Crystallography applied to Solid State Physics*, 2nd Edn. New Delhi: New Age International Pvt. Ltd., 2005.

[2] B. D. Cullity and S. R. Stock, *Elements of X-Ray Diffraction*, 3rd Edn. UK: Pearson Education Ltd., 2014.

[3] Charles Kittel, *Introduction to Solid State Physics*, 7th Edn. New York: John Wiley & Sons Inc., 1996.

[4] N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, New York: Harcourt College Publishers, 1976.

[5] L. Azaroff, *Introduction to Solids*, UK: McGraw Hill Education, 2017.

[6] H. Ibach and H. Luth, *Solid State Physics*: *An Introduction to Principles of Materials Science*, 4th Edn., Berlin: Springer-Verlag, 2009.

[7] M. Ali Omar, *Elementary Solid State Physics*, USA: Addison Wesley Pub. Co., 1975.

[8] A. C. Rose-Innes and E. H. Rhoderick, *Introduction to Superconductivity*, 2nd Edn., UK: Pergamon Press, 1978.

[9] R. L. Singhal, *Solid State Physics*, Meerut: Kedar Nath Ram Nath & Co., 1998

[10] J. P. McKelvey, *Solid State and Semiconductor Physics*, Florida: Krieger Pub. Co., 1982.

[11] J. S. Blakemore, *Solid State Physics*, 2nd Edn., UK: Cambridge University Press, 2008.

[12] S. O. Pillai, *Solid State Electronic Engineering Materials*, New Delhi: Wiley Eastern Ltd., 1991.

PHY 5252: NUMERICAL METHODS AND COMPUTATIONAL PHYSICS

[4 0 0 4]

Course Outcomes:

1. The students will be able to solve the problems of physics using computational methods
2. The students will be able to write programs in C to carry-out computations

Introduction to C Programming Language: C character set, Data types, Declarations, Expressions, statements and symbolic constants
Input-Output Functions: getchar, putchar, scanf, printf functions.
Pre-processor Directives: Eg. #include, #define
Operators and Expressions: Arithmetic, unary, logical, bit-wise, assignment and conditional operators.
Loop Control and Decision Control Statements: while-do, do-while, for statement, nested loops, if-else, switch, break, continue, and goto statements, comma operators.
Functions: Defining and accessing, passing arguments, Function prototypes, Recursion, Library functions, Static functions
Arrays: Defining and processing, Passing arrays to a function, Multi dimensional arrays
File Handling: File operations - read, write, update text/data files
18 hours
Solution of Algebraic Equations: Bisection method, False Position method, Iteration method, Newton- Raphson method and secant method.
Matrices and Linear Systems of Equation: Gauss Elimination, Gauss-Jordan and LU decomposition methods.
Interpolation: Finite Differences, forward differences, backward differences, central differences, Newton's Interpolation, Lagrange's Interpolation, Inverse Interpolation – successive approximation and Lagrange's method.
Least Square curve fitting: Linear and nonlinear curve fitting, Weighted Least Square, Least Square for continuous functions. **13 hours**

Numerical differentiation and integration: Divided difference method for differentiation. Newton-Cotes formula. Trapezoidal rule, Simpson's 1/3 and 3/8 rules.
Ordinary differential equations: Taylor's series method, Euler's method and its modifications, Runge-Kutta method (II order), Predictor-Corrector Methods (Adams – Moulton and Milne's methods), Applications- Free, Damped and
Forced oscillators, LCR Electrical Circuits. Boundary value problems by finite difference method – application in Schrödinger wave equation.
Partial differential equations: Finite difference equations, Laplace's equation – steady state system, Poisson's Equation – electrostatics and torsion in a rod examples, Parabolic equations – diffusion equation and application, Hyperbolic Equations-wave equation.
13 hours
Monte Carlo methods: Random numbers, Monte-Carlo crude integration, Particles in a box, and Radioactive Decay, Generation of random variables having specified distribution, Central Limit Theorem, Importance Sampling, Acceptance-Rejection method. **4 hours**

References:

[1] Brian W. Kernighan, Dennis M. Ritchie, *The C Programming Language*, 2nd Edition, New Delhi: Prentice Hall India Pvt Ltd, 2012.
[2] Yashavant Kanetkar, *Let Us C*, 12th Edition, New Delhi BPB Publications, 2012.
[3] S.S. Sastry, *Introductory Methods of Numerical Analysis*, 4th Edition, New Delhi: Prentice Hall of India Pvt Ltd, 2010.
[4] Verma, R C, Ahluwalia, P K, Sharma, K C, *Computational Physics – An Introduction*, 1st Edition, New delhi: New Age International (P) Limited Publishers, 2005.

[5] M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Delhi: New Age International (P) Limited Publishers, 2012.
[6] E Balagurusamy, *Numerical Methods*, 1st Edition, New Delhi: Tata McGraw-Hill Publishing Company Ltd, 1999.

PHY 5253: QUANTUM MECHANICS – II [4 0 0 4]

Course Outcomes:

At the end of this course, students will be able to:

1. Understand the concepts like identical particles, indistinguishability, pure and mixed states, entanglement and their physical implications.
2. Describe various approximation methods in quantum mechanics and apply these to some physical systems
3. Explain time dependent perturbation theory and calculate transition probabilities in simple time-dependent quantum systems
4. Describe quantum scattering theory and calculate differential cross-sections for some simple scattering problems.
5. Discuss Klein-Gordon equation and Dirac equation.

Identical Particles: Many-particle systems; Interchange symmetry; Systems of distinguishable non-interacting particle; Systems of identical particles; Exchange degeneracy; Symmetrization postulate; Constructing symmetric and antisymmetric functions; Systems of identical non-interacting particles; Pauli's exclusion principle; Density matrices – properties; Pure and mixed density matrices; Entanglement; EPR paradox; Bell inequality **8 Hours**

Time-Independent Perturbation Theory: Non-degenerate perturbation theory; Degenerate perturbation theory; Applications **7 Hours**

Variational Method and WKB Approximation: Variational principle – General theory; Examples; Ground state of helium; WKB approximation – General formalism; Bound states for potential wells; Connection formulae; Tunneling **7 Hours**

Time-Dependent Perturbation Theory: Time-dependent perturbation theory – General Theory; Transition probability; Constant perturbation; Fermi's golden rule; Harmonic perturbation; Adiabatic and sudden approximations; Interaction of atoms with radiation; Transition rates for absorption and emission of radiation; Transition rates within the dipole approximation; Electric dipole selection rules; Spontaneous emission **10 Hours**

Scattering Theory: Classical scattering theory; Differential cross-section; Examples; Quantum scattering theory; Scattering amplitude and Differential cross-section; Partial wave analysis; Phase shifts; Born approximation; Optical theorem; Breit-Wigner formula; Yukawa scattering and Rutherford scattering **10 Hours**

Relativistic Quantum Mechanics: Klein-Gordon equation; Dirac equation; Dirac and gamma matrices; Plane wave solutions of Dirac equation; Spin and magnetic moment of the electron

6 Hours

References:

[1] Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, 2nd Edition, New Delhi: Wiley, 2016.
[2] D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*, 3rd Edition, Cambridge: Cambridge University Press, 2018.
[3] R. Shankar, *Principles of Quantum Mechanics*, 2nd Edition, New York: Springer, 1994.
[4] J. J. Sakurai and Jim J. Napolitano, *Modern Quantum Mechanics*, 2nd Edition, Cambridge: Cambridge University Press, 2017.
[5] B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, 2nd Edition, New Delhi: Pearson Education, 2000.

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[14] David Griffiths, *Introduction to Elementary Particles*, 2^{nd} Edition, Weinheim: Wiley-VCH, 2008.
[15] J. J. Sakurai, *Advanced Quantum Mechanics*, 1^{st} Edition, New Delhi: Pearson Education, 2009.
[16] G. Aruldhas, *Quantum Mechanics*, 2^{nd} Edition, Delhi: Prentice Hall India, 2018.

