Centre for Physical and Mathematical Sciences

M.Sc. Physics					
Semester-I					
Course Code	**Course Title**	**Credit Hours**			
		Theory	**Practical**	**Research**	**Total**
PHY.501	Mathematical Methods – I	3	–	–	3
PHY.502	Classical Mechanics	3	–	–	3
PHY.503	Statistical Mechanics	3	–	–	3
PHY.504	Electronic Circuits Theory	3	–	–	3
PHY.505	Computational Methods	2	–	–	2
PHY.554	Electronic Circuits Laboratory	–	5	–	5
PHY.555	Computational Methods Laboratory	–	2	–	2
	Total	**14**	**7**	–	**21**
Semester-II					
PHY.506	Mathematical Methods – II	3	–	–	3
PHY.507	Quantum Mechanics - I	3	–	–	3
PHY.508	Electromagnetic Theory – I	3	–	–	3
PHY.509	Atomic, Molecular, and Laser Physics	3	–	–	3
PHY.510	Digital Electronics	3	–	–	3
PHY.559	Modern Physics Laboratory	–	3	–	3
PHY.560	Digital Electronics Laboratory	–	3	–	3
CCH.100	Humanities for Science Students	1	–	–	1(NC)
	Total	**17**	**6**	–	**22**
Semester-III					
PHY.511	Quantum Mechanics – II	3	–	–	3
PHY.512	Solid State Physics	3	–	–	3
PHY.513	Nuclear Physics	3	–	–	3
PHY.514	Electromagnetic Theory – II*	3	–	–	3
PHY.515	Introduction to Particle Physics*	2	–	–	2
PHY.562	Solid State Physics Laboratory	–	4	–	4
PHY.563	Nuclear Physics Laboratory	–	4	–	4
PHY.599	Seminar in Physics	1	–	–	1
	Total	**15**	**8**	–	**23**
Semester-IV					
PHY.516	Introduction to Nanophysics	4	–	–	4
PHY.517	Modern Functional Materials	4	–	–	4
PHY.518	Thin Films and Nanoscience	4	–	–	4
PHY.500	Dissertation Research	–	–	12	12
	Total	**12**	–	**12**	**24**
	Grand Total	**57**	**21**	**12**	**90**

*****These are optional courses. Students may choose either these courses or any courses of same credit from any other centre of the University.

Semester I

PHY.501 **Mathematical Methods – I** **Credit Hours: 3**

Unit I

Delta, Gamma, and Beta Functions: Dirac delta function, Properties of delta function, Gamma function, Properties of Gamma function and Beta function.

Unit II

Fourier and Laplace Transforms: Fourier series, Dirichlet condition, General properties of Fourier series, Fourier transforms, their properties, and applications, Development of Fourier integral, Laplace transforms, Properties of Laplace transform, Inverse Laplace transform and application.

Unit III

Differential Equations: Linear ordinary differential equations of first and second order, Method of separation of variables for partial differential equations, Boundary value problems and Euler equation.

Unit IV

Complex Variable: Geometrical representation of complex numbers, Functions of complex variables, Properties of elementary trigonometric and hyperbolic functions of a complex variable, Cauchy-Riemann equations, Cauchy theorem, Properties of analytical functions, Contours in complex plane, Integration in complex plane, Deformation of contours, Cauchy integral representation, Taylor series representation, Isolated and essential singular points, Laurent expansion theorem, Poles, Residues at an isolated singular point, Cauchy residue theorem and applications of the residue theorem.

Recommended Books:

1. Mathematical Methods for Physicists by George Arfken, Hans Weber, Frank Harris (Elsevier Academic Press, 2012).
2. Advanced Engineering Mathematics by Erwin Kreyszig (John Wiley & Sons Canada, Limited, 2011).
3. Advanced Engineering Mathematics by Dennis G. Zill (Jones & Barlett Learning, 2012).
4. Mathematical Physics by P. K. Chattopadhyay (New Age International (P) Limited, 2000).

PHY.502 **Classical Mechanics** **Credit Hours: 3**

Unit I

Lagrangian Formalism: Classification of constraints, D'Alembert's principle and its applications, Generalized coordinates, Lagrange's equation for conservative, non-conservative, and dissipative systems, Lagrangian for a charged particle moving in an electromagnetic field, Motion of charged particle on surface of earth, Body sliding on a slide plane, Harmonic oscillator, Simple and compound pendulum etc., Cyclic-coordinates, Symmetry and conservations Laws.

Unit II

Hamiltonian Formalism: Calculus of variations, Principle of least action, Hamilton's principle, Hamilton's equation of motion, Derivation of Lagrange equations of motion from Hamilton's principle, Derivation of Hamilton's equations of motion from Hamilton's principle, Hamilton's principle to non-conservative and non-holonomic systems, Hamiltonian of a charged particle in an electromagnetic field.

Unit III

Canonical Transformations and Hamilton - Jacobi theory: Conditions for canonical transformation and problems, Poisson brackets, Canonical equations in terms of Poisson bracket, Integral invariants of Poincare, Infinitesimal canonical transformation and generators of symmetry, Relation between infinitesimal transformation and Poisson bracket, Hamilton–Jacobi equation for Hamilton's principal function, Linear harmonic oscillator problem by Hamilton-Jacobi method, Action angle variables, Application to Kepler's problem.

Unit IV

Rigid Body Dynamics: Euler's angles, Euler's theorem, Moment of inertia tensor, Formal properties of the transformation matrix, Angular velocity and momentum, Equations of motion for a rigid body, Torque free motion of a rigid body - Poinsot solutions, Motion of a symmetrical top under the action of gravity, Coriolis force, Faucault's pendulum.

Unit V

Two Body Problems: Reduction to the equivalent one-body problem, Differential equation for the orbit, Condition for closed orbits, Bertrand's theorem, Virial theorem, Kepler's laws and their derivations, Classification of orbits, Rutherford scattering in laboratory and centre-of-mass frames.

