DEPARTMENT OF PURE AND APPLIED PHYSICS
M.Sc. (Physics) Course structure under CBCS/LOCF
Academic year 2021 – 2022

Sem	Course Opted	Course Code	Name of the course	Credit	L:T:P	Internal	External	Total
I	Core-1	PPPATT1	Classical Mechanics	5	4+1+0	30	70	100
	Core -2	PPPATT2	Quantum Mechanics	4	3+1+0	30	70	100
		PPPALT2	Quantum Mechanics Lab	1	0+0+1	30	70	100
	Core -3	PPPATT3	Electronic and Experimental Methods	3	3+0+0	30	70	100
		PPPALT3	Electronic and Experimental Methods Lab	2	0+0+2	30	70	100
	Open Elective		Opted from the pool and offered by other departments	5		30	70	100
	Other if any							
			TOTAL	**20**				**500**
		Open Elective offered by department						
	Open Elective	OPNPPT1	Nanomaterials and its Applications	3	3+0+0	30	70	100
		OPNPPL1	Nanomaterials and its Applications Lab	2	0+0+2	30	70	100
	Open Elective	OPNPPT2	Advanced characterization and computational techniques in Physics	3	3+0+0	30	70	100
		OPNPPL2	Advanced Characterization and Computational Techniques in Physics Lab	2	0+0+2	30	70	100
II	Core-4	PPPBTT1	Concepts of Mathematical Physics	5	4+1+0	30	70	100
	Core -5	PPPBTT2	Advanced Quantum Mechanics	4	3+1+0	30	70	100
		PPPBLT2	Advanced Quantum Mechanics Lab	1	0+0+1	30	70	100
	Core -6	PPPBTT3	Statistical Mechanics	5	4+1+0	30	70	100
	Discipline Specific elective 1	PPPBTD1	Computational Physics and Programming	3	3+0+0	30	70	100
		PPPBLD1	Computational Physics and Programming Lab	2	0+0+2	30	70	100
	Other if any							
			TOTAL	**20**				**1000**
III	Core-7	PPPCTT1	Nuclear and Particle Physics	5	4+1+0	30	70	100
	Core-8	PPPCTT2	Condensed Matter Physics	3	3+0+0	30	70	100
		PPPCLT2	Condensed Matter Physics Lab	2	0+0+2	30	70	100
	Research Methodology	PPPCTR1#	Research Methodology in Physics	2	2+0+0	30	70	100
	Discipline Specific elective 2	PPPCTD1	Molecular Physics and Group Theory	5	4+1+0	30	70	100
	Discipline Specific elective - 3	PPPCTD2	i. Advanced Condensed Matter Physics-I	3	3+0+0	30	70	100
			ii. Advanced Nuclear Physics –I		3+0+0	30	70	100
			iii. Astronomy and Astrophysics-I		3+0+0	30	70	100
			iv. Molecular Spectroscopy-I		3+0+0	30	70	100
			v. Material Science –I		3+0+0	30	70	100
			vi. Accelerator Physics-I		3+0+0	30	70	100
		PPPCLD2	Respective Discipline Specific elective Lab - 3	2	0+0+2	30	70	100
	*Certificate/ FC/UEC			2		30	70	100
	Other if any							
			TOTAL	**22+2 ***				**1300**

IV	Core-9	PPPDTT1	Atomic and Molecular Physics	5	4+1+0	30	70	100
	Core-10	PPPDTT2	Electrodynamics	5	4+1+0	30	70	100
	Discipline Specific elective 4	PPPDTD1	i. Advanced Condensed Matter Physics-II	3	3+0+0	30	70	100
			ii. Advanced Nuclear Physics –II		3+0+0	30	70	100
			iii. Astronomy and Astrophysics-II		3+0+0	30	70	100
			iv. Molecular Spectroscopy-II		3+0+0	30	70	100
			v. Material Science –II		3+0+0	30	70	100
			vi. Accelerator Physics-II		3+0+0	30	70	100
		PPPDLD1	Respective Discipline Specific elective Lab - 4	2	0+0+2	30	70	100
	**Dissertation /Project	PPPDD01#	Major Project Work With Dissertation	8		30	70	100
	Other if any							
			TOTAL	**23**				**1000**

#The Code generated by the Department.

L = Lecture, T = Tutorial, P = Practical (Lab)

* Additional Credit courses (not mandatory in nature)

The Discipline specific courses will be treated as special paper of old pattern as and when needed.

Semester – I

Core –1: Classical Mechanics
Course Code: PPPATT1 **Credits = 5 (4+1+0)**

Course Objectives:
The course aims to develop an understanding of:
- To solve advanced problems involving the dynamic motion of classical mechanical systems.
- To use conservation of energy, linear and angular momentum to solve dynamics problems.
- To constructing the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulations of classical mechanics.
- The motion under central force and inverse square force.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:
- The significance of conservation of various physical quantities to discuss the motion of dynamical system.
- The constraints and their significance to solve the equations of motion of the dynamical system.
- The necessity of Lagrangian and Hamiltonian formulations for simplified treatments of many complex problems in classical mechanics.
- This course enables the students to model dynamical systems, both in inertial and rotating frames, using Lagrange and Hamilton equations.
- The essential features of a problem (like motion under central force and rigid body dynamics), use them to set up and able to solve the appropriate mathematical equations under central force and inverse force
- The theory of small oscillations and its importance in several areas of physics.

Unit–I Elementary Principles:
Mechanics of a Particle, Mechanics of a System of Particles, Conservation Laws, Work Energy Theorem, Constraints, Classification of Constraints, Degree of Freedom, Generalized Coordinates,Virtual displacement and virtual work, Principle of Virtual Work, D'Alembert's Principle, Lagrange's Equation from D'Alembert's Principle, Properties of Kinetic Energy Function.

Unit–II Lagrangian Formulation:
Lagrangian equation of motion from D'Alembert's Principle, Lagrangian equation of motion from Calculus of Variations, Properties of Kinetic Energy Function and Kinetic energy in terms of generalized coordinates. Gyroscopic Forces, Dissipative Forces, Rayleigh's Dissipation Function, Lagrangian equation of motion for Dissipative System, Linear Generalized Potential, Generalized Momenta and Energy, Jacobi Integral, Gauge Function for Lagrangian, Cyclic Coordinates, Integrals of Motion, Symmetry of Space and Time with Conservation Laws – Homogeneity and Isotropy, Invariance of Lagrangian equation of motion under Galilean Transformation.

Unit–III Rotating Frames, Central Force and Rigid Dynamics:
Inertial and Rotating Frames, Inertial Forces in Rotating Frame, Pseudo forces – centrifugal, Coriolis and Euler forces and their derivation from Newtonian and Lagrangian Formulation,Definition and Properties of Central Force, Two–body Central Force Problem, General Featuresof Central Force Motion and its Orbits, Stability of Orbits and Conditions for Closure, Motion under Inverse Square Force (Kepler's Problem) and Shapes of Orbits, Unbound Motion - Rutherford Scattering. Euler's angles, Inertial forces, Angular momentum of rigid body, Euler's equation of rigid body, free motion of rigid body.

Unit–IV Hamiltonian Formulation and Small Oscillations:
Hamilton's Variational Principle Hamilton's Variational Principle from Lagrangian equation of motiom, Hamilton's Canonical Equations of Motion, Hamilton's Canonical Equations from Hamilton's Variational Principle, Principle of Least Action, Canonical Transformations and Generating Functions, Example of Canonical Transformations, Condition for Canonical Transformations, Hamilton – Jaccobi Equation, Hamilton's Principal and Characteristic Functions, Poison Bracket, Invariance of Poisson Brackets with

Respect to Canonical Transformations, Equations of Motion in Poisson Bracket Form, Poisson's Theorem, Angular Momentum in Poisson Bracket, Small Oscillations, Normal Modes and Normal Coordinates.

References:

1. Classical Mechanics, N.C. Rana and P.S. Joag, (TATA McGraw-Hill, 1991).
2. Classical Mechanics, H. Goldstein, (Addition Wesley, 1980).
3. Classical Mechanics, H. Goldstein, C. Poole, and J. Safko, (Pearson Education, Inc, 2002).
4. Classical Mechanics, J.C. Upadhaya (Himalaya Publishing House)
5. Classical Mechanics, Gupta, Kumar and Sharma (PragatiPrakashan)
6. Classical Mechanics by P.V. Panat, (Narosa Book Distributors Private Ltd)

Core –2: Quantum Mechanics
Course Code: PPPATT2 **Credits = 4 (3+1+0)**

Course Objectives:

- To introduce the modern concepts of quantum mechanics in a stimulating, elegant, exhaustive and explanatory manner.
- To explore the nature of the microscopic world into substantial depth in terms of meaning and interpretation so as to acquaint the learners to initiate thinking and analyzing the physically observable phenomena quantum mechanically without exceeding the mathematical level of complexity.
- To lay down the foundation and enhance capabilities of students to pursue various aspects of modern physics and interdisciplinary fields confidently.

Course Outcomes:

After the completion of course, students should be able to understand and grasp.

- The basic concepts of quantum mechanics including the solution of wave equation, interpretation of dynamical variables and applying wave mechanics to various situations in terms of boundary value problems so as to understand the quantum well, barriers and particle motion in different types of force field (potentials).
- Applying special functions as the solutions of differential equation as the wave function/state functions and understanding the physical situations where these can be applied.
- Calculating states of electrons in hydrogen atom and harmonic oscillators and the interpretation of quantum states.
- Applying the stationary perturbation problems to various problems including particle states splitting in electric and magnetic field.

