M.Sc. (Physics): Optoelectronics

Semester I		Semester II	
Title of Paper	**Credits**	**Title of Paper**	**Credits**
1. Classical Mechanics	**(3-1-0)**	1. Statistical Mechanics	**(3-1-0)**
2. Mathematical Physics –I	**(3-1-0)**	2. Mathematical Physics -II	**(3-1-0)**
3. Quantum Mechanics –I	**(3-1-0)**	3. Quantum Mechanics-II	**(3-1-0)**
4. Condensed Matter Physics	**(3-0-2)**	4. Fiber optics and Non-linear optics	**(3-0-2)**
5. Physics Lab-I	**(3-0-2)**	5. Physics Lab-II (Non-linear optics)	**(3-0-2)**
Total credits of Semester –I:	**20**	**Total credits of Semester –II:**	**20**
Semester III		**Semester IV**	
Title of Paper	**Credits**	**Title of Paper**	**Credits**
1 Electromagnetic Theory & Electrodynamics	**(3-1-0)**	1 Project	**(0-0-8)**
2 Atomic & Molecular Physics	**(3-1-0)**	2 Particle Physics & Nuclear Physics	**(3-1-0)**
3 Optoelectronics & Semiconductor Devices	**(3-1-0)**	3 Fiber Optics and Photonics	**(3-1-0)**
4 Advanced Lasers And Nonlinear Optics	**(3-0-2)**	4 Elective Paper: Only one elective paper is to be chosen as given in **Table-A** below.	**(3-0-2)**
5 Physics Lab -III (Optoelectronics)	**(3-0-2)**	5 Physics Lab- IV	**(3-0-2)**
Total credits of Semester –III:	**20**	**Total credits of Semester –IV :**	**20**

Total Course Credits: 20 x 4 = 80

TABLE-A

List of elective papers:
1. *Physics of Engineering Materials*
2. *Physics of Nano-Materials*
3. *Science & Technology of Thin Films and their preparation*

Semester - I

Paper-I

Course Code	Paper Title	Credit (L-T-P)
####	**CLASSICAL MECHANICS**	**3-1-0**

Lagrangian Formulation: Mechanics of a system of particles; constraints of motion, generalized coordinates, D'Alembert's Principle and Lagrange's velocity - dependent forces and the dissipation function, Applications of Lagrangian formulation.

Hamilton's Principles: Calculus of variations, Hamilton's principle, Lagrange's equation from Hamilton's principle, extension to nonholonomic systems, advantages of variational principle formulation, symmetry properties of space and time and conservation theorems.

Hamilton's Equations: Legendre Transformation, Hamilton's equations of motion, Cyclic-coordinates, Hamilton's equations from variational principle, Principle of least action.

Canonical Transformation and Hamilton-Jacobi Theory: Canonical transformation and its examples, Poisson's brackets, Equations of motion, Angular momentum, Poisson's Bracket relations, infinitesimal canonical transformation, Conservation Theorems. Hamilton-Jacobi equations for principal and characteristic functions, Action-angle variables for systems with one-degree of freedom.

Rigid Body Motion: Independent co-ordinates of rigid body, orthogonal transformations, Eulerian Angles and Euler's theorem, infinitesimal rotation, Rate of change of a vector, Coriolis force, angular momentum and kinetic energy of a rigid body, the inertia tensor, principal axis transformation, Euler equations of motion, Torque free motion of rigid body, motion of a symmetrical top.

Small Oscillations: Eigen value equation, Free vibrations, Normal Coordinates, Vibrations of a tritomic molecule.

Reference Books :

1. Mechanics , L.D. Landau and E. M. Lifshitz, (2nd Edition, Pergamon Press, 1976)
2. Classical Mechanics and Relativity, Herald J. W. Muller-Kirsten, (World Scientific, 2008)
3. Classical Mechanics, H. Goldstein, (3rd Edition, Addison-Wesley, 2001)
4. Classical Mechanics of Particles and Rigid bodies, K. C. Gupta, (John Wiley, 1988)
5. Advanced Classical and Quantum Dynamics, W. Dittrich, W. M. Reuter, (Springer, 1992)
6. Classical Mechanics, T. W. Kibble, Frank H. Berkshire, (Imperial College Press, 2004)
7. Mathematical Methods of Classical Mechanics, V. I. Arnold, (Springer, 1989)
8. Classical Mechanics, Rana & Joag, (Tata McGraw Hill, 2001)

Paper-II

Course Code	Paper Title	Credit (L-T-P)
####	**MATHEMATICAL PHYSICS –I**	**3-1-0**

Complex Variables: Introduction, Cauchy-Riemann conditions, Cauchy's Integral formula, Laurent expansion, singularities, calculus of residues, evaluation of definite integrals, Dispersion relation.
Delta and Gamma Functions: Dirac delta function, Delta sequences for one dimensional function, properties of delta function, Gamma function, factorial notation and applications, Beta function.
Differential Equations: Partial differential equations of theoretical physics, boundary value problems, Neumann & Dirichlet Boundary conditions, separation of variables, singular points, series solutions, second solution.
Special Functions: Bessel functions of first and second kind, Generating function, integral representation and recurrence relations for Bessel's functions of first kind, orthogonality. Legendre functions: generating function, recurrence relations and special properties, orthogonality, various definitions of Legendre polynominals. Associated Legendre functions: recurrence relations, parity and orthogonality, Hermite functions, Laguerre functions.