PHY 5254: NUCLEAR AND PARTICLE PHYSICS **[4 0 0 4]**

Course Outcomes:

At the end of this course, the student should be able to,

1. Understand general properties of the nucleus and nuclear decay.
2. Comprehend Nuclear models and Nuclear reactions:
3. Understand Interaction of radiation with matter and radiation detectors
4. Realise Nuclear forces and elementary particles

General properties of the nucleus: Constituents of nucleus and their properties. Mass of the nucleus-binding energy. Charge and charge distribution. Size - estimation and determination of the nuclear radius. Nuclear radius from mirror nuclei - spin statistics and parity. Electric and Magnetic moment of the nucleus. **4 hours**

Nuclear decay - Alpha decay - quantum mechanical tunnelling - wave mechanical theory. Beta decay - continuous beta ray spectrum - neutrino hypothesis. Detection of neutrino - non-conservation of parity in beta decay. Gamma decay - selection rules - multipolarity - Internal conversion (qualitative only). **6 hours**

Interaction of radiation with matter, radiation detectors and particle accelerators: Energy loss of charged particles in matter, Bethe-Bloch formula. Bremsstrahlung. Interaction of gamma rays with matter - photoelectric effect, Compton scattering, Klein-Nishina formula (qualitative discussion) and pair production processes. Ionization chamber, proportional counter and GM counter. Scintillation detector. Particle accelerators: Betatron, microtron and linear accelerators (qualitative) **12 hours**

Nuclear Models: Liquid drop model-Weissacker's formula and its applications. Shell model-single particle potentials, spin-orbit coupling and level scheme. Magic numbers. Fermi gas model. Rotational Model. **5 hours**

Nuclear reactions: Cross section for a nuclear reaction. 'Q' equation of a reaction in laboratory system - threshold energy for a reaction. Centre of mass system for nucleus-nucleus collision. Nonrelativistic kinematics. Relation between angles and cross sections in lab and CM systems. Compound nucleus and direct reactions. Fission and Fusion. **9 hours**

Nuclear force: General features of nuclear forces; spin dependence, charge independence, exchange character etc. Two nucleon problem, Meson theory of nuclear forces- Yukawa's theory. **5 hours**

Elementary particle interactions and families: Classification of fundamental forces and elementary particles. Photons, gluons, baryons, mesons and leptons; quark model, Gellmann-Nishijima scheme. Properties of elementary particles -charge, isospin, mass, time reversal, spin and parity, strangeness. Conservation laws, CPT invariance. Application of symmetry arguments to particle reactions, Relativistic kinematics. **7 hours**

References:

[1] K. S. Krane, *Introductory Nuclear Physics*, 1st edition, New Delhi: Wiley India Pvt. Ltd., 2008.
[2] S. N. Ghoshal, *Nuclear Physics*, 1st edition, New Delhi: S Chand & Co. Ltd., 2009.
[3] G. F. Knoll, *Radiation Detection and Measurement*, 4th Edition, New York: Wiley, 2010.
[4] R. D. Evans, *The Atomic Nucleus*, 1st edition, New Delhi: Tata McGraw Hill Publishing Co. Ltd., 1972.
[5] S. L. Kakani and S. Kakani, *Nuclear and Particle Physics*, 2nd Edition, New Delhi: Viva Books Pvt. Ltd., 2013.
[6] D. Griffiths, *Introduction to Elementary Particles*, 2nd Edition, Weinheim: Wiley-VCH, 2008.
[7] H. A. Enge, *Introduction to Nuclear Physics*, 1st edition, Boston: Addison Wesley Pub. Co., 1966.

PHY 5255: PHYSICS LAB – III **[0 0 4 2]**

Course Outcomes (COs):
At the end of this course, the student should be able to
1. Understand the theory of charge transport in semiconductors.
2. Analyze the magnetic properties of solids.
3. Evaluate the electrical properties of metals.
4. Understand the electrical conductivity of amorphous solids.

The students are expected to perform at least TEN of the following experiments*

1. Hall Effect in Semiconductors.
2. Electron Spin Resonance (ESR).
3. Fermi Energy of a Metal.
4. Hysteresis Loop Tracer.
5. Diamagnetic Susceptibility using Gouy's method.
6. Paramagnetic Susceptibility using Gouy's method.
7. Energy gap of a semiconductor by four-probe method.
8. Electrical conductivity of amorphous solids.
9. Solar cell characteristics.
10. Ferromagnetic transition temperature.
11. Dispersion relation, acoustical mode and optical mode of a diatomic lattice using lattice dynamics kit.

12. Dipole moment of liquids/solids.

* *Additional experiments may be included*.

PHY 5256: COMPUTATIONAL PHYSICS LAB **[0 0 4 2]**

Course Outcomes:

1. Students will be able to use the programming tools to solve physics problems
2. Students will be familiar with solving some of the fundamental physics related problems.

Part A: Introduction to C programming: programs to introduce the usage of if-else and switch statement; while, do-while and for loops; built in mathematical functions; user defined functions; arrays; pointers.

Basics of MATLAB programming, Array operations in MATLAB, Loops and execution control, Working with files: Scripts and Functions, Plotting and program output

Part B: C programming for numerical methods (Minimum ten experiments have to be performed)

1. Finding the root of given equation by bi-section method.
2. Finding root of given equation by false position method.
3. Generating backward/forward difference table.
4. Linear least square fit of given data points.
5. Integrating given function by trapezoidal method.
6. Integrating given function by Simpson's 1/3 rule.
7. Capacitor charging/discharging by Euler's method.
8. Oscillation of driven oscillator by Euler's method.
9. Solving Schrödinger wave equation (time independent) by finite difference method.
10. Integration of given function by Monte-Carlo crude integration.
11. Radioactive decay of one type of nucleus by Monte-Carlo simulation.
12. Solving particles in a box problem by Monte-Carlo method.

* *Additional experiments may be included*.

PHY 5257: RESEARCH METHODOLOGY & TECHNICAL COMMUNICATION **[3 0 0 3]**

Course Outcomes:

1. Students are introduced to research field.
2. Students will be able to do literature review and identify the research gaps
3. Students will be able to write objectives, methodology.
4. Students will be aware of research ethics, plagiarism, journal publication procedures.

Introduction to Research Methodology: Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection using questionnaire, interviewing, and experimentation. Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Criterion for hypothesis construction, Nature of hypothesis, Need for having a working hypothesis, Characteristics and Types of hypothesis, Procedure for hypothesis testing. Applications in Physics **12 hours**

Sampling Methods and Data Analysis: Measurement and Scaling Techniques, Methods of Data Collection, Processing & Analysis of Data, Measures of Central Tendency, Dispersion, Skewness Regression Analysis and Correlation, Sampling Fundamentals, Central Limit Theorem, Estimation Testing of Hypotheses, Chi-Square Test. Applications in Physics
12 hours

Literature Review and Journal Communications: Importance of literature review. Performance of literature review and identification of research gap, Defining scope and objectives of the research problem, IEEE and Harvard styles of referencing. Preparation of conference presentations (Oral and Poster) through case study, Effective Presentation. Journal communication, Copyrights, and avoiding plagiarism. Preparation of dissertation.
12 hours

References:

[1] Ranjit Kumar, *Research Methodology; A Step-by-Step Guide for Beginners*, 2nd Edition, Chennai: Pearson, 2005.
[2] Geoffrey R. Marczyk, David De Matteo & David Festinger, *Essentials of Research Design and Methodology*, New Jersey: John Wiley &Sons, 2004
[3] John W. Creswel, *Research Design: Qualitative, Quantitative, and Mixed Methods approaches*, Singapore: SAGE, 2004.
[4] C. R. Kothari, *Research Methodology; Methods & Techniques*, New Delhi: New age international publishers, 2008.
[5] Michael P Marder, *Research Methods for science*, London: Cambridge University Press, 2014.

PHY 6101: ATOMIC AND MOLECULAR SPECTROSCOPY **[4 0 0 4]**

Course Outcomes:

At the end of this course, the student should be able to,

1. Understand the Interaction of electromagnetic radiation with atoms and molecules and general features of spectroscopic experimental methods and laser.
2. Comprehend X-ray Spectra and Resonance spectroscopy, Microwave spectra, infrared spectra and Raman spectroscopy.
3. Understand the concept of Electronic spectroscopy.

