FYUGP/FYIMP Physics Department

Program Outcome (PO)

On completion of the program, the students will acquire a strong foundation in theoretical and experimental physics. The students will develop practical skills through laboratory work and gain exposure to research methodologies through project dissertation and internships.

Program Specific Outcome (PSO)

After completion of the program, the students will be able to opt for teaching, entrepreneurship, research and higher studies in the frontiers of physics, R & D activities in defense, space, aeronautics and information technology in national and international organizations.

Programme name	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						Lecture	Tutorial	Practical			
FYUGP in Physics (Major/ Minor/Common courses)	10+2 or equivalent passed with pass mark in physics and mathematics	1	Mathematical Physics & Mechanics **Major 1 & Minor 1**	PHY0100104	4	3	-	1		30	70
		2	Mathematical Physics & Electricity and Magnetism **Major 2 & Minor 2**	PHY0200104	4	3	-	1	Physics at Higher Secondary Level	30	70
		3	Waves and Optics **Major 3 & Minor 3**	PHY0300104	4	3	-	1		30	70

			Electromagnetic Theory **Major 4**	PHY 0300204	4	3	-	1		30	70
		4***	Classical Mechanics **Major 5**	PHY 0400104	4	3	1	-		40	60
			Quantum Mechanics-I **Major 6**	PHY 0400204	4	3	-	1		30	70
			Analog Electronics **Major 7 & Minor 4**	PHY 0400304	4	3	-	1		30	70
			Mathematical Physics **Major 8**	PHY 0400404	4	3	-	1	Mathematical Physics in SEM I and II	30	70
		5***	Atomic and Molecular Physics **Major 9**	PHY 0500104	4	3	1	-	Quantum Mechanics-I in SEM IV	40	60
			Condensed Matter Physics **Major 10**	PHY 0500204	4	3	-	1		30	70
			Heats & Thermodynamics **Major 11 & Minor 5**	PHY 0500304	4	3	-	1		30	70

		6***	Nuclear & Particle Physics **Major 12**	PHY 06001 04	4	3	1	-		40	60
			Digital Electronics **Major 13 & Minor 6**	PHY 06002 04	4	3	-	1		30	70
			Astronomy & Astrophysics **Major 14**	PHY 06003 04	4	3	1	-		40	60
			Statistical Mechanics **Major 15**	PHY 06004 04	4	3	1	-	Must have studied Heat & Thermodynamics (or thermal physics) and Quantum Mechanics	40	60

***Please indicate the compulsory course for the students who took admission only with MINOR subjects. The FYUGP Curriculum and Credit Framework state that a student with MINOR subjects must complete 21 courses over a period of three years, with seven minor courses from each subject. This means a student with MINOR subjects must take two courses of a given subject either in the fourth, fifth, or sixth semesters. Therefore, **each department or centre must define the four required/compulsory courses during fourth to sixth semesters for students who have been admitted with MINOR subjects.**

Programme name (AEC/VAC/MDC/SEC)	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	Credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						L	T	P			
SEC	No	2	**Basic Workshop Skills in Physics and Electronics**		3	1	0	2		30	45

Template for Common courses

A. FYUGP in Physics with Honours

Programme name	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						Lecture	Tutorial	Practical			
FYUGP in Physics (	Physics as a MAJOR or MINOR	7	Classical Mechanics-II	PHY0700104	4	3	1	0		40	60
			Mathematical Physics-II	PHY0700204	4	3	1	0		40	60

Honours)	Subject upto 3rd Year		Quantum Mechanics-II	PHY070030 4	4	3	1	0		40	60
			Experimental Techniques	PHY070040 4	4	0	0	4		40	60
			Research Methodology-I	PHY070050 4	4	3	1	0		40	60
		8	Electrodynamics	PHY080010 4	4	3	1	0		40	60
			Choose any three from the following (Institutions will decide as per the availability of infrastructure) (i) Atomic & Molecular Physics	PHY080020 4	4	3	0	1		30	70
			(ii) Astrophysics & Cosmology	PHY080030 4	4	3	1	0		40	60
			(iii) Nuclear Physics	PHY080040 4	4	3	0	1		30	70
			(iv) Advanced Electronic	PHY080050 4	4	3	0	1		30	70
			(v) Advanced Condensed Matter Physics	PHY080060 4	4	3	0	1		30	70

			(vi) Particle Physics	PHY0800704	4	3	1	0		40	60
			(vii) Nanophysics	PHY0800804	4	3	1	0		40	60
			(viii) Plasma Physics-I	PHY0800904	4	3	1	0		40	60
			One seminar/project based course and presentation	PHY-Seminar	4						

B. FYUGP in Physics Honours with Research

Programme name	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						Lecture	Tutorial	Practical			
FYUGP in Physics (Honours with	Physics as a MAJOR or MINOR Subject	7	Classical Mechanics-II	PHY0700104	4	3	1	0		40	60
			Mathematical Physics-II	PHY0700204	4	3	1	0		40	60
			Quantum Mechanics-II	PHY0700304	4	3	1	0		40	60

research)	upto 3rd Year		Experimental Techniques	PHY0700404	4	0	0	4		40	60
			Research Methodology-I	PHY0700504	4	3	1	0		40	60
		8	Dissertation	PHY-Dissertation	16						
			One seminar/project based course and presentation	PHY-Seminar	4						

II. 1-year PG Programme: The programme is consists of three (3) curricular components which are mutually exclusive; (A) Research Components (B) Course work Components (C) Research and Course work components. A student can avail ONLY one component.

