

Centre for Physical Sciences (M.Sc. Physics)

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.507 | Quantum Mechanics-II | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 2 | PHY.508 | Electromagnetic Theory | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 3 | PHY.509 | Solid State Physics | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 4 | PHY.510 | Nuclear Physics | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 5 | PHY.511 | Solid State Physics Laboratory | C | 0 | 0 | 8 | 4 | - | - | - | - | 100 |
| 6 | PHY.512 | Nuclear Physics Laboratory | C | 0 | 0 | 8 | 4 | - | - | - | - | 100 |
| 7 | PHY.402/ XXX.XXX | Inter-Disciplinary Elective | E | 2 | 0 | 0 | 2 | 25 | 25 | 25 | 25 | 50 |
| 8 | XXX.XXX | Non-Credit Course | C | 1 | 0 | 0 | 1 | - | - | - | - | - |
| | | | | 19 | | 8 | 27 | | | | | 650 |
| Inter-Disciplinary Courses offered by Centre for Physical Sciences | | | | | | | | | | | | |
| 1 | PHY.402 | 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.403 | Numerical Methods | F | 2 | 0 | 0 | 2 | 25 | 25 | 25 | 25 | 50 |
| 2 | PHY.404 | Computer Laboratory | F | 0 | 0 | 8 | 4 | - | - | - | - | 100 |

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|---|---------|----------------------------|---|----|---|---|----|----|----|----|----|-----|
| 3 | PHY.601 | Statistical Mechanics | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 4 | PHY.602 | Atomic & Molecular Physics | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 5 | PHY.603 | Particle Physics | C | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 6 | PHY.XXX | Elective Course-I | E | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 7 | PHY.599 | Seminar | F | - | - | - | 2 | - | - | - | - | 50 |
| | | | | 16 | 0 | 8 | 24 | | | | | 600 |

***Elective Courses**

| | | | | | | | | | | | | |
|-----------------------------|---------|-----------------------------------|---|---|---|---|---|----|----|----|----|-----|
| PHY.XXX - Elective Course-I | | | | | | | | | | | | |
| 1 | PHY.605 | Fundamentals of Materials Physics | 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 | Research Methodology | F | 2 | 0 | 0 | 2 | 25 | 25 | 25 | 25 | 50 |
| 2 | PHY.406 | Characterization Techniques | F | 2 | 0 | 0 | 2 | 25 | 25 | 25 | 25 | 50 |
| 3 | PHY.XXX | Elective Course-II | E | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |
| 4 | PHY.XXX | Elective Laboratory | E | 0 | 0 | 8 | 4 | - | - | - | - | 100 |
| 5 | PHY.600 | Dissertation | E | - | - | - | 8 | - | - | - | - | 200 |
| | | | | 10 | 0 | 8 | 20 | | | | | 500 |

***Elective Courses**

| | | | | | | | | | | | | |
|-----------------------------|---------|----------------------------------|---|---|---|---|---|----|----|----|----|-----|
| PHY.XXX -Elective Course-II | | | | | | | | | | | | |
| 1 | PHY.615 | Functional Materials and Devices | E | 4 | 0 | 0 | 4 | 25 | 25 | 25 | 25 | 100 |

| | | | | | | | | | | | | |
|---------------------|---------|--------------------------|---|---|---|---|---|---|---|---|---|-----|
| Elective Laboratory | | | | | | | | | | | | |
| 1 | PHY.625 | Nanomaterials Laboratory | E | 0 | 0 | 8 | 4 | - | - | - | - | 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.

* More elective courses may be included in future.

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 Laguerre 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 - Poinso 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.

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*, 2nd 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 heterojunction 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, Barkhausen criteria, Gain 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 subtractor and full subtractor.
23. Decoders and code converters.
24. Up/Down Counters.
25. Shift Register.

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 Title: 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, 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: 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. Culity 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: 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, relativistic 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, Density functional theory: Hohenberg-Kohn theorems and Kohn-Sham equations.

