Appendix-I

Centre for Physical and Mathematical Sciences
Scheme of Programme: M.Sc. in Physics (2015-16)

SEMESTER 1

S. No.	Paper Code	Course Title	L	T	P	Cr	% Weightage				E
							A	B	C	D	
1	PHY.501	Mathematical Physics–I	4	1	0	4	25	25	25	25	100
2	PHY.502	Classical Mechanics	4	1	0	4	25	25	25	25	100
3	PHY.503	Statistical Mechanics	4	1	0	4	25	25	25	25	100
4	PHY.504	Electronic Circuits Theory	4	1	0	4	25	25	25	25	100
5	PHY.505	Computational Methods	2	1	0	2	25	25	25	25	50
6	PHY.506	Electronic Circuits Laboratory	0	0	8	4	25	25	25	25	50
7	PHY.507	Computational Methods Laboratory	0	0	4	2	25	25	25	25	50
8		Inter-Disciplinary Elective -1 (From Other Departments)	2	1	0	2	25	25	25	25	50
			20	6	12	26					600

Interdisciplinary courses offered by Physics Faculty (For students of other Centres)											
01	PHY.508	Concepts of Physics	2	1	0	2	25	25	25	25	50
02	PHY.509	Physics in Everyday Life	2	1	0	2	25	25	25	25	50

SEMESTER 2

S. No.	Paper Code	Course Title	L	T	P	Cr	% Weightage				E
							A	B	C	D	
1	PHY.510	Mathematical Physics – II	2	1	0	2	25	25	25	25	50
2	PHY.511	Quantum Mechanics - I	4	1	0	4	25	25	25	25	100
3	PHY.512	Electromagnetic Theory – I	4	1	0	4	25	25	25	25	100
4	PHY.513	Atomic and Molecular Physics	4	1	0	4	25	25	25	25	100
5	PHY.514	Digital Electronics	4	1	0	4	25	25	25	25	100
6	PHY.515	Modern Physics Laboratory	0	0	8	4	25	25	25	25	50
7	PHY.516	Digital Electronics Laboratory	0	0	8	4	25	25	25	25	50
8	CCH	Humanities for Science Students	1	0	0	0	25	25	25	25	(NC)

8		Inter-Disciplinary Elective -2 (From Other Departments)	2	1	0	2	25	25	25	25	50
			20	6	16	28					600

Interdisciplinary courses offered by Physics Faculty (For students of other Centres)											
03	PHY.517	Introduction to Nanoscience	2	1	0	2	25	25	25	25	50
03	PHY.518	Essential of Electricity	2	1	0	2	25	25	25	25	50

SEMESTER 3

S. No.	Paper Code	Course Title	L	T	P	Cr	% Weightage				E
							A	B	C	D	
1	PHY.601	Quantum Mechanics – II	4	1	0	4	25	25	25	25	100
2	PHY.602	Solid State Physics	4	1	0	4	25	25	25	25	100
2	PHY.603	Laser Physics	2	1	0	2	25	25	25	25	50
3	PHY.604	Nuclear Physics	4	1	0	4	25	25	25	25	100
2	PHY.605	Introduction to Particle Physics	2	1	0	2	25	25	25	25	50
4	PHY.606	Electromagnetic Theory –II	4	1	0	4	25	25	25	25	100
7	PHY.607	Solid State Physics Laboratory	0	0	8	4	25	25	25	25	50
8	PHY.608	Nuclear Physics Laboratory	0	0	8	4	25	25	25	25	50
			18	5	16	26					600

SEMESTER 4 (Specialization in Nanophysics)

S. No.	Paper Code	Course Title	L	T	P	Cr	% Weightage				E
							A	B	C	D	
1		Elective 1*	4	1	0	4	25	25	25	25	100
2		Elective 2*	4	1	0	4	25	25	25	25	100
3	PHY.613	Seminar	0	0	4	2	_	_	_	_	50
4	PHY.614	Dissertation	_	_	_	14	_	_	_	_	350
			8	2		24					600

*The elective papers will be offered depending upon the availability of the teacher

Semester	Paper Code	List of Electives	L	T	P	Cr	% Weightage				E
							A	B	C	D	
Elective 1											
1	PHY.609	Introduction to Nanophysics	4	1	0	4	25	25	25	25	100
2	PHY.610	Modern Functional Materials	4	1	0	4	25	25	25	25	100
Elective 2											
3	PHY.611	Thin Films and Nanoscience	4	1	0	4	25	25	25	25	100
4	PHY.612	Characterization of Nanomaterials	4	1	0	4	25	25	25	25	100

A: Continuous Assessment: Subjective by enlarge
B: Mid-Term Test-1: Based on Objective Type & Subjective Type Test
C: Mid-Term Test-2: Based on Objective Type & Subjective Type Test
D: End-Term Exam (Final): Based on Objective Type Tests
E: Total Marks
L: Lectures T: Tutorial P: Practical Cr: Credits

Semester 1

Course Title: Mathematical Physics – I
Paper Code: PHY.501
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The course on Mathematical Physics - I is introduced to familiarize the students with the vector algebra, idea about transformation of coordinates and complex functions which will be useful in understanding theoretical treatment, communication devices and for developing a strong background to pursue research in theoretical and experimental physics.

Unit I **(16)**

Vector Algebra and Matrices: Vector algebra and vector calculus, Linear algebra, matrices, Caley-Hamilton theorem, Eigen values and Eigen function, Curvilinear coordinates.

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

Unit II **(14)**

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 **(13)**

Differential Equations: Linear ordinary differential equations of first and second order, Partial differential equations (Laplace, wave and heat equation in two and three dimensions), Boundary value problems and Euler equation.

Unit IV **(17)**

Complex Variable: Elements of complex analysis, Analytical functions, 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 and Laurent series, Isolated and essential singular points, Poles, Residues and evaluation of integerals, Cauchy residue theorem and applications of the residue theorem.

Recommended Books:

1. G. Arfken, H. Weber and F. Harris, *Mathematical Methods for Physicists* (Elsevier Academic Press, Massachusetts, USA) 2012.
2. E. Kreyszig, *Advanced Engineering Mathematics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
3. D. G. Zill, *Advanced Engineering Mathematics* (Jones & Barlett Learning, Massachusetts, USA) 2012.
4. P. K. Chattopadhyay, *Mathematical Physics* (New Age International (P) Limited, New Delhi, India) 2000.