Fourier and Laplace Transforms: Fourier transform, Sine, Cosine and Complex transforms with examples, Definition, Properties and Representations of Dirac Delta Function, Properties of Fourier Transforms, Transforms of derivatives, Parseval's Theorem, Convolution Theorem, Momentum representation, Applications to Partial differential equations, Discrete Fourier transform, Laplace transform, Properties and examples of Laplace Transform, Convolution theorem and its applications, Laplace transform method of solving differential equations.

Reference Books:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 9th Edition, (John Wiley & Sons, Inc., 2006)
2. Mathematical Methods for Physicists: G. Arfken and H.J. Weber 7th Edition, (Academic Press, San Diego, 2012)
3. Mathematical Physics: P.K. Chattopadhyay (Wiley Eastern, New Delhi, 2004)
4. Mathematical Physics: A.K. Ghatak, I.C. Goyal and S.J. Chua (MacMillan, India, Delhi, 1096)
5. Mathematical Methods in the Physical Sciences – M.L. Boas 3rd Edition, (Wiley, New York, 2007)
6. Special Functions: E.D. Rainville (MacMillan, New York, 1960)
7. Mathematical Methods for Physics and Engineering: K. F. Riley, M. P. Hobson and S.J. Bence, (3rd Edition, Cambridge University Press, Cambridge, 2006)

Paper-III

Course Code	Paper Title	Credit (L-T-P)
####	**QUANTUM MECHANICS –I**	**3-1-0**

Basic Concepts: De Broglie waves and Group velocity concept, uncertainty principle and its application, Davission-Germer experiment, Derivation of Schrödinger equation for time independent and time dependent cases. Postulates of quantum mechanics, significance of wave function.

Application of Schrödinger wave Equation for a free particle (one dimensional and three dimensional case), particle in a box (one dimensional and three dimensional), simple harmonic oscillator(one dimensional and three dimensional), theory of hydrogen atom.

Linear Vector and Representation Theory: Linear vector space, Dirac notations of Bra - Ket notation, Matrix representation of Observables and states, Determination of eigenvalues and eigenstate for observables using matrix representations, Change of representation and unitary transformations, Coordinate and momentum representations, Equations of motion in Schroedinger and Heisenberg pictures.

Theory of Angular Momentum: Symmetry invariance and conservation laws, relation between rotation and angular momentum commutation rule, matrix representation, addition of angular momentum and Clebsch Gordon coefficients, Pauli's spin matrices. Green's function, method of solving inhomogeneous differential equations, Boundary Conditions, Application to One-dimensional problems.

Scattering Theory: Differential and total Scattering cross-sections laws, partial wave analysis and application to simple cases; Integral form of scattering equation, Born approximation validity and simple applications.

Reference Books:

1. Quantum Mechanics: L.I. Schiff, (McGraw Hill, 1968)
2. Modern Quantum Mechanics: J.J. Sakurai. (Addison Wesley, 1993)
3. Introduction to Quantum Mechanics: C.J. Joachain and B.H. Bransden (Pearson Education, 2000)
4. Introduction of Quantum Mechanics: D.J. Griffiths (Pearson Education 2004)
5. Principles of Quantum Mechanics: P.A.M. Dirac (4^{th} Edition, Oxford Scientific Publications, 1981)

Paper- IV

Course Code	Paper Title	Credit (L-T-P)
####	**CONDENSED MATTER PHYSICS**	**3-0-2**

Classification of solids, space lattices, bravais lattice, primitive and unit cell, reciprocal lattice, co-ordination number, atomic packing factor, atomic radii, crystal structure and miller indices, inter planner spacing, some important structures.Various kinds of crystal imperfections, point defect, Schottky and Frenkel defect, Dislocations, edge and screw dislocation, grain boundary, effect of defects on electrical properties of materials

Bragg's law, laue pattern, X-ray difractometer, determination of lattice parameter using XRD, absorption of X-rays, absorption edge. Primary and secondary bonds, ionic bond, covalent bond, metallic bond, hydrogen bond, Vander-wall bond, forces between atoms, bond dislocation energy, cohesive energy.

Electrons in a periodic potential: Bloch theorem, Nearly free electron model; tight binding method; Semiconductor Crystals, Band theory of solids; elementary idea of semiconductor superlattices.