Introduction: Atomic models. Total angular momentum, quantum numbers, energy levels, transition rates, selections rules. Simple spectra of hydrogen and hydrogen like ions. Ground state of multi electron atoms. LS and jj coupling, doublet structure, triplet structure, penetrating and non-penetrating orbitals, transition and intensity rules. Quantum mechanical treatment of fine and hyperfine structure. Zeeman Effect, Paschen-Bach & Stark effects. **4 hours**

Interaction of EM-radiation with Atoms and Molecules: Absorption and emission of radiation, line width, broadening mechanisms, removal of line broadening. Lasers: Einstein coefficients, Light amplification, threshold condition, laser rate equation, 2,3 & 4-level systems. **8 hours**

X-ray Spectra: Review of emission & absorption of X-ray spectra (critical voltage, absorption coefficient, edge, filters) regular and irregular doublet law, Auger spectra. **4 hours**

Resonance Spectroscopy: Spin and an applied field, nuclear magnetic resonance spectroscopy (both hydrogen nuclei and other than hydrogen) techniques & instrumentation, Relaxation Processes, Bloch Equations, Chemical shift, structural study. Electron spin resonance spectroscopy: Principle of ESR, Hyperfine structure, ESR spectrum. **8 hours**

Microwave Spectra, Infrared Spectra and Raman Spectroscopy: Theory of rotational spectra of diatomic molecules - Experimental technique - structural information. Theory of vibrating rotator, vibration - rotation spectra, IR spectrometer. Application in chemical analysis. Rotational and vibrational Raman spectra - correlation with IR spectra - polarization of Raman lines - laser Raman studies. FT Raman spectroscopy. **12 hours**

Electronic Spectroscopy: Electronic spectra of diatomic molecules - coarse structure - Frank-Condon principle - rotational fine structure - formation of band head and shading of bands. Fluorescence and phosphorescence: mirror image symmetry of absorption and fluorescence bands. Basic principles of photoelectron spectra-determination of ionization potential. Mossbauer spectroscopy. Principles of Mossbauer spectroscopy. Applications. **12 hours**

References:

[1] H E White, *Introduction to Atomic Spectroscopy*, Mc Graw Hill Book Company Inc., 1934.
[2] G. Aruldhas*, Molecular structure and Spectroscopy,* 2nd Edition, Prentice Hall of India, 2001.
[3] J.M.Hollas, *Modern Spectroscopy*, 4th Edition. John Wiley, 2004.
[4] Robert Eisberg and R Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei & Particles*, 2nd Edition, John Wiley & Sons, 2006.
[5] Beiser A, *Concept of Modern Physics*, 5th Edition, Tata McGraw Hill, 1997.
[6] Lakowicz J R, *Principles of fluorescence spectroscopy*, 2nd Edition, Springer, 2006.
[7] Banwell C N and E M McCash, *Fundamentals of Molecular Spectroscopy*, 4th Edition, Tata McGraw Hill, 1994.

[8] Chatwall Gurdeep, *Spectroscopy*, 3rd Edition. Himalayas, 1994.
[9] Herzberg, *Molecular Spectra and Molecular Structure*, Van Nostrand Co., 1966.
[10] Ghatak & Thyagarajan, Optical Electronics, Cambridge University Press, 1991.

PHY 6102: ELECTROMAGNETIC THEORY **[4 0 0 4]**

Course Outcomes:

1. Understanding basics and applications of electrostatics and magnetostatics
2. Comprehending the concepts and applications of electrodynamics
3. Understanding basics of electromagnetic theory and EM radiations

Electrostatics and Magnetostatics: Laplace and Poisson equations, Boundary-Value problems in electrostatics, method of images. Multipole expansion, Field due to the polarized object, Gauss law in the presence of dielectric.
Biot-Savart law, Ampere's theorem, Vector Potential, magnetostatic boundary condition, multipole expansion of the vector potential. Magnetic properties of matter. Magnetisation, Field due to magnetized object, Ampere's law in magnetized objects. **12 hours**

Classical Electrodynamics: Electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions; Energy and momentum in electrodynamics; Scalar and vector potentials; Gauge Transformations: Lorentz Gauge and Coulomb Gauge, fields of a moving point charge. **12 hours**

Electromagnetic wave propagation: Electromagnetic waves in vacuum and matter, Propagation in linear media, Reflection and transmission in normal and oblique incidence. Absorption and dispersion, Reflection at a conducting surface, wave guides. **8 hours**

Plasma; Dynamics of charged particles in static and uniform electromagnetic field, Debye shielding distance, pinch effect **4 hours**

Radiation: Electric dipole radiation, Magnetic dipole radiation, Retarded potential, Lienard-Wiechert potential, radiation from arbitrary source, power radiated by point charge, Radiation reaction. **6 hours**

Relativistic Electrodynamics: Magnetism as a relativistic phenomenon, Field transform, Field tensor, electrodynamics in tensor notation, potential formulation of relativistic electrodynamics. **6 Hours**

References:

[1] David J. Griffiths, Introduction to Electrodynamics, 4th Edition, Essex: Pearson New International Ed, 2013.
[2] J. D. Jackson, Classical Electrodynamics, 3rd Edition, USA: Wiley Eastern, 1998.
[3] J.R. Reitz, F.J. Milford and R. W. Christy, Foundations of Electromagnetic Theory, 4th Edition, India ; Narosa Pub. House, 2008.
[4] Francis F Chen, Introduction to plasma physics and controlled fusion, 2nd Edition, New York: Springer, 2006

PHY 6103: EXPERIMENTAL METHODS IN PHYSICS [4 0 0 4]

Course outcomes:

At the end of the course, student should be able to

1. learn about the data interpretation and error analysis
2. get an insight into various electronic instrumentation techniques
3. explain the construction, working principle and applications of vacuum production, measurement, temperature measurements, transducers, thin films
4. explain the construction, working principle and applications of different experimental techniques used in modern day research

Data interpretation and analysis: Precision and accuracy, types of errors, error analysis, propagation of errors, Gaussian or Normal Distribution, significance of standard deviation in measurements, basic ideas about data acquisition using a PC. **7 hours**

Instrumentation: Voltmeter, ammeter, frequency generator, CRO, measurements using CRO, storage type CRO, capacitance bridge, Impedance meter, production of vacuum (rotary, diffusion, turbo and cryogenic pumps), measurement of vacuum, thin film deposition techniques (Physical and Chemical methods), thickness measurements for thin films, pressure gauge, cryogenics, measurement of temperature, types of thermocouples, resistive strain gauge. **16 hours**

Material analysis techniques I: Four probe method, Hall Effect, thermal conductivity, thermoelectric power, specific heat, Thermal analysis, thermal expansion, powder X-Ray diffraction; Static and dielectric measurements for para and ferroelectric materials. **11 hours**

Material analysis techniques II: Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Raman spectroscopy, X-ray photoelectric spectroscopy (XPS), Ultraviolet photoelectric spectroscopy (UPS), elemental analysis, Energy dispersive X-ray spectroscopy (EDAX), Secondary Ion Mass Spectrometry (SIMS), Auger electron spectroscopy (AES), vibrating sample magnetometer (VSM) and superconducting quantum interference infrared detectors (SQUID). **14 hours**

References:

[1] Albert D. Helfrick and William D. Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, Prentice Hall of India Private Limited, New Delhi, Original edition, 1990.

[2] A Pipko, Boris Kuznetsov, *Fundamentals of Vacuum Techniques*, MIR, Original edition,1984.

[3] K.L. Chopra , *Thin film phenomena*, McGraw-Hill Inc , Ist edition, 1969.

[4] V.V.Rao, T.B. Ghosh, K.L.Chopra , *Vacuum science and technology*, Allied Publishers Pvt. Ltd. 3rd edition, 2008.

[5] A.R.West, *Solid State Chemistry and its applications*, John Wiley Publications, 2nd edition,1987.

[6] V. A. Phillips, *Modern Metallographic Techniques and Their Applications*, John Wiley & Sons Inc, Ist edition, 1972.

[7] C. E. Hall, *Introduction to electron microscopy*, McGraw-Hill, 2nd edition,1966.

[8] D. B. Williams, C. B. Carter, *Transmission Electron Microscopy-A text book of materials science*, Springer, 2nd edition, 2009.