Course Title: Classical Mechanics
Paper Code: PHY.502
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Objective:
The overall goal of this course is to provide tools and applications of classical mechanics that student can use these in various branches of physics. Student will gain solid understanding of classical mechanics (Newton's laws, Lagrangian mechanics, conservation principles, Hamiltonian formalism, Hamilton - Jacobi theory, central force, scattering, rigid body dynamics, small oscillations). Establish firm physics and math foundation on which student can build a good carrier in physics.

Unit-I (16)

Lagrangian Formalism: Newton's laws, Classification of constraints, D'Alembert's principle and its applications, Generalized coordinates, Lagrange's equation for conservative, non-conservative and dissipative systems and problems, Lagrangian for a charged particle moving in an electromagnetic field, Cyclic-coordinates, Symmetry, Conservations laws, Invariance and Noether's theorem.

Hamiltonian Formalism: Variational principle, Principle of least action, Hamilton's principle, Hamilton's equation of motion, Lagrange and Hamilton equations of motion from Hamilton's principle, Hamilton's principle to non-conservative and non-holonomic systems, Dynamical systems, Phase space dynamics and stability analysis.

Unit-II (14)

Canonical Transformations and Hamilton - Jacobi theory: 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-III (16)

Rigid Body Dynamics: Euler's angles, Euler's theorem, Moment of inertia tensor, Non-inertial frames and pseudo forces: Coriolis force, Foucault's pendulum, 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.

Two Body Problems: Central force motions, 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, Two body collisions, Scattering in laboratory and centre-of-mass frames.

Unit-IV (14)

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

Special Theory of Relativity: Lorentz transformations, Relativistic kinematics and mass energy equivalence, General theory of relativity (information only).

Recommended books:

1. S.T. Thornton and J.B. Marion, *Classical Dynamics of Particles and Systems* (Cengage Learning, Boston/Massachusetts, United State), 5th edition, 2013.
2. J. Safko, H. Goldstein and C. P. Poole, *Classical Mechanics* (Pearson, New Delhi, India) 2011.
3. Systems of Particles and Hamiltonian Dynamics, G. Walter, *Classical Mechanics* (Springer, New York, USA) 2010.
4. P.S. Joag and N.C. Rana, *Classical Mechanics* (Tata McGraw-Hill, Noida, India) 1991.

Course Title: Statistical Mechanics
Paper Code: PHY.503
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: This course is designed to provide basic concept of thermodynamics and statistical mechanics to M.Sc. Physics students. The course has been framed to teach the techniques of ensemble theory to understand the macroscopic properties of the matter in bulk in terms of its microscopic constituents.

Unit I **(12)**

Introduction: Laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell relations, Micro- and macro- states, Ergodic hypothesis, Postulate of equal a priori probability, Boltzmann's postulate of entropy, Phase space, Phase equilibria, Entropy of ideal gas, Gibbs' paradox, Liouville's theorem.

Unit II **(12)**

Canonical Ensemble: System in contact with a heat reservoir, Expression of entropy, Partition function, Free energy and its connection with thermodynamics quantities, Fluctuation of internal energy, Micro-canonical, Canonical and grand-canonical ensembles, 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 **(18)**

Classical and Quantum Statistics: Black body radiation and Plank’s distribution law, Quantum Liouville theorem, Identical particles in B-E and F-D distributions, Quantum mechanical ensemble theory, Super-fluidity in liquid He II, First and second order phase transitions, Low temperature behaviour of Bose and Fermi gases, Ising model, Mean-field theory in zeroth and first approximations, Exact solution in one dimension. **Diffusion:** Diffusion equation, Random walk and Brownian motion, Introduction to nonequilibrium processes.

Unit IV **(18)**

Ideal 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, Ferromagnetism, de Hass van Alphen effect, Principle of detailed balance.
Non-ideal Gas: Mean field theory and van der Waal's equation of state, Cluster integrals and Mayer-Ursell expansion.

Recommended books:

1. R.H. Swendsen, *An Introduction to Statistical Mechanics and Thermodynamics* (Oxford University Press, Oxford, U.K.) 2012.
2. M.V. Sadovskii, *Statistical Physics* (Walter de Gruyter GmbH and Co. KG, Berlin/Boston, USA) 2012.
3. R.K. Patharia and Paul D. Beale, *Statistical Mechanics* (Elsevier, USA) 2011.
4. B.B. Laud, *Fundamentals of Statistical Mechanics* (New Age International, New Delhi, India) 2012.
5. K. Huang, *Statistical Mechanics* (Wiley India Pvt. Ltd., New Delhi, India) 1987.

Course Title: Electronic Circuits Theory
Paper Code: PHY.504
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The course on Electronic Circuits Theory is introduced to familiarize the students with the idea of electronic devices, circuits, operations, signal processing and applications.

Unit I **(10)**

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

Power Supplies: Fourier transforms, 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 II **(20)**

Transistor Amplifiers: Theory of semiconductors, Semiconductor devices: diode, homo and hectojunction devices, Transistor, Device structure and characteristics, Amplifiers, Frequency dependence and applications, Impedance matching, 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, Noise reduction, Low frequency power amplifiers, High frequency devices.

Unit III **(12)**

Optoelectronic Devices and Transducers: Solar cell, Photo detector and LEDs, Transducers, Measurement and control, Shielding and grounding.

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 IV **(18)**

Feedback: The gain of an amplifier with feedback, General characteristics of negative feedback/instrumentation 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, lockin detector , Box Car integrator and modulation techniques.

Operational Amplifier and Their Applications: Characteristics of an ideal operational amplifier, Amplification, Applications of operational amplifiers: Inverting and non-inverting amplifiers, Summing circuits, Integration and differentiation, Waveform generators signal conditioning and recovery.

Recommended books:

1. J. Millman, C. Halkias and C. Parikh, *Integrated Electronics : Analog and Digital Circuits and Systems* (Tata McGraw - Hill Education, Noida, India) 2009.
2. R.L. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory* (Pearson, New Delhi, India) 2009.

3. B. L. Theraja, *Basic Electronics: Solid State* (S. Chand & Company Ltd., New Delhi, India) 2010.
4. D. Chattopadhyay and P. C. Rakshit, *Electronics: Fundamentals and Applications* (New Age International, New Delhi, India) 2008.

