Centre for Physical Sciences (M.Sc. Physics, 2017-19)

Semester I

S. No.	Paper Code	Course Title	Course Type	L	T	P	Cr	% Weightage				E
								A	B	C	D	
1	PHY.501	Mathematical Physics	C	4	0	0	4	25	25	25	25	100
2	PHY.502	Classical Mechanics	C	4	0	0	4	25	25	25	25	100
3	PHY.503	Quantum Mechanics-I	C	4	0	0	4	25	25	25	25	100
4	PHY.504	Electronics	C	4	0	0	4	25	25	25	25	100
5	PHY.505	Electronics Laboratory	C	0	0	8	4	-	-	-	-	100
6	PHY.506	Modern Physics Laboratory	C	0	0	8	4	-	-	-	-	100
7	PHY.401/ XXX.XXX	Inter-disciplinary Elective	E	2	0	0	2	25	25	25	25	50
				18	0	16	26					650
Interdisciplinary Course offered by Centre for Physical Sciences												
1	PHY.401	Physics in Everyday Life	E	2	0	0	2	25	25	25	25	50
	XXX.XXX	Inter-Disciplinary Courses offered by other Centers										

Semester II

S. No.	Paper Code	Course Title	Course Type	L	T	P	Cr	% Weightage				E
								A	B	C	D	
1	PHY.402	Numerical Methods	F	2	0	0	2	25	25	25	25	50
2	PHY.403	Computer Laboratory	F	0	0	8	4	-	-	-	-	100
3	PHY.507	Quantum Mechanics-II	C	4	0	0	4	25	25	25	25	100
4	PHY.508	Electromagnetic Theory	C	4	0	0	4	25	25	25	25	100
5	PHY.509	Solid State Physics	C	4	0	0	4	25	25	25	25	100
6	PHY.510	Solid State Physics Laboratory	C	0	0	8	4	-	-	-	-	100
7	PHY.404/ XXX.XXX	Inter-Disciplinary Elective	E	2	0	0	2	25	25	25	25	50
				16	0	16	24					600
Inter-Disciplinary Courses offered by Centre for Physical Sciences												
1	PHY.404	Introduction to Nanotechnology	E	2	0	0	2	25	25	25	25	50
	XXX.XXX	Inter-Disciplinary Courses offered by other Centers										
Non-Credit Course												
1	XXX.XXX	Humanities for Science Students	C	1	0	0	1	-	-	-	-	(NC)

Semester III

S. No.	Paper Code	Course Title	Course Type	L	T	P	Cr	% Weightage				E
								A	B	C	D	
1	PHY.601	Statistical Mechanics	C	4	0	0	4	25	25	25	25	100
2	PHY.602	Atomic & Molecular Physics	C	4	0	0	4	25	25	25	25	100
3	PHY.603	Nuclear and Particle Physics	C	4	0	0	4	25	25	25	25	100
4	PHY.604	Nuclear Physics Laboratory	C	0	0	8	4	-	-	-	-	100
5	PHY.XXX	Elective Course-I	E	4	0	0	4	25	25	25	25	100
6	PHY.611	Simulation/Experimental Laboratory	E	0	0	8	4	-	-	-	-	100
				16	0	16	24					600

PHY.XXX - Elective Course-I												
1	PHY.606	Advanced Solid State Physics	E	4	0	0	4	25	25	25	25	100
2	PHY.607	Particle Physics	E	4	0	0	4	25	25	25	25	100
3	PHY.608	Electronic Structure Theory of Solids	E	4	0	0	4	25	25	25	25	100

Semester IV

S. No	Paper Code	Course Title	Course Type	L	T	P	Cr	% Weightage				E
								A	B	C	D	
1	PHY.405	Characterization Techniques	F	2	0	0	2	25	25	25	25	50
2	PHY.XXX	Elective Course-II	E	4	0	0	4	25	25	25	25	100
3	PHY.599	Seminar	F	-	-	-	2	-	-	-	-	50
4	PHY.600	Project Work	E	-	-	-	8	-	-	-	-	200
				6	0	0	16					400

PHY.XXX -Elective Course-II												
1	PHY.616	Introduction to Mesoscopic Physics	E	4	0	0	4	25	25	25	25	100
2	PHY.617	Nuclear Techniques	E	4	0	0	4	25	25	25	25	100
3	PHY.618	Physics of Materials	E	4	0	0	4	25	25	25	25	100

A: Continuous Assessment
B: Mid-Term Test-1
C: Mid-Term Test-2
D: End-Term Exam (Final)

Abbreviation:
C: Core;
E: Elective and Interdisciplinary;
F: Foundation;
L: Lectures; T: Tutorial; P: Practical; Cr: Credits.

Semester-I

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

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The course on Mathematical Physics is introduced to familiarize the students with the idea about transformation of coordinates and complex functions, 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 **(15)**

Vector Calculus, Matrices & Tensors: Vector calculus: properties of Gradient, divergence and Curl, matrix algebra, Caley-Hamilton theorem, Eigen values and Eigen vectors, curvilinear coordinates.(spherical and cylindrical coordinates) Tensors, Symmetric and antisymmetric, kronecker and Levi Civita tensors.

Elements of group theory: Group postulates, Lie group and generators, representation, Commutation relations, SU(2), O(3).

Unit-II **(15)**

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

Special Functions: Legendre, Bessel, Hermite and Laguerre functions, recurrence relations, Orthogonality and special properties. Associated Legendre functions: recurrence relations, Parity and orthogonality, functions, Green's function,

Unit-III **(15)**

Complex Variable: Elements of complex analysis, Analytical functions, 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 integrals, Cauchy residue theorem and applications of the residue theorem.

Unit-IV **(15)**

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

Differential Equations Solutions of Hermite, Legendre, Bessel and Laugerre Differential equations, basics properties of their polynomials, and associated Legendre polynomials, Partial differential equations (Laplace, wave and heat equation in two and three dimensions), Boundary value problems and Euler equation.

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) Ltd., New Delhi) 2000

6. Mathematical Physics, B.S. Rajput, Pragati Prakashan

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

L	T	P	Credits	Marks
4	0	0	4	100

Course 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 and special relativity). Establish firm physics and math foundation on which student can build a good carrier in physics.