Unit VI

Theory of Small Oscillations: Types of equilibria, General formulation of the problem, Lagrange's equations of motion for small oscillations, Normal coordinates and normal frequencies, Applications to Linear triatomic molecule, Two and three coupled pendulums, Double pendulum and N-Coupled oscillators.

Recommended books:

1. Classical Dynamics of particles and systems by Stephen T. Thornton and Jerry B. Marion, 5e, (Cengage Learning, 2013).
2. Classical Mechanics by John Safko, Herbert Goldstein, and Charles P. Poole (Pearson, 2011).
3. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics by Greiner Walter (Springer, 2010).
4. Classical Mechanics by Joag & Rana (Tata McGraw-Hill, 1991).

PHY.503 **Statistical Mechanics** **Credit Hours: 3**

Unit I

Introduction: Macrostates, Microstates, Phase space and ensembles. Ergodic hypothesis, Postulate of equal a priori probability, Boltzmann's postulate of entropy, Counting the number of microstates in phase space, Entropy of ideal gas, Gibbs' paradox, Liouville's Theorem.

Unit II

Canonical Ensemble: System in contact with a heat reservoir, Expression of entropy, Canonical partition function, Helmholtz free energy, Fluctuation of internal energy, Grand Canonical ensemble, System in contact with a particle reservoir, Chemical potential, Grand canonical partition function and grand potential, Fluctuation of particle number, Chemical potential of ideal gas.

Unit III

Non-ideal Gas: Mean field theory and van der Waal's equation of state, Cluster integrals and Mayer-Ursell expansion.

Unit IV

Quantum Statistical Mechanics: Quantum Liouville theorem, Density matrices for microcanonical, Canonical and grand canonical systems, Identical particles in B-E and F-D distributions, Quantum mechanical ensemble theory, Super-fluidity in liquid He II, Low temperature behaviour of Bose and Fermi gases, Ising model, Mean-field theory in zeroth and first approximations, Exact solution in one dimension.

Unit V

Bose and Fermi gas: Ideal gas in different quantum mechanical ensembles, Equation of state, Bose-Einstein condensation, Equation of state of ideal Fermi gas, Fermi gas at finite temperature. Thermodynamics, Pauli paramagnetism, Landau diamagnetism, de Hass van Alphen effect.

Recommended books:

1. An Introduction to Statistical Mechanics and Thermodynamics by Robert H. Swendsen (Oxford University Press, 2012).
2. Statistical Physics by Michael V. Sadovskii (Walter de Gruyter GmbH and Co. KG, Berlin/Boston, 2012).
3. Statistical Mechanics by R. K. Patharia and Paul D. Beale (Academic Press, 2011).
4. Fundamentals of Statistical Mechanics by B. B. Laud (New Age International, 2012).
5. Statistical Mechanics by K. Huang (John Wiley, 1987).

PHY.504 **Electronic Circuits Theory** **Credit Hours: 3**

Unit I

Network Theorems: Superposition theorem, Thevenin's and Norton's theorems, A. C. equivalent circuits of networks with active devices.

Unit II

Power Supplies: Half-wave, Full-wave and bridge rectifiers with capacitive input, Inductance input, T and π filters, Regulated power supplies: Shunt regulated power supplies using Zener diodes.

Unit III

Transistor Amplifiers: Theory of semiconductors, Transistor configurations, Amplifiers, Low-frequency amplifiers, H and R parameters and their use in small signal amplifiers, Conversion formulae for the h-parameters of the different transistor configurations, Analysis of a transistor CE amplifier at low frequencies using h-parameters, CE amplifier with unbypassed emitter resistor, Emitter follower at low frequencies, Emitter-coupled differential amplifier and its characteristics, Cascaded amplifiers, Transistor biasing, Self-bias and thermal stability, Low frequency power amplifiers, bipolar junction transistor at high frequency.

Unit IV

Field Effect Transistor: Field effect transistor and its small signal model, CS and CD amplifiers at low frequencies, Biasing the FET, CS and CD amplifiers at high frequencies.

Unit V

Feedback: The gain of an amplifier with feedback. General characteristics of negative feedback amplifiers, Stability of feedback amplifiers, Barkhaussen criteria, Grain and phase margins, Compensation, Sinusoidal oscillators: RC oscillators: Phase shift and the Wien's bridge oscillators, LC oscillators, Frequency stability and the crystal oscillators.

Unit VI

Operational Amplifiers: Characteristics of an ideal operational amplifier, Applications of operational amplifiers: Inverting and non-inverting amplifiers, Summing circuits, Integration and differentiation, Waveform generators.

Recommended books:

1. Integrated Electronics: Analog and Digital Circuits and Systems by Jacob Millman, Christos Halkias, Chetan Parikh (Tata McGraw - Hill Education, 2009).
2. Electronic Devices and Circuit Theory by Robert L. Boylestad, Louis Nashelsky (Pearson 2009).
3. Basic Electronics: Solid State by B. L. Theraja (S. Chand & Company Ltd., 2010).
4. Electronics: Fundamentals and Applications by D. Chattopadhyay, P. C. Rakshit (New Age International, 2008).

PHY.505 **Computational Methods** **Credit Hours: 2**

Unit I

Programming with C: Introduction to the concept of object oriented programming, Advantages of C over conventional programming languages, Introduction to classes, objects, C programming syntax for Input/Output, Operators, Loops, Decisions, Simple and inline functions, Arrays, Strings, Pointers.

Unit II

Roots of Algebraic and Transcendental Equations: One point and two-point iterative methods such as bisection method and Newton Raphson methods.

Unit III

Integration and Differential: Integration by Trapezoidal and Simpson's rule, Solution of first order differential equation using Runge-Kutta method and Euler's methods.

Interpolation: Linear interpolation, Lagrangian interpolation, Newton's interpolation.

Unit IV

Least square fitting: Least square fitting to a straight line and polynomial.

Random numbers: Introduction to random numbers, Monte Carlo method for random number generation.