Course Title: Computational Methods
Paper Code: PHY.505
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The course on Computational Methods has been framed to equip the students of M.Sc. Physics with knowledge of programming in C, roots of equation, interpolation, curve fitting, numerical differentiation, numerical integration, solution of ordinary differential equations and probability.

Unit I **(07)**

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 **(07)**

Roots of Algebraic and Transcendental Equations: Element of computational techniques: roots of functions, Interpolation, Extrapolation, One point and two-point iterative methods such as bisection method and Newton Raphson methods.

Unit III **(08)**

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

Data Interpretation and Error analysis: Dimensional analysis, Precision and accuracy, error analysis, Propagation and errors.

Unit IV **(08)**

Least square fitting: Least square fitting, Linear and nonlinear curve fitting, Chi square test.

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

Probability Theory: Elementary probability theory, Random variables, Binomial, poisson and normal distributions, Central limit theorem.

Recommended Books:

1. P.R. Bevington and D. K. Robinson, *Data Reduction and Error analysis for Physical Sciences* (McGraw Hill, Noida, India) 2003.
2. Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
3. E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
4. S. S. Sastry, *Introductory Methods of Numerical Analysis* (PHI Learning Pvt. Ltd., New Delhi, India) 2012.

Course Title: Electronic Circuit Laboratory
Paper Code: PHY.506
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	50

Course objective: The laboratory exercises have been so designed that the students can verify some of the concepts learnt in the electronic circuit theory classes. During these laboratory they will get sufficient training to carrying out precise measurements and handling sensitive equipment.

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

Course Title: Computational Methods Lab
Paper Code: PHY.507
Total Hours: 60

L	T	P	Credits	Marks
0	0	4	2	50

Course objective: The laboratory exercises have been so designed that the students learn to verify some of the mathematical concepts. They are trained in carrying out numerical problems using C language.

Student has to perform at least eight experiments out of the following list of 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. P.R. Bevington and D. K. Robinson, *Data Reduction and Error analysis for Physical Sciences* (McGraw Hill, Noida, India) 2003.
2. Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
3. E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
4. S. S. Sastry, *Introductory Methods of Numerical Analysis* (PHI Learning Pvt. Ltd., New Delhi, India) 2012.

Course Title: Concepts of Physics
Paper Code: PHY.508
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The course Concepts of Physics introduces basic concepts of physics and science for non-physics students. The course has been framed to provide understanding to the non-physics students.

Unit I **(08)**

Measurement: SI Units, Dimensional analysis, Errors and uncertainties, Scalars and vectors. **Mechanics:** Motion, Force and Newton's laws, Momentum, Projectile and circular motions, Gravitation, Planetary motion and earth satellites, Communication satellites, Work, Energy conversion, Power and energy, Energy and environment, Rotational motion. Kinematics of uniform circular motion, Centripetal acceleration, Centripetal force.

Unit II **(07)**

Properties of Matter: Three states of matter, Binding forces, Fluid pressure and thrust, Applications of fluid pressure, Pascal law, Archimedes principle, Capillary action, Bernoulli's principle, Viscosity.

Wave Motion: Progressive waves, Transverse and longitudinal waves, Polarisation, Determination of frequency and wavelength, Superposition, Stationary waves,

Unit III **(08)**

Heat and Sound: Internal energy, Temperature scales, Specific heat capacity, Specific latent heat, First law of thermodynamics, The ideal gas equation, Kinetic energy of a molecule, Measurement of heat and temperature, Clinical thermometer, Heat transfer, Thermos flask, Effect of pressure on boiling point and melting point, Heat engines, Steam engine, Diesel engine, Sound and music, Reverberation, Acoustics of building, Recording and reproduction of sound in film.

Unit IV **(07)**

Electricity and Magnetism: Coulomb's law, Action of points, Lightening arrester, Ohm's law, Electric power, Electrical safety, Electromagnetic induction, Faraday's law, Lenz law, Transformers. **Light:** Interference, Diffraction, Two-source interference patterns, Diffraction grating, Optical instruments. **Nuclear Phenomena:** Nuclear energy, Fission and fusion, Nuclear power plants, Atom bomb and hydrogen bomb.

Recommended Books:

1. Sears and Zemansky, *University Physics* (Addison Wesley, Boston, USA) 2007.
2. M. Nelkon and P. Parker, *Advanced Level Physics* (Heinemann International, London, U.K.) 2012.
3. B. Lal and Subramaniam, Electricity and Magnetism (Ratan Prakashan Mandir, Agra, India) 2013.
4. E. Hecht, *Optics* (Addison Wesley, Boston, USA) 2001.
5. H. C. Verma, *Concepts of Physics* (Bharati Bhawan Publishers and Distributers, New Delhi, India) 2011.

Course Title: Physics in Everyday Life
Paper Code: PHY.509
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: For non-physics students, the course introduces physics and science in everyday life, considering objects from our daily environment and focusing on their principles of operation, histories, and relationships to one another.

Unit I **(08)**

Physics in Earth's Atmosphere: Sun, Earth's atmosphere as an ideal gas; Pressure, temperature and density, Pascal's Law and Archimedes' Principle, Coriolis acceleration and weather systems, Rayleigh scattering, the red sunset, Reflection, refraction and dispersion of light, Total internal reflection, Rainbow.

Unit II **(07)**

Physics in Human Body: The eyes as an optical instrument, Vision defects, Rayleigh criterion and resolving power, Sound waves and hearing, Sound intensity, Decibel scale, Energy budget and temperature control.

Unit III **(08)**

Physics in Sports: The sweet spot, Dynamics of rotating objects, Running, Jumping and pole vaulting, Motion of a spinning ball, Continuity and Bernoulli equations, Bending it like Beckham, Magnus force, Turbulence and drag.

Unit IV **(07)**

Physics in Technology: Microwave ovens, Lorentz force, Global Positioning System, CCDs, Lasers, Displays, Optical recording, CD, DVD Player, Tape records, Electric motors, Hybrid car, Telescope, Microscope, Projector etc.

Recommended Books:

1. Sears and Zemansky, *University Physics* (Addison Wesley, Boston, USA) 2007.
2. M. Nelkon and P. Parker, *Advanced Level Physics* (Heinemann International, London, U.K.) 2012.
3. B. Lal and Subramaniam, Electricity and Magnetism (Ratan Prakashan Mandir, Agra, India) 2013.
4. E. Hecht, *Optics* (Addison Wesley, Boston, USA) 2001.
5. H. C. Verma, *Concepts of Physics* (Bharati Bhawan publishers and distributers, New Delhi, India) 2011.