Unit – I: Introduction to Schrodinger equation; probability interpretation, probability current, continuity equation; Ehrenfest theorem; Admissible wave functions; Stationary states, Schrodinger equation in one dimensional problems, wells and barriers; Harmonic oscillators by Schrodinger Equation

Unit – II: Uncertainty relation of x and p, States with minimum uncertainty product; General Formalism of wave mechanics; Commutation Relations; Representation of states and dynamical variables; Completeness of eigen functions; Dirac delta function; Bra and ket Notation; Matrix representation of an operator; Unitary transformation. Solution of Harmonic oscillator by operator method.

Unit – III: Angular momentum in QM, Central force problems: Solution of Schrodinger equation for spherically symmetric potentials; Hydrogen atom problem.

Unit – IV: Time independent perturbation theory; Non-degenerate and degenerate cases; Applications such as Stark effect etc.

Reference Books:

1. Quantum mechanics, by L I Schiff
2. Quantum physics by S Gasiorowicz
3. Quantum mechanics by B Craseman and J D Powell
4. Quantum mechanics by A P Messiah
5. Modern Quantum mechanics by J J Sakurai.

6. Qunatum mechanics by Mathews and Venkatesan

Core –2: Quantum Mechanics Lab
Course Code: PPPALT2 **Credits = 1 (0+0+1)**

1. To determine the Planck Constant and work function
2. Measurement of wavelength of He-Ne LASER (Grating)
3. To determine the wavelengths of Hydrogen spectrum and determine the value of Rydberg's constant.

Core –3: Electronics and Experimental Methods
Course Code: PPPATT3 **Credits = 3 (3+0+0)**

Course Objectives:
- The course mainly focuses on developing the Electronics, experimental and instrumentation skills of the students.
- To develop the understanding of physics of semiconductor, semiconductor junctions, metal-semiconductor, homo-junction, and hetero-junction and metal-oxide semiconductor contacts.
- Semiconductor photonic devices and hetero-structures for detection and production of optical radiation.
- To understand the concept of Data Interpretation and Analysis of results.

Course Outcomes:
- Students understand the basic of semiconductor and electronics devices.
- Students understand the current voltage characteristics of semiconductor devices, metal-semiconductor, homo-junction, and hetero-junction and metal-oxide semiconductor contacts.
- Student understands the basic mechanism involves in optoelectronics devices.
- Understanding of sensors and transducers for temperature, vacuum, optical and vibration measurements

Unit – I: Energy band in semiconductors, Carrier concentration in intrinsic and extrinsic semiconductors, Fermi levels in intrinsic and doped semiconductors, Concept of degenerate and non-degenerate semiconductors, temperature and doping dependent energy band gap of semiconductors.

Unit – II: Carrier mobility and drift velocity, Resistivity and conductivity, diffusion current, Einstein's relationship, Generation and recombination of carriers, Continuity equation, Carrier Injection and excess carriers, Decay of carriers.

Unit – III: P-N junction; device structure, energy band diagram, depletion region (abrupt junctions), depletion capacitance and C-V characteristics, I-V characteristics, Varactor diode, Tunnel diode principle of operation and I-V characteristics, Semiconductor hetero-junctions, Metal-semiconductor junction, Ohmic contacts. Solar cells, Photo-detectors, LEDs.

Unit – IV: Precision and Accuracy, Error Analysis, Types of errors,Propagation of errors, Curve fitting: Least square fitting, chi-square test. Measurement techniques: Sensors and Transducers (Temperature, vacuum, optical, particle and radiation detectors etc.), Signal and Noise.

References:
1. Semiconductor devices- Physics and Technology by S.M.Sze
2. Electronic Devices and Circuit Theory by Boylestad and Nashelky
3. Integrated Electronics : Milliman and Halkias
4. Measurement, Instrumentation, and Experimental design in Physics and Engineering: Michael Sayer, AbhaiMansingh
5. Transducers and Instrumentation:DVSMurty

Core –3: Electronics and Experimental Methods Lab
Course Code: PPPALT3 **Credits = 2 (0+0+2)**

1. Study the operational Amplifier as inverting and non-inverting amplifier
2. Study the operational Amplifier as a summing amplifier (Voltage adder and voltage subtraction).
3. Study the operational Amplifier as a differentiator and integrator.

4. A study of V-I characteristics of light emitting diode (LED).
5. A study of V-I characteristics of Tunnel diode.
6. Study of Solar Cell characteristics
7. Photoconductivity (Photocurrent as a function of irradiance at constant voltage)
8. Design of regulated Power Supply
9. Verification of De Morgan's Theorem
10. To design a digital to analog converter (DAC) of given specifications

Open Elective: Nanomaterials and Its Applications
Course Code: OPNPPT1 **Credits = 3 (3+0+0)**

Course Objectives:
The objective of the subject is that the student acquires knowledge
- To foundational knowledge of the Nanomaterials and related fields.
- To understand the influence of dimensionality of the object at nanoscale on their properties
- To make the students acquire an understanding the basic Nanoscience/Nanotechnology and their Applications .
- Students gain knowledge about the principles of various synthesis techniques**.**

Learning Outcomes:
After completing this course students will be able to:
- Learn about the background on Nanoscience
- Understand the various synthesis methods of Nanomaterials and their application and the impact of Nanomaterials on environment
- Apply their learned knowledge to develop new Nanomaterial's.

Unit – I: History of nano- materials, Ancient Indian Culture and Nanotechnology, Role of Feynman in development of Present Nano-sciences, what are Nanoscience and Nanotechnology?Atomic structure and atom size and their effects, Types of 1D, 2D, 3D Nano-structured materials, Influence of nano over micro/macro.

Unit – II: Properties of Nano materials: Physical, Magnetic, Optical, Thermal, Mechanical, Electrical for nano materials and Chemical Properties, Size effects, Surface Effects and Surface to Volume ratio.

Unit – III : Type of Nanomaterials: different type of nano materials,Carbon nanotube, Fullerene, Type of CNT: SWNT (Single wall nano tube), Multi wall nano tubes. 2D nano material, Graphite and Graphene, metal nano particle silver and gold, ZnO and TiO_2 metal oxides, Semiconductors, Nano-composites,Creating nanoparticles by using software.

Unit – IV: Synthesis of nano materials**:** Top- down or bottom up approach, Physical Methods, PLD, Sputtering, Thermal evaporation, Chemical Methods – CVD, Sol-gel, Hydrothermal, Biological Methods – Green Synthesis, mechanical milling, sputtering and microwave plasma, chemical reduction and oxidation, hydrothermal, micelles, sol-gel processes, photolysis, and metal organic chemical vapor deposition

Reference Books:

1. Introduction to Nano Science and Nano Technology – K.K. Chattopadhyay & A. N. Banerjee PHI Pvt. Ltd., 2009.
2. Nano technology: Principles and practices - Sulabha K. Kulkarni, Capital Publisher Co., 2015.
3. Introduction to nano technology: Charles P. Poole, Jr. Frank J. Owen, Wiley, Interscience Pub., May, 2003.
4. Nanostructures & Nanomaterials Synthesis Properties & Applications. Guozhong Cao, Imperials College Press London. 2004
5. Textbook of Nanoscience and Nanotechnology-B.S.Murty, P.Shankar, BaldevRaj, B.B. Rath and James Murday Universities press, IIM, Metallurgy and Materials Science
6. Principles of Nanoscience & amp; Nanotechnology M.A. Shah, Tokeer Ahmad, Narosa Publishing House

7. Nanocrystals: Synthesis, Properties and Applications C.N. Rao, P.J. Thomas, G.U. Kulkarni
8. Nano materials Handbook – Yury Gogotsi
9. Introduction to Nano science and Nano technology – K K Chatopadhayya & Banerjee, PHI
10. Introduction of Nano Technology - Cahrles P. Poole Jr and Franks J. Qwens
11. Nano: The Essentials. T. Pradeep, McGraw Hill Education.20/01/2007
12. Handbook of Nanostructures: Materials and nanotechnology, H.S. Nalwa, Vol 1-5, Academic Press, Bostan. I Ed.,Oct., 1999.

Open Elective: Nanomaterials and Its Applications Lab
Course Code: OPNPPL1 **Credits = 2 (0+2+0)**

1. To determine the crystallite size of given sample and observe the influence of do-pants through given XRD data.
2. To analyze the particle size Scanning Electron Microscopy and Transmission Electron Microscopy images of given samples.
3. To determine the crystallinity and phase composition of the given sample through selective area electron diffraction.
4. To determine the electronic band-gap of given sample through Tauc plots derived from UV-Vis diffused reflectance spectroscopy.
5. To identify Hydrogen bond through FTIR spectroscopy.
6. To analyze the elemental species present in the given sample through X-ray Photoelectron Spectroscopy.

Semester - II

Core-4: Concepts of Mathematical Physics **Credit: 5 (4+1+0)**
Course Code: PPPBTT1

Course Objectives:
The course aims to develop an understanding of:

- Vectors and Matrices are applied in the Quantum Mechanics, Solid state physics, atomic and molecular spectroscopy and Nuclear Physics etc.
- Complex variables is very important tool to handle complex integrations in different brances of physics.
- In physics, generally we encounter different types differential equations. Ordinary differential equations and series solution methods with special functions are taught here in this course to solve various types of differential equations.
- Students will learn Integral transforms and their applications to solve and understand different types of signals and their characteristics.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- Vector space and eigen value problems
- Students are able to solve difficult integrations in complex plane.
- Students are able to solve differential equations using special functions.
- Students are able to solve differential equations by Integral transforms.

Unit – I: Vector algebra and vector calculus, linear independence, basis expansion, Schmidt orthogonalisation. Matrices: Representation of linear transformations and change of basis; Eigen values and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues; Orthonormality of eigenvectors, Concepts of tensors.