Electronic transport from classical kinetic theory; Introduction to Boltzmann transport equation; electrical and thermal conductivity of metals; thermoelectric effects; Hall effect & Quantum Hall effect, magnetoresistance.

Behaviour of dielectrics in ac and dc fields. Dielectric loss and loss factor, piezo, pyro- and ferro-electricity and its origin, Ferroelectric hysteresis.

Superconductivity: Experimental Survey; Basic phenomenology; Meissner effect, BCS pairing mechanism and nature of BCS ground state; Flux quantization; Change in thermodynamic parameters in superconducting state, frequency dependence of superconductivity, Type – I & Type II superconductors; Tunneling Experiments; High T_c superconductors, Applications of superconductors, present status of superconductors.

Reference Books:

1. Introduction to Solid State Physics, C. Kittel (8th edition Wiley, New York, 2005)
2. Quantum Theory of Solidsm C. Kittel (Wiley, New York 1987)
3. Principles of the Theory of Solids, J. Ziman (Cambridge University Press, 1972)
4. Solid State Physics, H. Ibach and H. Luth (3rd edition Springer Berlin, 2002)
5. Solid State Theory, Walter A. Harrison (Tata McGraw-Hill, New Delhi 1970)
6. Liquid Crystals, S. Chandrasekhar (Cambridge University, 2nd edition 1992)
7. The Liquid Crystal Phases: Physics & Technology, T.J. Sluckin, (Contemporary Physics, Taylor & Francis, 2000)

Paper-V: Physics Lab - I

Course Code	Paper Title	Credit (L-T-P)
####	**PHYSCIS LAB-I**	**3-0-2**

1. To Study Malus law of polarization.
2. To study characteristic of BJT.
3. Estimation of Rydberg Constant.
4. Verification of Hartmann's Equations
5. To study the Michelson Interferometer.
6. To determine Planck's constant using photocell.
7. To determine the electric charge of an electron using Millikan's oil drop experiment.
8. To determine the Hall coefficient for a given semi-conductor.
9. To study the Characteristic of a Tunnel Diode.
10. To study the characteristics of a P-N junction with varying temperature & capacitance of the junction

Semester – II

Paper – I

Course Code	Paper Title	Credit (L-T-P)
####	**STATISTICAL MECHANICS**	**3-1-0**

Introduction: Phase space and specification of states, Liouvilles theorem, relation between statistics and thermodynamics, fluctuation in energy, density of states, macro states & microstates, ensembles and their classifications, partition function, classical ideal gas, entropy of ideal gas, Gibbs paradox and fundamental postulates of statistical mechanics.

Classical Statistics: Types of assembly of particles, Maxwell-Boltzmann Statistics, Maxwell-Boltzmann distribution laws (average and rms speed distributions). Macroscopic properties of ideal gas, radiation inside hollow sphere.

Quantum Statistics: Bose-Einstien distribution law, Planck's radiation formula, Bose Einstein condensation (Liquid He), Fermi-Dirac distribution law, Fermi energy, free electrons in metals, applications to low specific heat of metals, total energy of fermions. Electron spin paramagnetism, Fermi temperature and Fermi velocity.

Elements of Phase Transitions: Introduction, a dynamical model of phase transitions, Isingmodel in zeroth approximation.

Reference Books:

1. Statistical Mechanics, R.K. Pathria and P.D. Beale (3rd Edition, Butterworth-Heinemann, Oxford, 2011)
2. Statistical Mechanics, K. Huang (Wiley Eastern, New Delhi, 1987)
3. Statistical Mechanics, B.K. Agarwal and M. Eisner (2nd edition, Wiley Eastern, New Delhi, 2011)
4. Elementary Statistical Physics, C. Kittel (Wiley, New York, 2004)
5. Statistical Mechanics, S.K. Sinha (Tata McGraw Hill, New Delhi, 1990)

Paper – II

Course Code	Paper Title	Credit (L-T-P)
####	**MATHEMATICAL PHYSICS-II**	**3-1-0**

Group Theory: Basic concepts, Multiplication table, conjugate elements and classes,subgroups, Isomorphism and Homomorphism, definition of representation and its properties, Reducible and irreducible representations, Schur's lemmas (only statements), characters of a representation. Example of C_{4v}, Topological groups and Lie groups, three dimensional rotation group, special unitary groups SU(2) and SU(3).

Tensors: Introduction, definitions, contraction, direct product, Quotient rule, Levi-Civitasymbol, Non-cartesian tensors, metric tensor, Covariant differentiation.

Fourier Series and Integral Transforms: Fourier series, Dirichlet conditions, Generalproperties, advantages and applications, Gibbs phenomenon, Fourier transforms, Development of the Fourier integral, Inversion theorem, Fourier transforms of derivatives; Momentum representation, Laplace transforms, Laplace transforms of derivatives, Properties of Laplace transform, Inverse Laplace transformation.