[9] B. D. Cullity, S.R. Stock, *Elements of X ray diffraction*, Addison-Wesley, 3rd edition, 2014.
[10] G. Haugstad, *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications*, Wiley, Ist edition, 2012.

PHY 6001: CONDENSED MATTER PHYSICS – I **[3 0 2 4]**

Course outcomes:

At the end of this course, the student should be able to

1. Analyze crystal defects in solids.
2. Understand the transport properties of solids.
3. Analyze and apply the band structure to create metal-semiconductor devices.
4. Understand the emergence of nanotechnology.

Crystal Defects: Point Defects: Lattice vacancies - Schottky defect & Frenkel defect, Diffusion, Fick's law, activation energy, self-diffusion, Colour centers – F centers, polorons, excitons, other centers in alkali halides. Shear strength of single crystals, Dislocations – Burgers vectors, Stress fields of dislocations, Low angle grain boundaries, Dislocation densities, Dislocations and crystal growth – Whiskers, Hardness of materials. Luminescence: Excitation and emission – Franck Condon principle, Radiationless transition, temperature dependence of luminescence, Decay mechanisms, Thermoluminescence and glow curves, Electroluminescence. **10 hours**

Transport Properties of Solids: Boltzmann equation, Electrical conductivity, Calculation of relaxation time, Impurity scattering, Ideal resistance, Carrier mobility, General transport coefficients, Thermal conductivity in metals, Thermal expansion, Mechanical effects on electrical resistance, Conductivity at high frequencies, Joule's law, Effect of magnetic fields-Hall effect, Magnetoresistance, Thermionic emission. **8 hours**

Band Theory of solids: Fermi Surfaces and Metals: Reduced zone scheme, Periodic zone scheme, Construction of Fermi surfaces, Nearly free electrons, Electron orbits, hole orbits and open orbits, Calculation of energy bands – Tight binding method, Wigner Seitz method, pseudopotential method, experimental methods in Fermi surface studies – Quantization of orbits in magnetic field, De Haas-van Alphen effect. **9 hours**

Metal – Semiconductor Devices and Nanotechnology: Metal - Semiconductor Contacts: Energy band relation, Schottky effect, Current transport processes, Characterization of barrier height, Device structures, Ohmic contact. Degenerate semiconductors. Emergence of nanotechnology: Bottom Up and Top Down approaches, Fundamentals of Zero-Dimensional nanostructures: nanoparticles, Basics of One-Dimensional nanostructures: Nanowires and nanorods, Introduction to Two-Dimensional nanostructures: Thin films, Overview of special nanomaterials - Carbon fullerenes and Carbon nanotubes, Core-Shell structures. **9 hours**

Experiments: (ANY FIVE)

1. Study of continuous and characteristic X-rays from Mo & Cu targets.
2. Hall Effect in metals.

3. Optical energy band gap of semiconducting thin films
4. Thin film thickness measurement by Fizeau and spectrophotometric method.
5. Study of Thermoluminescence of F-Centers.
6. Indexing of hexagonal and tetragonal crystal systems.
7. Production and measurement of high vacuum.
8. Synthesis and characterization of nanomaterials.

* *Additional experiments may be included.*

References:

[1] Charles Kittel, *Introduction to Solid State Physics*, 7th Edn. New York:John Wiley & Sons Inc.,1996.
[2] A. J. Dekker, *Solid State Physics*, 1st Edn, Noida, Macmillan Publishers India Ltd.,2009.
[3] V. Raghavan, *Materials Science and Engineering*, 5th Edn., New Delhi, PHI Learning Pvt. Ltd.,2011.
[4] J. M. Ziman, *Principles of the theory of solids*, 2nd Edn. USA:Cambridge University Press, 1995.
[5] S O Pillai, *Solid State Electronic Engineering Materials*, New Delhi:Wiley Eastern Ltd., 1991.
[6] S. M. Sze, *Physics of Semiconductor Devices*, 2nd Edn, New York :John Wiley & Sons Inc., 1981.
[7] Guozhong Cao, *Nanostructures and Nanomaterials: Synthesis, Properties & Applications*, London: Imperial College Press, 2004.

PHY 6002: OPTOELECTRONICS - I **[3 0 2 4]**

Course outcomes:

1. Understanding basics and working of laser system
2. Comprehending the EM wave propagation in optical fibers
3. Understanding the working principles of various optoelectronic devices

EM interaction with matter: Einstein coefficients. Light amplification. Threshold condition. Laser rate equations- frequency dependence of spontaneous to emission rate, Two, Three and Four level system (Qualitative). Line shape function – interaction with broadband and near monochromatic interaction. Variation of laser power around threshold and attainment of low threshold population. Optimum output coupling. Line broadening mechanisms-Natural broadening, collision broadening, and Doppler broadening. **10 hours**

Laser: Modes of rectangular cavity and the open planar resonator. The quality factor. The ultimate line width of laser of the laser. Mode selection. Q-switching-Methods of Q-Switching: Electrooptic Q-switching; Rotating prism; Acousto-optical Q-switching; Saturable absorber Q-switching. Mode locking in lasers- Techniques of mode locking. Types of lasers: Continuous and Pulsed lasers: Solid-State Lasers, Semiconductor Lasers, CO_2 Laser, Nd : YaG Laser. Ultraviolet Lasers: Excimers. Laser Safety. **12 hours**

Electromagnetic analysis of optical waveguide: Classification of modes for a planar waveguide, TE modes in a symmetric step index planar waveguide, TM modes in a symmetric step index planar waveguide, The relative magnitude of the longitudinal components of the E and H fields, Power associated with a mode, Radiation modes, Excitation of guided modes, Maxwell's equations in inhomogeneous media: TE and TM modes in planar waveguides. **6 hours**

Leaky modes in optical waveguides: Quasi-modes in a planar structure, Leakage of power from the core, the matrix method for determining the propagation characteristics of planar structures which may be leaky or absorbing, Calculation of bending loss in optical waveguides. **4 hours**

Optoelectronic Devices-I: Guided wave devices-Phase modulator, Mach-Zender interferometer modulator and switch, the optical direction coupler. Optical sources – LED's and laser diode. Optical detectors - pn detector, pin detector, avalanche photodiode- Principles of operation. Solar cells, VCSELs **4 hours**

Experiments: (ANY FIVE)

1. Verification of Gaussian nature of the given laser beam.
2. Evaluation of divergence angle of the laser beam.
3. Measurement of numerical aperture of an optical fiber.
4. Measurement of refractive index of the air using Interferometer.
5. Characterization of LED
6. Analyze the intensity of the given laser beam and hence verify the Malus Law
7. Determination of wavelength of a Helium-Neon laser beam using Mach- Zender Interferometer

* *Additional experiments may be included.*

References:

[1] A. K. Ghatak and K. Thyagarajan, *Optical Electronics*. Cambridge University Press, 1989.
[2] A. Ghatak and K. Thyagarajan, *Introduction to Fiber Optics*. Cambridge University Press, 1998.
[3] G. Keiser, *Optical Fiber Communications*. McGraw-Hill, 2011.
[4] S. M. Sze . Kwok K. Ng, *Physics of Semiconducting Devices*, 3rd ed. John Wiley & Sons, 2007.
[5] S. C. Gupta, *Optoelectronic Devices and Systems*, 2nd ed. PHI Learning, 2014.