Unit-I **(18)**

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 **(10)**

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 **(17)**

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 **(15)**

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, Double pendulum and N-Coupled oscillators.

Special Theory of Relativity: Lorentz transformations and its consequences, Relativistic kinematics and mass energy equivalence, Relativistic Lagrangian and Hamiltonian, Four vectors, Covariant formulation of Lagrangian, Hamiltonian and Electrodynamics.

Scattering: Scattering by inverse square law, scattering in lab and centre of mass frames.

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. G. Walter, *Systems of Particles and Hamiltonian Dynamics* (Springer, New York, USA) 2010.
4. P.S. Joag and N.C. Rana, *Classical Mechanics* (Tata McGraw-Hill, Noida, India) 1991.

Course Title: Quantum Mechanics-I
Paper Code: PHY.503
Total Lectures: 60

L	T	P	Credits	Marks
4	0	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, Schrodinger equation and applies it to simple physical systems, angular momentum and perturbation theories with emphasis on the physical structure of the theory and its applications.

Unit-I **(14)**

Mathematical Formulation and Postulates of Quantum Mechanics: Review of linear vector spaces and related algebra and Hilbert space, Dirac notation, Operators: Hermitian, Unitary & Projection operators, Matrix representations of kets, bras and operators, Change of basis, Basic postulates of quantum mechanics, Schrödinger wave equation (time dependent and time independent), Expectation values, Commutation relations, Ehrenfest theorem. Generalized Heisenberg uncertainty principle, density matrix, Schrodinger, Heisenberg and Interaction pictures.

Unit-II **(16)**

Applications of Schrödinger Wave Equation: Solution of Harmonic oscillator using wave mechanics and matrix mechanics: matrix representation and eigen values of various operators, Anisotropic and isotropic harmonic oscillator, The box potential,

Hydrogen Atom: Motion in central potential, Solution of Schrodinger equation for hydrogen atom. energy spectra of Hydrogen atom.

Angular Momentum: eigenvalues and eigen vectors of orbital angular momentum, Spherical harmonics, Angular momentum algebra and commutation relations, Matrix representation of angular momentum, Stern-Gerlach experiment, Spin angular momentum: Pauli matrices and their properties.

Unit-III **(16)**

Addition of Angular Momenta: Addition of two angular momenta, Transformation between bases: Clebsch-Gordan Coefficients, Eigenvalues of J^2 and J_z, Coupling of orbital and spin angular momenta. Wigner-Eckart Theorem (statement only)

Time-independent Perturbation Theory: Non-degenerate (1st and 2nd order)and degenerate case, Application of perturbation theory: charged oscillator in an electric field, the Stark effect and Zeeman effect in hydrogen, hyperfine splitting in hydrogen, anomalous Zeeman effect.

Unit-IV **(14)**

The Variational Method: Theory and its applications to ground state of harmonic oscillator and hydrogen atom, the ground state of helium and hydrogen molecule ion.

WKB Method and its Applications: General formulation of WKB method, validity of WKB approximation, Bound states of potential wells with zero, one and two rigid walls, Application of WKB method to barrier penetration and cold emission of electrons from metals.

Recommended books:

1. N. Zettili, *Quantum Mechanics-Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
2. E. Merzbacher, *Quantum Mechanics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
3. L.I. Schiff, *Quantum Mechanics* (Tata McGraw-Hill Education, Noida, India) 2010.
4. K. Venkatesan, P.M. Mathews, *A Textbook of Quantum Mechanics* (Tata McGraw - Hill Education, Noida, India) 2010.
5. J. J. Sakurai, *Modern Quantum Mechanics* (Pearson Education, India) 2009.
6. D. J. Griffiths, *Introduction to Quantum Mechanics*, 2^{nd} Ed. (Pearson Education, India) 2015.
7. G. D. Mahan, Quantum Mechanics in a Nutshell (Princeton University Press) 2009.
8. P.M. Mathews & K. Venkatesan, Tata-McGraw Pub. N. Delhi
9. V.K. Thankappan, Quantum Mechanics, New Age Pub. N. Delhi.

Course Title: Electronics
Paper Code: PHY.504
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

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

Unit-I **(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, filtering, Noise reduction, Low frequency power amplifiers, High frequency devices.

Unit-II **(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-III **(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.

Unit-IV **(10)**

Combinational and Sequential Logic: Adders-subtractors, Carry look ahead adder, BCD adder, Magnitude comparator, Multiplexer/demultiplexer, Encoder/decoder, Comparator Asynchronous/ripple counters, Synchronous counters, Shift counters, Shift registers, Universal shift register.

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. 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 & L. Nashelsky, *Electronic Devices and Circuit Theory* (Pearson, New Delhi) 2009.
3. B. L. Theraja, *Basic Electronics: Solid State* (S. Chand & Company Ltd., New Delhi) 2010.
4. D. Chattopadhyay and P. C. Rakshit, *Electronics: Fundamentals and Applications* (New Age International, New Delhi, India) 2008.

Course Title: Electronics Laboratory
Paper Code: PHY.505
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

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.

15. Realization of universal logic gates.
16. Implementation of the given Boolean function using logic gates in both SOP and POS form.
17. Perform the logic state tables of RS and JK flip-flops using NAND & NOR gates.
18. Perform the logic state tables of T and D flip-flops using NAND & NOR gates.
19. Perform the Verification of logic state tables of master slave flip flop using NAND & NOR gates.
20. Triggering mechanism of flip flop.
21. Perform the Realization of Half adder and full adder.
22. Perform the Half substractor and full substractor.
23. Decoders and code converters.
24. Up/Down Counters.
25. Shift Resistor.

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 & L. Nashelsky, *Electronic Devices and Circuit Theory* (Pearson, New Delhi) 2009.
3. B. L. Theraja, *Basic Electronics: Solid State* (S. Chand & Company Ltd., New Delhi) 2010.
4. D. Chattopadhyay and P. C. Rakshit, *Electronics: Fundamentals and Applications* (New Age International, New Delhi, India) 2008.
5. G. Saha, A.P. Malvino and D.P. Leach, *Digital Principles and Applications* (Tata McGraw - Hill Education, Noida, India) 2011.
6. P. Malvino and J.A. Brown, *Digital Computer Electronics* (Tata McGraw - Hill Education, Noida, India) 2011.
7. C. Hawkins and J. Segura, *Introduction to Modern Digital Electronics* (Scitech Publishing, New York, USA) 2010.