Recommended Books:

1. Data Reduction and Error analysis for Physical Sciences by Philip R. Bevington and D. Keith Robinson (McGraw Hill, 2003).
2. Let Us C by Yashwant Kanetkar (BPB Publications, 2012).
3. Numerical Methods by E. Balaguruswamy (Tata McGraw Hill, 2009).
4. Introductory Methods of Numerical Analysis by S. S. Sastry (PHI Learning, 2012).

PHY.554 **Electronic Circuits Laboratory** **Credit Hours: 5**

Student has to perform any of eleven experiments from the following experiments.

1. Power supplies: Bridge rectifiers with capacitive input filters.
2. Power supplies: Shunt Voltage regulator using Zener diode.
3. Clipping and Clamping along with CRO.
4. Common Emitter Amplifier with and without feedback.
5. Determination of h-parameters in the CE configuration using the measured input and output characteristics of a BJT.
6. Common Source and Common Drain Amplifiers using JFET.
7. RC Oscillators: Phase shift oscillator using RC ladder network as the phase shifting Network.
8. Wien's Bridge Oscillator.
9. Colpitts Oscillators.

10. Hartley Oscillators.
11. Emitter Coupled Differential Amplifier using BJT's.
12. Multivibrators – Bistable, Monostable and Free Running multivibrators
13. Op-Amp characteristics: $V_{io,}$ I_b, $V_{ol,}$ CMRR, Slew Rate. Applications of Op-amps: inverting Amplifier, Unity Gain Buffer, Summing Amplifier.
14. 555 IC timers. Free Running and Monostable Multivibrators, Sawtooth wave generator.

Recommended books:

1. Integrated Electronics: Analog and Digital Circuits and Systems by Jacob Millman, Christos Halkias, Chetan Parikh (Tata McGraw - Hill Education, 2009).
2. Electronic Devices and Circuit Theory by Robert L. Boylestad, Louis Nashelsky (Pearson 2009).
3. Basic Electronics: Solid State by B. L. Theraja (S. Chand & Company Ltd., 2010).
4. Electronics: Fundamentals and Applications by D. Chattopadhyay, P. C. Rakshit (New Age International, 2008).

PHY.555 **Computational Methods Lab** **Credit Hours: 2**

List of Numerical Problems:

Student has to perform any of eight experiments from the following experiments.

1. Data handling: find standard deviation, mean, variance, moments etc. of at least 25 entries.
2. Choose a set of 10 values and find the least squared fitted curve.
3. To find the roots of quadratic equations.
4. Perform numerical integration on 1-D function using Simpson rules.
5. Perform numerical integration on 1-D function using Trapezoid rule.
6. To generate random numbers between (i) 1 and 0, (ii) 1 and 100.
7. To find the value of π using Monte Carlo simulation.
8. To find the solution of differential equation using Runge-Kutta method.
9. To find the solution of differential equation using Euler's method.
10. To find the value of y for given value of x using Newton's interpolation method.

Recommended Books:

1. Data Reduction and Error analysis for Physical Sciences by Philip R. Bevington and D. Keith Robinson (McGraw Hill, 2003).
2. Let Us C by Yashwant Kanetkar (BPB Publications, 2012).
3. Numerical Methods by E. Balaguruswamy (Tata McGraw Hill, 2009).
4. Introductory Methods of Numerical Analysis by S. S. Sastry (PHI Learning, 2012).

Semester II

PHY.506 Mathematical Methods – II Credit Hours: 3

Unit I

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

Unit II

Special Functions: Bessel, Legendre and Hermite polynomials: Generating function, integral representation and recurrence relations, orthogonality and special properties. Associated Legendre functions: recurrence relations, parity and orthogonality, Laguerre functions.

Unit III

Group Theory: Definition, 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, Topological and Lie groups, Three dimensional rotation group, Special unitary groups SU(2) and SU(3).

Unit IV

Tensors: Introduction, Definitions, Contraction, Direct product, Quotient rule, Levi-Civita symbol, Christoffel's symbols, Non-cartesian tensors, Metric tensor, Co-variant differentiation.

Recommended Books:

1. Mathematical Methods for Physicists by George Arfken, Hans Weber, Frank Harris (Elsevier Academic Press 2012).
2. Advanced Engineering Mathematics by Erwin Kreyszig (John Wiley & Sons Canada, Limited 2011).Applied Mathematics for Engineers and Physicist by Louis Albert Pipes (McGraw-Hill, 1985).
3. Advanced Engineering Mathematics by Dennis G. Zill (Jones & Barlett Learning, 2012).
4. Mathematical Physics by P. K. Chattopadhyay (New Age International (P) Limited, 2000).

PHY.507 Quantum Mechanics – I Credit Hours: 3

Unit I

Limitations of Classical Physics: Black body radiation, Photoelectric effect, Compton Effect, Electron diffraction.

Unit II

Formulation of Quantum Mechanics: Review of linear algebra and introduction to Hilbert space, Dirac's Bra-Ket notations, Symmetry and conservation laws, Matrix mechanics.

Unit III

Wave Mechanics: Schrödinger wave equation, Physical interpretation of wave function, Postulates of quantum mechanics, Probability current density and conservation of probability, Free particle wave function, Observables, Hermitian operators, Expectation values, Ehrenfest's theorem, Stationary states, Superposition principle, Commutation relations, Schrodinger, Heisenberg and Interaction pictures.

Unit IV

Applications of Schrödinger Wave Equation: Particle in one dimensional Box, Potential Step, Square well, Rectangular potential barrier and tunneling, Linear harmonic oscillator, Spherically symmetric potential, Hydrogen atom.

Unit V

Angular momentum: Commutation relations, Eigen-functions of the angular momentum operators, Concept of spin, Stern-Gerlach experiment, Linear harmonic oscillator problem using commutation relations, Matrix representation of angular momentum operators, Addition of angular momenta.

Unit VI

Scattering Theory: Scattering theory, Central force problem, Partial wave analysis, Optical theorem, Bound states and resonances, Scattering cross section, Green's functions, Born approximation, Scattering for different kinds of potentials, Applications.