Unit – II: Complex variables: Recapitulation: Complex numbers, triangular inequalities, Schwarz inequality. Function of a complex variable : single and multiple-valued function, limit and continuity; Differentiation; Cauchy-Riemann equations and their applications; Analytic and harmonic function; Complex integrals ,Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy's Integral Formula and its corollaries; Series - Taylor and Laurent expansion; Classification of singularities;

Branch point and branch cut; Residue theorem and evaluation of some typical real integrals using this theorem.

Unit – III: Theory of second order linear homogeneous differential equations Singular points: regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions: Wronskian, second solution. Sturm-Liouville theory; Hermitian operators, Special functions: Basic properties (recurrence and orthogonality relations, series expansion) of Bessel, Legendre, Hermite and Laguerre functions and its generating functions.

Unit – IV: Integral transforms: Fourier and Laplace transforms and their inverse transforms, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms]; Transform of derivative and integral of a function; Solution of differential equations using integral transforms, Delta function.

Reference Books:

1. Mathematical methods for physics, by G ARFEKEN
2. Advanced engineering mathematics, by E KREYSZIG
3. Complex Variables with an introduction to CONFORMAL MAPPING and its applications, Second Edition Murray R. Spiegel, Seymour Lipschutz, John J. Schiller, Dennis Spellman.
4. Mathematical Physics by Dass H. K.
5. Special functions, by E D RAINVILLE
6. Special functions by W W BELL
7. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence,3rded., 2006, Cambridge University Press
8. Mathematics for physicists, by MARY L BOAS

Core –5: Advanced Quantum Mechanics **Credit: 4 (3+1+0)**
Course Code: PPPBTT2

Course Objectives:

- To introduce the advanced concepts of quantum mechanics and the applications of quantum mechanical methods in problems of many electron systems, scattering problems.
- To explore the nature of the microscopic world into substantial depth in terms of meaning and interpretation so as to acquaint the learners to initiate thinking and analysing the physically observable phenomena quantum mechanically without exceeding the mathematical level of complexity.
- To lay down the foundation and enhance capabilities of students to pursue various aspects of modern physics and interdisciplinary fields confidently.

Course Outcomes:

After the completion of course, students should be able to understand:

- The basic concepts of quantum mechanics including the solution of wave equation, interpretation of dynamical variables and applying wave mechanics to various situations in terms of boundary value problems so as to understand the quantum well, barriers and particle motion in different types of force field (potentials).
- Applying special functions as the solutions of differential equation as the wave function/state functions and understanding the physical situations where these can be applied.
- Calculating states of electrons in hydrogen atom and harmonic oscillators and the interpretation of quantum states.
- Applying the stationary perturbation problems to various problems including particle states splitting in electric and magnetic field.
- The case studies and problem-solving exercises will be given as assignments and group activities in both the courses so as to enhance the experiential learning and induce group learning.

Unit – I: Approximation methods, higher order time independent perturbation, Variational method, WKB approximation, turning points and applications.

Unit – II: Time dependent perturbation theory, harmonic perturbation, Fermi's golden rule, Adiabatic and sudden approximation. Semi-classical theory of radiation, transition probability for absorption and induced emission, electric dipole and forbidden transitions, selection rules.

Unit – III: Collision in 3-D and scattering, laboratory and CM reference frames, scattering amplitude, differential scattering cross section and total scattering cross section, scattering by spherically symmetric potential, partial waves and phase shifts, scattering by perfectly rigid sphere and by square well potential

Unit – IV: Identical particles, symmetric and anti-symmetric wave functions, collision of identical particles, spin angular momentum, spin function for a many electrons system.
Relativistic Quantum Mechanics: Klein-Gordon and Dirac equations; Properties of Dirac matrices. Plane wave solutions of Dirac equation; Spin and magnetic moment of the electron. Nonrelativistic reduction of the Dirac equation. Spin-orbit coupling. Energy levels in a Coulomb field.

Reference Books:

1. L I Schiff, Quantum Mechanics (McGraw- Hill).
2. J.J. Sakurai, Modern Quantum Mechanics
3. Griffiths, Introduction to Quantum Mechanics
4. A.P. Messiah, Quantum Mechanics Vol 2, (North-Holland, 1962).
5. R. Shankar, Principles of Quantum Mechanics (Plenum 1994)
6. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Mechanics (McGraw-Hill 1964)
7. B.K. Agarwal and Hari Prakash, Quantum Mechanics (Prentice-Hall 2007)

Core –5: Advanced Quantum Mechanics Lab **Credit: 1 (0+0+1)**
Course Code: PPPBLT2

1. By analyse the Zeeman Effect in mercury vapour, determine the fine structure constant by Fabry-Perot Interferometry. (Experiment)
2. Calculate the energy difference between the singlet and triplet state of He Atom. (Mathematical solutions only)
3. Two identical particles of spin 1/2 are enclosed in a one-dimensional box potential of length L with walls at x=0 and x=L. Find the Ground state energy. (You can use any programming language)

Reference Books:

1. Modern*Quantum Mechanics*, by J. J. *Sakurai*&Jim Napolitano, 2^{nd} Edition. Addison-Wesley.
2. *Quantum Mechanics*. Concepts and Applications. Second Edition. Nouredine *Zettili*.

Core –6: Statistical Mechanics **Credit: 5 (4+1+0)**
Course Code: PPPBTT3
Course Objectives:

- To understand connection between Thermodynamics and Statistical Mechanics.
- To understand different Ensemble and their applications.
- To understand different distribution law
- To learn the Application of different distribution function
- To understand phase transition

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- Concept of ensemble theory
- Fundamental difference of classical and quantum statistical distribution
- Application of Fermi distribution function and B-E distribution function to calculate various physical parameters
- Concept of different Phase

Unit – I: Review of Thermodynamic potentials and Macrostate& Microstate, Concept of distribution function of Microcanonical Ensemble, Canonical ensemble, Grand Canonical ensemble, Phase Space, Dynamical variable, Relation of partition function with thermodynamic Functions, application of partition function, Motion of the point in phase space (Liouville equation), fluctuations of energy in canonical ensemble and no. of particles in grand canonical ensemble (15 Lectures)

Unit – II: Maxwell-Boltzmann Distribution Law, B-E distribution law, Fermi-Dirac Distribution Law, Derivation of Ideal Quantum gas equation, adiabatic quantum gas relations. (10 Lectures)

Unit – III: Application of Fermi-Dirac Statistics: Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Fermi sphere, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. Application of B-E statistics: Bose Einstein condensation, properties of liquid He (qualitative description), Blackbody Radiation, heat capacity (20Lectures)

Unit – IV: Phase transition, (P, T), (V, T) and (P. V) Phase diagram, Real gas equation, tie line, order parameter, Landau theory with example. Ising Model(15 Lectures)

Reference Books:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Statistical Mechanics, By K Huang.
4. Statistical Physics, By Landau and Lifshitz.
5. *Statistical Mechanics* by *Donald* A. *Mc Quarrie* (Harper & Row, New York, 1976)

DSE – 1: Computational Physics and Programming **Credit: 3 (3+0+0)**
Course Code: PPPBTD1

Course Objectives:
The course aims to develop an understanding of:
- Basic methods, tools and techniques of computational physics with Fortran 90/95.
- Developing practical computational problem solving skills.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:
- identify modern programming methods and describe the extent and limitations of computational methods in physics,
- independently program computers using leading-edge tools,
- formulate and computationally solve a selection of problems in physics,

Unit – I: Basic in computer programming, programming preliminaries, Fortran 90 programming: Constants and Variables, Arithmetic expression, I/O statements, Conditional statements

Unit – II: Loops and Logical expressions, Functions and Subroutines, Arrays, Format specifications, Files Processing in Fortran 90

Unit – III: Numerical methods: solution of linear and nonlinear algebraic equations and transcendental equations, bisection method, false position method, Newton Raphson method, Solution of simultaneous linear equations, Matrix inversion, Gaussian elimination, iterative Method.

Unit – IV: Interpolation (with equally spaced and unevenly spaced point), Curve fitting, Numerical integration, Trapezoidal rule, Simpson's method, Numerical solution of ordinary differential equation by Runga-Kutta method.

Reference Books:

1. Sastry: Introductory methods of Numerical Analysis.
2. Rajaraman: Numerical Analysis and Fortran Programming
3. *Numerical Recipes in FORTRAN: The Art of Scientific Computing*, Press, et al. (Cambridge University Press)
4. *Fortran 90 Programming*, Ellis, Philips and Lahey (Addison-Wesley)
5. *Fortran 90/95 Explained*, Metcalf and Reid (Oxford)
6. *Fortran 90/95 for Scientists and Engineers*, Chapman (McGraw-Hill Higher Education)

DSE – 1: Computational Physics and Programming Lab **Credit: 2 (0+0+2)**
Course Code: PPPBLD1
Name of the experiments

1. Implementation of solving the non algebraic equation using Fortran 90
2. Implementation of Numerical Integration using Fortran 90
3. Implementation of Solving Differential equation using Fortran 90
4. Implementation of Solving linear equations using Fortran 90

Semester – III

Core–7: Nuclear and Particle Physics **Credit: 5 (4+1+0)**
Course Code: PPPCTT1
Course Objectives:
The course aims:

- To develop the basic concepts and knowledge of nuclear properties to understand structure of nucleus.
- To understand various theories of nuclear force
- To understand various nuclear models to explain its shapes
- To impart knowledge about nuclear physics properties and nuclear models for understanding of related reaction dynamics
- To get preliminary knowledge of particle physics and quark structure.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- Explain the ground state properties of the nucleus for study of the nuclear structure behavior.
- Explain the deuteron behavior at ground and excited states.
- Apply Nucleon-Nucleon scattering to understand the nuclear forces.
- Demonstration of the shell model and collective model descriptions.
- Apply various aspects of nuclear reactions in view of compound nuclear dynamics.
- Basic understanding of particle physics and quark structure of hadrons.