PHY 6003: NUCLEAR PHYSICS – I **[3 0 2 4]**

Course outcomes:

1. Understanding the physics of nuclear forces
2. Understanding the working principle of various nuclear detectors

Nuclear forces: Two nucleon systems at low energies (deuteron), Low energy nucleon-nucleon scattering, pp and np scattering at low energies, Spin dependence of N-N interaction, Exchange interactions, Static moments of deuteron, High energy np scattering, High energy pp scattering. Experiments with polarized nucleon beams. **12 hours**

Nuclear Models: The single particle shell model - energy levels according to harmonic oscillator potential; effect of spin-orbit interaction, It's applications - nuclear spin; parity; and magnetic moment, Collective model - collective behavior of nuclei; collective vibration and rotation, Permanent deformation and collective rotation, Symmetry properties of deformation, The rotational spectra of even-even nuclei, Rotator particle coupling-spectra of odd A nuclei, Nilsson model and representation of Nilsson diagram. **12 hours**

Nuclear detectors: Basic radiation interaction mechanism, Scintillation detectors - different types of scintillators - photomultiplier tubes, measurement with scintillation detectors - NaI (Tl), plastic scintillator - Scintillation spectrometer. Spectrum analysis. Semiconductor detectors - semiconductor properties - physics of semiconductor detectors - diffused junction, surface barrier and ion-implanted detectors. Si (Li), Ge (Li) and HPGe detectors - semiconductor detector spectrometer. SSNTD and TLD. Neutron detectors - Neutron detection from nuclear reactions. BF3 counters, He-3 counters, fission detectors, activation method for neutron flux measurement. **12 hours**

Experiments: (ANY FIVE)

1. Random nature of radioactive decay
2. Absorption of beta rays
3. End point energy of beta particles
4. Energy calibration of gamma ray spectrometer (study of linearity)
5. Study of Cs-137 spectrum and calculation of FWHM & resolution for a given scintillation detector
6. Unknown energy of a radioactive isotope
7. Variation of energy resolution with gamma energy
8. Rutherford's Scattering experiment

* *Additional experiments may be included.*

References

[1] Ghoshal S N, *Atomic and Nuclear Physics*, S Chand & Company, New Delhi, 1994.

[2] Kenneth S Krane, Introductory Nuclear Physics, John Wiley, 1986.

[3] Knoll G F, Radiation Detection and Measurement, 2nd Edition, John Wiley, 1989.

[4] Kapoor S S and Ramamoorthy V S, *Radiation Detectors*, Wiley Eastern, 1986.

[5] Evans R D, *Atomic Nucleus*, Tata McGraw Hill, 1972.

[6] S. L. Kakani and Shubra Kakani, *Nuclear and particle Physics*, Viva books Pvt.Ltd. 2011.

[7] S. N. Mukherjee*, Elements of Nuclear Theory*, 1st Edition, CBS Publishers & Distributors Pvt Ltd, New Delhi, 2010.

[8] S. N. Ghoshal, *Nuclear Physics,* 1st Edition, S Chand & Company Limited, New Delhi 1994.

[9] R. R. Roy and B. P. Nigam, *Nuclear Physics Theory and Experiment***,** 1st Edition, New Age International(P) Limited, Publishers, 1967.

PHY 6004: ELECTRONICS - I **[3 0 2 4]**

Course Outcomes:

1. To understand analysis and realization of LTI systems, DFT and FFT algorithms.
2. Students will have learnt the basic concepts involved with basic mathematical tools/techniques used for processing of digital signals, signal transmission and high speed data transfer in modern day communication systems and networks.
3. Understand the architecture, hardware details, working principle and programming using microcontroller 8051 model.
4. Students will correlate programming using 8085 microprocessor with theory.

Programming with 8085 microprocessors: 8085 instructions – data transfer, arithmetic, logic and branch operations. Writing assembly language programs. Programming techniques with additional instructions. Counters and time delays. **12 hours**

Microcontrollers and embedded processors; Overview of the 8051 family: Microcontroller vs. General-Purpose Microprocessor, Microcontrollers for Embedded Systems, Choosing a Microcontroller and criteria for choosing a Microcontroller, Over view of 8051 Microcontroller family: various 8051 Microcontrollers, 8051 Assembly language programming, Inside the 8051-Registers, MOV and ADD instructions, structure of assembly language programming, Assembling and running 8051 programming, Program counter and ROM space, 8051 Data types and directives, Flag bits and PSW Register, Register banks and stack,Introduction jump, loop and call instructions with simple examples, Addressing modes, Brief introduction on arithmetic and logical instructions with examples**.** **12 hours**

Digital Signal Processing: Classification of signals, properties of discrete time signals and systems – linearity, stability and causality concepts. LTI systems – convolution. Fourier analysis of discrete time signals and systems. Sampling and modulation principles, aliasing effect, sampling theorem. Discrete Fourier transform (DFT) and IDFT. Circular convolution – properties of DFT, FFT algorithms (Radix 2) – flow charts. **12 hours**

Experiments: (ANY FIVE)

Programming using Microprocessor 8085

1. Data transfer operators (8bit/16bit)
2. Arithmetic operators
3. Logical operators
4. Loop statements
5. Branching statements (conditional / unconditional)
6. Memory addressing
7. Time delay

* *Additional experiments may be included.*

References:

[1] Gaonkar Ramesh S, Microprocessor architecture programming and applications with 8085, Penram International Publishing Pvt. Ltd (2012).

[2] McClellan James H;others, Signal processing first, Pearson Education (2003)

[3] Haykin S, Signals and Systems, John Wiley (1998).

[4] Oppenheim A V, Willsky A S and Nawab S H, Signals and Systems, II Edn. PHI (1997).

[5] Proakis J G and Manolakis D G, Digital Signal Processing, III Edn., PHI (1992)

[6] Muhammad Ali Mazidi, Janice Gillispie Mazidi, The 8051 Microcontroller and Embedded systems , Pearson (2002)

PHY6005: THEORETICAL PHYSICS - I [4 0 0 4]

Course outcomes:

At the end of the course the students should

1. Have understanding about classification of elementary particles, their properties, kinematics, and various discrete symmetry operations.
2. Be able to analyze quark model of hadrons group theoretically.
3. Be able to evaluate different scattering processes by applying Feynman diagrams.
4. Have understanding of quantum chromodynamics, weak interaction, electroweak unification and gauge theories of these interactions.

Introduction: Historical introduction to the elementary particles, the four forces, decays and conservation laws, unification schemes. **3 hours**

Kinematics and symmetries: Review of special theory of relativity, relativistic collisions. Symmetries, groups, and conservation laws, review of angular momenta, flavor symmetries, parity, charge conjugation, CP violation, time reversal and CPT theorem. **8 hours**

Quark model of hadrons : unitary symmetry in two dimensions, Lie algebra of SU(2), fundamental representation, SU(2) representations, unitary symmetry in three dimensions, Lie algebra of U(n), SU(n), representations of SU(3), decuplet tensor, SU(3) of flavor; SU(2) of spin and the SU(6), quark statistics and color, baryon, SU(4) of isospin and spin, wavefunctions for different hadron multiplets, Application of quark model - magnetic moment and mass of hadrons. **10 hours**

The Feynman calculus and QED : review of the Dirac equation, the photon, bilinears covariants, Feynman diagrams, the Feynman rules for quantum electrodynamics, examples, Casimir trick and the trace theorems, cross sections and lifetimes, some scattering processes. **9 hours**

Standard model : Quantum chromodynamics – asymptotic freedom; color confinement; Feynman rules for chromodynamics, Quarkonium physics, Weak interactions – charged leptonic weak interactions; charged weak interactions of quarks; neutral weak interactions, Electroweak unification – chiral fermion states; weak isospin and hypercharge; electro-weak mixing. **10 hours**

Gauge theory : Lagrangians in relativistic field theories, local gauge invariance, Yang – Mills theory, Chromodynamics, Feynman rules from Lagrangians, the mass term, spontaneous symmetry breaking, the Higgs mechanism. **8 hours**

Refrences:

[1] David Griffiths, *Introduction to Elementary Particles,* 1st Edition, Singapore: John Wiley & Sons, 1987.

[2] M. P. Khanna, *Introduction to Particle Physics*, 1st Edition, New Delhi: PHI Learning Private Limited, 2009.

[3] Fayyazuddin, Riazuddin, *A Modern Introduction to Particle Physics,* 3rd Edition, Singapore: World Scientific, 2012.

[4] F. Halzen, A. D. Martin, *Quarks and Leptons: An Introductory Course in Modern Particle Physics,* 1st Edition, Singapore: John Wiley & Sons, 1984.

[5] T. P. Cheng, L. F. Li, *Gauge theory of elementary particle physics,* 1st Edition, Oxford: Oxford University Press, 1984.
[6] W. N. Cottingham, D. A. Greenwood, *An introduction to the standard model of particle physics*, 2nd Edition, Cambridge: Cambridge University Press, 2007.