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, Superfluidity, 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: Nuclear Physics

Paper Code: PHY.510

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

(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, HPGe detectors, Slow and fast neutron detection methods.

Accelerators: Motion of charged particles in electric and magnetic fields, dynamics of relativistic particles, Electron source, Ion source, Van de Graaf generator, Cyclotron, Linear accelerator

Unit-IV

(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.

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: Solid State Physics Laboratory

Paper Code: PHY.511

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.

- 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.
- 11) UV-Visible spectral analysis of nanomaterials and thin films.
- 12) FTIR studies of nanomaterials and thin film.
- 13) Dielectric studies of nanomaterials, thin films and liquid crystals.
- 14) FESEM micrograph study of nanomaterials and thin films.
- 15) 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 Title: Nuclear Physics Laboratory

Paper Code: PHY.512

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: Introduction to Nanotechnology

Paper Code: PHY.402

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, Imperial 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: 30

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| 1 | 0 | 0 | 1 | NC |

Semester-III

Course Title: Numerical Methods
Paper Code: PHY.403
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 Differentiation 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.404

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 air drag 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: 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. Sadoyskii, *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 Title: 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: H₂, 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 CO₂ and H₂O 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: 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 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: Classification of elementary particles: Fermions and bosons, Elementary Particles and antiparticles, Quarks model, baryons, mesons and leptons, 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

Recent developments: Qualitative ideas of Glashow-Weinberg-Salam model, Higgs boson, and quantum chromodynamics, standard model and status of unification of fundamental forces.

Recommended books:

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

Course Title: Fundamentals of Materials Physics

Paper Code: PHY.605

Total Lecture: 60

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| 4 | 0 | 0 | 4 | 100 |

Course Objective: It aims to introduce basics of nanomaterials, their properties and synthesis via different methods and the applications of nanomaterials. This course will also introduce the theory of

the modelling of materials through modern computational tools to analyze the materials physics at nanoscale.

Unit I **(15)**

Introduction to Nanomaterials: Low-dimensional materials: Quantum dot, tube and well, Some special nanomaterials: Synthesis, properties and applications of Fullerenes, Carbon Nanotubes (SWCNT and MWCNT) and Nanowires, Graphene, Porous materials: Porous silicon, Aerogel, Quantum size effect, Self assembly of Nanomaterials, Structural, Electrical, optical, mechanical, chemical, and magnetic properties at nanoscale, Applications and benefits of nanotechnology, Nanotechnology Ethics and Environment, Challenges and Future of nanotechnology.

Unit II **(15)**

Synthesis of Nanomaterials: Fabrication methods i.e. top-down and bottom-up approach, Synthesis of nanomaterials by Physical, Chemical and Biological methods, Thin Film classification, 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 of Thin Film and monitoring: Electrical, Mechanical, Optical interference methods.

Unit-III **(15)**

Electronic Structure Theory of Nanomaterials: Practical implementation of Kohn-Sham equations: local density approximation and generalized gradient approximation, Electrons in periodic potential: k-space, irreducible Brillouin zone, special k-points, Determination of electronic structure: plane waves and localized orbitals methods, Electronic structure of Graphene, Electronic structure of metals and semiconductors, Fermi surface and band gap, Interpretation of Kohn-Sham eigenvalues in relation with ionization potential, Excited states properties of materials: dielectric functions and absorption spectra.

Unit-IV **(15)**

Modelling of Nanomaterials: Materials Modelling using density functional theory: SCF cycles, mixing scheme, smearing, Plane wave expansions of Kohn-Sham quantities: energy cutoffs, Geometry optimization, Face centered cubic materials, Hexagonal closed packed materials, 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. 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.
5. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
6. June Gunn Lee, *Computational Materials Science: An Introduction*, (CRC Press 2011)
7. Efthimios Kaxiras, *Atomic and Electronic Structure of Solids* (Cambridge Unive. Press) 2007.