Unit – I: Static properties of Nuclei: Nuclear size determination from electron scattering, nuclear charge distribution. Angular momentum, spin and moments of nuclei. Binding energy, semi-empirical mass formula, Liquid drop model, fission and fusion
Two Nucleon Systems & Nuclear Forces: Dipole and quadrupole moments of the deuteron, Central and tensor forces, Evidence for saturation property, Neutron-proton scattering, Protonproton scattering, S-wave effective range theory, charge independence and charge symmetry, exchange character, spin dependence. General form of the nucleon-nucleon force. Yukawa interaction

Unit – II: Nuclear Models: Liquid drop model, nuclear shapes. Experimental evidence for shell effects, shell model, spin Orbit coupling, Magic numbers, angular momenta and parities of nuclear ground states,Magnetic moments and Schmidt lines, failure of shell model,Collective model of Bohr and Mottelson, rotational model, Qualitative discussion and estimates of transition rates.

Unit – III: Nuclear decay and Reactions: Alpha decay: Geiger-Nuttall law, Electromagnetic decays: selection rules,Fermi theory of beta decay. Kurie plot. Fermi and Gamow-Teller transitions, Parity violation in beta-decay.
Direct and compound nuclear reaction mechanism, reaction cross section, cross sections in terms of partial wave amplitudes, compound nucleus -scattering matrix, Reciprocity theorem, Breit-Wigner one Level formula-Resonance scattering.

Unit – IV: Elementary Particles (quarks, baryons, mesons, leptons). Classification: spin and parity assignments; isospin, strangeness. Elementary ideas of SU(2) & SU(3). Gell-Mann-Nishijima scheme. C, P and T invariance and application of symmetry arguments to particle reaction. Properties of quarks and their classification. Introduction to the standard model, Hicks bosons, Parity non-conservation in weak interactions,

Reference books:

1. Nuclear Physics by S.N. Ghoshal, S. Chand & Company Ltd,2004
2. Introducing Nuclear Physics by K. S. Krane (Wiley India., 2008) .
3. Nuclear Physics - Theory & Experiments by R.R. Roy &B.P.Nigarn (New Age lnternational, 2005)
4. Nuclear & Particle Physics: An Introduction by B. Martin (Willey,2006)
5. Introduction to Elementary Particles by D. J. Griffiths (Academic Press 2nd Ed.2008)
6. Concept of Nuclear Physics by B. L. Cohen (McGraw-Hill,2003)

Core–8: Condensed Matter Physics **Credit: 3 (3+0+0)**
Course Code: PPPCTT2
Course Objectives:
The course aims to develop an understanding of:

- Crystal structure and determination through diffraction techniques
- Phonon dynamics
- Energy band in solids
- Magnetism in solids
- Superconductivity in solids

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- To determine the crystal classes and crystal structures
- To study the electronic and magnetic properties.

Unit – I: The crystal lattice. Basis vectors. Unit cell. Symmetry operations. Point groups and space groups. Plane lattices and their symmetries. Three dimensional crystal systems. Miller indices. Directions and planes in crystals. Bravais lattices, crystal structure, reciprocal lattice, Brillouin zones.Diffraction: Theory and experimental methods (X – ray and Neutron)

Unit – II: Lattice dynamics: Phonons, density of states, specific heat, thermal conductivity. Electron theory: Free electron model, elementary band theory, metals, semiconductors, electrical conductivity.

Unit – III: Energy bands in solids. The Bloch theorem. Bloch functions. Review of the Kroning-penney model. Brillouin zones. Number of states in the band. Band gap in the nearly free electron model. The tight binding model. The fermi surface. Electron dynamics in an electric field. The effective mass. Concept of hole. (elementary treatment)

Unit – IV: Origins of magnetism in condensed matter: localized moments (from atoms to solids, delocalized electrons, diamagnetism), Paramagnetism of localized moments, Interacting moments: origin of the exchange interaction, Heisenberg Hamiltonian , Mean field treatment of interacting magnetic systems: ferro-, antiferro-, and ferrimagnetism

Reference books:

1. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
2. Ibach & Luth: Solid State Physics
3. M. Ali Omar: Elementary solid state physics (Addison-wesley)
4. C. Kittel: Solid-state physics (Wiley eastern)(5th edition).

Core–8: Condensed Matter Physics Lab **Credit: 2 (0+0+2)**
Course Code: PPPCLT2
Name of the experiments

1. Hall effect experiment
2. Four probe measurement for electrical resistivity
3. Magnetic susceptibility measurement
4. Band gap estimation through UV – Vis spectroscopy
5. Raman spectra of a known system
6. FT – IR spectra of a known system

7. Determination of crystal structure through XRD
8. Lande-g factor by ESR method.

Credit: 2 (2+0+0)

Research Methodology: Research Methodology in Physics
Course Code: PPPCTR1
Objective:
To introspect the fundamentals of research methodology and its association in diverse areas of science**.**

Course Outcomes: After completion of this course, post graduate will be able to
- Identify the research gap and various methodologies to solve the problems
- Analyze the data by using different methods and develop presentation skills
- Engage in research in the field of pure and applied physics and involve in lifelong learning

Unit – I: Research and Research Design: Introduction to Research, Types of research: exploratory, conclusive, modeling and algorithmic, , Tools used for review, journals, conferences, books, magazines and their quality and authenticity, effective searches, find relevant papers related to your area of research, capture critical information, understand and identify the bias, theoretical position and evidence produced, compare ideas and concepts from different papers, distinguishing own work from others work and acknowledging such references.

Unit – II: Problem identification and its solution: Identification of research problems, Identify key areas in research field, Identification of a problem and literature survey. Collection of data and analysis, Determine the nature and extension of papers that should be read, Identify the research gaps, Formulate the Problem Statement, Examples of effective and ineffective titles.

Unit – III: Data Analysis: Identify problem and experimental/theoretical data for comparison with proposed model, extrapolate/scale data for validation, Error Analysis and Numerical Methods, editing and coding of data, tabulation, graphic presentation of data, cross tabulation, testing of hypotheses.

Unit – IV: Presentation: Scientific Writing: Goals and Objectives, Structure of documents, importance of clear title, abstract or summary, Main message of presentation, highlight review points, structure of presentation key components of an oral presentation, show support material, feedback on oral presentation, prepare a set of questions.

Reference Books:
1. R L Dominowski: Research Methods (Prentice Hall of India, N J 1980)
2. John R Rice: Numerical Methods, Software and Analysis (Mc Graw Hill ISE, 1985)
3. Gaur R. R., Sangal R., & Bagaria G. P. (2010). A foundation course in human values and professional ethics. New Delhi: Excel Publishers.
4. Naagarazan R. S. (2006). A textbook on professional ethics and human values. New Delhi: New Age International Pvt Ltd.
5. Verma R. (2003). Modern trends in teaching technology. New Delhi: Anmol publishers Pvt. Ltd.
6. Rao U. (2001). Educational teaching. New Delhi: Himalaya publishing house.

DSE– 2: Molecular Physics and Group Theory **Credit: 5 (4+1+0)**
Course Code: PPPCTD1

Course Objectives:
The course aims to develop an understanding of:
- The basic principles, theory and experimental details for understanding the structure, properties and applications of materials.
- Defects, diffusion and phase transitions in solids and how these affect the properties.
- Also gives an overview of various methods for the synthesis of single crystals, thin films and nanomaterials.

Course Outcome:

At the end of the course, students will be able to understand:

- The symmetry properties and vibrational intensities of molecules.
- Learned about group theory to molecular vibrations.

Unit – I: Vibration in polyatomic molecules; Normal Coordinates and Normal Modes; Overtone and Combination Bands Normal Coordination Analysis; Symmetry properties of Normal coordinates; Vibrational Intensities: Interpretation and Use for Diagnostics Purposes

Unit – II: Group Theory: Definition and theorem of group theory, Properties of groups, sub-groups and classes; Molecular symmetry elements and operations; Symmetry planes and reflections, proper and improper rotations; product of symmetry operations; Effect of symmetry lowering on vibrational Spectra.

Unit – III: Representation of point group; Matrix representation of the symmetry elements of point group, Great Orthogonality Theorem; Character tables; Reducible and irreducible representations; Symmetry species; Character tables for point groups.

Unit – IV: Applications of group theory to molecular vibrations, Analysis of reducible representation; characters for the reducible representation of molecular motions; number of normal modes of various symmetry types.

Reference Books:

1. Chemical Application of Group Theory: F.A. Cotton.
2. Introduction to Molecular Spectroscopy: G.M. Barrow.

DSE – 3: i. Advanced Condensed Matter Physics–I **Credit: 3 (3+0+0)**
Course Code: PPPCTD2
Course Objectives:
The aim of the proposed course is to introduce the basic notion of the condensed matter physics and to familiarise the students with the various aspects of the interactions effects. This course will be bridging the gap between basic solid state physics and quantum theory of solids. The course is proposed for postgraduate students. The courses begins with the review of some of the basic concepts of introductory condensed matter physics and then sequentially explore the interaction effects of electron-electron/phonon, optical properties of solids, interaction of light with matter and finally the Magnetism behaviour in solids.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- Advanced concepts condensed matter physics be cleared
- Advanced device applications may be derived

UNIT – I: Reconstruction and relaxation phenomena, work function, thermionic emission, electronic surface states, magnetoresistence. Disorder in condensed matter, substitutional, positional and topographical disorder, short and long range order.