PHY 6201: STATISTICAL MECHANICS **[4 0 0 4]**

Course outcomes:

At the end of this course students will be able to:

1. Describe the laws of thermodynamics and their consequences; discuss thermodynamic potentials and Maxwell relations; Understand the statistical basis of thermodynamics and relate thermodynamic quantities to statistical quantities
2. Describe different ensembles in statistical mechanics, their distribution functions, ranges of applicability and the corresponding thermodynamic potentials
3. Understand quantum mechanical ensemble theory and their applications
4. Discuss the thermodynamics of ideal Bose and ideal Fermi gas and their physical applications.
5. Understand the theory of phase transitions

Statistical Basis of Thermodynamics: Review of thermodynamics; Laws of thermodynamics and their consequences; Thermodynamic potentials; Maxwell relations; Macrostates and microstates; Contact between statistics and Thermodynamics: Expressing T, P and μ in terms of Ω; The classical Ideal gas; Entropy of mixing and the Gibbs paradox; Sackur-Tetrode equation; Phase space of a classical system; Liouville's theorem **9 Hours**

Ensemble Theory: Microcanonical ensemble; Examples: Classical Ideal gas, harmonic oscillator; Canonical ensemble; Equilibrium between a system and a heat reservoir; Physical significance of the various statistical quantities in the canonical ensemble; Alternative expressions for the partition function; Examples: Classical Ideal gas, harmonic oscillators; Statistics of paramagnetism; Energy fluctuations in the canonical ensemble; Equipartition theorem; Virial theorem; Grand canonical ensemble; Equilibrium between a system and a particle-energy reservoir; Physical significance of the various statistical quantities in the grand canonical ensemble; Example: Classical Ideal gas; Density and energy fluctuations in the grand canonical ensemble **12 Hours**

Quantum Statistics: Quantum mechanical ensemble theory: Density matrix; Statistics of the various ensembles; Examples; Systems composed of indistinguishable particles; An ideal gas in a quantum-mechanical microcanonical ensemble; An ideal gas in other quantum-mechanical ensembles; Statistics of the occupation numbers; Gaseous systems composed of molecules with internal motion; monoatomic and diatomic molecules **10 Hours**

Ideal Bose and Fermi Systems: Thermodynamic behavior of ideal Bose gas; Bose-Einstein condensation; Thermodynamics of black body radiation and Planck's law; Specific heats of solids; Thermodynamic behavior of an ideal Fermi gas; Magnetic behavior of an ideal Fermi gas; Electron gas in metals **11 Hours**

Phase Transitions: First and second order phase transitions; Phase equilibrium; Clausius-Clapeyron equation; Critical point; Ising model **06 Hours**

References:

[1] R. K. Pathria and Paul D. Beale, *Statistical Mechanics*, 3rd Edition, Cambridge: Academic Press, 2011.

[2] Kerson Huang, *Statistical Mechanics*, 2nd Edition, New York: Wiley, 1987.

[3] Avijit Lahiri, *Statistical Mechanics*, 1st Edition, India: Universities Press, 2008.

[4] Palash B. Pal, *An Introductory Course of Statistical Mechanics*, 1st Edition, India: Narosa, 2009.
[5] Roger Bowley and Mariana Sanchez, *Introductory Statistical Mechanics,* 2nd Edition, United Kingdom: Oxford University Press, 2000.
[6] F. Reif, *Fundamentals of Statistical and Thermal Physics*, 1st Edition, New York: McGraw Hill, 2008.
[7] F. Mandl, *Statistical Physics,* 2nd edition, New York: Wiley, 1991.
[8] Linda E Reichl, *A Modern Course in Statistical Physics*, 4th Edition, New York: Wiley, 2016.
[9] Mehran Kardar, *Statistical Physics of Particles,* 1st Edition, Cambridge University Press, 2007.
[10] L. D. Landau and E. M. Lifshitz, *Statistical Physics*, 3rd Edition, United Kingdom: Butterworth-Heinemann, 1980.
[11] Daniel V. Schroeder, *An Introduction to Thermal Physics*, 1st Edition, London: Pearson, 1999.
[12] Herbert B. Callen, *Thermodynamics and An Introduction to Thermostatistics*, 2nd Edition, New York: Wiley, 2006

PHY 6202: GENERAL RELATIVITY AND COSMOLOGY **[4 0 0 4]**

Course Outcomes:

1. The students will be equipped with the necessary mathematical foundation to understand the concepts of general theory of relativity
2. The students will be able to differentiate between the Newtonian concept of gravity and relativistic concept of gravity
3. The students will be able to understand the modern cosmological models based on general theory of relativity

Mathematical formulation of General Relativity: review of special theory of relativity, four vectors, Principle of equivalence, equality of inertial mass and gravitational mass, gravitational red shift, covariant and contravariant tensors, quotient law, parallel transport, covariant differentiation, the Riemannian affine connection, Christoffel symbol of first kind, Christoffel symbol of second kind, geodesic equation, geodesic coordinates, Riemann Christoffel curvature tensor, the Ricci tensor, scalar curvature, condition for flat space, the Einstein tensor, Bianchi identities, tidal force field in a curved space time, Lie differentiation, Killing equations, the Killing vector field and its properties. **15 hours**

Physics in curved space-time: Energy-momentum tensor, the Einstein equations: derivation, the Newtonian approximation, gravitational waves, plane gravitational waves, polarization states of gravitational waves. The Schwarzschild solution: the spherically symmetric space-time, solutions, Birkhoff's theorem, The experimental tests of general theory of relativity: the gravitational redshift, mercury orbit precession, bending of light, the radar echo delay. **13 hours**

Black holes : introduction of black holes, non – rotating black hole - singularities, Eddington – Finkelstein coordinates : metric, solution, white holes, Schwarzschild metric in Kruskal – Szekers coordinates : solutions, wormhole, charged black hole : Reissner – Nordstrom solution, analysis of solution, rotating black hole : null tetrads, Kerr solutions, properties of Kerr solution. **10 hours**

Cosmology : The cosmological principle, Weyl postulate, Newtonian cosmology, Hubble's law, homogeneity and isotropy, spaces of different curvature, the Robertson – Walker metric and Friedmann equations, different models of universe : the flat space models, models with vanishing cosmological constant, inflationary models, horizon problem, flatness problem, Eintstein and de Sitter universes.

References:

[1] R. d'Inverno, *Introducing Einstein's Relativity*, 1st edition, Oxford: Clarendon Press, 1992.
[2] B. Schutz, *A First Course in Relativity*, 2nd Edition, Cambridge: Cambridge University Press, 2009.
[3] L. Ryder, *Introduction to General Relativiy*, 1st edition, Cambridge: Cambridge University Press, 2009.
[4] K. D. Krori, *Fundamentals of Special and General Relativity*, 1st edition, New Delhi: PHI Learning Pvt. Ltd., 2010.
[5] J. V. Narlikar, *An Introduction to Relativity*, 1st edition, New Delhi: Cambridge University Press, 2010.

PHY 6011: CONDENSED MATTER PHYSICS – II **[3 0 2 4]**

Course outcomes:

At the end of this course, the student should be able to

1. Comprehend the dielectric properties of solids.
2. Understand and apply the magnetic properties of solids.
3. Analyze the theory and properties of superconductivity.
4. Understand the basics of glasses, polymers and liquid crystals.

Dielectrics and Ferroelectrics: Dielectric properties of solids: Polarization, Macroscopic electric field, Depolarization field, Local electric field at an atom, Lorentz field, Field of dipoles inside cavity - Lorentz relation, Dielectric constant, Polarizability, Clausius-Mossotti relation, Electronic polarizability, Static ionic polarizability of molecules, Orientational polarization, Complex dielectric constant, Dielectric losses and relaxation time, Classical theory of electronic polarization and optical absorption, Frequency dependence of polarizability, Lyddane-Sachs-Teller (LST) relation, General properties of ferroelectric materials, Classification of ferroelectrics, Dipole theory of ferroelectricity, Thermodynamics of ferroelectric transitions, Ferroelectric domains, Antiferroelectricity, Piezoelectricity.