Course Tile: Modern Physics Laboratory
Paper Code: PHY.506
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

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 this 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. Fabry-Perot Interferometer
7. Dual nature of electron experiment.
8. Millikan’s oil drop experiment.

9. Stefan's law
10. Zeeman effect experiment

Recommended books:

1. R.A. Serway, C.J. Moses & C.A. Moyer, *Modern physics,* Brooks Cole, Massachusetts,USA2012.
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 Tile: Physics in Everyday Life
Paper Code: PHY.401
Total Lectures: 30

L	T	P	Credits	Marks
2	0	0	2	50

Course Objective: Physics is playing an important role in the everyday life of human beings. Therefore, this course is design to introduce students with physics and science in everyday life by considering objects from our daily environment and focuses on their principles of operation and relationships to one another. Out of these considerations arise better understanding of physics principles spanning motion, forces, heat, electromagnetism optics and modern physics.

Unit-I **(15)**

Materials for Everyday life: Physics of materials (various type including nanostructures, physical properties, advantages, limitations, and synthesis protocols), Importance, designing and development of devices (i.e. sensors, solar cells, smart windows, defence, batteries, magnetic memory devices, Audio Players, amplifiers, and transistors etc.).

Unit-II **(15)**

Modern Physics: Lasers, LEDs, Optical Recording and Communication, Cameras, optical illusions, Medical imaging and radiation, Nuclear weapons and nuclear reactors, space craft technology.

Recommended Books:

1. How Things Work THE PHYSICS OF EVERYDAY LIFE, Louis A. Bloomfield, Wiley, 2013.
2. Handbook of Inorganic Electrochromic Materials, by C.G. Granqvist; Elsevier Science, 1995.
3. Lithium Batteries: Advanced Technologies and Applications, by Bruno Scrosati, K. M. Abraham, Walter Van Schalkwijk, and Jusef Hassoun; John Wiley & Sons, Inc, 2013.
4. B.D. Cuility and C.D. graham, *Introduction to Magnetic Materials* (Willey, New Jersey) 2009.
5. S. O. Kasap, *Principles of Electronic Materials and Devices* (McGraw Hill Publications)

Semester II

Course Title: Numerical Methods
Paper Code: PHY.402
Total Lectures: 30

L	T	P	Credits	Marks
2	0	0	2	50

Course Objective: The course on Numerical 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.

Unit-I **(15)**

Programming with C: Computer Algorithm, Data types, C programming syntax for Input/Output, Control statements: if, if-else and nested-if statements. Looping: while, for and do-while loops, Functions: Call by values and by references, Arrays and structures: one dimensional and two-dimensional arrays, Pointers, Idea of string and structures. Preprocessors.

Roots of Nonlinear Equations: Element of computational techniques: Error analysis, Propagation of errors. Roots of functions, Bracketing and open end methods: Bisection Method, False position method and Newton Raphson method.

Unit-II **(15)**

Numerical Differentialtion and Integration: Differentiation of continuous functions Integration by Trapezoidal and Simpson's rule.

Interpolation and Least Square Fitting: Linear Interpolation, Lagrange and Newton Interpolation, Linear and non-linear curve fitting

Numerical Solution of Ordinary Differential Equations: Euler method and Runge-Kutta method.

Random Numbers: Introduction to random numbers, Monte Carlo method for random number generation, Chi square test.

Recommended Books:

1.Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
2.E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
3.S. S. Sastry, *Introductory Methods of Numerical Analysis*, PHI Learning Pvt.Ltd., NewDelhi,2012.
4.R. C. Verma, P. K. Ahluwalia & K. C. Sharma, Computational Physics, New Age, 1st edition,1999.

Course Title: Computer Laboratory
Paper Code: PHY.403
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

Course objective: The laboratory exercises have been so designed that the students learn the usage of C language to numerical methods and various physics problems, so that they are well equipped in the use of computers for solving physics based problems.
Students have to perform at least five experiments from Part-A and five experiments from Part-B.

Part-A

1. To find the root of nonlinear equation using Bisection method.
2. To study the numerical convergence and error analysis of non-linear equation using Newton Raphson method.
3. To find the value of y for given value of x using Newton's interpolation method.
4. Perform numerical integration on 1-D function using Trapezoid rule.
5. Perform numerical integration on 1-D function using Simpson rules.
6. To find the solution of differential equation using Runge-Kutta method.
7. To find the solution of differential equation using Euler's method.

8. Choose a set of 10 values and find the least squared fitted curve.

Part-B

1. Study the motion of spherical body falling in viscous medium using Euler method.
2. To study the path of projectile with and without airdrag using Fynmen-Newton method.
3. Study the motion of an artificial satellite around a planet.
4. Study the motion of one dimensional harmonic oscillator without and with damping effects.
5. To obtain the energy eigenvalues of a quantum oscillator using Runge-Kutta method.
6. Study the motion of charged particles in uniform electric field, uniform magnetic field and combined uniform EM field.
7. To study the phenomenon of nuclear radioactive decay.
8. To study the EM oscillation in a LCR circuit using Runge-Kutta method.

Recommended Books:

1. Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
2. E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
3. S. S. Sastry, *Introductory Methods of Numerical Analysis* (PHI Learning Pvt. Ltd., New Delhi, India) 2012.
4. R. C. Verma, P. K. Ahluwalia and K. C. Sharma, Computational Physics (New Age, 1st edition, India) 1999.
5. Tao Pang, an Introduction to Computational Physics (Cambridge University Press) 2nd edition, 2006.

Course Title: Quantum Mechanics-II
Paper Code: PHY.507
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The objective of this course is to introduce the students about the formal structure of the subject and equip them with time dependent perturbation theory, scattering theory, relativistics quantum mechanics and many electron systems.