Semester 2

Course Title: Mathematical Physics – II
Paper Code: PHY.510
Total Lecture: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The course on Mathematical Physics - II is introduced to familiarize the students with the special functions, group theory, and tensors which will be useful in understanding theoretical treatment and for developing a strong background to pursue research in theoretical physics.

Unit I **(06)**

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 **(09)**

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, Green's function.

Unit III **(09)**

Introductory 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), SU(3) and O(3).

Unit IV **(06)**

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. G. Arfken, H. Weber and F. Harris, *Mathematical Methods for Physicists* (Elsevier Academic Press, Massachusetts, USA) 2012.
2. E. Kreyszig, *Advanced Engineering Mathematics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
3. L. A. Pipes, *Applied Mathematics for Engineers and Physicist* (McGraw-Hill, Noida, India) 1985.
4. D. G. Zill, *Advanced Engineering Mathematics* (Jones & Barlett Learning, Massachusetts, USA) 2012.
5. P. K. Chattopadhyay, *Mathematical Physics* (New Age International (P) Limited, New Delhi) 2000.

Course Title: Quantum Mechanics – I
Paper Code: PHY.511
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective:
The objective of this course is to develop familiarity with the physical concepts of quantum mechanics and its mathematical formulation. Student will learn basics of the subject and make them understand the concept of operators, observables, Hilbert space, matrix mechanics, Schrodinger equation and applies it to simple physical systems, angular momentum, scattering theory etc with emphasis on the mathematical structure of the theory.

Unit-I **(14)**

Limitations of Classical Physics: Black body radiation, Photoelectric effect, Compton effect, Electron diffraction, Wave particle duality and Heisenberg uncertainty principle.
Formulation of Quantum Mechanics: Review of linear algebra and introduction to Hilbert space, Dirac notation for state vectors, Symmetry and conservation laws, Matrix mechanics.

Unit-II **(14)**

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

Unit-III **(18)**

Applications of Schrödinger Wave Equation: Eigen value problems; Particle in one dimensional box, Potential step, Square well, Tunneling through barrier, Linear harmonic oscillator, Spherically symmetric potential, Hydrogen atom.
Angular momentum: Motion in central potential: orbital angular momentum, Angular momentum algebra, Commutators, Concept of spin, Stern-Gerlach experiment, Linear harmonic oscillator problem using commutation relations, Matrix representation of angular momentum operators, Addition of angular momenta, C.G. coefficients.

Unit-IV **(14)**

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

Recommended books:

1. E. Merzbacher, *Quantum Mechanics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
2. L.I. Schiff, *Quantum Mechanics* (Tata McGraw-Hill Education, Noida, India) 2010.
3. N. Zettili, *Quantum Mechanics-Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
4. K. Venkatesan, P.M. Mathews, *A Textbook of Quantum Mechanics* (Tata McGraw - Hill Education, Noida, India) 2010.

Course Title: Electromagnetic Theory – I
Paper Code: PHY.512
Total Lecture: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course objective: The Electromagnetic Theory – I is a course that covers electrostatics, magnetostatics, dielectrics, and Maxwell equations. The course has also been framed to solve the boundary value problems.

Unit I **(12)**

Electrostatics: Gauss's law and its applications, 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 **(12)**

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 **(18)**

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

Maxwell's Equations: Maxwell's equations in free space and linear isotropic media, Boundary conditions on the fields at interfaces.

Unit IV **(18)**

Magnetostatics: Biot-Savart law and Ampere's theorem, Electromagnetic induction, 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.

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

Recommended books:

1. M.A. Heald and J.B. Marion, *Classical Electromagnetic Radiation* (Dover Publications, New York, USA) 2012.
2. D.J. Griffiths, *Introduction to Electrodynamics* (Prentice Hall of India Pvt. Ltd., New Delhi) 2012.
3. A. Zangwill, *Modern Electrodynamics* (Cambridge University Press, Cambridge, U.K.) 2012.
4. J.D. Jackson, *Classical Electrodynamics* (Wiley India (P) Ltd., New Delhi, India) 2004.
5. E.M. Lifshitz, L.D. Landau and L.P. Pitaevskii, *Electrodynamics of Continuous Media* (Elsevier, New York, USA) 1984.

Course Title: Atomic and Molecular Physics
Paper Code: PHY.513
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course objective: The main objective of the course on Atomic, Molecular, and Laser Physics for the students of M.Sc. Physics is to teach the knowledge of atomic, molecular, electronic rotational, vibrational, and Raman spectra. The course also covers the basic concepts and applications of lasers.

Unit I **(18)**

One and Two Electrons Systems: Quantum state of an electron in an atom, Spectrum of hydrogen, helium and alkali atoms, Electron spin, 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, Relativistic correction for energy level of hydrogen atom, Selection rules, Lamb shift, Zeeman effect. Paschen-Back effect, Stark effect, Hyperfine structure and isotopic shift, Width of spectral lines.

Unit II **(10)**

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

Unit III **(18)**

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.

Unit IV **(14)**

Molecular Spectra: Electronic, Vibrational and rotational spectrum of diatomic molecules, Frank-Condon principle, Raman transitions and Raman spectra, Normal vibrations of CO_2 and H_2O molecules.

Recommended Books:

1. C.J. Foot, *Atomic Physics* (Oxford University Press, Oxford, U. K.) 2005.
2. W. Demtroder, *Molecular Physics* (Springer, New York, USA) 2008.
3. J.M. Hollas, *Basic Atomic and Molecular Spectroscopy* (Royal Society of Chemistry, London, U.K.) 2002.
4. G. Herzberg, *Atomic Spectra and Atomic Structure* (Dover Publications, New York, USA) 2010.

Course Title: Digital Electronics
Paper Code: PHY.514
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The course on Digital Electronics is introduced to familiarize the students with the idea of logic in designing of electronic devices, circuits, operations, data signal processing and applications.

Unit I **(14)**

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 **(14)**

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

Unit III **(17)**

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 and similar circuits, MSI and LSI based design, MSI and LSI implementation on sequential circuit.

Unit IV **(15)**

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.

Data Converters: Analog to digital (A/D) data converters, Digital to analog (D/A) data converters, Logic families, Microprocessors and micro controller basics.