UNIT – II: Atomic correlation function, Anderson model for random systems and electron localization, mobility edge, qualitative application of the idea to amorphous semiconductors and hopping conduction.

UNIT – III: Magnetic properties of solids : Quantum theory of magnetic susceptibility, Pauli paramagnetism, magnetic properties of two-electron system, spin Hamiltonian and Heisenberg model, magnetic interaction in free electron gas, mean field theory, Exchange interaction, one-and two-dimensional ising model, spin waves, magnons.

UNIT – IV : Optical properties of solids: band to band absorption, excitions, Polarons, Colour centres, Luminescence. Photoconductivity,: Optical reflectance, Excitons, Kramers-kronig relations, Electronic inter-band transitions.

Reference Books:

1. Introduction to Condensed Matter Physics – K.C. Barua (Alpha Science International Ltd.)

2. A Basic Course in Crystallography – JAK. Tareen & TRN Kutly. (Universities Press, India Pvt.)
3. An Introduction to Crystallography, F.C. Phillips, Longman Higher Education.
4. Crystallography Applied to Solid State Physics – A.R. Verma and O. N. Srivastava, New Age International limt., 2nd Ed. Reprint 2005.
5. Elements of Solid state Physics, M. Ali omor Peasson Education 3rd Indian reprint, 2002
6. Solid state Physics, C. Kittel, Wiley. 5th Edition.
7. Solid state Physics, A.J. Dekkar, Macmillan.
8. Elementary Solid state Physics: Principles and Applications, M. Ali Omar, Addison-Wesley.
9. Introduction to Solids, L.V. Azaroff, Tata Mc-Graw Hill.
10. Solid state Physics: An introduction to Principles of Materials Science, H. Ibach and H. Luth, Springer.
11. Solid state Physics, S.O. Pillai, New Age International.
12. Condensed matter Physics, M.P. Mardar,Wiley.
13. Physics of solids, C.A. Wert and R. M. Thomson, McGraw-Hill.
14. Fundamentals of Solid state Physics, J. R. Christmaan, Wiley.
15. Solid State Physics- Structure and Properties of materials, M.A. Wahab, Narosa Publishing House

DSE – 3: ii. Advanced Nuclear Physics –I **Credit: 3 (3+0+0)**
Course Code: PPPCTD2
Course Objectives:
The course aims to develop an understanding of:
- To develop the knowledge of nuclear structure through various from simple shell model to mean field theory.
- To understand many exotic features of exotic nuclei

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:
- Explain the shell model, collective model, mean field theory of atomic nucleus.
- Explain the many recent observed features of nucleus

Unit – I: Nuclear Shell Model:
Shell model: Review of the Shell Model, magic numbers, single particle shell model, wave function, quantum numbers, Residual interaction and configuration mixing, effective interaction and operators, Description of two or more particles outside a closed core. Classification of shells, Seniority, Pairing force, Energy level calculations. Spectra of closed shell nuclei, lp-lh excitations.

Unit – II: Collective models: Nuclear vibrations and excited states, isoscalar vibrations, sum rule in vibration model, Collective model of Bohr and Mottelson, Energy levels and electromagnetic properties of even-even and odd-A deformed nuclei, Permanent deformation, Nuclear shapes, super deformed and hyper deformed shapes. Particle states in nonspherical nuclei-Nilsson's model, Coupling of particle states and collective motion in unified model.

Unit – III: Mean Field models and behavior at high spin physics: Nuclear mean field, Hartree-Fock theory, Hartree-fockBogolieubov, Pairing plus quadrupole interactions. Production of high spin states, level structure, behavior of nuclei at high spin state, Qualitative discussion and estimates of transit ion rates, Nuclear moment of inertia, Back bending.

Unit – IV: Exotic Nuclei: Nuclear landscape: proton and neutron drip lines, nuclear structure at the extremes of stability, nuclear halos, neutron skins, proton rich nuclei and beyond, decay modes of exotic nuclei, Production of exotic nuclei – RIB and ISOL facility (an overview)

Reference books:
1. Introducing Nuclear Physics by K. S. Krane (Wiley India., 2008) .
2. Introductory Nuclear Physics S. M. Wong (Wiley-VCH Verlag GmbH & Co. KGaA)
3. Nuclear Structure from a Simple Perspective: R. F. Caston (Oxford Studies in Nuclear Physics)
4. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP- Institute of Physics Publishing, 2004)
5. Nuclear Physics - Theory & Experiments by R.R. Roy &B.P.Nigarn (New Age lnternational, 2005)

6. Nuclear structure – Bohr and Mottelson (World Scintific)
7. Kaplan Irving, Nuclear Physics, Narosa Publishing House, (2000).
8. Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991)

DSE – 3: iii. Astronomy and Astrophysics–I **Credit: (3+0+0)**
Course Code: PPPCTD2
Course Objectives:
The course aims to develop an understanding of:
- The basic idea of stellar astrophysics
- The formation of evolution of stars the binary stars and star clusters
- And their classifications.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:
- The basic quantities used in astronomy such as coordinates, Stellar Distance, magnitude, and Stellar Luminosity etc. and measurement techniques of astrophysical quantities as well as spectral classification of stars.
- Formation and Evolution of Star, and the fate of low and high mass stars, as well as the physics of white dwarfs, neutron starts, pulsars and black holes.
- Binary Stars and Star Clusters, as well as their Classifications. the workings of astronomical instruments as well as their use.

Unit – I: Basic Stellar Astrophysics: Celestial Sphere, Stellar Parallax, Units of stellar distance, stellar magnitude sequence, Apparent and Absolute magnitudes, distance modulus, stellar distances, bolometric magnitude, color index, luminosities of stars, spectral classification, Henry-Draper and modern M_K classification scheme, H-R diagram of stars, empirical mass – luminosity relation.
Stellar interiors: The basic equation of stellar structure, hydrostatic equilibrium, thermal equilibrium, virial theorem, energy Eourse, energy transport by radiation and convection, equation of state.

Unit – II: Formation and evolution of stars: Inter stellar Dust and Gas, Formation of Pro-stars, Pre-main sequences evolution, Evolution on the Main sequence for Low and High Mass Stars, Post Main Sequence evolution, End States of Stars, Degenerate States, White Dwarf and Chandrashekhar Limit, Fate of Massive Stars, Neutron Stars, Pulsars and Black holes, Suprenovae and its Characteristics

Unit – III: Binary Stars and Star Clusters: Binary Stars: Binary Stars and their classification, Close Binaries, Roche Lobes, Evolution of Semidetached systems: Algols, Cataclysmic variables and X-ray Binaries. Star Clusters: Galactic Clusters, Globular Clusters, H-R diagram of star clusters

Unit – IV: Astronomical Instrumentation: Telescope- Basic Optics, Focal Plane, Plate Scale, Resolution and Rayleigh Criterion, Seeing Aberrations, Brightness of an Image, Refracting Telescope, Reflecting Telescope, Telescope mounts, Large aperture telescope, Adaptive optics, Space-based observatories, Telescope for Infrared, Ultraviolet, X-ray, Gamma-ray and Radio Astronomy, Stellar Photometry using CCD.

Reference Books:

1. An Introduction to Astrophysics, Baidyanath Basu, Prentice Hall of India.
2. Textbook of Astronomy and Astrophysics with Elements of Cosmology, V.B. Bhatia, New Delhi, Narosa Publishing House.
3. Theoretical Astrophysics, Vol. I: Astrophysical processes T. Padmanabhan, Cambridge University Press.
4. Theoretical Astrophysics, Vol. II: Stars and Stellar Systems, T. Padmanabhan, Cambridge University Press.
5. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th edition, Saunders College Publishing.
6. The New Cosmos, A. Unsold and B. Baschek, Newyork, Springer Velas.
7. Astronomical Photometry, A.A. Henden, and R.H. Kaitchuk, Willmann-Bell.
8. Handbook of CCD Astronomy, S.B. Howell, Cambridge University Press.

9. A Workbook for Astronomy, Jerry Waxman
10. Telescope and Techniques, C.R. Kitchin, Springer.
11. Astrophysical Techniques, C.R. Kitchin, CRC Press.
12. Observational Astrophysics, R.C. Smith, Cambridge University Press.
13. Telescopes and Techniques, C.R. Kitchin , Springer
14. Observational Astronomy, D.S. Binney, G. Gonzalez, and D. Oesper, Cambridge University Press

DSE – 3: Astronomy and Astrophysics–I Lab
Course Code: PPPCLD2 **Credit: 2 (0+0+2)**
Name of the experiments
1. Study of Quasar
2. Study of the Orbit of a visual Binary Star
3. Determine the mass of Saturn and its rotational velocity
4. Verification of Hubble's law and determination of Hubble's constant and age of the Universe
5. Study of light curves of Cepheid variable stars
6. Study of proper motion of stars
7. Determination of period and distance of pulsar
8. Photoelectric photometry of Pleiades star cluster
9. Study of expansion of the universe and calculate the age of universe using computer program CLEA
10. Determine the distance of small Magellanic Cloud (SMC) using Period-Luminosity Relation of Cepheid Variable star

DSE – 3: iv. Molecular Spectroscopy–I **Credit: (3+0+0)**
Course Code: PPPCTD2
Course Objectives
- To provide theoretical basis of molecular states (Rotational, vibrational and electronic) and their interaction
- Interpretation of rotational, vibrational and electronic spectra of molecules
- Techniques for calculating the electronic wave functions of molecules
- Measuring the vibrational spectra (FT-IR, Raman) and their applications in understanding molecular structure and intermolecular interaction, structural-spectral correlations
- Measuring electronic spectra (UV-VIS) and its spectral analysis and applications

Unit – I: Classification of molecule: Linear, Symmetric top, Asymmetric top and Spherical top; Rotational Energy of Spherical, Prolate and Oblate Symmetric Rotors, Rotational Raman Spectra; Parallel and Perpendicular type Bands in Linear and symmetric Rotor Molecules. Qualitative description of Type A, B and C bands in Asymmetric Rotor Molecules.