Unit-I **(14)**

Time-dependent Perturbation Theory: Time development of states and transition probability, Adiabatic and sudden approximations, Fermi golden rule and its application to radiative transition in atoms, Spontaneous emission: Einstein's A and B coefficients, Selection rules for emission and absorption of light

Unit-II **(16)**

Scattering Theory: Quantum Scattering theory, Scattering cross-section and scattering amplitude, Born scattering formula, Central force problem, Partial wave analysis, Phase shifts, Optical theorem, Low energy s-wave and p-wave scatterings, Bound states and resonances, Breit-Wigner resonance formula (statement only), Green's functions in scattering theory, Born approximation and its validity, Scattering for different kinds of potentials, Scattering of identical particles.

Unit-III **(14)**

Relativistic Quantum Mechanics: Klein-Gordon equation: charge and current density, continuity equation, Klein-Gordon equation in electromagnetic field, Difficulties of Klein-Gordon equation, Dirac relativistic equation: probability and current density and continuity equation, Properties of Dirac matrices, Significance of negative energy, Spin-orbit interaction, Dirac equation for a particle in central field, Fine structure of hydrogen atom, Interpretation of relativistic correction. Covariant form of Dirac equation.

Unit-IV **(16)**

Many Particle Systems: Identical particles, Fermions and bosons, Pauli Exclusion Principle and Slater determinant, Spin statistics theorem, Exchange energy in two electron systems, Parahelium and orthohelium, Central field approximation, Ground state energy of many electron systems, Hartree-Fock equations, Pair distribution function, Correlation energy, Thomas-Fermi theory, Elementary idea of density functional theory.

Recommended books:

1. K. Venkatesan, P.M. Mathews, *A Textbook of Quantum Mechanics* (Tata McGraw - Hill Education, Noida, India) 2010.
2. J.J Sakurai, *Advanced Quantum Mechanics* (Pearson, New Delhi, India) 2006.
3. J.J. Sakurai, J. Napolitano, *Modern Quantum Mechanics* (Pearson India, New Delhi,) 2014.
4. N. Zettili, *Quantum Mechanics: Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
5. D. J. Griffiths, *Introduction to Quantum Mechanics*, Second Edition (Pearson Education, India) 2015.
6. G. D. Mahan, Quantum Mechanics in a Nutshell (Princeton University Press) 2009.
7. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
8. V.K. Thankappan, Quantum Mechanics, New Age Pub. N. Delhi.
9. M.P. Khanna, Quantum Mechanics, Har Anand Pub. N. Delhi. (1999)

Course Title: Electromagnetic Theory
Paper Code: PHY.508
Total Lecture: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The Electromagnetic Theory is a course that covers electrostatics, magnetostatics, dielectrics, and Maxwell equations. The course has also been framed to solve the boundary value problems. The course contains the 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 **(18)**

Electrostatics: Gauss's law and its applications, Work and energy in electrostatics, Electrostatic potential energy, Poisson and Laplace equations, Uniqueness theorem I & II, Energy density and capacitance.

Boundary Value Problems: General methods for the solution of boundary value problems, Solutions of the Laplace equation, Various boundary value problems.

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, , Electrostatic energy in dielectric media.

Unit-II **(12)**

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.

Unit-III **(16)**

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

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.

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, Skin effect, Transmission lines and wave guides, TE mode, TM mode, Cut off wavelength, Phase Velocity, Group velocity and Guide wave length.

Unit-IV **(14)**

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. **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.

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: Solid State Physics
Paper Code: PHY.509
Total Lectures: 60

L	T	P	Credits	Marks
4	0	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, superconductivity so that they are able to use these techniques in investigating the aspects of the matter in condensed phase.

Unit-I **(15)**

Crystal Structure and its determination: Bravais lattices, Crystal structures, Reciprocal lattices, Ewald sphere, X-ray diffraction, Lattice parameter determination, Atomic and crystal structure factors, Intensity of diffraction maxima, Electron and neutron diffraction, 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, Thermal expansion, Thermal conductivity.

Unit-II **(15)**

Band Theory of Solids: Free electron theory, Density of states, Boltzmann transport equation, Drude model of electrical and thermal conductivity and Sommerfield theory, Hall effect and quantum Hall effect, 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, Thermoelectric power, Response and relaxation phenomena.

Unit-III **(15)**

Magnetic Properties of Solids: Classical and quantum theory of diamagnetism and paramagnetism, Pauli paramagnetism, Landau diamagnetism, Cooling by adiabatic demagnetization, 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, Spin waves, Bloch $T^{3/2}$ law, ESR, NMR and chemical shifts.

Unit-IV **(15)**

Defects and Dislocations: Point defects (Frenkel and 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, 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 Tile: Solid State Physics Laboratory
Paper Code: PHY.510
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

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 ten experiments from the following experiments.

2) Determination of carrier concentration and their sign in semiconductor at room temperature by Hall Effect.
3) Dielectric constant of insulating and ferroelectric materials at room and elevated temperatures.

4) Electrons spin resonance.
5) Magnetic parameters of a magnetic material by hysteresis loop tracer.
6) To determine the magnetic susceptibility of $NiSO_4$, $FeSO_4$, $CoSO_4$ by Gauy's method.
7) To determine magneto resistance of a Bismuth crystal as a function of magnetic field.
8) Determination of critical temperature of high temperature superconductor and Meissner effect for a high T_c superconductor.
9) Determination of ferromagnetic to paramagnetic phase transition temperature (T_C = Curie temperature).
10) Photoconductivity measurements.
11) NMR spectrometer.
12) UV-Visible spectral analysis of nanomaterials and thin films.
13) FTIR studies of nanomaterials and thin film.
14) Dielectric studies of nanomaterials, thin films and liquid crystals.
15) FESEM micrograph study of nanomaterials and thin films.
16) TGA analysis of polymers.

Recommended books:

1. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, New Delhi) 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 Tile: Introduction to Nanotechnology
Paper Code: PHY.404
Total Lectures: 30

L	T	P	Credits	Marks
2	0	0	2	100

Unit 1 **(15)**

Introduction: Definition, why and how, history of nano and nanotechnology, advantages and disadvantages, overview, from Feynman to Funding, Micro to nano from scientific and technological view. Global ethics of nanotechnology, fabrication methods i.e. top-down and bottom-up approach.