Recommended books:

1. An Introduction to Theory and Applications of Quantum Mechanics by Amnon Yariv (Dover Publications, 2013).
2. A Textbook of Quantum Mechanics by K. Venkatesan, P. M. Mathews (Tata McGraw - Hill Education 2010).
3. Quantum Mechanics by E. Merzbacher (Wiley India Pvt. Ltd., 2011).
4. Quantum Mechanics by L.I. Schiff (Tata McGraw-Hill Education, 2010).
5. Quantum Mechanics - Concepts And Applications by Nouredine Zettili (John Wiley & Sons, Inc. 2009).

PHY.508 Electromagnetic Theory – I Credit Hours: 3

Unit I

Electrostatics: Differential and integral form of Gauss law, Surface distribution of charges and dipoles, Work and energy in electrostatics, Electrostatic potential energy, Poisson and Laplace equations, Uniqueness theorem I & II, Energy density and capacitance.

Unit II

Electrostatics Boundary Value Problems: General methods for the solution of boundary value problems, Solutions of the Laplace equation in rectangular cartesian, spherical polar and cylindrical coordinates, Various boundary value problems.

Unit III

Multipoles and Dielectrics: Multipole expansion, Multipole expansion of the energy of a charge distribution in an external field, Dielectrics, Gauss's law in the presence of dielectric, Boundary value problems with dielectrics, Molar polarizability and electrical susceptibility, Electrostatic energy in dielectric media.

Unit IV

Magnetostatics: Differential equation of magnetostatics and Ampere's law, Vector potential and magnetic induction for a circular current loop, Magnetic fields of a localized current distribution, Boundary condition on B and H, Uniformly magnetized sphere.

Unit V

Magnetic Fields in Matter: Magnetization, Dia, para and ferro-magnetic materials, Field of a magnetized object, Magnetic susceptibility and permeability.

Maxwell's Equations: Maxwell's equations for electrostatics and magnetostatics in differential and integral form, Maxwell equations in dielectrics.

Recommended books:

1. Classical Electromagnetic Radiation by Mark A. Heald and Jerry B. Marion (Dover Publications, 2012).
2. Introduction to Electrodynamics by David J. Griffiths (Addison-Wesley Professional, 2012)
3. Modern Electrodynamics by Andrew Zangwill (Cambridge University Press, 2012)
4. Classical Electrodynamics by J. D Jackson (John Wiley & Sons, 2004).
5. Electrodynamics of Continuous Media by E. M. Lifshitz, L. D. Landau, L. P. Pitaevskii (Butterworth-Heinemann, 1984).

PHY.509 Atomic, Molecular, and Laser Physics Credit Hours: 3

Unit I

One and Two Electrons Systems: Spectrum of hydrogen atom, Spin - orbit coupling, Mass correction term, Two electron system, Pauli's Exclusion Principle, Level scheme for two electron atoms- LS and JJ coupling – multiplet splitting – Lande's 'g' factor, Lande's interval rule, Fine structure, Selection rules, Lamb shift, Zeeman effect. Paschen-Back effect, Stark effect, Hyperfine structure and isotope shift.

Unit II

Many Electron Atom: Independent particle model, Central field approximation for many electron atom; Slater determinant; L-S and j-j coupling; Equivalent and nonequivalent electrons; Energy levels and spectra, Spectroscopic terms; Hund's rule.

Unit III

Molecular Structure: Molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Molecular orbital and electronic configuration of diatomic molecules: H_2, and NO, LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and overlap integral, Shapes of molecular orbital, sigma and pi bond. Electronic, vibrational and rotational structure, Frank-Condon principle, Raman transitions and Raman spectra, normal vibrations of CO_2 and H_2O molecules.

Unit IV

Lasers: Einstein relations. Cavity modes, Pumping threshold condition, Laser Rate equations for two, three and four level lasers. Laser systems: Nd-YAG solid state lasers, He-Ne laser, Semiconductor lasers, Pulsed operation of laser: Q-switching and mode locking, Few novel applications of laser.

Recommended Books:

1. Atomic Physics by C. J. Foot (Oxford University Press, 2005).
2. Molecular Physics by W. Demtroder (John Wiley & Sons, 2008).
3. Basic Atomic and Molecular Spectroscopy by J. M. Hollas (Royal Society of Chemistry, 2002).
4. Lasers - Fundamentals and Applications by K. Thyagrajan and A.K. Ghatak (Springer, 2010).
5. Lasers and Non-Linear Optics by B. B. Laud (New Age International, 2011)
6. Atomic Spectra and Atomic Structure by Gerhard Herzberg (Dover Publications, 2010).

PHY.510 Digital Electronics Credit Hours: 3

Unit I

Digital Circuits: Logic gates and their realization using diodes and transistors, Boolean algebra, Boolean equation of logic circuits, de-Morgan theorem, Method of realization a circuit for given truth table, Sum of product (SOP) and product of sum (POS) representation, Karnaugh map and their applications, Half adder and full adder circuits, Half substractor and full sbubstractor.

Unit II

Combinational Circuits: Design procedure, Adders-subtractors, Carry look ahead adder, BCD adder, Magnitude comparator, Multiplexer/demultiplexer, Encoder/decoder, parity checker, Code converters, Implementation of combinational logic.

Unit III

Sequential Circuit: SR, JK, D and T flip flop, Master slave flip flops, Triggering mechanism of flip flop, Realization of one flip flop using other flip flops, Asynchronous/ripple counters, Synchronous counters, Shift counters, Shift registers, Universal shift register, MSI and LSI based design, MSI and LSI implementation on sequential circuit.

Unit IV

Memory Devices: Classification of memories, RAM write operation and read operation, Static RAM cell and Bipolar RAM cell, Programmable logic device (PLD), Programmable logic array (PLA), Implementation of ROM and PLA.

Unit V

Data Converters: Analog to Digital (A/D) data converters, Digital to analog (D/A) data converters, logic families, microprocessors.