Recommended books:

1. G. Saha, A.P. Malvino and D.P. Leach, *Digital Principles and Applications* (Tata McGraw - Hill Education, Noida, India) 2011.
2. P. Malvino and J.A. Brown, *Digital Computer Electronics* (Tata McGraw - Hill Education, Noida, India) 2011.
3. C. Hawkins and J. Segura, *Introduction to Modern Digital Electronics* (Scitech Publishing, New York, USA) 2010.

Course Tile: Modern Physics Laboratory
Paper Code: PHY.515
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	50

Course objective: The laboratory exercises have been so designed that the students can verify some of the concepts learnt in the Atomic Molecular and Laser Physics theory classes. During these laboratory they will get sufficient training to carrying out precise measurements and handling sensitive equipment.

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. R.A. Serway, C.J. Moses and C.A. Moyer, *Modern physics* (Brooks Cole, Massachusetts, USA) 2012.
2. S.T. Thornton, *A. Rex Modern Physics for Scientists and Engineers* (Thomson Brooks/Cole, Massachusetts, USA) 2012.
3. K.S. Krane, *Modern Physics* (Wiley India (P) Ltd., New Delhi, India) 2012.
4. A. Beiser, *Concepts of Modern Physics* (Tata McGraw - Hill Education, Noida, India) 2007.

Course Title: Digital Electronics Laboratory
Paper Code: PHY.516
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	50

Course objective: The laboratory exercises have been so designed that the students can verify some of the concepts learnt in the Digital Electronics classes. During these laboratory they will get sufficient training to carrying out precise measurements and handling sensitive equipment.

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. G. Saha, A.P. Malvino and D.P. Leach, *Digital Principles and Applications* (Tata McGraw - Hill Education, Noida, India) 2011.
2. P. Malvino and J.A. Brown, *Digital Computer Electronics* (Tata McGraw - Hill Education, Noida, India) 2011.
3. C. Hawkins and J. Segura, *Introduction to Modern Digital Electronics* (Scitech Publishing, New York, USA) 2010.

Course Title: Fundamentals of Nanoscience
Paper Code: PHY.517
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The course Fundamentals of Nanoscience gives the basic concepts of physics at nanoscale. The course has been framed to provide understanding to the nonoscience and nanotechnology of interdisciplinary students.

Unit I **(07)**

Introduction: Scientific Revolutions, Types of Nanotechnology, Periodic table, Atomic Structure, Molecules and phases, Energy-Molecular and atomic size, Surfaces and dimensional space, top down and bottom up approach for nanomaterials preparations.

Unit II **(07)**

Electrostatic and Molecular Interactions: Forces between atoms and molecules, Particles and grain boundaries, strong Intermolecular forces, Electrostatic and Vander Waals forces between surfaces, similarities and differences between intermolecular and inter particle forces, covalent and coulomb interactions, interaction among polar molecules, Basic physics behind self-assembly.

Unit III **(08)**

Nanoscience: Opportunity at the nanoscale length and time scale, Inter dynamic aspects of inter molecular forces, Evolution of band structure and Fermi surface, Quantum dots, Nanowires,Nano tubes.

Unit IV **(08)**

Properties of Nanomaterials: Influence of nano structuring on mechanical, optical, electronic, magnetic and chemical properties, electronic transport in quantum wires and carbon nano tubes, magnetic behavior of single domain particles and nanostructures applications of quantum dots and quantum wires.

Recommended Books:

1. M. Wilson, K. Kannangara, G. smith, *Nanotechnology: Basic Science and Emerging Technologies* (Overseas press, New Delhi, India) 2005.
2. C.P. Poole and. F.J. Owens, *Introduction to Nanotechnology,* (Wiley Interscience, New Jersey, USA) 2003.
3. M.A. Ratner, D. Ratner, *Nanotechnology: A gentle introduction to the next Big idea*, Pearson Education, New Jersey, USA) 2003.
4. H.S. Nalwa, *Nanostructured materials and Nanotechnology,* Academic press, Massachusetts, USA) 2001.

Course Title: Essentials of Electricity
Paper Code: PHY.518
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The course Essentials of Electricity gives the basic concepts of electricity and its application in daily life to the non Physics students..

UNIT – I **(08)**

Electricity: Electrification by friction, Two kinds of electricity, Electric field, Conductors, Capacitor, Principle of condenser and types, Condenser boxes, Electrolytic condenser, Condenser in series, Condensers in parallel.

UNIT - II **(08)**

Potential and Resistance: Electric potential, Ohm's law, Electrical energy and power, Resistance, Types of resistance, Fixed resistance, Variable resistance.

UNIT - III **(10)**

Electrical Appliances: Colour Codes, Resistance in series, Resistance in parallel, Kirchhoff's law, Application to Wheatsotne's Network, Working principle of electrical appliance: air conditioner, refrigerator, geyser, invertor, electrical iron etc.

UNIT - IV **(04)**

Cell and Batteries: Primary cell, Daniel, Lechlanche, Dry cell, Secondary cell: Lead acid, Nickle (Principle only), Cadmium cell, Rechargeable cell and Batteries.

Recommended Books:

1. Sears and Zemansky, *University Physics* (Addison Wesley, Boston, USA) 2007.
2. M. Nelkon and P. Parker, *Advanced Level Physics* (Heinemann International, London, U.K.) 2012.
3. B. Lal and Subramaniam, Electricity and Magnetism (Ratan Prakashan Mandir, Agra, India) 2013.
4. H. C. Verma, *Concepts of Physics* (Bharati Bhawan publishers and distributers, New Delhi, India) 2011.

Semester 3

Course Title: Quantum Mechanics – II
Paper Code: PHY.601
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective:
This is the second of two courses in quantum mechanics. Its aim is to provide a solid grounding in important applications of approximation methods and apply them to complex problems, many-electron systems, scattering theory, relativistic quantum mechanics and quantum field theory.

Unit-I **(17)**

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.

Time-independent Perturbation Theory and its Applications: Stationary perturbation theory: Degenerate case, Variational methods, Polarizability of hydrogen, Non-degenerate perturbation theory, Harmonic oscillator subject to perturbing potential, Degenerate perturbation theory, Stark effect, spin orbit coupling, Fine structure of hydrogen, Zeeman effect.

Unit-II **(17)**

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.

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, Spin statistics connections, Helium atom, Central field approximation, Thomas-Fermi model of the atom, Hartree and Hartree-Fock equations, Quantum mechanics of molecules, Born-Oppenheimer approximation.