Unit 2 **(15)**

Properties and Applications: Types of nanomaterials (i.e. Zero (0), One (1), Two (2), and Three (3) dimensional), Science (Physics and Chemistry) at nanoscale, unique electrical, optical, mechanical, chemical, and magnetic properties at nanoscale. Bio and environmental nanotechnology, Use and benefits of nanotechnology, Challenges and Future of nanotechnology, Going Public: Risk, Trust and Public Understanding. Devices by nanotechnology.

Recommended books:

1. An introduction to Nanoscience and Nanotechnology by Alain Nouailhat, Wiley (2006)
2. Introduction to Nanotechnology by Henrik Bruus, Springer (2004)
3. NANOTECHNOLOGIES: Principles, Applications, Implications and Hands-on Activities by Luisa Filipponi and Duncan Sutherland, European Union, (2012) Luxembourg

4. Nanostructure and Nanomaterials (Synthesis, Properties and Applications) by Guozhong Cao, Imperical College Press (2004) London.
5. Nanotechnology and Nanoelectronics by W. R. Fahrner, Springer (2005) Berlin

Course Title: Humanities for Science Students
Paper Code: XXX.XXX
Total Hours: 15

L	T	P	Credits	Marks
1	0	0	1	NC

Semester-III

Course Title: Statistical Mechanics
Paper Code: PHY.601
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: This course is designed to provide statistical basis of thermodynamics and physical significance of various statistical quantities. 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 **(14)**

Basics of Thermodynamics: Laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell relations.

Statistical Basis of Thermodynamics: Micro- and macro- states, Postulate of equal a priori probability, Contact between statistics and thermodynamics, Classical ideal gas, Entropy of mixing, Gibbs' paradox and its solution.

Unit-II **(16)**

Elements of Ensemble Theory: Phase space and Liouville's theorem, Microcanonical ensemble theory and its application to classical ideal gas and simple harmonic oscillator, System in contact with a heat reservoir, Thermodynamics of canonical ensemble, Partition function, Classical ideal gas in canonical ensemble, Energy fluctuation.

Grand Canonical Ensemble: System in contact with a particle reservoir, Chemical potential, Grand canonical partition function, Classical ideal gas in grand canonical ensemble theory, Density and energy fluctuations.

Unit-III **(14)**

Elements of Quantum Statistics: Quantum statistics of various ensembles, Ideal gas in various ensemble, statistics of occupation number, Thermodynamics of black body radiations.

Phase Transitions: Thermodynamic phase diagrams, Super-fluidity in liquid He II, First and second order phase transitions, Dynamic model of phase transition, Ising and Heisenberg model.

Unit-IV **(16)**

Ideal Bose and Fermi Gas: Thermodynamical behavior of ideal Bose gas, Bose-Einstein condensation, Gas of photons and phonons. Thermodynamical behavior of ideal Fermi gas, Heat capacity of ideal Fermi gas at finite temperature, Pauli paramagnetism, Landau diamagnetism, Ferromagnetism.

Thermodynamic Fluctuations: Diffusion equation, Random walk and Brownian motion, Introduction to nonequilibrium processes.

Recommended books:

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

Course Tile: Atomic and Molecular Physics
Paper Code: PHY.602
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The main objective of the course on Atomic and Molecular 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 1 **(14)**

Atomic Structure and Atomic Spectra: Revision of quantum numbers, Pauli's exclusion principle, electron configuration, Hund's rule etc. origin of spectral lines, selection rules, some features of one-electron, two-electron spectra and X-ray spectra, fine spectra, hyperfine structure, Level scheme for two electron atoms- LS and JJ coupling – multiplet splitting – Lande's 'g' factor, Lande's interval rule, Zeeman effect, Width of spectral lines.

Unit 2 **(16)**

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 3 **(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.

Unit 4 **(16)**

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, Relativistic correction for energy level of hydrogen atom, Lamb shift, Paschen-Back effect, Stark effect, and isotopic shift, Independent particle model, Central field approximation for many electron atom, Slater determinant, Equivalent and nonequivalent electrons, Energy levels and spectra, Spectroscopic terms.

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 Soc. of Chemistry, London,2002.

4. G. Herzberg, Atomic Spectra and Atomic Structure (Dover Publications, New York, USA) 2010.
5. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).

Course Title: Nuclear and Particle Physics
Paper Code: PHY.603
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The objective of the course on Nuclear and Particle Physics is to teach the students the basic of nuclear properties, nuclear interactions, nuclear decay, nuclear models, detectors, nuclear reactions and elementary particles.

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.

Two Nucleon Problems: Nature of nuclear forces, Deuteron problem, Spin dependence of nuclear forces, Form of nucleon-nucleon potentials, Electromagnetic moment and magnetic dipole moment of deuteron, General form of nuclear force. 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-II **(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, Selection rules for Fermi and Gamow-Teller transitions. Double beta decay.

Nuclear Models: Evidence of shell structure, Single particle shell model, its validity and limitations, Rotational spectra, Shell model, Liquid drop model, Collective model, Semi empirical mass formula. Exchange force model. Double beta decay.

Unit-III **(14)**

Nuclear Reactions: Types of Nuclear Reactions and conservation laws, Energetic of Nuclear reactions, Isospin, Reaction Cross sections, Coulomb Scattering, Optical model, Compound nucleus reactions, Direct Reactions, Resonance reactions, Heavy Ion reactions,

Neutron Physics: Neutron Sources, absorption and moderation of neutrons, Introduction to nuclear fission and fusion.

Unit-IV

Elementary Particle Physics: Classification of particles: Fermions and bosons, Elementary Particles and antiparticles, Quarks model, baryons, mesons and leptons, Classification of fundamental forces: Strong, Electromagnetic, Weak and Gravitational. Conservation laws of momentum, energy, Angular momentum, Parity non conservation in weak interaction, Pion parity, Isospin, Charge conjugation, Time reversal invariance, CPT invariance. Baryon and Lepton numbers, Strangeness, charm and other additive quantum numbers, Gell Mann Nishijima formula.

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.
6. B. Povh, K. Rith, C. Scholz, *Particles and Nuclei: An Introduction to the Physical Concepts* (Springer, New York, USA) 2012.
7. D.H. Perkin, *Introduction to High Energy Physics* (Cambridge University Press, Cambridge, U.K.) 2000.
8. I.S. Hughes, *Elementary Particles* (Cambridge University Press, Cambridge, U.K.) 1991.
9. W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments* (Springer, New York, USA) 2009.
10. T. Stefan, *Experimental Techniques in Nuclear and Particle Physics* (Springer, New York, USA) 2010.
11. D.J. Griffiths, *Introduction to Elementary Particles* (Wiley-VCH Verlag GmbH, Germany) 2008.