Recommended books:

1. Digital Principles and Applications by Gautam Saha, Albert Paul Malvino, Donald P Leach (Tata McGraw - Hill Education, 2011).
2. Digital Computer Electronics by P. Malvino and J. A. Brown (Tata McGraw - Hill Education 2011).
3. Introduction to Modern Digital Electronics by Charles Hawkins, Jaume Segura (Scitech Publishing, 2010).

PHY. 559 **Modern Physics Laboratory** **Credit Hours: 4**

Student has to perform any of seven experiments from the following experiments.

1. Ionization potential by Franck Hertz experiment.
2. Photo electric effect.
3. Band gap of a semiconductor by Four Probe method.
4. Wavelength measurement of laser using diffraction grating.
5. Michelson interferometer.
6. Dual nature of electron experiment.
7. Millikan’s oil drop experiment.
8. Stefan’s law
9. Zeeman effect experiment

Recommended books:

1. Modern physics by Raymond A. Serway, Clement J. Moses, Curt A. Moyer (Brooks Cole, 2012).
2. Modern Physics for Scientists and Engineers by Stephen T. Thornton, Andrew Rex (Thomson Brooks/Cole, 2012).
3. Modern Physics by Kenneth S. Krane (John Wiley & Sons, 2012).
4. Concepts of Modern Physics by A. Beiser (Tata McGraw - Hill Education, 2007).

PHY.560 **Digital Electronics Laboratory** **Credit Hours: 3**

Student has to perform any of nine experiments from the following experiments.

1. Realization of universal logic gates.
2. Implementation of the given Boolean function using logic gates in both SOP and POS form.
3. Verification of logic state tables of RS and JK flip-flops using NAND & NOR gates.
4. Verification of logic state tables of T and D flip-flops using NAND & NOR gates.
5. Verification of logic state tables of master slave flip flop using NAND & NOR gates.
6. Triggering mechanism of flip flop.
7. Realization of Half adder and full adder.
8. Realization of Half substractor and full substractor.
9. Decoders and code converters.
10. Up/Down Counters.
11. Shift Resistor.

Recommended books:

1. Digital Principles and Applications by Gautam Saha, Albert Paul Malvino, Donald P Leach (Tata McGraw - Hill Education, 2011).
2. Digital Computer Electronics by P. Malvino and J. A. Brown (Tata McGraw - Hill Education 2011).
3. Introduction to Modern Digital Electronics by Charles Hawkins, Jaume Segura (Scitech Publishing, 2010).

Semester III

PHY.511 **Quantum Mechanics – II** **Credit Hours: 3**

Unit I

WKB Approximation and its Applications: WKB approximation, Development and validity of WKB approximation, Application of WKB technique to barrier penetration, Cold emission of electrons from metals, Alpha-decay of nuclei.

Unit II

Time-independent Perturbation Theory: Stationary perturbation theory: Degenerate case, Variation methods, Polarizability of hydrogen, Non-degenerate perturbation theory, Harmonic oscillator subject to perturbing potential, Degenerate perturbation theory, Stark effect, Fine structure of hydrogen, Zeeman effect,

Unit III

Time-dependent Perturbation Theory: Time development of states and transition probability, Constant perturbation, Fermi golden rule, Adiabatic approximation. Semi-classical theory of radiations: Interaction of one-electron atom with electromagnetic field, Harmonic perturbation theory, Spontaneous emission: Einstein A and B coefficients, Selection rules for electric dipole transitions, Lifetime and line-width.

Unit IV

Many Electron Systems: Identical particles, Pauli exclusion principle, Inclusion of spin, Spin in a time dependent magnetic field, Spin functions for two and three-electrons, Helium atom, Central field approximation, Thomas-Fermi model of the atom, Hartree and Hartree-Fock equations, Quantum mechanics of molecules, Born-Oppenheimer approximation.

Unit V

Relativistic Quantum Mechanics: Klein Gordon equation, Particle and antiparticles two component framework, Bohr Somerfield semi classical solution of coulomb problem, Dirac equation, Properties of Dirac matrices, Positive and negative energy states, Free Dirac particle in an external electro-magnetic field, Gyromagnetic ratio, Hydrogen atom problem, Interpretation of relativistic correction, Klein paradox.

Unit VI

Elements of Field Theory: Lagrangian field theory: Lagrangian and Hamiltonian formulation, Quantization of the field, Non-relativistic fields: System of Bosons, System of Fermions, Relativistic fields: Klein-Gordon field, Dirac field, Electromagnetic field, Gupta-Bleuler formalism, Lorentz condition, Interacting fields: Feynman diagrams, Normal products, Dyson chronological product, Wick's chronological product, Contraction, Wick's theorem, Electromagnetic coupling, Scattering matrix.

Recommended books:

1. Principles of Quantum Mechanics by P. A. M. Dirac (Oxford University Press, 2004).
2. Quantum Mechanics - Concepts and Applications by Nouredine Zettili (John Wiley & Sons, 2009).
3. Quantum Mechanics: Theory and Experiment by Mark Beck (Oxord University Press, 2012).
4. Advanced Quantum Mechanics by J. J Sakurai (Pearson, 2006).
5. Modern Quantum Mechanics by J. J. Sakurai, Jim Napolitano (Addison Wesley Longman, 2010).
6. Quantum Field Theory by Franz Mandl, Graham Shaw (John Wiley, 2010).

PHY.512 **Solid State Physics** **Credit Hours: 3**

Unit I

Crystal Structure: Bravais lattice, Crystal structures, Symmetry, Reciprocal lattices and its applications to diffraction techniques, Ewald sphere, X-ray production and properties, Interaction of X-rays with matter, Absorption of X-rays, Powder X-ray diffraction technique, Indexing of powder photographs and lattice parameter determination, Atomic and crystal structure factors, Intensity of diffraction maxima.