8. Richard M. Martin, *Electronic Structure: Basic Theory and Practical Methods*(Cambridge University Press) 2008.
9. Feliciano Giustino, *Materials Modelling Using Density Functional Theory: Properties and Predictions*, Wiley (2009).
10. Rajendra Prasad, *Electronic Structure of Materials*, Taylor and Francis (2013).
11. www.vasp.at/index.php/documentation
12. <http://departments.icmab.es/leem/siesta/Documentation/Manuals/manuals.html>

Course Title: Seminar

Paper Code: PHY.599

Total Hours: 60

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| - | - | - | 2 | 50 |

Course Objective: Seminar been introduced 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.

Semester IV

Course Title: Research Methodology

Paper Code: PHY.405

Total Lectures: 30

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| 2 | 0 | 0 | 2 | 50 |

Course Objective: The course Research Methodology has been framed to introduce basic concepts of Research Methods. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism, laboratory safety issues etc.

Unit-I

(15)

Introduction: Meaning and importance of research, Different types and styles of research, Role of serendipity, Critical thinking, Creativity and innovation, Hypothesis formulation and development of research plan, Art of reading and understanding scientific papers, Literature survey, Interpretation of results and discussion.

Library: Classification systems, e-Library, Reference management, Web-based literature search engines, Intellectual property rights (IPRs).

Entrepreneurship and Business Development: Importance of entrepreneurship and its relevance in career growth, Types of enterprises and ownership.

Unit-II

(15)

Scientific and Technical Writing: Role and importance of communication, Effective oral and written communication, Scientific writing, Research paper writing, Technical report writing, Making R and D proposals, Dissertation/Thesis writing, Letter writing and official correspondence, Oral and poster presentation in meetings, Seminars, Group discussions, Use of modern aids; Making technical presentations.

Research and Academic Integrity: Plagiarism, Copyright issues, Ethics in research, and case studies.

Laboratory Safety Issues: Lab, Workshop, Electrical, Health and fire safety, Safe disposal of hazardous materials.

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical techniques* (Deep and Deep Publications (P) Ltd. New Delhi, India) 2005.
2. C. R. Kothari, *Research Methodology* (New Age International, New Delhi, India) 2008.
3. **Web resources:** www.sciencedirect.com for journal references, www.aip.org and www.aps.org for reference styles.
4. **Web resources:** www.nature.com, www.sciencemag.org, www.springer.com, www.pnas.org, www.tandf.co.uk, www.opticsinfobase.org for research updates.

Course Title: 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)

Course Title: Functional Materials and Devices

Paper Code: PHY.615

Total Lectures: 60

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| 4 | 0 | 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 various advanced functional materials.

Unit-I

(15)

Polymers and Composites: Basic Concepts on Polymers, Polymers (Insulating, electronic and functionalized), Polymer Configuration (Tacticity), Polymer Conformation (Trans, Staggered, Gauche, Eclipsed), Polymer processing: Hot molding, Film blowing, Melt spinning etc
Composites: Varieties, Role of Matrix Materials, Mixing Rules, Polymer composites and nanocomposites (PNCs), PNCs for Li-ion battery, Supercapacitor, fuel cell, LED's and solar cell, synthesis and engineering of PNCs.

Unit-II

(15)

Advanced Ceramic Materials: Ceramic Materials: classification, Preparation and Properties, Smart materials exhibiting: Ferroelectric, Piezoelectric, Thermoelectric, Optoelectric, Superalloys, Shape memory alloys, Semiconductors (types, basic concepts, materials), Giant magnetoresistance (GMR), Colossal magnetoresistance (CMR), La and Bi-based Perovskite, Spin-Glass, Magnetic tunnel junction, Spin transfer torque, Multiferroics, Soft and hard magnetic materials, Ferrites, Magnetic materials for recording and computers.