Course Title: Nuclear Physics Laboratory
Paper Code: PHY.604
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

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 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.

Course Title: Advanced Solid State Physics
Paper Code: PHY.606
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The purpose of this course is to introduce students to the fundamental and advanced concepts of solid state physics. The topics include Fermi surfaces and its determinations, band gap in semiconductor, Plasmons, Dielectric, Ferroelctrics and optical processes in crystalline and amorphous solids.

Unit-I **(13)**

Fermi Surfaces and Metals: Zone schemes, Construction of Fermi surfaces, Electron orbits, Hole orbits and open orbits, Calculation of energy bands: Wigner-seitz Method, Pseuopotential Method, Experimental methods in Fermi surface studies: De Haas-van Alphen Effect, Fermi Surface of Cu and Au, Magnetic Breakdown.

Unit-II **(13)**

Semiconductor Crystals: Direct and indirect band gap, Equation of motion, Intrinsic and extrinsic semiconductors, Physical interpretation of effective mass, Effective masses in semiconductors, Cyclotron resonance, Intrinsic carrier concentration, Fermi level and electrical conductivity, Metal-metal contacts, Thermoelectric effects: Diode and transistors.

Unit-III **(15)**

Dielectrics and Ferroelectrics: Local field, Clausius-Mossotti relation, Components of polarizability: Electronic, Ionic, Orientational, Measurements of dielectric constant, Pyroelectric and ferroelectric crystals and classification, Electrostatic screening, Plasma oscillations, Transverse optical modes in plasma, Interaction of EM waves with optical modes: Polaritons, LST relation, Electron-electron interaction, Electron-phonon interactions: Polarons.

Unit-IV **(19)**

Plasmons and Optical Processes: Connection between optical and dielectric constants, Optical reflectance, Optical properties of metals, Luminescence, Types of luminescent systems, Electroluminescence, Color centers, Production and properties, Types of color centers, Excitons (Frenkel, Mott-Wannier), Experimental studies (alkali halide and molecular crystals), Raman effect in crystals, Diffraction pattern and low energy excitations in amorphous solids

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: Particle Physics
Paper Code: PHY.607
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The objective of the course on Particle Physics is to teach the students the basic of properties, interactions , reactions, decays, symmetries, and quark models for elementary particles and cosmic rays.

Unit-I **(15)**

Particles and Forces: Production and basic properties of elementary particles in cosmic rays and accelerators experiments, mass spectra and decays of elementary particles, Fundamental interactions: basic properties of Strong, weak and electromagnetic and gravity. Yukawa theory of pion exchange.

Unit-II

Kinematics: Kinematics of decay and scattering, Scattering in lab and centre of mass frames, Two and Three body decay phase space, Dalitz plot.

Symmetries and Conservation Laws: Space- time symmetries, Invariance Principles, Parity, Intrinsic parity, Parity constraints on the S- Matrix for Hadronic Reactions, Time – Reversal Invariance, conservation of Quantum Numbers, Isospin, Charge Conjugation, G- parity, CP and CPT Invariance (statement and consequences only).

Unit-III **(15)**

Internal symmetries:, Isospin, strangeness, charm quantum numbers, unitary groups, Isospin and SU (2), SU(3), Octet and decuplet irreducible representations of SU(3), SU(3) classification of mesons and baryons, Applications of Flavor SU(3), Gell- Mann Okubo Mass Formula, omega-phi mixing, Isospin relations for Pion-nucleon strong interaction.

Quark Model:- Quark structure of strange and nonstrange hadrons, need of colour quantum number. observation of new flavour states, charm, bottom hadrons, higher symmetries (brief description). Application of quark model for electromagnetic decays of vector mesons.

Unit-IV **(15)**

Weak Interactions: Classification of weak Interactions; Leptonic Semi- Leptonic and Non-Leptonic Decay, Tau- Theta Puzzle, Parity Violation in Weak Decays Selection Rules Semileptonic Decays, and nonleptonic decays, Universality of Weak Interactions, Fermi Theory of weak interactions, Intermediate Vector – Boson Hypothesis, Helicity of Neutrino, Two Component Theory of Neutrino, K0-K0bar Mixing and CP Violation

Recommended books:

1. D.J. Griffiths, *Introduction to Elementary Particles* (Wiley-VCH GmbH, Germany) 2008.
2. D.H. Perkin, *Introduction to High Energy Physics* (Cambridge Univ. Press, U.K.) 2000.
3. V.K. Mittal, R.C. Verma & S.C. Gupta, Nuclear & Particle Physics, Prentics Hall Pub. N. Delhi, 3rd edition, (2015)
4. W.E. Burcham and M. Jobes, Nuclear Physics, (Indian edition) Addison Wesley. Pub.
5. I.S. Hughes, *Elementary Particles* (Cambridge University Press, Cambridge, U.K.) 1991.
6. M.P. Khanna, Particle Physics, Prentics Hall. Pub., N. Delhi.
7. V.K. Thankappan, Quantum Mechanics, New Age Pub. N. Delhi.
8. M.P. Khanna, Quantum Mechanics, Har Anand Pub. N. Delhi. (1999)
9. W. R. Leo, *Techniques for Nuclear and Particle Physics Experiments* (Springer, New York, USA) 2009.
10. T. Stefan, *Experimental Techniques in Nuclear and Particle Physics* (Springer, New York, USA) 2010.

Course Title: Electronic Structure Theory of Solids
Paper Code: PHY.608
Total Lecture: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: It aims to introduce basics of the electronic structure theory. This course will introduce the theory of model Hamiltonian, practical density functional theory and electronic structure determination of bulk and cryatal surfaces.

Unit-I **(15)**

Model Hamiltonian: Second quantization, Tight binding model, Hubbard model, Heisenburg model, t-j model, Ising model, Monte-carlo simulation.