Integral Equations: Definitions and classifications, integral transforms and generatingfunctions, Neumann series, Separable Kernels, Hilbert-Schmidt theory, Green's functions in one dimension.

Numerical Techniques: Roots of functions, Interpolation, Extrapolation, Differentiation,integration by trapezoid and Simpson's rule, Runge Kutta method and finite difference method.

Reference Books:

1. Group Theory for Physicists: A.W. Joshi (Wiley Eastern, New Delhi, 2011)
2. Mathematical Methods for Physicists, G. Arfken and H.J. Weber, (7th edition Academic Press, San Diego, 2012)

3. Matrices and Tensors in Physics, A.W. Joshi (Wiley Eastern, New Delhi, 2005)
4. Numerical Mathematical Analysis, J.B. Scarborough (4th edition Oxford Book Co., Kolkata)
5. A First Course in Computational Physics, P.L. Devries (Wiley, New York, 1994)
6. Mathematical Physics, P.K. Chatopadhyay (Wiley Eastern, New Delhi, 2011)
7. Introduction to Mathematical Physics, C. Harper (Prentice Hall of India, New Delhi, 2006)

Paper-III

Course Code	Paper Title	Credit (L-T-P)
####	**QUANTUM MECHANICS – II**	**3-1-0**

Relativistic Quantum Mechanics: Klein Gordon equation, Dirac equation, negative energy solutions, antiparticles, Dirac hole theory, Feynman interpretation of antiparticles, Gama-matrics and their properties, Convariance of Dirac equation, Charge conjugation, Parity & Time reversal invariance, Bilinear covariants, Plane wave solution, Two component theory of neutrino, Spin & Helicity, Relativistic Hydrogen atom problem.

Identical Particles: Permutation symmetry, symmetrization postulates, self consistent field approximation, Slater determinant, Hartree Fock method.

Approximation Methods: Time-independent Perturbation theory (non-degenerate and degenerate) and applications to fine structure splitting, Zeeman effect (Normal and anomalous), Stark effect, and other simple cases, Variational method and applications to helium atom and simple cases; WKB approximation and applications to simple cases. Time-dependent Perturbation theory, Fermi's Golden rule, Semi-classical theory of interaction of atoms with radiation.

Field Quantization: Lagrangian density and equation of motion for field, Symmetries and conservation laws, Noether's theorem, canonical quantization of scalar field, Complex scalar field, electromagnetic field and Dirac field, Problem in quanitizing electromagnetic field, Gupta & Bleuler method, Feynman rules (without derivation), Feynman diagrams.

Reference Books:

1. Relativistic Quantum Mechanics: J.D. Bjorken and S.D. Drell.
2. Relativistic Quantum Fields: J.D. Bjorken and S.D. Drell.
3. A First Book on Quantum Field Theory: Amitabha Lahiri and P.B. Pal.
4. Introduction to QFT: F. Mandle and G. Shaw.
5. Modern Quantum Mechanics: J.J.Sakurai.
6. Principles of Quantum Mechanic: R. Shankar.

Paper-IV

Course Code	Paper Title	Credit (L-T-P)
####	**FIBER OPTICS AND NON-LINEAR OPTICS**	**3-0-2**

Optical Fiber and its Properties: Introduction, basic fiber construction, propagation of light,modes and the fiber, refractive index profile, types of fiber, dispersion, data rate and bandwidth, attenuation, leaky modes, bending losses, cut-off wavelength, mode field diameter, other fiber types.

Non-linear Process: Propogation of electromagnetic waves in non-linear medium, self focusing, phase matching conditions, stimulated Raman and Brillion scattering, Introduction, anharmonic potentials and nonlinear polarization, non-linear susceptibilities and mixing coefficients, parametric and other non-linear processes, macroscopic and microscopic susceptibilities.

Electro-Optic Effects: Introduction to the electro-optic effects.

Applications: Applications of fiber optics and non-linear optics in optical fiber communications, Application of non-linear optics (harmonic generation).

Reference Books:

1. The Elements of Fiber Optics, S.L.Wymer and Meardon (Regents Prentice Hall, 1993)
2. Lasers and Electro-Optics, C.C. Davis (Cambridge University Press, 1996)
3. Optical Electronics, Gathak & Thyagarajan (Cambridge Univ. Press, 1989)
4. The Elements of Non-linear Optics: P.N. Butcher & D. Cotter (Cambridge University Press, 1991)

Paper-V: Physics Lab – II

Course Code	Paper Title	Credit (L-T-P)
####	**PHYSCIS LAB – II (NON-LINEAR OPTICS)**	**3-0-2**

1. To study temperature-dependence of conductivity of a given semiconductor crystal using four probe method.
2. To determine dipole moment of an organic molecule, Acetone.
3. Temperature dependence of a ceramic capacitor - Verification of Curie-Weiss law for the electrical susceptibility of a ferroelectric material.
4. To measure dielectric constant of barium titanate as function of temperature and frequency and hence to study its phase transition.
5. Tracking of the Ferromagnetic-paramagnetic transition in Nickel through electrical resistivity.
6. To measure numerical aperture and propagation loss and bending losses for optical fiber as function of bending angle and at various wavelengths.
7. Measurement of minority carrier lifetime in semiconductors Hyne Shockley experiment.
8. To study the Frank Hertz experiment.
9. To study the characteristic of B-H curve using Ferromagnetic standards.
10. To study the characteristics of a LED and determine activation energy.