Unit II

Lattice Dynamics: Classical theory of lattice vibration under harmonic approximation, Vibrations of linear monatomic and diatomic lattices, Acoustical and optical modes, Long wavelength limits, Optical properties of ionic crystal in the infrared region, Normal modes and phonons, Inelastic scattering of neutron by phonon, Lattice heat capacity, models of Debye and Einstein, Comparison with electronic heat capacity.

Unit III

Band Theory of Solids: Electrons in periodic lattice, Bloch theorem, Kronig Penny model, Classification of solids on the basis of band theory, Effective mass, Fermi surface and Fermi gas, Hall effect, Nearly free electron bands, Band gap, Number of states in a band, Tight binding method, Effective mass of an electron in a band, Concept of holes, Classification of metal, Semiconductor and insulator, Topology of Fermi-surface, Boltzmann transport equation, Summerfield theory of electrical conductivity.

Unit IV

Magnetic Properties of Solids: Diamagnetism: quantum theory of atomic diamagnetism, Paramagnetism: classical and quantum theory of paramagnetism, Ferromagnetism: Weiss theory of ferromagnetism, Curie-Weiss law, Heisenberg's model and molecular field theory, Curie-Weiss law for susceptibility, Neel model of antiferromagnetism and ferrimagnetism.

Unit V

Imperfections in Solids: Point defects (Frenkel & Schottky), Line defects (slip, plastic deformation, Edge dislocation, Screw dislocation, Burger's vector, Concentration of line defects, Estimation of dislocation density, Frank-Reid mechanism of dislocation multiplication (dislocation reaction), Surface (Planar) defects, Grain boundaries and stacking faults.

Unit VI

Superconductivity: Meissner effect, Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect, BCS theory, Ginzburg-Landau theory, London equation, Flux quantization, Coherence, AC and DC Josephson effect, High T_C superconductors (information only).

Recommended books:

1. Principles of the Theory of Solids by J. Ziman (Cambridge University Press-new Delhi, 2011).
2. Introduction to Solid State Physics by C. Kittel (John Wiley & Sons, 2007).
3. Solid State Physics by R. J. Singh (Pearson, 2011).
4. Elements of Solid State Physics by J. P. Srivastava (PHI Learning, 2011).
5. Solid State Physics by A. J. Dekker (Macmillan, 2012).

PHY.513 **Nuclear Physics** **Credit Hours: 3**

Unit I

Basic Nuclear Properties: Nuclear size from electron scattering and form factor, Nuclear radius and charge distribution, Mass and binding energy, Saturation of nuclear force, Abundance of nuclei, Spin, Isospin, Mirror nuclei, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment.

Unit II

Two Nucleon Problems: Schrodinger equation and its solution for ground state of deuteron, RMS radius, Spin dependence of nuclear forces, Electromagnetic moment and magnetic dipole moment of deuteron, General form of nuclear force and the necessity of tensor forces.

Experimental n-p scattering data, Partial wave analysis and phase shifts, Scattering length, Magnitude of scattering length and strength of scattering, Nature of nuclear forces: charge independence, Charge symmetry and iso-spin invariance of nuclear forces.

Unit III

Nuclear Decay: Different kinds of particle emission from nuclei, Alpha decay, Fine structure of α spectrum, Beta emission and Gamma decay. Fermi's theory of allowed beta decay, Fermi-Curie plot, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu's experiment.

Unit IV

Detectors: Properties of radiation detectors, Gas detectors: GM counter, Proportional counters, Ionization chambers, Scintillation detectors: NaI(Tl), CsI(Tl), Photomultiplier tubes, Semiconductor diode detectors, Different kinds of silicon detectors, HPGe detectors, Slow and fast neutron detection methods.

Nuclear Models: Independent particle model, Shell model, Liquid drop model, Bethe-Weizsacker binding energy/mass formula.

Unit V

Nuclear Reactions: Different types of nuclear reactions, Conservation laws, Reaction cross section. Compound nucleus formation, Fusion-evaporation and fusion-fission reactions, Optical model; Super-heavy nuclei.

Recommended books:

1. Nuclear & Particle Physics: An Introduction by B. Martin (John Wiley & Sons, 2011).
2. A Modern Introduction to Particle physics by Fayyazuddin Riazuddin (Word Scientific Publishing Co. Pte Ltd., 2012)
3. Introductory Nuclear Physics by K. S. Krane (John Wiley & Sons, 2008).
4. Nuclear Physics in a Nutshell by C. A. Bertulani (Princeton University Press, 2007).
5. Introductory Nuclear Physics by Samuel S. M. Wong (John Wiley & Sons, 2008).
6. Basic Ideas and Concepts in Nuclear Physics: An Introductory approach by K. Heyde (CRC Press, 2004).

PHY.514 **Electromagnetic Theory – II** **Credit Hours: 3**

Unit I

Time Varying Fields and Conservation Laws: Vector and scalar potentials, Gauge transformation, Lorentz gauge and Coulomb gauge, Poynting theorem and conservations of energy and momentum for a system of charged particles, EM fields.

Unit II

Plane Electromagnetic Waves and Wave Equations: Review of Maxwell's equations, Dispersion characteristics of dielectrics, Waves in a conducting and dissipative mediums, Linear, circular and elliptical polarization, Reflection, Refraction and dispersion, Propagation in conductors and plasmas, Skin effect, Propagation in waveguides (TE and TM modes), Rectangular wave guides.

Unit III

Radiation from Moving Point Charges: Retarded potentials, Lienard-Wiechert potentials, Radiation from a moving point charge and oscillating electric and magnetic dipoles, Dipole radiation, Multipole expansion for radiation fields.

Unit IV

Relativistic Electrodynamics: Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion, Field invariants, Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field, Generalised momentum, Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Recommended books:

1. Introduction to Electrodynamics by David J. Griffiths (Addison-Wesley Professional, 2012).
2. Classical Electromagnetic Radiation by Mark A. Heald and Jerry B. Marion (Dover Publications, 2012)
3. Modern Electrodynamics by Andrew Zangwill (Cambridge University Press, 2012)
4. Electrodynamics of Continuous Media by E. M. Lifshitz, L. D. Landau, L. P. Pitaevskii (Butterworth-Heinemann, 1984)
5. Classical Electrodynamics by J. D Jackson (John Wiley & Sons, 2004).