Unit II **(15)**

Electrons in Periodic Potential: k-space, irreducible brillouin zone, special k-points, Origin of energy gap, Wave equation of electron in periodic potential, Empty lattice approximation, Electronic structure of metals and semiconductors, Optical processes: Kramers-Kronig Relations, electronic interband transitions, Dielectric functions and absorption spectra, Excitons, Energy loss of fast particles in a solid.

Unit III **(15)**

Electronic Structure Determination: Hohenberg-Kohn theorems, Idea of functional, Practical implementation of Kohn-Sham equations: local density approximation and genetalized gradient approximation, Pseudopotential, Determination of electronic structure: plane waves and localized orbitals methods.

Unit-IV **(15)**

Supercell and Periodic Boundary Conditions: Plane wave expansions of Kohn-Sham quantities: energy cutoffs, Geometry optimization, Crystal structure prediction, Phase transformations, Reducing the calculation size: supercell approach, k-point sampling, Periodic boundary conditions and slab model, Surface relaxation, Surface reconstruction, Effects of surface coverage.

Recommended Books:

1. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
2. June Gunn Lee, *Computational Materials Science: An Introduction*, (CRC Press 2011)
3. Efthimious Kaxiras, *Atomic and Electronic Structure of Solids* (Cambridge Unive. Press) 2007.
4. Richard M. Martin, *Electronic Structure: Basic Theory and Practical Methods*(Cambridge University Press) 2008.
5. Feliciano Giustino, *Materials Modelling Using Density Functional Theory: Properties and Predictions,* Wiley (2009).
6. Rajendra Prasad, *Electronic Structure of Materials*, Taylor and Francis (2013).

Course Title: Experimental/Simulation Laboratory
Paper Code: PHY.611
Total Hours: 120

L	T	P	Credits	Marks
0	0	8	4	100

Course Objective: The experimental/simulation laboratory experiments have been so designed that the students learn both synthesis & characterization of materials along with the characterization of materials with theoretical thechniques.

Students have to perform ten experiments out of the following list of experiments.

1. Synthesis of nanomaterials by Sol-Gel, co-precipitation Solid State Reaction and Solution cast techniques
2. Microwave synthesis of nanomaterials
3. Structure-property and Microstructure-Property relations in nanomaterials
4. Surface area measurements of the nanomaterials.
5. Band gap measurements of oxide film using Uv-Vis Spectroscopy.
6. Study and understanding the XRD and EDS spectra of the materials.
7. Study and understanding the TEM, HRTEM and SAED of the materials.
8. PL analysis of nanomaterials
9. Estimation of Glass Transition and Glass Melting temperature of Polymer
10. TGA of Nanomaterials and nanocomposites
11. Study of Lotus effect by FESEM
12. Impedance and dielectric Spectroscopy of Nanomaterials

13. Find out equilibrium bond length and ground state energy of Hydrogen molecule using First Principle methods.
14. Determination of value of pi using metropolis algorithm
15. Monte Carlo simulation of 2D Ising model
16. Using Tight binding model, determine the band structure of graphene numerically
17. Compute and analyze the electronic structure of semiconductors such as Si and Ge.
18. Compute and analyze the electronic structure of metals such as Au and Pt.
19. Electronic structure of graphene using density functional calculations.
20. Electronic structure of 1D lattice.

Semester IV

Course Tile: Characterization Techniques
Paper Code: PHY.406
Total Lectures: 30

L	T	P	Credits	Marks
2	0	0	2	50

Course Objective: Scientific community is playing an important role in the development of various scientific and technological applications. To improve the applications of these applications one should consider the optimization of the properties of various functional materials. Therefore, characterization of materials is of special importance. This course is designed to introduce various techniques for the characterisation of variety of thin films, composites, polymers and nanomaterials.

Unit-I **(15)**

Microscopy: Optical Microscopy, Scanning Electron Microscopy (SEM), Field Emission Scanning Electron Microscopy (FESEM), Transmission Electron Microscopy (TEM), High resolution TEM, Scanning Tunnelling Microscope (STM), Atomic Force Microscope (AFM), Selected area electron diffraction (SAED) spectroscopy, Energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), X-ray photoemission spectroscopy (XPS), Angle Resolved XPS (ARPS), Valance Band Spectroscopy (VBS), Ultraviolet-visible spectroscopy (UV-vis), Raman, Auger Spectroscopy.

Unit-II **(15)**

Differential Scanning Calorimetry (DSC), Thermogravimetry analysis (TGA), Superconducting Quantum Interference Device (SQUID), Vibrating Sample Magnetometer (VSM), Rutherford Back Scattering (RBS), Proton Induced X-ray emission spectroscopy (PIXE), Nuclear Magnetic Resonance (NMR), Carbon Dating.

Recommended Books:

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd Edition, by Yang Leng, WILEY (2013).
2. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications, by Greg Haugstad, WILEY (2012)
3. Introduction to Scanning Tunneling Microscopy, by C. Julian Chen, Oxford Unive. Press (1993)
4. An Introduction to Surface Analysis by XPS and AES, by John F. Watts, and John Wolstenholme, WILEY (2003)

5. Transmission Electron Microscopy and Diffractometry of Materials, Second Edition, by Brent Fultz and James M. Howe, SPRINGER (2001)
6. Elements of X-Ray Diffraction, by B.D. Cullity, Addison-Wesley (1956)
7.

Course Title: Introduction to Mesoscopic Physics
Paper Code: PHY:616
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: Mesoscopic physics is the area of solid state physics that covers the transition regime between macroscopic and microscopic object. The purpose of this course is to introduce the physical concepts underlying the phenomena in this field. In the mesoscopic regime, new topics arises such as: quantization of electrical conductance, Coulomb Blockade, quantum capacitance and etc.