Unit – II: Molecular orbitals, Separation of electronic and nuclear wavefunctions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, Coulomb, Exchange and Overlap integral, Symmetries of electronic wavefunctions; Shapes of molecular orbital; σ and π bond; Term symbol for simple molecules.

Unit – III: UV-visible absorption spectroscopy: Principle, Lambert-Beer's law, Absorption law, Deviation from Beer's law, Instrumentation. Single beam and split beam instruments. Quantitative & Quantitative and Analysis of absorption spectra, Molecular transitions, Luminescence spectroscopy (fluorescence, phosphorescence, chemiluminescence)

Unit – IV: Infrared Spectroscopy: Theory and Instrumentation of dispersive and FT-IR spectroscopy, Raman Spectroscopy: Theory and Instrumentation; Spectra-Structure Correlations in Raman Spectroscopy; Electron Spin Resonance (ESR) Spectroscopy; Nuclear Magnetic Resonance (NMR) spectroscopy, Chemical shift; shielding and DE shielding of protons, Nuclear spin-spin interaction.

Reference Books:

1. Fundamentals of Molecular Spectroscopy: C.N. Banwell.
2. Molecular Spectra and Molecular Structure-III Electronic Spectra and Electronic structure of polyatomic Molecules: G. Herzberg.
3. Modern Spectroscopy: J.M. Hollas.
4. Introduction to Molecular Spectroscopy: G.M. Barrow.
5. Chemical Applications of Group Theory: F.A. Cotton.

DSE – 3: v. Material Science –I **Credit: (3+0+0)**
Course Code: PPPCTD2

Course Objectives:
The course aims to develop an understanding of:
- The basic principles, theory and experimental details for understanding the structure, properties and applications of materials.
- Defects, diffusion and phase transitions in solids and how these affect the properties.
- Also gives an overview of various methods for the synthesis of single crystals, thin films and nanomaterials.

Course Outcome:
At the end of the course, students will be able to understand:
- The structure property relationship of solid-state materials.
- Learned about different types of advanced materials, its synthesis and properties.

Unit – I: Uniary and Binary phase diagrams (water, Iron, Lead-tin and Iron-carbon phase diagram), Lever rule, homogeneous and heterogeneous nucleation, growth and transformation kinetics, micro-structural changes during cooling and heating.

Unit – II: Preparation of bulk, thin film and nano-materials: solid state reactions method, sol-gel method, precipitation method, nanomaterials: Bottom up method, Top down method, lithography, advantages and disadvantages of various synthesis methods.

Unit – III: Polymers, mechanism of polymerization, Molecular weight distribution in linear polymers, condensation. Polymers, size distribution in polymer molecules, Effect of polymer structure on properties, conducting polymer,

Unit – IV: Ferroelectric materials, important characteristics and applications of ferro-electric materials, para, ferro, anti-ferro magnetic properties of materials, hysteresis losses, hard and soft magnetic materials, structure and properties of spinals, garnets and hexagonal ferrites and their uses..

References:
1. Materials Science &Engineering: V. Raghavan
2. Elements of materials science &Engineering: L.H. Van
3. The Structure and properties of materials: R.M. Rose & J. Wulff
4. KP Jain, Physics of semiconductor nanostructures, Narosa Publishing House.
5. G. Cao, Nanostructures and nanomaterials: synthesis, properties and applications, Imperial College Press.

DSE – 3: vi. Accelerator Physics–I **Credit: (3+0+0)**
Course Code: PPPCTD2
Course Objective

The course aims to develop an understanding of:
- This course will give knowledge to the students about the fundamentals of accelerators and different type of accelerator.
- This course will help the students to understand the different ion sources and their applications.

- This course will help the students to understand the beam optics, beam transport and beam line components.

Learning Outcome

Upon successful completion of this course, students will be able to address following points:

- The students will have understanding about the fundamentals of accelerators and different type of accelerator.
- The students will be able explain different ion sources and their applications.
- The students to will be able to demonstrate the beam optics, beam transport and beam line components.

Unit – I: Some Basics of Accelerator: History of Accelerators, Livingston plots, Fundamental concepts of Accelerator, Motion of charge particle in electric and magnetic field, Achievements of Accelerators, Brief descriptions of Accelerators centers worldwide, Accelerator Centers in India, Applications of accelerators in medical science, semiconductors, industry, food sterilization etc.

Unit – II: Accelerators: Electrostatic accelerators: DC Accelerators, Cockcroft-Walton Accelerator, Van-de-Graaff Accelerator, Principle of Tandem Accelerator, Tandem Pelletron Accelerator,IUAC tandem pelletron Accelerator, GGV Tandem Pelletron Accelerator

Pulsed Accelerators: Cyclotron accelerator, SynchrotronAccelerators and RRCAT Indore synchrotron,Concept of synchrotron radiation in linear and circular accelerator, Betatron Accelerator, Radio frequency (RF) accelerators: Linear Accelerators (LINAC); Physics of Collision and concept of Storage Rings.

Unit – III: Ion Sources: Production of charged particles, impact ionization,I-V characteristics of electrical discharge, Extraction & focusing geometries, positive and negative ion sources, radio frequency (RF) ion sources, penning ionization source, plasmatron&duo-plasmatron, ECR source, TORVIS, sputter ion source: SNICS and MC-SNICS.

Unit – IV: Beam Optics & Beam Transport: Motion of charged particles in electric and magnetic Felds; Electric rigidity, Magnetic Rigidity, Beam and beam emittance, focusing devices: Magnetic Dipole, Einzel lens, Magnetic and Electrostatic steerer, Electrostatic Raster Scanner, solenoid, Magnetic and Electrostatic quadrupole, quadrupole matrix, Beam Line component: Beam profile monitor, Faraday cup, slit.

Reference Book

1. Accelerator Physics, S.Y. Lee, World Scientific, Singapore, 1999
2. Principles of Cyclic Particle Accelerators, J.J. Livingood, D. Van Nostrand Co. 1961
3. The physics of particle accelerators: an introduction by Klaus Wille, Oxford Press USA, 2000.
4. Particle Accelerators, J.P. Blewett, McGraw Hill Book Co.
5. Particle Accelerator physics by H. Wiedemann, Springer, Year: 2007

DSE – 3: Respective Discipline Specific elective Lab – 3 **Credit: 2 (0+0+2)**
Course Code: PPPCLD2

Semester – IV

Core–9: Atomic and Molecular Physics **Credit: 5 (4+1+0)**
Course Code: PPPDTT1
Course Objectives:

The course aims to develop

- An understanding of Vector atom model and Coupling Schemes
- Ability to understand the splitting of spectral lines and understanding the phenomenon related to the application of electric and magnetic field.
- Understanding the different molecular spectra and deeper understanding of branches.
- Ability to Understand Raman phenomenon and its versatile applications
- Understanding of different molecular states

Learning Outcomes:

At the end of this course student will demonstrate the ability to:

- Understand the classical and quantum mechanical description of the atomic structure and related phenomena. Vector atom model and coupling of spin and angular momenta.
- Understand the origin of different spectra of alkali materials, Coupling schemes, Breit scheme, and splitting of energy levels for lighter and heavy atoms.
- Understand the origin of different molecular spectra. Molecular symmetry, vibrational and rotational spectra and phenomena related to it.
- Understand the relations and connections between vibrational spectra.(such as IR and Raman) and symmetry of polyatomic molecules along with their electronic structure.
- Apply the knowledge of molecular states to explain the molecular spectra.

Unit – I: Quantum state of one electron atoms, Atomic orbits, Hydrogen spectrum Pauli's principle, Spectra of alkali elements, Spin orbit interaction and fine structure in alkali spectra. Selection rules, concept of parity. Quantum mechanical description of Helium atom.

Unit – II: Equivalent and non-equivalent electrons, normal and anomalous Zeeman effect, Paschen Back effect, Stark effect. Multi electron atom. Interaction energy in LS and JJ coupling. Hyperfine structure of Spectral lines. X-Ray Spectra, Line broadening mechanisms.

Unit – III: Type of molecules-Diatomic linear symmetric top, asymmetric top and spherical top molecules, Rotational spectra of diatomic molecules as a rigid rotor, Energy levels and spectra of non rigid rotor-intensity of rotational lines. Vibration energy of diatomic molecule –PQR branches, IR spectrometer (qualitative). General idea of IR and Raman spectroscopy, analysis of simple diatomic molecules, Intensities of vibrational lines. Selection rules.

Unit – IV: Electronic Spectra: Franck-Condon Principle, Electronic band spectra in absorption, Rotational structure of electronic bands, Molecular electronic states, Forbideden transitions in molecular spectra, Determination of Molecular states.

Reference Books:

1. Introduction to atomic spectra-H.E.White
2. Fundamentals of molecular spectroscopy-C.B.Benwell
3. Spectroscopy Vol. I II III- Walker & Straughen
4. Introduction of molecular spectroscopy- G.M.Barrow
5. Spectra of diatomic molecules –Herzberg
6. Molecular spectroscopy Jeanne L Michele
7. Modern spectroscopy –J.M.Holias
8. Molecular spectroscopy –J.M.Brown
9. Spectra of atoms and molecules -P.F.Bernath

Core–10: Electrodynamics **Credit: 5 (4+1+0)**
Course Code: PPPDTT2
Course Objective:

- To study basics law of electromagnetic field, Maxwell's equations and electromagnetic boundary conditions.
- To study dielectric and polarizations and its theory.
- To study Electromagnetic wave in Matter, Propagation in linear media, reflection and transmission at normal incident, and oblique incidence.
- To study wave Guide, Coulomb and Lorentz Gauge.
- To study the laws of electrodynamics under relativistic motion and the concept, and principle of electromagnetic radiation.