PHY.515 **Introduction to Particle Physics** **Credit Hours: 2**

Unit I

Introduction: Classification of particles: Fermions and bosons, Particles and antiparticles, Quarks and leptons, Classification of fundamental interactions: Strong, electromagnetic, weak and gravitational.

Unit II

Conservation Laws: Conservation laws of momentum, energy, angular momentum, parity, Pion parity, Charge conjugation, Positronium decay, Time reversal invariance, CPT theorem, Introduction to baryon, Lepton numbers, Strangeness, charm and other additive quantum numbers, Resonance and their quantum numbers, Gell Mann Nishijima formula.

Unit III

Relativistic Kinematics and Phase Space: Relativistic kinematics, Particle reactions, Lorentz invariant phase space, Two-body and three-body phase space, Recursion relation, Effective mass, Dalitz, K-3π decay, τ-θ puzzle, Dalitz plots for dissimilar particles, Breit-Wigner resonance formula, Mandelstem variables.

Recommended Books:

1. A Modern Introduction to Particle Physics by Fayyazuddin Riazuddin (World Scientific Publishing Co. Pte Ltd., 2012).
2. Particles and Nuclei: An Introduction to the Physical Concepts by Bogdan Povh, Klaus Rith, Christoph Scholz (Springer, 2012).
3. Nuclear & Particle Physics: An Introduction by B. Martin (John Wiley & Sons, 2011).
4. Introduction to High Energy Physics by D. H. Perkin (Cambridge University Press, 2000).
5. Elementary Particles by I. S. Hughes (Cambridge University Press, 1991).
6. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (Springer, 2009).
7. Experimental Techniques in Nuclear and Particle Physics by Tavernier, Stefan (Springer, 2010).
8. Introduction to Elementary Particles by David J. Griffiths (Wiley-VCH Verlag GmbH, 2008.)

PHY.562 Solid State Physics Laboratory Credit Hours: 4

Student has to perform any of six experiments from the following experiments.

1) Determination of carrier concentration and their sign in semiconductor at room temperature by Hall Effect.

2) Dielectric constant of insulating and ferroelectric materials at room and elevated temperatures.

3) Electrons spin resonance.

4) Magnetic parameters of a magnetic material by hysteresis loop tracer.

5) To determine the magnetic susceptibility of $NiSO_4$, $FeSO_4$, $CoSO_4$ by Gauy's method.

6) To determine magneto resistance of a Bismuth crystal as a function of magnetic field.

7) Determination of critical temperature of high temperature superconductor and Meissner effect for a high T_c superconductor.

8) Determination of ferromagnetic to paramagnetic phase transition temperature (T_C = Curie temperature).

9) Photoconductivity measurements.
10) NMR spectrometer.

Recommended books:

1. Principles of the Theory of Solids by J. Ziman (Cambridge University Press-new Delhi, 2011).
2. Elements of Solid State Physics by J. P. Srivastava (PHI Learning, 2011).
3. Solid State Physics by R. J. Singh (Pearson, 2011).
4. Introduction to Solid State Physics by C. Kittel (John Wiley & Sons, 2007).

PHY.563 Nuclear Physics Laboratory Credit Hours: 4

Student has to perform any of four experiments from the following experiments.

1) G. M. counter: characteristics, dead time and counting statistics.
2) Scintillation detector: energy calibration, resolution and determination of gamma ray energy.
3) Alpha Spectroscopy using Surface Barrier Detectors.
4) Mass Attenuation of Gamma Radiation from 60Co in Al and/or Pb.
5) Mass attenuation Coefficient of Beta Radiation of Different End-point Energies.
6) Gamma Spectroscopy using Single Channel Analyser-Differential and Integral Pulse Height Spectra of Cs-137. Detector Resolution.

Recommended books:

1. Radiation Detection and Measurement by G. F. Knoll (John Wiley & Sons, 2010).
2. Techniques for Nuclear and Particle Physics Experiments: a how-to approach By William R Leo (Springer, 2012).
3. An Introduction to Radiation Protection by Karen Beach, Sam Harbison, Alan Martin (CRC Press, 2012)
4. Measurement and Detection of Radiation by Nicholas Tsoulfanidis, Sheldon Landsberger (CRC Press, 2010).
5. Interaction of Radiation with Matter by Hooshang Nikjoo, Shuzo Uehara, Dimitris Emfietzoglou (CRC Press, 2012).

PHY.599: Seminar in Physics **Credit Hours: 1**

Semester IV

PHY.516 **Introduction to Nanophysics** **Credit Hours: 4**

Unit I

Quantum Confinement: History and significant concepts, Specific heat, Phonons, Real space vs. reciprocal space, Electronic structure and related properties, Bloch theorem phonons, Nearly free electron theory, Band structure calculation methods, Thermal conductivity due to electrons and phonons, Brillouin zones, Band theory, Density of occupied states.

Unit II

Nanostructure in Equilibrium: Two dimensional electron gas, Graphene, Carbon nanotubes (SWCNT and MWCNT), Quantum dots and quantum wires, Topological insulators, Elements of density functional theory.

Unit III

Nanostructure Out of Equilibrium: Conductance quantization, Weak and strong localization, Quantum hall effect, Quantum interferometers, Quantum pumping, Magnetic tunnel junction, Spin transfer torque, Coulomb blockade.

Unit IV

Theoretical Techniques: Boltzmann Equation, Spin and charge diffusion equitation, Scattering formalism, Non-equilibrium Green function (NEGF) technique, Ion beam techniques.

Unit V

Experimental Technique: X-Ray Diffraction, Raman Spectroscopy, Scanning tunnelling and atomic force microscopy (STM and AFM).

Unit VI

Applications: Nanoelectronics, Thermoelectronics and Spintronics.