Semester - III

Paper-I

Course Code	Paper Title	Credit (L-T-P)
####	**ELECTROMAGNETIC THEORY AND ELECTRODYNAMICS**	**3-1-0**

Maxwell's Equation; fundamental problems of electromagnetic theory, scalar and vector potential. Gauge transformations, Coulomb and Lorentz Gauges, review of special theory of relativity and its application to electromagnetic theory. Concepts of invariant intervals, light cone events and world lines. Four vectors, tensors. Lorentz transformations as Four vectors transformations. Transformation properties of electric and magnetic fields, electromagnetic field tensor, covariance of Maxwell's equations.

Relativistic charge particle dynamics in electromagnetic fields, motion in uniform static magnetic fields, uniform static electric fields and crossed electric and magnetic fields. Particle drift in non-uniform static magnetic fields. Adiabatic invariance of magnetic moments of a charge particle and Torus principle of magnetic mirror.

Green's function for relativistic wave equation. Radiation from localized oscillating charges, near and far zone fields, multipole expansion, dipole and quadrapole radiation, central fed linear antenna, radiation from and accelerated point charge, Lienard Weichart potentials, power radiated by a point charge, Leinard Formula and its non-relativistic limit, angular distribution of radiated power for linearly and circularly accelerated charges.

Lagrangian for a free relativistic particle, for a charge particle in an electromagnetic field, for free electromagnetic field, for interacting charged particles and fields, energy momentum tensor and related conservation laws.

Reference Books:

1. Classical Electrodynamics, J. D. Jacson, (3rd edition Wiley, 1998)
2. Introduction to Electrodynamics, D. J. Griffith, (3rd edition Benjamin Cummings, 1999)
3. Principles of Electrodynamics, Melvin Schwartz, (Dover Pub. 1987)
4. Modern Problems in Classical Electrodynamics, C. A. Brau, (Oxford Uni. 2003)
5. Electrodynamics Including Quantum Effect, H. J. W. Muller – Kirsten, (Word Scientific, 2004)
6. Electrodynamics of Continuous Media, L. D. Landau and E. M. Lifsitz and L. P. Pitaevskii (Oxford, 2005)

Paper-II

Course Code	Paper Title	Credit (L-T-P)
####	**ATOMIC & MOLECULAR PHYSICS**	**3-1-0**

Introduction: Introduction: Bohr-Sommerfield theory of Hydrogen atom, Sommerfield extension of Bohr's Model, Sommerfield's relativistic correction, shortcomings of Bohr-Sommerfield theory.

Angular momentum and parity for hydrogen atom, spin orbit term, Intensity of fine structure lines. The ground states of two electron atoms, many electron atoms – LS and JJ coupling schemes, lande interval rule. Idea of Hartrec-Fock equations, the spectra of alkalis elements and alkaline earth elements, Zeeman and Stark effects, Selections rules for electric and magnetic multipoles radiations. Hyperfine structure of spectral lines.

Pure rotational spectra, vibrational- rotational spectra, I-R spectroscopy, Raman spectra, electronic spectra, Frank- Condon principle, isotope effect on electronic spectra, structure determination using Raman spectroscopy, Laser Raman spectroscopy.

Reference Books:

1. Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, (2nd edition, Pearson education, 2003)
2. Atomic Physics, C. J. Foot, (Oxford University Press, 2005)

3. Atomic Spectroscopy, H.E. White
4. Fundamentals of Molecular & Spectroscopy, C. M. Banwell and E. M. McCash, (4th edition, Tata Mc Graw Hill, 2008)
5. Molecular Spectra and Molecular, G. Herzberg, (Van Nostrand, 1950)
6. Laser Spectroscopy, W. Demtroder, (3rd edition, Springer, 2003)

Paper-III

Course Code	Paper Title	Credit (L-T-P)
####	**OPTOELECTRONIC & SEMICONDUCTOR DEVICES**	**3-1-0**

Power Semiconductor Devices: Power bipolar junction transistors (BJT), Power MOSFET, VMOS and DMOS transistors, Uni-junction transistors (UJT), Silicon Controlled Rectifier (SCR), Diac, Triac.