Course outcome:

After completion of this course, the students will be able to:

- Explain basic law of Electrodynamics, Maxwell's equations in matter and Poynting's theorem.
- Explain laws of reflection, refraction as outcomes of electromagnetic boundary condition
- Understand the idea of electromagnetic wave propagation through waveguides and transmission lines.

- Express the laws of electrodynamics under relativistic methods and the concept and principle of electromagnetic radiation.

Unit – I: Electromagnetic field:Motion of charged particle in electromagnetic field, Uniform E and B fields, Nonuniform fields, Diffusion across magnetic fields, Time varying E and B fields, Adiabatic invariants, First, second and third adiabatic invariant.
Electromotive force and Electromagnetic induction: Poynting's theorem, Wave equations for electric and magnetic fields and their solutions.

Unit – II: Relativistic Electrodynamics: Four-vector and Lorentz transformation in four dimensional space, Proper time and Proper Velocity, Relativistic energy and Momentum, relativistic Kinematics, Magnetism as Relativistic phenomenon, Relativistic Potentials, electromagnetic field tensor in four dimensions and Maxwell's equations, Dual field tensor.
Potentials and Fields: Vector and scalar potential, Retarded potential, LienardWienchert Potential,Gauge Transformation, Coulomb and Lorentz Gauge.

Unit – III: Electromagnetic Wave: Electromagnetic wave in matter, Propagation in linear media, Reflection and Transmission at Normal incident and Oblique incidence, Electromagnetic Waves in conductors, Skin depth, relative directions, phase of E and H in conducting medium. Boundary conditions on the field at interface of two media, Frequency dependence of Permittivity, introduction of Wave Guide.

Unit – IV: Electric Fields in Matter: Dielectric materials, Polarization, Electric field of a polarized material, Bound charges, Gauss's law in dielectric materials, Linear dielectric materials, Boundary conditions at the interface of two dielectrics. **Radiations**: Dipole radiation, Electric and Magnetic dipole radiation, Radiation from arbitrary source, angular distribution of power radiated, Bremsstralung, Introduction of matter radiation interaction.

Reference Books:

1. Classical Electrodynamics, J. D. Jackson, (John Wiley).
2. Introduction to electrodynamics, D. J. Griffiths,
3. Classical theory of fields, L. D. Landau and E. M. Lifshitz, (Addison-Wesley).
4. Electrodynamics of continuous media, L. D. Landau and E. M. Lifshitz, (AddisonWesley).
5. Electrodynamics, A. Somerfield, (Academic Press, Freeman and Co.).
6. Classical Electricity and Magnetism, W.K.H. Panofsky and M. Phillips: (AddisonWesley).
7. Feynman Lectures Vol. II.
8. Berkeley Series Volume II.
9. Electricity and Magnetism, Reitz, Milford, Christy
10. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa)

DSE – 4: i. Advanced Condensed Matter Physics–II **Credit: 3 (3+0+0)**
Course Code: PPPDTD1
Course Objectives:
The course aims to develop an understanding of:
- Understanding of various methods of density functional theory
- Super conductivity and its applications be understood.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:
- Advanced concepts condensed matter physics be cleared
- Advanced device applications may be derived

Unit – I: Electrons in a periodic lattice: the tight-binding method, elementary ideas of cellular, APW, OPW and pseudo potential methods of calculating band structures.

Unit – II: Many electron interactions: Hartree and Hartree-Fock approximations, self-consistent field method, correlation energy, dielectric screening, dielectric function of an electron gas, random phase approximation.

Unit – III: Electron-electron interaction: quasi-particle, Landau's Fermi liquid theory, Meissner effect, London equations, coherence length, Cooper pair, BCS theory of superconductivity, concept of Ginzburg-Landau theory.

Unit – IV: Electron-photon interaction: polarons, transport phenomena, Onsager relations, Boltzmann transport equations and its linearization, relaxation time approximation, application to lattice and electronic conduction in insulators and metals.

Reference Books:

1. Madelung : Introduction to solid state theory
2. Huang : Theoretical solid state physics
3. Charles Kittel : Quantum Theory of Solids, 2nd Revised Edition ,Wiley
4. Verma & Srivastave : Crystallogrphy for solid state physics
5. Charles Kittel : Solid state physics, Wiley
6. Aschroft & Mermin : Solid State Physics,
7. M A Wahab: Solid State Physics
8. Omar: Elementary Solid State physics

DSE – 4: ii. Advanced Nuclear Physics – II **Credit: (3+0+0)**
Course Code: PPPDTD1
Course Objectives:
The course aims to develop an understanding of:

- To develop deep understanding about nuclear reactions
- To develop the understanding of nuclear instrumentations and learn basic electrons involved in the experiments.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- Perform the experiments with basic understanding of nuclear instrumentation.
- Details of nuclear reaction theory to understand the exciting nuclear structure

Unit – I: Nuclear Reactions: Classification of nuclear reactions, Direct and Compound nuclear reaction mechanisms, Discussion of Compound nucleus model, Resonance, level density, decay, cross-section, entrance channel effect, Statistical model, Pre-equilibrium model, Direct reactions: elastic and inelastic scattering, examples of direct reactions, nuclear spectroscopy from direct reactions. Concept of Optical Model, Rearrangement collision: DWBA approach.

Unit – II: Heavy ion induced nuclear reactions: Heavy ion reactions (Semiclassical approach), Elastic scattering, Coulomb excitation, Deep inelastic collisions, Fusion, Fission, Coulomb excitation and its applications. Spontaneous fission, Mass energy distribution of fission fragments.

Unit – III: Measurements Techniques: Interaction of charged particles and radiation with matter, Simplified detector model , Detection technique, detector characteristics (sensitivity, response, efficiency, dead time), Ionizing Radiations, gas detectors, Scintillation counters **:** Organic and inorganic scintillators **-** Theory, characteristics and detection efficiency Solid state detectors: semiconductor detectors, surface barrier detectors, experimental techniques in particle and gamma ray spectroscopy, gamma detector arrays, coincidence method.

Unit – IV: Nuclear Electronics and Statistics: Analog and digital pulses, Signal pulses, Transient effects in an R-C Circuit, Pulse shaping, Linear amplifiers, Pulse height discriminators, General characteristics of single & multi-channel methods, Introduction to data acquisition system (MCA,CAMAC and VME). Statistics of counting, Poisson and Gaussian distribution, statistical quality of data, chi-square test.

Reference books:

1. Introducing Nuclear Physics by K. S. Krane (Wiley India., 2008) .

2. Introductory Nuclear Physics S. M. Wong (Wiley-VCH Verlag GmbH & Co. KGaA)
3. Nuclear Physics - Theory & Experiments by R.R. Roy &B.P.Nigarn (New Age lnternational, 2005)
4. Kaplan Irving, Nuclear Physics, Narosa Publishing House, (2000).
5. Introduction to nuclear reaction - Carlos Bertulani, Pawel Danielewicz
6. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
7. Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991)
8. Techniques for Nuclear and Particle Physics Experiments. W.R. Leo, (Springer- Verlag,1993)

DSE – 4: iii. Astronomy and Astrophysics– II **Credit: (3+0+0)**
Course Code: PPPDTD1
Course Objectives:
The course aims to develop an understanding of:

- The type of waves and various phenomenon of optics.
- The superposition of waves, progressive and stationary waves, optical phenomenon based on superposition of waves such as Interference and Diffraction.

Learning Outcomes:
Upon successful completion of this course, students will be able to address following points:

- The basic quantities used in astronomy such as coordinates, Stellar Distance, magnitude, and Stellar Luminosity etc. and measurement techniques of astrophysical quantities as well as spectral classification of stars.
- Formation and Evolution of Star and the fate of low and high mass stars, as well as the physics of white dwarfs, neutron starts, pulsars and black holes.
- Binary Stars and Star Clusters, as well as their Classifications.
- The workings of astronomical instruments as well as their use.

Unit – I: Variable Stars: Classification of Variable Stars, Cepheid Variables, Period-Luminosity Relations of Cepheid Variables, RV Tauri Variables, Mira Variables, Red Irregular and Semi-regular Variables, Beta Canis Major Variables, U Geminorum and Flare Stars, Pulsation theory of Variable Stars.

Unit – II: Milkyway Galaxy and Normal Galaxies: The Milkyway Galaxy: Structure of the Milkyway, Oort's Theory of Galactic Rotation, Dynamics of the Spiral Arms, Distribution of Interstellar matter, Central regions of the Milkyway. Normal Galaxies: Classification of galaxies, Hubble Sequence: Elliptical, Lenticulars and Spiral Galaxies, and Their Properties, Distribution of Light and Mass in Galaxies, Brightness Profiles, Distribution of Gas and Dust in Galaxies.

Unit – III: Active galaxies: Active Galactic Nuclei (AGNs), Seyfert galaxies, BL Lac Objects, LINERs, and Radio Galaxies: General Properties, Superluminal motion, Quasars: Properties and Energy Requirements, Nature of Quasar redshifts, Supermassive Black Hole Model and Unified model of AGNs.

Unit – IV: Cosmology: Cosmology: Cosmological Principle, Robertson-Walker Line Element, Cosmological Red shift, Hubble's Law, Models of the Universe, Friedman Models, Density Evolution, Critical Density, Models with the Cosmological Constant, Observable Quantities – Luminosity and Angular Diameter Distances, Red shift- Magnitude Relation, Steady State Cosmology.
Relics of the Big Bang, Early Universe, Thermodynamics of the Early Universe, Primordial Neutrinos, Helium Synthesis and Other Nuclei, Cosmic Microwave Background (CMB).