10 hours

Magnetic properties of Solids: Magnetization, Magnetic susceptibility, Origin of permanent magnetic dipoles, Diamagnetism and Larmor precession, Paramagnetism, Classical theory of paramagnetism, Quantum theory of paramagnetism, Ferromagnetism, Curie-Weiss law, Ferromagnetic domains, Coercive force and hysteresis, Antiferromagnetism, Ferrimagnetism, Structure of ferrites, Nuclear magnetic resonance (NMR), Soft and hard magnetic materials.

8 hours

Superconductivity: Special magnetic behavior of superconductor – Meissner effect, permeability and susceptibility, surface currents, penetration depth, London's theory, Entropy of superconducting state, Specific heat and latent heat, Ginzburg-Landau theory, microscopic theory of superconductivity –Concept of energy gap, electron-lattice interaction, Cooper pairs, Superconducting ground state and properties of ground state, Macroscopic properties from BCS theory. Superconducting Quantum Interference Devices (SQUIDS), High T_C superconductors. **8 hours**

Glasses, Polymers and Liquid Crystals: Structural and kinetic theories of glass formation, Optical properties, Compositions and properties of commercial glasses. Ceramics. Composites. Polymers : Classification, Chain polymerization, Step polymerization, Molecular weights – average, number-average, weight-average, Degree of polymerization, Microstructure based on chemical and geometrical structures, Glass transition temperature, Crystallinity, Conducting polymers. Liquid crystals: Molecular Structures and Chemical Compositions, Electronic properties, Lyotropic, polymeric and thermotropic liquid crystals - Nematics, Cholesterics and Smectics, Other liquid crystalline phases and molecular engineered structures, Liquid crystal displays. **10 hours**

Experiments: (ANY FIVE)

1. Characterization of cubic crystals by powder method of X-ray diffraction.
2. Determination of transition temperature in ferrites.
3. Measurement of magneto resistance.

4. Determination of transition temperature in ferroelectrics.
5. Thermal diffusivity and thermal conductivity of brass.
6. Zeeman Effect.
7. Preparation of thin films by spray pyrolysis technique and their characterization.

* *Additional experiments may be included.*

References:

[1] Charles Kittel, *Introduction to Solid State Physics*, 8th Edition, New York: John Wiley & Sons Inc., 2012.

[2] A. J. Dekker, *Solid State Physics*, 1st Edition, New Delhi: Macmillan Publishers India Ltd. 2009.

[3] A. C. Rose-Innes, E. H. Rhoderick, *Introduction to Superconductivity*, 2nd Edn., UK: Pergamon Press, 1978.

[4] James E. Shelby, *Introduction to Glass Science and Technology*, 2nd Edn., UK: Royal Society of Chemistry, 2005.

[5] V. R. Gowariker, N. V. Viswanathan, J. Sreedhar, *Polymer Science*, New Delhi: New Age International Pvt. Ltd., 2015.

[6] I. C. Khoo, *Liquid Crystals*, 2nd Edn, New Jersey: John Wiley & Sons Inc., 2007.

PHY 6012: OPTOELECTRONICS - II **[3 0 2 4]**

Course outcomes:

On successful completion of this course, student should be able to:

1. explain fundamental physical and technical basis of nonlinear optics in condensed matter
2. apply the nonlinear optical effects in various optoelectronic applications
3. describe the basic phenomena governing the electro and acousto optical effect and their applications
4. describe the applications of optoelectronics devices in communication
5. explain the properties of ultrafast lasers and applications in photonics

Nonlinear optics: Introduction to Nonlinear Optics: Optics & Wave propagation in anisotropic medium. Nonlinear optical process: Harmonic generation, Phase Matching, Nonlinear Refraction and Absorption, Multiphoton Processes, Self-focusing, Self-phase-modulation, Parametric Effects- Optical Parametric Oscillators. Optical Switching and Solitons. Nonlinear optical Techniques & Materials: Z-Scan, Four-Wave Mixing, Third Harmonic Generation. **12 hours**

The electrooptic and acoustooptic effect: Review of Electro-optics – Uniaxial and biaxial crystals. Introduction to electro-optic effect: The electro-optic effect in KDP crystals: longitudinal mode, the electro-optic effect in KDP crystals: transverse mode, general considerations on modulator design. Acousto-optic effect Raman – Nath diffraction and Bragg diffraction, experiment to observe Raman – Nath and Bragg diffraction. **6 hours**

Optoelectronic Devices II: Electro-Optic and Acousto-optic Modulators, Optical fibers: The Optical Fiber. The numerical aperture, Attenuation in Optical Fibers, Modes of a Step-Index Fiber, Single-Mode Fiber (SMF), Pulse Dispersion in Optical Fibers, Fiber Bragg Gratings, Fiber optic sensors. Optical Amplifiers: Erbium-Doped Fiber Amplifiers (EDFAs), Raman Fiber Amplifier (RFA) **4 hours**

Optical fiber communication: Fiber-optic components, Optical Fibers, Sources for Optical Transmitters, Detectors for Optical Receivers (Review): Evolution of Optical Fiber Communication System, Performance of Optical Fiber Systems, Bit-Error Rates, Receiver Sensitivity, Attenuation and Dispersion Limited Systems- Power Budget, Time Budget. Attenuation and Dispersion Compensation and Management. Modulation and multiplexing. **6 hours**

Ultrafast Photonics: Femtosecond Laser Pulses: Linear Properties of Ultrashort Light Pulses. Generation of Femtosecond Laser Pulses via Mode Locking. Measurement Techniques for Femtosecond Laser Pulses. Ultrafast THz Photonics and Applications-Sub picosecond Electrical Pulses, THz Waveguides. An Optoelectronic THz Beam System. **8 hours**

Experiments: (ANY FIVE)

1. Measurement of refractive index of the transparent material using Interferometer.
2. Determination of refractive index of the given samples by Brewster's angle method.
3. Measurement of propagation loss in optical fiber
4. Measurement of bending loss in optical fiber.
5. Characterization of opto-coupler
6. Characterization of phototransistor
7. Characterization of photodiode

* *Additional experiments may be included.*

References:

[1] R. W. Boyd, *Nonlinear Optics*. 3rd ed. Academic Press, 2008.
[2] G. P. Agrawal, *Nonlinear Fiber Optics*. Elsevier Science, 2013.
[3] A. K. Ghatak and K. Thyagarajan, *Optical Electronics*. Cambridge University Press, 1989.
[4] D. R. Grischkowsky, "Ultrafast THz Photonics and Applications," in *Springer Handbook of Lasers and Optics*, Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 1399–1459.
[5] B. E. A. Saleh and M. C. Teich, *Fundamentals of Photonics*. John Wiley & Sons, 1991.
[6] G. Keiser, *Optical Fiber Communications*. McGraw-Hill Companies, 2011.

PHY 6013: NUCLEAR PHYSICS - II **[3 0 2 4]**

Course Outcomes:

1. Comprehend the nuclear reaction mechanisms and the theories developed.
2. Understand the working of nuclear reactors and various reactor types.

Nuclear Reactions: Reactions mechanism and cross sections, Compound nucleus cross-section, Cross section from nuclear interactions, Optical model, S-wave neutron scattering, Theory of compound nucleus resonances, The Breit Wigner formula, Direct nuclear reactions - distorted wave theory; cross-sections for rearrangement collisions; deuteron stripping reaction. **10 hours**

Nuclear Fission: Introduction to fission. Nature of fission fragments-Energy distribution between fission fragments-Emission of neutrons in fission-Energetics of fission process-Bohr-Wheeler theory- Cross section of neutron induced fission-fertile material-particle induced and photo-fission. Shell effect and shape isomerism. **10 hours**

Neutron and Reactor physics: Classification of neutrons according to their energy - neutron sources. - slow neutron cross section measurements - neutron monochromators. Fundamentals of nuclear fission – fission fuels. Neutron chain reaction, multiplication factor. Condition for chain reaction - the Four-factor formula- Condition for criticality – Breeding phenomena. Slowing down of neutrons by elastic collisions - logarithmic decrement in energy - number of collisions for thermalisation. **10 hours**

Elementary theory of diffusion of neutrons - spatial distribution of neutron flux in an infinite medium with point source at the centre. Reflection of neutrons. Slowing down density - Fermi age equation. Corrections for absorption - resonance escape probability. The pile equations - Buckling. Critical size for spherical and rectangular piles. Different types of reactors. Thermal neutron reactor - Fast breeder reactor. **6 hours**

Experiments: (ANY FIVE)

1. Attenuation of gamma rays
2. Rest mass energy of electron
3. Inverse square law for gamma radiation
4. Study of Co-60 spectrum and calculation of resolution of detector in terms of energy
5. Spectrum analysis of Co-60 & Cs-137 and to explain some of the features of Compton edge and backscatter peak
6. Efficiency of alpha counting system
7. Range of alpha particles in air

* *Additional experiments may be included.*

References

[1] Ghoshal S N, *Atomic and Nuclear Physics*, S Chand & Company, New Delhi, 1994.