Optoelectronic Devices: Radiative and non-radiative transitions, direct and indirect band gap materials, light emitting electronic materials, SC quantum dots, photon absorption and emission in semiconductors, Electron-Hole pair generation, Light emitting diode (LED) construction, working principle, generation of light and external quantum efficiency, high performance compound SC & hetrostructures, high frequency limit, effect of surface and indirect recombination current in LED. Photoconductive Cells, Photodiodes, Laser diodes, Super luminescent diodes, Phototransitors, Light activated SCR (LASCR), opto-couplers, Solar cells- Open circuit voltage, short circuit current, Fill factor, Imaging detectors, Recent advances in optoelectronic materials, organic semiconductors.

High Frequency Devices: Frequency dependence of gain, transit time effect in bipolar and in field effect transistors, Schottky Barrier FET (MES FET), modulation doped transistor (MODFET or HEMT), Ballistic transistors-Metal base transistors, High frequency compound semiconductor devices, ballistic GaAs Transistors, Two terminal devices- Gunn diode, IMPact avalanche and transit time (IMPATT) diode, Tunnel diode.

Memory and other devices: Complementary metal oxide semiconductor (CMOS), MOSFET transistors as n-channel (NMOS), static random access memory (SRAM) and dynamic random access memory (DRAM), Read only memory (ROM), electrically programmable ROM (EPROM) and electrically erasable programmable ROM (EEPROM), volatile and nonvolatile memory, Magnetic, Optical and ferroelectric memories and devices, Charge coupled device (CCD), Piezoelectric, electrostrictive and magnetostrictive effect related materials and their application in devices.

Reference Books:

1. Electrical Engineering Materials, R.K.Shukla,
2. Optical Electronics: A. Ghatak and K. Thygrajan
3. Introduction to Semiconductor Devices, M.S.Tyagi
4. Physics & Technology of Semiductor Devices: S.M.Sze

Paper – IV

Course Code	Paper Title	Credit (L-T-P)
####	**ADVANCED LASERS AND NONLINEAR OPTICS**	**3-0-2**

Laser Analysis (I): Modes of Rectangular Cavity, Open Planner Resonator, Quality Factor - Q of a Cavity, Origin of Line Shape Function, Shape And Width of Spectral Lines, Threshold Condition For Laser Oscillations, Spiking Behaviour of Laser Production of Giant Pulse: Q-Switching- Kerr Effect.

Laser Analysis (II): Peak Power Admitted During the Pulse, Giant Pulse Dynamics, Laser Amplifiers, Mode Locking Distributed Feedback Lasers, The Ultimate Line Width of The Laser, Laser Rate Equations And Population Inversion In Three And Four Energy Level Schemes, Comparison of Three And Four Level Laser Systems.

Types of Lasers: He - Ne Laser, Argon ion Laser, N_2 Laser, CO_2 Laser, Excimer Laser, Ruby Laser, Nd - YAG Laser, Dye Laser, Semiconductor Laser. Holography and Its Applications.

Non - Linear Optics: Harmonic Generation, Second Harmonic Generation, Phase Matching, Third Harmonic Generation , Optical Mixing, Parametric Generation of Light, Self-Focusing of Light, Multi-Quantum Photoelectric Effect, Two Photon Processes, Multi-photon Processes, Parametric Generation of Light, Parametric Light Oscillator, Frequency Upconversion, Phase Conjugate Optics.

Scattering: Rayleigh and Raman Scattering, Stimulated Raman Effect, Hyper Raman Effect, Coherent Anti-Stokes Raman Scattering, Spin Flip Raman Laser, Free Electron Laser, Photo-Acoustic Raman Spectroscopy Brillouin Scattering.

Reference Books:

1. Laser And Nonlinear Optics: BB Laud
2. Laser: Theory And Applications – K. Thyagrajan and A. K.
3. Laser Fundamentals - William Silfvast
4. Essential of Laser and Nonlinear Optics- GD Baruah

Paper-V: Physics Lab – III

Course Code	Paper Title	Credit (L-T-P)
####	PHYSCIS LAB – III (OPTOELECTRONICS)	3-0-2

1. To determine Percolation threshold and temperature dependence of resistance in composites.
2. SCR Characteristics and its applications as a switching device.
3. UJT characteristics and its application as relaxation oscillator or triggering of triac.
4. To study electromagnetic damping using Ballistic Galvanometer.
5. Measurement of Vacuum using the pirani / thermocouple guage.
6. To determine the velocity of ultrasonic waves using interferometer as a function of temperature.
7. Temperature dependence of a ceramic capacitor: Verification of Curie – Weiss law for the electrical susceptibility of a ferroelectric material.
8. To study the Characteristic of Hartley Oscillator
9. Determination of velocity of light using modulated Laser method.
10. To study Zeeman Effect.

Semester- IV

Paper-I

Course Code	Paper Title	Credit (L-T-P)
####	**PROJECT**	**0-0-8**

Paper-II

Course Code	Paper Title	Credit (L-T-P)
####	**PARTICLE PHYSICS & NUCLEAR PHYSICS**	**3-1-0**

Fundamental Concepts of Nuclear Models:
Nuclear size, alpha decay and alpha scattering, nuclear stability, binding energy, mass defect and packing fraction, semi-empirical mass formula, angular momentum of nucleus, nuclear magnetism, nuclear models (liquid drop, alpha particle, cell, collective, optical).