Unit-III **(13)**

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-IV **(13)**

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. P.A.M. Dirac, *Principles of Quantum Mechanics* (Oxford University Press, Oxford, U.K.) 2004.
2. N. Zettili, *Quantum Mechanics: Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
3. M. Beck, *Quantum Mechanics: Theory and Experiment* (Oxford University Press, Oxford, U.K.) 2012.
4. J.J Sakurai, *Advanced Quantum Mechanics* (Pearson, New Delhi, India) 2006.
5. J.J. Sakurai, J. Napolitano, *Modern Quantum Mechanics* (Pearson India, New Delhi, India) 2014.
6. F. Mandl, G. Shaw, *Quantum Field Theory* (John Wiley & Sons Ltd., Sussex, U.K) 2010.

Course Title: Solid State Physics
Paper Code: PHY.602
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective:
The objectives of this physics course are to provide the student with a clear and logical presentation of the basic and advanced concepts and principles of solid state physics. The contents of the course are designed so as to expose the students to the topics like crystal structure, lattice vibrations, band theory of solids, magnetic properties of solids, defects and dislocations, superconductivity so that they are able to use these techniques in investigating the aspects of the matter in condensed phase.

Unit I **(18)**

Crystal Structure and its determination: Bravais lattices, Crystal structures, Reciprocal lattices, Ewald sphere, Interaction of X-rays with matter, X-ray diffraction, Lattice parameter determination, Atomic and crystal structure factors, Intensity of diffraction maxima, Bonding of solids.

Lattice Dynamics: Elastic properties of solids, 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 II **(14)**

Band Theory of Solids: Electrons motion in periodic potentials, Bloch theorem, Kronig Penny model, Nearly free electron theory, Band gap, Number of states in a band, Tight binding method, Effective mass of an electron in a band, Classification of metal, Semiconductor and insulator, Fermi gas, Topology of Fermi-surface, Boltzmann transport equation, Drude model of electrical and thermal conductivity and Sommerfield theory, Hall effect and quantum Hall effect, Thermoelectric power, Response and relaxation phenomena.

Unit III **(10)**

Magnetic Properties of Solids: Classical and quantum theory of diamagnetism and paramagnetism, Weiss theory of ferromagnetism, Curie-Weiss law, Heisenberg's model and molecular field theory, Domain structure and Bloch wall, Neel model of antiferromagnetism and ferrimagnetism, ESR, NMR and chemical shifts.

Unit IV **(18)**

Defects and Dislocations: 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.

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, Superfluity, High T_C superconductors (information only).

Recommended books:

1. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, Cambridge, U.K.) 2011.
2. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. A.J. Dekker, *Solid State Physics* (Macmillan, London, U.K.) 2012.

Course Title: Laser Physics
Paper Code: PHY.603
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective: The main objective of the course on Laser Physics is to teach the basic concepts and applications of lasers to M. Sc. Physics students.

Unit I **(10)**

Basic concepts: Spontaneous and stimulated emission, Einstein A and B Coefficients, Population Inversion, Lifetime of an atom in an excited state, Shape and width of spectral lines, Line broadening mechanism, Role of line broadening in laser emission, Cavity modes, Optical pumping and threshold condition, Modes of resonators and coherence length, Quality factor.

Unit II **(08)**

Laser Rate Equations and Laser Systems: Laser rate equations for two, three and four level lasers, He-Ne laser, CO_2 laser, Four level solid state lasers. Dye lasers, Ar^+ laser, Excimer lasers, Nd-YAG solid state lasers, Semiconductor lasers, Pulsed operation of laser: Few novel applications of laser.

Unit III **(06)**

Properties of Laser Beam: directionality, monochromacity, intensity, coherence (temporal and Spatial). Q-switching and mode locking,

Unit IV **(06)**

Applications of Lasers: Laser induced fusion. Isotope separation

Recommended Books:

1. K. Thyagrajan and A.K. Ghatak, *Lasers - Fundamentals and Applications* (Springer, New York, USA) 2010.
2. B.B. Laud, *Lasers and Non-Linear Optics* (New Age International, New Delhi, India) 2011

Course Title: Nuclear Physics
Paper Code: PHY.604
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The objective of the course on Nuclear Physics is to teach the students of M.Sc. Physics with the knowledge of basic nuclear properties, nuclear interactions, nuclear decay, and nuclear models.

Unit I **(12)**

Basic Nuclear Properties: Nuclear size, shape and charge distribution, Form factor, 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 **(14)**

Two Nucleon Problems: Nature of nuclear forces, Deuteron problem, RMS radius, Spin dependence of nuclear forces, Form of nucleon-nucleon potentials, 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, Charge independence, Charge symmetry and iso-spin invariance of nuclear forces.

Unit III **(16)**

Nuclear Decay: Different kinds of particle emission from nuclei, Alpha decay, Fine structure of α spectrum, Beta and Gamma decay and their selection rules. 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.

Nuclear Models: Evidence of shell structure, Single particle shell model, Its validity and limitations, Rotational spectra, Shell model, Liquid drop model, Semi empirical mass formula.

Unit IV **(18)**

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

Recommended books:

1. B. Martin, *Nuclear & Particle Physics* An Introduction : (John Wiley & Sons, Inc., New Jersey, USA) 2011.
2. K.S. Krane, *Introductory Nuclear Physics* (John Wiley & Sons, Inc., New Jersey, USA) 2008.

3. C.A. Bertulani, *Nuclear Physics in a Nutshell* (Princeton University Press, Princeton, USA) 2007.
4. S.S.M. Wong, *Introductory Nuclear Physics* (John Wiley & Sons, Inc., New Jersey, USA) 2008.
5. K. Heyde, *Basic Ideas and Concepts in Nuclear Physics* An Introductory approach : (CRC Press, London, U. K.) 2004.

Course Title: Introduction to Particle Physics
Paper Code: PHY.605
Total Lectures: 30

L	T	P	Credits	Marks
2	1	0	2	50

Course Objective:

The contents of the course are designed so as to expose the students to the basics topics of particle physic so that they are familiar with elementary particles and their properties.

Unit-I (10)

Introduction: Classification of particles: Fermions and bosons, Elementary Particles and antiparticles, Quarks model, baryons, mesons and leptons and leptons, Classification of fundamental forces: Strong, Electromagnetic, Weak and Gravitational.