[2] Kenneth S Krane, *Introductory Nuclear Physics*, John Wiley, 1986.

[3] Samuel Glasstone and Alexander Sesonske, *Nuclear Reactor Engineering*, Van Nostrand Reinhold Company, 1967.

[4] Evans R D, *Atomic Nucleus*, Tata McGraw Hill, 1972.

[5] S. L. Kakani and Shubra Kakani, *Nuclear and particle Physics*, Viva books Pvt.Ltd., 2011.

[6] S. N. Mukherjee, *Elements of Nuclear Theory*, 1st Edition, New Delhi: CBS Publishers & Distributors Pvt Ltd, 2010.

[7] S. N. Ghoshal, *Nuclear Physics*, 1st Edition, New Delhi: S Chand & Company Limited, 1994.

[8] R. R. Roy and B. P. Nigam, *Nuclear Physics Theory and Experiment*, 1st Edition, New Age International(P) Limited, 1967.

PHY 6014: ELECTRONICS - II [3 0 2 4]

Course Outcomes:

1. Student can understand the concepts of op-amp and its linear and non linear applications.

2. Understanding the concepts of interfacing and how it can be used in devices.

3. Students would understand theoretical concepts by implementing through experiments.

Characteristics and simple applications of special semiconductor devices - Schottky barrier diode - Varactor diode - Tunnel diode - Photo diode – LED - Thermistor - Solar cell, IGBT and CMOS inverter.
Amplifiers - Cascade amplifier - Cascode amplifier. Darlington connection. Current mirror circuit. Power amplifiers - Class A, Class B & Class AB amplifiers, push – pull amplifier
12 hours

Operational amplifiers: Voltage references (5V) - voltage level detector - Comparator IC 311 - Phase shifter - precision rectifier - peak detector - instrumentation amplifier – Noise in electronic devices. Active filters - 40 dB/decade roll off (low pass, high pass & band pass). Precision triangle & square wave generator - IC AD630. Analog multiplier - IC AD633 - squaring a dc voltage and doubling the frequency of ac. Frequency multiplier using phase locked loop IC565. **12 hours**

Digital IC technologies and interfacing different logic families: Programmable logic devices - Programmable array logic PAL 16L8 - Generic array logic GAL 22V10. Implementation 8 bit serial in/parallel out shift register using GAL 22V10. Digital to analog converter AD 558. Successive binary approximation ADC - microprocessor compatible ADC AD 670. **12 hours**

Experiments: (ANY FIVE)

1. Analog to digital conversion
2. Digital to analog conversion
3. Precision rectifier using Op-Amp
4. BJT differential amplifier
5. PLL565 – Frequency synthesis
6. Phase shifter using op-amp
7. Push – pull amplifier
8. Digital counters

* *Additional experiments may be included.*

References:

[1] Sergio Franco, *Design with Op-amp and analog integrated circuits*, McGraw Hill, 1988.
[2] Boylestad R & Nashelsky L, *Electronic Devices and Circuit Theory,* VIII Edn, New Delhi, PHI, 2002.
[3] Coughlin R F & Driscoll F F, *Operational Amplifiers and Linear Integrated Circuits*, VI Edn. Chennai: Pearson Education Asia, 2002.
[4] Gayakwad R A, *Opamps and Linear Integrated Circuits*, IV Edn. New Delhi: PHI, 2002.
[5] Floyd T L, *Digital Fundamentals*, VII Edn. Chennai: Pearson Education Asia, 2002.

PHY6015: THEORETICAL PHYSICS - II **[4 0 0 4]**

Course outcomes:

At the end of this course the students should:

1. Know about the second quantization and propagators.
2. To do quantization of scalar, complex scalar, and Dirac fields.
3. To know derivation of Feynman rules and calculaton of scattering cross section.
4. To do quantization of electromagnetic field.

Basic concepts : need of quantum field theory, space and time in relativistic quantum theory, natural units, second quantization, harmonic oscillator in terms of creation and annihilation operators, propagators. **6 hours**

Classical Field theory : functionals, action principle and Euler-Lagrange equations, Hamiltonian formalism and Poisson brackets, Euler-Lagrange equations in field theory, Hamiltonian formalism, Noether theorem. **6 hours**

Quantization of scalar fields and complex scalar field : equation of motion, the field and its canonical quantization, Fourier decomposition of the field, ground state of the Hamiltonian and normal ordering, Fock space, complex scalar field – creation and annihilation operators, particle and antiparticles, ground state and Hamiltonian, propagator. **8 hours**

Quantization of Dirac fields : Dirac Hamiltonian, Dirac equation, plane wave solutions of Dirac equation, positive and negative energy spinors, projection operators – projection operators for positive and negative energy states, helicity projection operators, chirality projection operators, spin projection operators, Lagrangian for a Dirac field, Fourier decomposition of the field, propagator. **7 hours**

The S-matrix expansion : examples of interactions, evolution operator, S-matrix, Wick's theorem, Feynman amplitude, Feynman rules, virtual particles, Amplitudes which are not S-matrix elements. **7 hours**

Cross-sections and decay rates : decay rate calculations, scattering cross section, generalities of 2-to-2 scattering – CM frame; lab frame, Inelastic scattering with four fermion interaction – cross-section in CM frame; cross-section in lab frame, Mandelstam variables, Some scattering processes, qualitative idea of renormalization. **8 hours**

Quantization of the electromagnetic field: classical theory of electromagnetic fields, problems with quantization, modification of the classical Lagrangian, propagator, Fourier decomposition of the field, physical states. **6 hours**

References:

[1] A. Lahiri, P. B. Pal, *A First Book of Quantum Field Theory,* 2nd Edition, New Delhi: Narosa Publishing House, 2004.

[2] Tom Lancaster, Stephen J. Blundell, *Quantum field theory for the gifted amateur,* 1st Edition, Oxford: Oxford University Press, 2014.

[3] F. Mandl, G. Shaw, *Quantum Field Theory*, 1st Edition, Chichester: John Wiley & Sons, 1984.

[4] W. Greiner, J. Reinhardt, *Field Quantization*, 1st Edition, New Delhi: Springer (India) Private Limited, 2005.
[5] M. E. Peskin, D. V. Shroeder, *An Introduction to Quantum Field Theory*, 1st Edition, Kolkata: Sarat Book House, 2005.

PHY 6051: FUNDAMENTALS OF ASTRONOMY AND ASTROPHYSICS

[3 0 0 3]

Course Outcomes:

1. The students will be able to understand the structure and life cycle of stars
2. The students will be able to understand the large scale structure of our universe

Properties of ordinary stars: Brightness of starlight; the electromagnetic spectrum; Colours of stars; stellar distances; absolute magnitudes; HR diagram**.** **6 Hours**

Stellar evolution: Formation of star; the main sequence; stellar structure; evolution off the main sequence; planetary nebulae; white dwarfs**.** The death of high mass stars: Supernovae; neutron stars; pulsars; stellar black holes. **24 hours**

Normal Galaxies: Types of galaxies; Dark matter in galaxies. Cosmology: The scale of universe; expansion of the universe; open or closed universe; the big bang; the cosmic background radiation; big bang nucleosynthesis. Astronomical instruments**.** **6 hours**

References:

[1] Marc L Kutner, *Astronomy: A physical Perspective*, Cambridge University Press,2003
[2] Baidyanath Basu, *An Introduction to Astrophysics*, II Edn, PHI Learning Pvt. Ltd, 2011.
[3] Michael Zeilik, *Introductory Astronomy and Astrophysics*, 4th edition, Saunders College Pub. 1992.