Radioactive Decays: Law of radioactive decay, half life of radioactive nuclide, average life of an atom, review of barrier penetration of alpha decay & Geiger-Nuttal law.Beta decays, Fermi theory, Kurie plots and comparative half-lives, Allowed and forbidden transitions, Experimental evidence for Parity-violation in beta decay, Electron capture probabilities, Double beta decay, Neutrino,detection of neutrinos, measurement of the neutrino helicity.

Multipolarity of gamma transitions, internal conversion process, transition rates, Production of nuclear orientation, angular distribution of gamma rays from oriented nuclei.

Two body problem, simple theory of deuteron, spin dependence and non central nature of nuclear forces, nucleon-nucleon scattering, scattering length and effective range theory, exchange theory and meson theory of nuclear force.

Elementary Particle Physics:

Four fundamental interactions, classification of elementary particles, Hadrons and Leptons, symmetry and conservation laws, CP violation and CT invariance, SU(2) and SU(3) multiplets, Eight fold way, Quark model, Basic ideas of standard model.

Nuclear Reactions: Nuclear reactions and cross-sections, Resonance, Breit–Wignerdispersion formula for l=0 and higher values, compound nucleus, Coulomb excitation, nuclear kinematics and radioactive nuclear beams.

Reference Books:

1. Nuclear Physics, Irving Kaplan (Narosa, 2002)
2. Basic Ideas and Concepts in Nuclear Physics, K. Hyde (Institute of Physics, 2004)
3. Introduction to Nuclear Physics, Herald Enge (Addison-Wesley, 1971)
4. Nuclei and Particles, E. Segre (W.A. Benjamin Inc., 1965)
5. Theory of Nuclear Structure, R.R. Roy and B.P. Nigam (New Age, New Delhi, 2005)
6. Nuclear physics, Experimental and Theoretical, H.S. Hans, (2^{nd} Edition New Academic Science, 2011)

Paper – III

Course Code	Paper Title	Credit (L-T-P)
####	**FIBER OPTICS AND PHOTONICS**	**3-1-0**

Modal Propagation In Optical Fiber:
Modal Propagation Characteristics of Step Index and Graded Index Fiber, Weakly Guided Step Index Fibers, Losses In Fibers, Material Dispersion, Numerical Techniques of The Analysis of Simple Optical Waveguides in Weak Guidance Approximation.

Fiber Optics Technology
Waveguide Dispersion and Design Consideration, Optical Materials, Fabrication, Cabling and Installation of Optical Fibers, Optical Joints and Couplers, Integrated Optical Waveguide types, Modes In Asymmetric Planar Waveguide, Channel and Stripped Waveguides.

Periodic Optical Fibers:
Guided and Defect Modes In Periodic Optical Waveguides, Optical Filters And Mono-chromators, Bragg's Reflection Waveguides and Bragg's Filters, Helically Cladded Optical Fiber and their Applications, Modes Selection In Different Fibers

Optical Solitons and Application of Fiber Optics
Analysis of Optical Solitons and their Applications, Leaky Modes, Optical Amplification and Si-Doped Waveguides, Application of Fiber Optics In Non Communication And Sensors

Photonic Band Gap Material
Photonic Crystals, Photonic Crystal Fiber, Photonic Bandgap Structure, Analytical and Numerical Study of Photonic Bandgap Fibers and their Dispersion Characteristics, Reflectance and Transmittance In PGB Fibers, Negative Refractive Index Materials, Optical Filters From Photonic Band Gap and Its Application In Loss Bands and High Q Cavities.

Reference Books

1. Mynbav & Scheiener: Fiber Optic Communication Technology, Prentice Hall Number
2. Ajay Ghatak and K. Thyagarajan: Introduction to Fiber Optics.
3. Peter L. Bocho, James. A Savage, et al: Optical Materials
4. E.D.Palik, et, al, Handbook of Optical Constants of Solids: Academic Press
5. Frederick Zolla et al. Foundation of Photonic Crystal Fibers.
6. C. M. Soukolis: Photonic Bandgap Materials.
7. Ralf Menzel: Photonics
8. R. N. Rampal: Nanophonics

Paper-IV: Elective Paper*

***List of Elective Papers:**

1. *Physics of Engineering Materials*
2. *Physics of Nano-Materials*
3. *Science & Technology of Thin Films and their preparation*

Elective Paper-1

Course Code	Paper Title	Credit (L-T-P)
####	**PHYSICS OF ENIGINEERING MATERIALS**	**3-1-0**

Photonics and Photonic Materials: Introduction and classification of optical materials, interaction of light with optical materials, materials for photonic devices, laser materials,

Electrical and Insulating Materials: Introduction and classification of electrical conducting materials, low resistivity copper alloys, Materials for Lamp filaments, preparation of Tungsten filaments, materials used for transmission lines, electrical contact materials and their selection, classification of contact materials, electrical carbon materials, Arc light carbon, uses of carbon in resistors and brushes, Introduction and classification of insulating materials (on the basis of structure): selection of the insulating materials and their properties, Chemical properties of the insulating Materials, Mica and various kinds, Mica products, Polystyreme, polythene Teflon, PVC, Epoxy glass and Bakelite.