Unit-III

(15)

Devices I:

Solar Energy, Nanogenerators, Nanoelectronics, LED, Electrochromic displays (n & p-type materials, electrolytes, device fabrication and property measurements), Field Emitters, Hydrogen production (Photovoltaic and photoelectrochromic), Resistive switching. Electronics and data storage (rewritable CDs and DVDs, magnetic hard disk technology, non-volatile memories for aerospace applications).

Devices II:

(15)

Supercapacitor and Li-ion batteries (types, properties, advantages and disadvantages, Ragone plot, Nyquist plot, types of electrolytes, charging-discharging, electrode materials), Fuel Cell (PEM, SOFC).

Sensors and Actuators Automotive (valve position, torque sensors for active steering, pedal positions, velocity, acceleration). Metal oxide based sensors, Principles of operation, Solid electrolyte sensors, Oxygen sensors, Optical Sensors, Thermal Sensors and Magnetic Sensors, Thermistors and related sensors.

Recommended Books:

1. Mel Schwartz, Smart Materials, CRC Press, Boca Raton, 2009
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. Advanced functional materials: a perspective from theory and experiment. Edited by Biplab Sanyal, and Olle Eriksson
5. S.B. Ogale, T.V. Venkatesan, M. Blamire, *Functional Metal Oxides* (Wiley-VCH Verlag GmbH, Germany) 2013.
6. S. Banerjee and A.K. Tyagi, *Functional Materials: Preparation, Processing and Applications* (Elsevier, Insights, Massachusetts, USA) 2011.
7. D.D.L. Chung, *Composite Materials: Functional Materials for Modern Technologies* (Springer, New York, USA) 2003.
8. Deborah D. L. Chung, *Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications* (World Scientific Publishing Company, Singapore) 2010.
9. B.D. Culity and C.D. graham, *Introduction to Magnetic Materials* (Willey, New Jersey) 2009.
10. K.C. Kao, *Dielectric Phenomena in Solids* (Elsevier, Academic Press, London, U. K.) 2004.
11. S. O. Kasap, *Principles of Electronic Materials and Devices* (McGraw Hill Publications)
12. B E Conway Brian E Conway Conway, *Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications* (Springer) 1999.

Course Title: Nanomaterials Laboratory**Paper Code: PHY.625****Total Hours: 120**

| L | T | P | Credits | Marks |
|---|---|---|---------|-------|
| 0 | 0 | 8 | 4 | 100 |

Course Objective: The nanomaterials laboratory experiments have been so designed that the students learn both synthesis & characterization of materials along with the characterization of materials with computational tool.

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

1. Synthesis of nanomaterials by Sol-Gel techniques
2. Synthesis of nanomaterials by co-precipitation techniques
3. Synthesis of nano composites by Solution cast techniques
4. Microwave synthesis of nanomaterials
5. Preparation of nanomaterials by Solid State Reaction methods
6. Structure-property relations at the nanomaterials
7. Microstructure-Property relation of nanomaterials
8. EDX study of nanomaterials
9. UV-Visible spectral analysis of nanomaterials
10. FTIR studies of nanomaterials
11. PL analysis of nanomaterials
12. Estimation of Glass Transition temperature of Polymer
13. Estimation of Glass Melting temperature of Polymer
14. TGA of Nanomaterials and nanocomposites

15. Study of Lotus effect by FESEM
16. Impedance Spectroscopy of Nanomaterials
17. Dielectric Spectroscopy of nanomaterials
18. Compute and analyze the electronic structure of semiconductors such as Si and Ge.
19. Compute and analyze the electronic structure of metals such as Au and Pt.
20. Compute and analyze the electronic structure of graphene.
21. Compute and analyze the electronic structure of atomic wires of noble metals.

Course Title: Dissertation Research

Paper Code: PHY.600

Total Hours: 240

| L | T | P | Credits | Marks |
|----------|----------|----------|----------------|--------------|
| - | - | - | 8 | 200 |

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