Recommended Books:

1. Textbook of Nanoscience and Nanotechnology by B.S Murty, P.Shankar, B. Raj, B. B. Rath, and J. Murday (Springer, 2013).
2. Nanostructured Materials and Nanotechnology by Claudia Gutirrez-Wing, Jos Luis Rodrguez-Lpez, Olivia A. Graeve, and Milton Muoz-Navia (Cambridge University Press, 2013).
3. Research Progress in Nanoscience and Nanotechnology by A. K. Haghi (Nova Science Publishers, 2012).

4. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications by Greg Haugstad (John Wiley & Sons, 2012).
5. Handbook of Nanophysics by Klaus D. Sattler (CRC press, 2010).
6. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience by Edward L. Wolf (John Wiley & Sons, 2008).
7. Nanoscience And Nanomaterials by Wei-Hong Zhong (Destech Publications, Inc, 2011).
8. An Introduction to Nanophysics and Nanotechnology by Avinashi Kapoor (Alpha Science International, Ltd., 2011).

PHY.517 **Modern Functional Materials** **Credit Hours: 4**

Unit I

Polymers and Composites: Polymers, Configuration (Tacticity), Conformation (Trans, Staggered, Gauche, Eclipsed), Polymer processing: Hot molding, Film blowing, Melt spinning, Composites: Classes, Role of Matrix Materials, Mixing Rules, Conducting polymers, Polymers for LED's and Photovoltaic applications: Materials synthesis and characterization, Fabrication of devices, Related problems.

Unit II

Advanced Ceramic Materials: Smart materials: Ferroelectric, Piezoelectric, Optoelectric, Semiconducting behavior, Superalloys, Shape memory alloys, Spintronics, Multiferroics, Gaint magnetoresistance (GMR), Colossal magnetoresistance (CMR), La-based Perovskite, C_{60} and graphene.

Unit III

Liquid crystals: Introduction of liquid crystals. Phase identification with Differential Scanning Calorimetry, Order parameter and its measurement by XRD, Classification of liquid crystal: Structural and Chemical standpoint, Mier-Saupe theory for nematic-isotropic and nematic-smectic-A transitions, Dielectric and electro-optical properties, Ferroelectric and discotic liquid crystals, Polymeric liquid crystals, and Applications.

Unit IV

Magnetic Materials: Soft and hard magnetic materials, Electric steel, Sheet steel, Cold rolled grain oriented silicon steel, Hot rolled grain oriented silicon steel, Hot rolled silicon steel sheet, Hysteresis loop, Magnetic susceptibility, Coercive force, Ferrites, Magnetic anisotropy and Induced magnetic anisotropy, Magneto-striction and effects of stress, Magnetic materials for recording and computers, Magnetic measurements Techniques.

Unit V

Electronic materials: Conductors, Semi-Conductors, Dielectrics and insulators, Electro-optical active materials.

Recommended Books:

1. Functional Metal Oxides by Satishchandra Balkrishna Ogale, T. Venky Venkatesan, Mark Blamire (Wiley-VCH Verlag GmbH, 2013).
2. Functional Materials: Preparation, Processing and Applications by S Banerjee (Editor), A.K. Tyagi (Editor) (Elsevier Insights, 2011).
3. Composite Materials: Functional Materials for Modern Technologies, Deborah D. L. Chung (Springer, 2003).
4. Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications by Deborah D. L. Chung (World Scientific Publishing Company, 2010).
5. Introduction to magnetic materials by B.D. Cuility and C.D. graham (Willey, 2009).
6. Dielectric Phenomena in Solids by K. C. Kao (Academic Press. 2004).
7. Liquid crystals: Nature's delicate phase of matter by Peter J. Collings (Princeton University Press, 2001)
8. Liquid Crystals by S. Chandrasekhar (Cambridge University Press, 1992).

PHY.518 Thin Films and Nanoscience Credit Hours: 4.

Unit I

Thin Films: Classification of thin films, Preparation methods: Electrolytic deposition, Thermal evaporation, Spray pyrolysis, Sputtering, Chemical vapour deposition, Molecular beam epitaxy, Thickness measurement and monitoring, Electrical, Mechanical, Optical interference.

Unit II

Analytical Techniques of Characterization: X-ray diffraction, Transmission electron microscopy (TEM), High and low energy electron diffraction, Auger emission spectroscopy, Photoluminescence (PL), UV-Vis-IR Spectrophotometer, AFM, Hall Effect, XPS, EDX.

Unit III

Properties and Applications of Films: Elastic and plastic behavior, Optical properties, Reflectance and transmittance spectra, Anisotropic and gyrotropic films, Electric properties of films: Conductivity in metal, semiconductor and insulating films, Dielectric properties, Micro and optoelectronic devices, data storage, Optical applications, Electric contacts, resistors, Capacitors and inductors, Active electronic elements, Integrated circuits.

Unit IV

Nanotechnology: Introduction to nanomaterials synthesis and applications, New forms of carbon: Fullerenes, Nanowires and Nanotubes, Types of nanotubes, Formation of nanotubes, Properties and uses of nanotubes, Quantum size effect of nano-materials and its applications.

Unit V

Methods of Preparation of Nanomaterials: Bottom up : Cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques, Ball milling, Ion Beam, Pulse laser deposition, Sputtering, LB, Spin coating, Dip coating solution cast, Tape casting, Sol gel.

Recommended Books:

1. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications by Greg Haugstad (John Wiley & Sons, 2012).
2. Textbook of Nanoscience and Nanotechnology by B.S Murty, P.Shankar, B. Raj, B. B. Rath, and J. Murday (Springer, 2013).
3. An Introduction to Nanophysics and Nanotechnology by Avinashi Kapoor (Alpha Science International, Ltd. 2011)
4. Vacuum Science and Technology by V. V. Rao (Allied Publishers Limited, 2001).
5. Handbook of Thin Film Deposition Processes by Krishna Seshan (Elsevier, 2012).

PHY.500: Dissertation Research **Credit Hours: 12**