Magnetic Materials: Origin of permanent magnetic dipoles in matters, classification of diamagnetism, paramagnetism, ferromagnetism, anti ferromagnetism and ferrimagnetisms, magnetostriction, properties of magnetic materials, soft and hard magnetic materials, permanent magnetic materials.

Special purpose Materials:, Oxide and non-oxide glasses, chalcogenide glasses, organic polymers, ceramics, introduction and classification of composite materials, organic semiconductors, nano-materials, basics principles of nano science and technology, preparation structure and properties and structure of fullerene, graphene, applications of nano-materials, refractory materials, special coated anti-radar communication materials.

Reference Books:

1. Electrical Engineering Materials, R. K. Shukla, A. Singh, (Tata McGraw Hill, 2016)
2. Electrical Engineering Materials**,** A. J. Dekker, (Prentice Hall of India)
3. Introduction to Solid State Physics: C. Kittel (Wiley, New York, 8^{th} ed. 2005)
4. Electrical Properties of Materials, Solimar, (Oxford University Press)
5. Material Science and Engineering: An Introduction, W. D. Callister, (Wiley)
6. Material Science and Engineering, V. Raghvan.

Elective Paper-2

Course Code	Paper Title	Credit (L-T-P)
####	**PHYSICS OF NANO-MATERIALS**	**3-1-0**

Introductory Aspects : Basic principles of nano-science and technology, preparation , structure and properties of fullerene and carbon nanotubes.

General Characterization Techniques : Determination of particle size, study of texture and microstructure, Increase in x-ray diffraction peaks of nanoparticles, shift in photo luminescence peaks, variation in Raman spectra of nanomaterials, photoemission, microscopy, scanning force microscopy.

Quantum Dots: Electron confinement in infinitely deep square well, confinement in one andtwo-dimensional wells, idea of quantum well structure, Examples of quantum dots, spectroscopy of quantum dots.

Applications of Nanomaterials: Engineering and medical applications**,** applications carbon nanotubes and nanofibers, Nanosized metal particles, Nanostructured polymers, Nanostructured films and Nano structured semiconductors.

Reference Books:

1. Nanotechnology - Molecularly Designed Materials, G.M. Chow & K.E. Gonsalves (American Chemical Society, 1996)
2. Nanotechnology Molecular Speculations on Global Abundance, B.C. Crandall (MIT Press, 1996)
3. Quantum Dot Heterostructures, D. Bimerg, M. Grundmann and N.N. Ledentsov (Wiley, 1998)
4. Nanoparticles and Nanostructured Films–Preparation, Characterization and Application: J.H. Fendler (Wiley, 1998)
5. Nano-fabrication and Bio-system, H.C. Hoch, H.G. Craighead and L. Jelinski (Cambridge Univ. Press, 1996)
6. Physics of Semiconductor Nanostructures: K.P. Jain (Narosa, 1997)
7. Physics of Low-Dimension Semiconductors, J.H. Davies (Cambridge Univ. Press 1998)
8. Advances in Solid State Physics (Vo.41), B. Kramer (Springer, 2001)

Elective Paper-3

Course Code	Paper Title	Credit (L-T-P)
####	**SCIENCE & TECHNOLOGY OF THIN FILMS AND THEIR PREPARATION**	**3-1-0**

Introduction of thin films, Mean free path, Gas impingement rate, monolayer formation time, Basics of vacuum science and technology, Vacuum pumps and gauges, Physical vapour deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGaAs and GSMBE), Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD).

Hybrid and modified PVD processes, e.g, Ion plating, Reactive evaporation, ion-beam-assisted deposition CVD advantages, Atomic layer deposition, Electro-deposition.

Reference Books:

1. Materials Science of Thin Films,Milton Ohring, (Academic Press, 2002)
2. Thin Film Deposition,Donald Smith, (Mc Graw Hill, 1995)
3. Thin Film Phenomena,K.L.Chopra, (Mc Graw Hill, 1970)

Paper-V

Course Code	Paper Title	Credit (L-T-P)
####	**PHYSCIS LAB - IV**	**3-0-2**

1. To study Photoconductivity of amorphous thin film.
2. Thin Film preparation of amorphous material using Vacuum Evaporation Technique.
3. To study dielectric constant and dielectric loss of a given material.
4. Study of High Field conduction in amorphous material.
5. Determination of optical band gap by using spectrophotometer.