Reference Books:

1. Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Addison-Wealey publishing Co.
2. The Physical Universe: An Introduction to Astronomy, F. Shu, Mill Valley: University Science Books.
3. Universe, R.A. Freedman and W.J. Kaufmann, W.H. Freeman & Co
4. Fundamental of Astronomy, H. Karttunen et al., Springer
5. The Physics of Stars, A.C. Phillips, John Wiley & Sons, Ltd.
6. An Introduction to Astrophysics, Baidyanath Basu, Prentice Hall of India.
7. Textbook of Astronomy and Astrophysics with Elements of Cosmology, V.B. Bhatia, New Delhi, Narosa Publishing House.
8. Theoretical Astrophysics, Vol. I: Astrophysical processes T. Padmanabhan, Cambridge University

Press.
9. Theoretical Astrophysics, Vol. – II: Stars and Stellar Systems, T. Padmanabhan, Cambridge University Press.
10. Theoretical Astrophysics, Vol. – III: Galaxies and Cosmology, T. Padmanabhan, Cambridge University Press.
11. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th edition, Saunders College Publishing.
12. The New Cosmos, A. Unsold and B. Baschek, Newyork, Springer Velas.
13. Galactic Astronomy, J. Binney and M. Merrifield, Princeton University Press.
14. Galactic Dynamics, J. Binney and S. Tremaine, Princeton University Press.
15. An Introduction to Active Galactic Nuclei, B.M. Peterson, Cambridge University Press.
16. Quasars and Active Galactic Nuclei, A.K. Kembhavi and J.V. Narlikar, Cambridge University Press.
17. Introduction to Cosmology, J. V. Narlikar, 3 rd edition, Cambridge University Press.
18. General relativity and Cosmology, J. V. Narlikar-Delhi: Macmillan Company of India Ltd.
19. Structure Formation in the Universe, T. Padmanbhan, Cambridge University Press.

DSE – 4: Astronomy and Astrophysics–II Lab
Course Code: PPPDLD1 **Credit: 2 (0+0+2)**
Name of the experiments
1. Study of Quasar
2. Study of the Orbit of a visual Binary Star
3. Determine the mass of Saturn and its rotational velocity
4. Verification of Hubble's law and determination of Hubble's constant and age of the Universe
5. Study of light curves of Cepheid variable stars
6. Study of proper motion of stars
7. Determination of period and distance of pulsar
8. Photoelectric photometry of Pleiades star cluster
9. Study of expansion of the universe and calculate the age of universe using computer program CLEA
10. Determine the distance of small Magellanic Cloud (SMC) using Period-Luminosity Relation of Cepheid Variable star

DSE – 4: iv. Molecular Spectroscopy– II **Credit: (3+0+0)**
Course Code: PPPDTD1

Unit – I: Properties of Laser Beams; Pumping Schemes; Threshold pump power, Optical resonators, Stability of resonators, Role of Plane and Confocal cavity resonators, Mode selection, Generation of Ultra short Pulses; Characteristics of Gaussian beam, Transverse and longitudinal modes, mode selection, losses in a resonator, mirror mounts, optical coating etc., Q-switching and Mode locking;

Unit – II: Types of Lasers: Solid-State, Dye, and Semiconductor Lasers; Laser Tuning; Reasons for Multimode Oscillation; Single-Mode Selection; Non-linear polarization of lasers and some applications: Second harmonic generation using non-linear optical methods.

Unit – III: Spectrograph and Monochromator, Interferometer, Comparisons between spectrometers and Interferometers; Detectors: Photomultiplier tube (PMT), Charge coupled detectors (CCD), Thermal detectors; Dispersion and Resolving power of prism and gating instruments;

Unit – IV: Non-linear Spectroscopy: linear and non-linear absorption; Two photon absorption, Stimulated Raman Scattering; Coherent Anti-Stokes Raman Scattering Special Techniques: Resonance Raman Spectroscopy; Surface Enhanced Raman Spectroscopy; Time-resolved Raman Spectroscopy.

Reference Books:
1. Laser Theory and Applications: K. Thyagarajan and A.K. Ghatak
2. Principles of Lasers : O. Svelto.
3. Laser Spectroscopy and Instrumentation : W. Demtroder.
4. Laser Material Processing : William M. Steen
5. Modern Spectroscopy, J. M. Hollas

6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E.M. Mc Cash,
7. Advances in Laser spectroscopy: Edited by F.T.Arecchi 8. Laser Applications: Monte Ross

DSE – 4: v. Material Science – II **Credit: (3+0+0)**
Course Code: PPPDTD1
The course aims to develop an understanding of:
- Student will gain knowledge about the advanced materials and classifications.
- This paper will help students to understand various Material characterization techniques.

Learning Outcome
Upon successful completion of this course, students will be able to address following points:
- The students will understand the basics of ion-solid interactions.
- The student will be able to understand various Materials Characterization techniques.
- The students will understand various thermal analysis.

Unit – I:: Elementary idea of Advanced materials: General features and classifications, Structure models for amorphous materials, Structure and properties of metallic glass and amorphous semiconductors, Quasicrystal line materials, Materials for solar cell applications, Hydride materials (Hydrogen storage materials), Materials for Sensors and transducers application

Unit – II: Materials Characterization techniques: X- ray diffraction methods for materials characterization, powder diffraction methods, Indexing of powder diffraction patterns, Determination of particle size, Increase in x-ray diffraction peaks of nanoparticles, Shift in photo luminescence peaks, Raman and FTIR spectroscopy of materials, Photoemission microscopy

Unit – III: Light / Optical Microscopy: Optical microscope- Basic principles & components, Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast, Polarised light, Hot stage, Interference techniques), Electron Microscope and its applications in materials characterisation.Principle of Scanning Electron Microscope, study of microstructure, determination of grain size etc, Advantages of Neutron diffraction.

Unit – IV: Thermal Analysis: Thermal analysis, Thermogravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry, Thermomechanical analysis and dilatometry,

Reference Books:
1. Introduction to solid state physics : C.Kittel
2. Superconductivity Today : T.V. Ramkr ishnan and C.V. R.R
3. Raghvan, V., Materials Science & Engineering, PHI (1998).
4. Callister, W.D., Materials Science & Engineering: An Introduction, Wiley & Sons (2001).
5. Smith, W., Principles of Materials Science and Engineering., McGraw Hill (1990).
6. Cao, G., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Emperial College Press (2004).

DSE – 4: vi. Accelerator Physics– II **Credit: (3+0+0)**
Course Code: PPPDTD1
Course Objective

The course aims to develop an understanding of:
- This course will help to know about the ion-solid interactions and its consequences.
- Student will gain knowledge about the use of ion beam induced materials modification, materials synthesis, synthesis of nanostructures and nanopatterns.
- This paper will help students to understand various nuclear/ion beam analysis techniques.
- This paper will be useful to the students to understand heavy ion nuclear reactions.

Learning Outcome
Upon successful completion of this course, students will be able to address following points:
- The students will understand the basics of ion-solid interactions.
- The student will be able design different experiments using ion beam.

- The students will understand various nuclear/ion beam analysis techniques.
- The students will understand heavy ion nuclear reactions.

Unit – I: Ion-Solid Interaction: Interaction of an energetic charged particle with a free electron gas, ion-solid interaction, and Energy loss process: nuclear stopping and electronic stopping, Synergic Effects of nuclear and electronic energy Loss, Coulomb explosion, Thermal spike, and pressure spike models, Range of ions, energy and range straggling, Basic ion beam simulation programs, SRIM & TRIM, limitations and modifications, stopping and range of ions in matter by Monte-Carlo methods,

Unit – II: Materials Modification with Ion Beam: Ion implantation, Ion Irradiation, radiation damage and structural change; Ion sputtering, phase transformations; Ion beam mixing, impurity incorporation; Synthesis of nanostructured materials under electronic excitation, Ion induced crystallizations and epitaxial crystallization, ion induced structural phase transitions, buried layers, Ion induced surface nano-structuring, nanostructures using self-organization

Unit – III: Nuclear Techniques/Ion Beam Analysis Techniques: Applications of Accelerator: Trace element analysis: various methods, Rutherford Backscattering Spectrometry (RB)S, RBS-channeling, Elastic Recoil Detection Analysis (ERDA), Particle Induced X-ray emission (PIXE), Nuclear Reaction Analysis (NRA), Particle Induced g-ray Emission (PIGE), Neutron Activation Analysis (NAA) technique, Accelerator Mass Spectrometry (AMS).

Unit – IV: Heavy Ion Nuclear Reactions: Special features of heavy ions scattering (Q-and L-window), semi classical models, deflection functions, rainbow and Glory scattering, quasi elastic and transfer reactions, deep inelastic scattering, complete and incomplete fusion, fission

Reference Book:

1. Ion Implantation and Synthesis of Material, M Nastasi and J W Mayer, Springer 2006.
2. Techniques for Nuclear and Particle Physics Experiment by W.R. Leo
3. Ion-Solid Interaction: Fundamentals & Applications By M. Nastasi, J.W. Mayer & J.K. Hirvonen.
4. Nano Fabrication by Ion Beam Sputtering, T Som and D Kanjilal.
5. Swift heavy ions for materials engineering and nanostructuring, D.K. Avasthi and G.K. Mehta, Capital publishing company, New Delhi (2011).
6. Material Science with Ion Beam, Harry Bernas, Springer 2010.

DSE – 4: Respective Discipline Specific elective Lab – 4
Course Code: PPPDLD1 **Credit: 2 (0+0+2)**