Unit I **(15)**

Introduction, Why Electrons Flow, Conductance Formula, Ballistic Conductance, Diffusive Conductance, Connecting Ballistic to Diffusive, Dispersion Relation, Drude Formula

Unit II **(15)**

Counting States, Density of States, Number of Modes, Electron Density, Conductivity vs. Electron Density, Quantum Capacitance, What and Where is the Voltage, A New Boundary Condition, Current from Quasi-Fermi Levels, Electrostatic Potential

Unit III **(15)**

Boltzmann Equation, Semiclassical Model,Quantum Model, Landauer Formulas, NEGF Equations, Self-Energy, Surface Green's Function, Current Operator, Scattering Theory, Transmission, Golden Rule, Quantum Master Equations

Unit IV **(15)**

Electronic Spin-Orbit Coupling, Spin Hamiltonian, Spin Density/Current, Spin Voltage, Spin Circuits, Seebeck Coefficient, heat Current, One-level Device, Second Law, Entropy

Recommended Books:

1. Quantum Transport Atom to Transistor by Supriyo Datta (CAMBRIDGE)
2. Lessons from Nanoelectronics: A New Perspective on Transport: Volume 1 & 2 by Supriyo Datta (World Scientific)
3. Theory of Quantum Transport at Nanoscale: An Introduction by Dmitry A Ryndyk (Springer)
4. Quantum Transport: Introduction to Nanoscience by Yuli V. Nazarov and Yaroslav M. Blanter (CAMBRIDGE)

Course Tile: Nuclear Techniques
Paper Code: PHY:617
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: This course aims to introduce different techniques use to study nuclear physics starting from design of different radiation source, detection, interaction and its applications.

Unit: 1

Accelerators: Motion of charged particles in electric and magnetic fields, Axial and radial magnetic field distributions in dipole, quadrupole and hexapole arrangement, Equipotential lines in different electrodes arrangement, Particle trajectory in electric and magnetic field, Electron sources, ion sources, Van de Graaf generator, DC linear accelerator, RF linear accelerator, Cyclotron, Microtone, introduction to advance accelerator (LHC)

Unit: 2

Detectors: Relation detectors Gaseous ionization, ionization and transport phenomena in gases, proportional counters, organic and inorganic scintillators, detection efficiency for various types of radiation, photomultiplier gain, semiconductor detectors, surface barrier detector, Si(Li), Gel(Li) and HPGe detectors.

Interaction of radiation with matter: General description of interaction processes, photoelectric effect, Compton Effect, pair production, interactions of directly ionizing radiation, stopping power, linear energy transfer, range of particles, interaction of indirectly ionizing radiation attenuation coefficient.

Unit: 3

Reactors and artificial radioisotopes: Neutron sources, neutron detectors, measurement of cross-sections for nuclear reaction, thermal and fast reactors, Q values, Fission, Fusion, production of radioisotopes, Reactor operation, thermal neutrons, neutron scattering and applications.

Unit: 4

Analysis Nuclear reaction: Elemental analysis by neutron activation analysis, proton induced X-ray emission, Rutherford backscattering, Resonance nuclear reaction, Elastic RDA, ion scattering and Neutron Depth Profile.

Books:

1. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy. (Wiley Eastern Limited, New Delhi,) 1986.
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng, (World Scientific), 1995.
3. Techniques for nuclear and particle physics, W. R. Len (Springer), 1955.
4. Nuclear radiation detection, W. J. Price, (McGraw-Hill, New York), 1964.
5. Alphas, beta and gamma-ray spectroscopy, K. Siegbahn, (North Holland, Amsterdam), 1965.
6. Introduction to experimental nuclear physics, R. M. Singru, (John Wiley and Sons), 1974.

Course Title: Physics of Materials
Paper Code: 618
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Unit I

Materials and Properties: Properties:, Mechanical, elastic, thermal, structural, magnetic, optical and chemical properties, Fullerenes, **Materials:** Dielectrics, Multiferroics, magnetoresistive, shape memory alloy, composites, magneto-electrics, dielectrics, magnetics, polymer, carbon, metal oxides, core-shell structures, and porous materials.

Unit II

Synthesis: Top down/Bottom up approach, thermal evaporation, electrode deposition, LB, Spin coating, Dip coating, Solution casting, Tape casting, Pulsed Laser Deposition, Sputtering, Chemical Vapor Deposition, Physical Vapor Deposition, Ball milling, Sol-gel, Hot-Filament Metal Vapor Deposition, Hydrothermal, composite processing, melt intercalation, Spray pyrolysis, Microwave synthesis, Low energy, high energy ion beam, Swift Heavy Ions (SHI), and Thermal combustion etc.

Unit III

Characterization techniques: Optical Microscopy, electron microscopy, Universal tensile testing, transport mechanism, Transference number, I-V characteristics, cyclic voltametry, charging/discharging of electrochemical devices, Chronoamperometry, Chronocoulometry, oxidation-reduction, Ragone plot, Nyquist plot, concept of photo emission, Fowler-Nordheim plot, and Stability (thermal, electrical, mechanical and electrochemical) properties.

Unit IV

Applications: Solar cell, LIB, Supercapacitors, Fuel Cell, smart windows, sensors, resistive switches, field emitters, hydrogen projection, Bio applications, Organic semiconductors.

Recommended Books:

1. Functional Metal Oxides: New Science and Novel Applications by S. B. Ogale, T. V. Venkatesan, and M. G. Blamire, Wiley-VCH (2013)
2. Physical Metallurgy, Vol. 1 and Vol. 2 by R. W. Chan and P. Hassen North Holland Publishing Company, New York, (1983).
3. Modern Physical Metallurgy and Materials Engineering 6th Edition by R. E. Smallman, Butterworth-Heinemann, (1999)
4. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications by Greg Haugstad (John Wiley & Sons, 2012).
5. Textbook of Nanoscience and Nanotechnology by B.S Murty, P.Shankar, B. Raj, B. B. Rath, and J. Murday (Springer, 2013).
6. Handbook of Nanophysics by Klaus D. Sattler (CRC press, 2010).
7. Nanostructured Materials and Nanotechnology by Claudia Gutirrez-Wing, Jos Luis Rodrguez-Lpez, Olivia A. Graeve, and Milton Muoz-Navia (Cambridge University Press, 2013).

Course Title: Seminar
Paper Code: PHY.599
Total Hours: 60

L	T	P	Credits	Marks
-	-	-	2	50

Course Objective: Seminar been introducted to well versed students with the communication and presentations skills. It is expected that students will prepare report and talk on the Physical concepts and issues related to the scientific and technological.

Course Title: Dissertation Research
Paper Code: PHY.600
Total Hours: 240

L	T	P	Credits	Marks
-	-	-	8	200

The time allowed to dissertation is equlvalent to the two practical labs per week.