Unit-II (08)

Conservation Laws: Conservation laws of momentum, energy, Angular momentum, Parity non conservation in weak interaction, Pion parity, Isospin, Charge conjugation, Positronium decay, Time reversal invariance, CPT invariance.

Unit-III (04)

Particle Quantum Number: Introduction to baryon, Lepton numbers, Strangeness, charm and other additive quantum numbers, Resonance and their quantum numbers, Gell Mann Nishijima formula.

Unit-IV (08)

Relativistic Kinematics and Phase Space: Relativistic kinematics, applications of symmetry arguments to 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. B. Povh, K. Rith, C. Scholz, *Particles and Nuclei: An Introduction to the Physical Concepts* (Springer, New York, USA) 2012.
2. B. Martin, *Nuclear and Particle Physics : An Introduction* (John Wiley & Sons, Sussex, U.K.) 2011.
3. D.H. Perkin, *Introduction to High Energy Physics* (Cambridge University Press, Cambridge, U.K.) 2000.
4. I.S. Hughes, *Elementary Particles* (Cambridge University Press, Cambridge, U.K.) 1991.
5. W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments* (Springer, New York, USA) 2009.
6. T. Stefan, *Experimental Techniques in Nuclear and Particle Physics* (Springer, New York, USA) 2010.
7. D.J. Griffiths, *Introduction to Elementary Particles* (Wiley-VCH Verlag GmbH, Germany) 2008.

Course Title: Electromagnetic Theory – II
Paper Code: PHY.606
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course objective: The course Electromagnetic Theory – II covers applications of Maxwell equations in propagation of electromagnetic waves in dielectrics, metals and plasma. The course also covers the motion of relativistic and non- relativistic charged particles in electrostatic and magnetic fields.

Unit I **(12)**

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

Unit II **(18)**

Plane Electromagnetic Waves and Wave Equations: EM wave in free space, Dispersion characteristics of dielectrics, Waves in a conducting and dissipative media, Reflection and refraction, Polarization, Fresnel's law, Interference, Coherence and diffraction, Dispersion relation in plasma, Skin effect, Transmission lines and wave guides.

Unit III **(12)**

Radiation from Moving Point Charges and Dipoles: 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 **(18)**

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 dynamics of a charged particle in static and uniform electromagnetic fields, Lorentz invariance of Maxwell equations, 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. M.A. Heald and J.B. Marion, *Classical Electromagnetic Radiation* (Dover Publications, New York, USA) 2012.
2. D.J. Griffiths, *Introduction to Electrodynamics* (Prentice Hall of India Pvt. Ltd., New Delhi) 2012.
3. A. Zangwill, *Modern Electrodynamics* (Cambridge University Press, Cambridge, U.K.) 2012.
4. J.D. Jackson, *Classical Electrodynamics* (Wiley India (P) Ltd., New Delhi, India) 2004.
5. E.M. Lifshitz, L.D. Landau and L.P. Pitaevskii, *Electrodynamics of Continuous Media* (Elsevier, New York, USA) 1984.

Course Tile: Solid State Physics Laboratory
Paper Code: PHY.607
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	50

Course objective: The Solid State Physics laboratory experiments have been so designed that the students learn basic concept of solid state physics learnt in the theory course.

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. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, New Delhi, India) 2011.
2. J.P. Srivastava, *Elements of Solid State Physics* (PHI Learning, New Delhi, India) 2011.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2014.

Course Title: Nuclear Physics Laboratory
Paper Code: PHY.608
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	50

Course objective: The nuclear physics laboratory experiments have been so designed that the students learn to decay process, detection, and absorption learnt in the theory course.

Student has to perform at least eight-ten experiments out of the following list of experiments.

1) Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope etc.
2) Verification of inverse square law for gamma rays.
3) Study of nuclear counting statistics.
4) Estimation of efficiency of the G.M. detector for beta and gamma sources.
5) To study beta particle range and maximum energy (Feather Analysis).
6) Backscattering of beta particles.
7) Production and attenuation of bremsstrahlung.
8) Measurement of short half-life
9) Demonstration of nucleonic level gauge principle using G.M counting system and detector.
10) Beam interruption detection system to check packs for content level, or counting of individual items.
11) Scintillation detector: energy calibration, resolution and determination of gamma ray energy.
12) Alpha spectroscopy using surface barrier detectors.
13) Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage
14) Study of Cs-137 spectrum and calculation of FWHM and resolution for a given scintillation detector.
15) Study of Co-60 spectrum and calculation of resolution of detector in terms of energy.
16) Energy calibration of gamma ray spectrometer (Study of linearity).
17) Spectrum analysis of Cs-137 and Co-60 and to explain some of the features of Compton edge and backscatter peak.
18) Unknown energy of a radioactive isotope.
19) Variation of energy resolution with gamma energy.
20) Activity of a gamma source (Relative and absolute methods).
21) Measurement of half value thickness and evaluation of mass absorption coefficient.
22) Back scattering of gamma Rays.

Recommended books:

1. G.F. Knoll, *Radiation Detection and Measurement* (John Wiley & Sons, Sussex, U.K.) 2010.
2. W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments: a how-to approach* (Springer, New York, USA) 2012.
3. K. Beach, S. Harbison, A. Martin, *An Introduction to Radiation Protection* (CRC Press, London, U.K.) 2012.
4. N. Tsoulfanidis, S. Landsberger, *Measurement and Detection of Radiation* (CRC Press, London , U.K.) 2010.
5. H. Nikjoo, S. Uehara, D. Emfietzoglou, *Interaction of Radiation with Matter* (CRC Press, London, U.K.) 2012.

Semester 4

Course Title: Introduction to Nanophysics
Paper Code: PHY.609
Total Lecture: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The course on Introduction to Nanophysics is introduced to familiarize the students with the idea about the Physics at nanoscale of the materials. So that they can understand about new development emerging idea in the area of nanomaterials and thin film technology.

Unit I **(15)**

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 **(18)**

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.

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 III **(12)**

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

Unit IV **(15)**

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

Applications: Nanoelectronics, Thermoelectronics and Spintronics.

Recommended Books:

1. B.S Murty, P..Shankar, B. Raj, B.B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology* (Springer, New Delhi, India) 2013.
2. C.G. Wing, J.L.R. Lpez, O.A. Graeve, and M.M. Navia *Nanostructured Materials and Nanotechnology* (Cambridge University Press, Cambridge, U.K.) 2013.
3. A.K. Haghi, *Research Progress in Nanoscience and Nanotechnology* (Nova Science Publishers, New York, USA) 2012.

4. G. Haugstad, *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications* (John Wiley & Sons, Inc., New Jersey, USA) 2012.
5. K.D. Sattler, *Handbook of Nanophysics* (CRC press, London, U. K.) 2010**.**
6. E.L. Wolf *Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience* (John Wiley & Sons, Inc., New Jersey, USA) 2008.
7. A. Kapoor, *An Introduction to Nanophysics and Nanotechnology* (Alpha Science International, Ltd., Oxford, U. K.) 2011.

Course Tile: Modern Functional Materials
Paper Code: PHY.610
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: Physicists and Chemists are now playing an important role in the growing field of materials research. The aim of this course is to introduce students to this area of modern materials. This class will review the fundamental principles of advanced functional materials (polymers and composites, advanced ceramic materials, liquid crystals, magnetic materials, and electronic materials).

Unit-I **(14)**

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 **(14)**

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

Unit-III **(15)**

Liquid Crystals: Introduction of liquid crystals, Ordered phases of matter: Translational and orientational order, Phase identification with Differential Scanning Calorimetry, Order parameter and its measurement by XRD, Kinds of liquid crystalline order: 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, Applications, Quasi crystals.

Unit-IV **(17)**

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.

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

Recommended Books:

1. S.B. Ogale, T.V. Venkatesan, M. Blamire, *Functional Metal Oxides* (Wiley-VCH Verlag GmbH, Germany) 2013.

2. S. Banerjee and A.K. Tyagi, *Functional Materials : Preparation, Processing and Applications* (Elsevier, Insights, Massachusetts, USA) 2011.
3. D.D.L. Chung, *Composite Materials : Functional Materials for Modern Technologies* (Springer, New York, USA) 2003.
4. Deborah D. L. Chung, *Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications* (World Scientific Publishing Company, Singapore) 2010.
5. B.D. Cuility and C.D. graham, *Introduction to Magnetic Materials* (Willey, New Jersey) 2009.
6. K.C. Kao, *Dielectric Phenomena in Solids* (Elsevier, Academic Press, London, U. K.) 2004.
7. Peter J. Collings, *Liquid crystals: Nature's delicate phase of matter* (Princeton University Press, Princeton, USA) 2001.
8. S. Chandrasekhar, *Liquid Crystals* (Cambridge University Press, Cambridge, U. K.) 1992.

Course Title: Thin Films and Nanoscience
Paper Code: PHY.611
Total Lecture: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: To introduce thin film deposition techniques and study of its optical, electrical, magnetic and mechanical properties and applications of thin films. It also aims to introduce basics of nanomaterials and their synthesis via different methods and applications.

Unit-I **(16)**

Thin Films: Classification of thin films, Preparation methods: Electrolytic deposition, Thermal evaporation, Spray pyrolysis, Sputtering Pulse laser deposition, LB, Spin coating, Dip coating solution cast, Tape casting, Sol gel, Chemical vapour deposition, Molecular beam epitaxy, Cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques, Thickness measurement and monitoring, Electrical, Mechanical, Optical interference.

Unit-III **(16)**

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-III **(14)**

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-IV **(14)**

Methods of Preparation of Nanomaterials: Top-down and bottom-up approaches, Physical and chemical methods for the synthesis, Ball milling, Ion Beam, Sol-gel, hydrothermal and microwave synthesis etc.

Recommended Books:

1. G. Haugstad, *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications* (John Wiley & Sons, Inc., New Jersey, USA) 2012.
2. B.S Murty, P. Shankar, B. Raj, B.B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology* (Springer, New York, USA) 2013.
3. A. Kapoor, *An Introduction to Nanophysics and Nanotechnology* (Alpha Science International, Ltd., U. K.) 2011.
4. K. Seshan, *Handbook of Thin Film Deposition Processes* (Elsevier, London, U. K.) 2012.

Course Title: Characterization of Nanomaterials
Paper Code: PHY.612
Total Lecture: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The course on Characterization of nanomaterials is introduced to familiarize the students with the idea about the varous facets related to characterization and study of diverse properties of the nanomaterials and thin films so that they can understand the new development and breakthrough in the area of Nanophysics.

Unit I **(20)**

Structural and Microstructural Analysis: High resolution X-Ray diffractogram, Phase identification, Strain & particle size, Phase diagram and texture determinations, Principles of image formation, Fluorescent microscopy, Scanning electron microscopy (SEM), Bright and dark field imaging, Field emission scanning electron microscopy (FESEM), High resolution transmission electron Microscopy (HRTEM).

Unit II **(10)**

Scanning Probe Microscopy (SPM): Scanning-probe microscopy (SPM), Electron probe micro analysis, Atomic force microscopy (AFM), Scanning tunneling microscopy (STM).

Unit III **(15)**

Spectroscopic Technique: Fourier Transform Infrared spectroscopy (FTIR), Raman spectroscopy, Impedance spectroscopy, Dielectric spectroscopy, optical absorption spectroscopy, emission spectroscopy, Auger spectroscopy.

Unit IV **(15)**

Thermal and Mechanical Characterizations: Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), Dynamic mechanical analysis, Universal tensile testing, Transport number, Electron spin resonance, UV spectrophotometer.

1. G. Haugstad, *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications* (John Wiley & Sons, Inc., New Jersey, USA) 2012.
2. K.D. Sattler, *Handbook of Nanophysics* (CRC press, London, U. K.) 2010**.**
3. E.L. Wolf *Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience* (John Wiley & Sons, Inc., New Jersey, USA) 2008.
4. A. Kapoor, *An Introduction to Nanophysics and Nanotechnology* (Alpha Science International, Ltd., Oxford, U. K.) 2011.
5. B.D. Cullity, *Elements of X- Ray diffraction*, (Addison Wesley publishing company, Boston, United State) 2014.

6. E. Sherrie, *Characterization of Nanomaterials (*LAP Lambert Academic Publishing, Saarbrücken Germany) 2010.

Course Title: Seminar
Paper Code: PHY.613
Total Hours: 30

L	T	P	Credits	Marks
0	0	4	2	50

Course Title: Dissertation Research
Paper Code: PHY.614

L	T	P	Credits	Marks
0	0	28	14	350