A. Research:

Semester	Course level	Course work (CORE*)	Research component/Project	Total Credits
9th	500	--	Dissertation phase 1	20
10th	500	--	Dissertation phase 2	20

OR

B. Course work:

Semester	Course level	Course work (CORE*)	Research component/Project	Total Credits
9th	500	5 courses with 4 credits each (5 X4=20)	--	20

10th	500	5 courses with 4 credits each (5 X4=20)	--	20

OR

C. Research and Course work:

Semester	Course level	Course work (CORE*)	Research component/Project	Total Credits
9th	500	5 courses with 4 credits each (5 X4=20)	--	20
10th	500	--	Dissertation of 20 credits	20

<u>One Year Postgraduate Programme</u>

<u>Subject: Physics</u>

Template for Physics <u>One Year Postgraduate Programme (Course Work)</u>

B. Course work:

Programme name	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						Lecture	Tutorial	Practical			
1-year PG Programme in Physics (Course Work)	FYUGP Physics (Honours or Honours with Research	9	Quantum Mechanics- III	PHY0900104	4	3	1	0		40	60
			Statistical Mechanics-II	PHY0900204	4	3	1	0		40	60
			Computational Physics	PHY0900304	4	2	0	2		40	60
			Elective A (Any one) (i) Quantum Field Theory and Gauge Theories	PHY0900404	4	3	1	0		40	60
			(ii) Electronics-I	PHY0900504	4	3	1	0		40	60
			(iii) Laser and Spectroscopy-I	PHY0900604	4	3	1	0		40	60
			(iv) Plasma Physics-II	PHY0900704	4	3	1	0		40	60

			Elective B (Any one)								
			(i) Nuclear Physics-I	PHY0900804	4	3	1	0		40	60
			(ii) Condensed Matter Physics-I	PHY0900904	4	3	1	0		40	60
			(iii) Nanophysics-I	PHY0901004	4	3	1	0		40	60
			(iv) Astronomy & Astrophysics-I	PHY0901104	4	3	1	0		40	60
		10	Research Methodology-II	PHY1000104	4	3	1	0		40	60
			Elective A (any one)								
			(i) Interactions at High Energy	PHY1000204	4	3	1	0		40	60
			(ii) Electronics-II	PHY1000304	4	3	1	0		40	60
			(iii) Laser and Spectroscopy-II	PHY1000404	4	3	1	0		40	60
			(iv) Plasma Physics-III	PHY1000504	4	3	1	0		40	60
			Elective B (any one)								
			(i) Nuclear Physics-II	PHY1000604	4	3	1	0		40	60
			(ii) Condensed Matter Physics-II	PHY1000704	4	3	1	0		40	60

			(iii) Nanophysics-II	PHY1000804	4	3	1	0		40	60
			(iv) Astronomy & Astrophysics-II	PHY1000904	4	3	1	0		40	60
			Laboratory for Elective A/Mathematical Physics (i) Mathematical Physics (In lieu of Laboratory elective A)	PHY1001004	4	3	1	0		40	60
			(ii) Electronics-II Laboratory	PHY1001104	4	0	0	4		40	60
			(iii) Laser and Spectroscopy Laboratory	PHY1001204	4	0	0	4		40	60
			Laboratory for Elective B (i) Nuclear Physics Laboratory	PHY1001304	4	0	0	4		40	60
			(ii) Condensed Matter Physics Laboratory	PHY1001404	4	0	0	4		40	60
			(iii) Nanophysics Laboratory	PHY1001504	4	0	0	4		40	60
			(iv) Astro Lab	PHY1001604	4	0	0	4		40	60

One Year Postgraduate Programme

Subject: Physics

Template for Physics One Year Postgraduate Programme (Research and Course Work)

C. Research and Course work

Programme name	Eligibility Criteria of the programme, if any	Semester	Course name	Course code	credits	Credit distribution of the course			Pre-requisite of the course (if any)	Internal marks	External Marks
						Lecture	Tutorial	Practical			
1-year PG Programme in Physics (Research and course work)	FYUGP Physics (Honours or Honours with Research	9	Quantum Mechanics- III	PHY0900104	4	3	1	0		40	60
			Statistical Mechanics-II	PHY0900204	4	3	1	0		40	60
			Elective A (Any one) (i) Quantum Field Theory and Gauge Theories	PHY0900404	4	3	1	0		40	60
			(ii) Electronics-I	PHY0900504	4	3	1	0		40	60
				PHY0900604	4	3	1	0		40	60

			(iii) Laser and Spectroscopy-I (iv) Plasma Physics-II	PHY0 90070 4	4	3	1	0		40	60
			Elective B (Any one) (i) Nuclear Physics-I	PHY0 90080 4	4	3	1	0		40	60
			(ii) Condensed Matter Physics-I	PHY0 90090 4	4	3	1	0		40	60
			(iii) Nanophysics-I	PHY0 90100 4	4	3	1	0		40	60
			(iv) Astronomy & Astrophysics-I	PHY0 90110 4	4	3	1	0		40	60
			Dissertation-I	PHY-Dissertation-I	4						
		10	Dissertation-II	PHY-Dissertation-II	20						

Four Year Undergraduate Course in Physics
Semester-I
Paper Name: Mathematical Physics & Mechanics
Paper Code= PHY0100104
Total number of lectures= 45
Total credit = 4 (Theory 3 +Laboratory 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcomes:

CO 1: Recognise physical problems where mathematical methods are used.

CO 2: Interpret the results of calculation.

CO 3: Solve problems in mechanics with the help of mathematical frameworks

CO 4: Integrate different mathematical concepts to understand dynamics of particles.

CO 5: Test applicability of mechanics to realise physical problems.

Part A
Mathematical Physics (Credit=1; Lectures=15)

Unit–I: Vector calculus(L=8)

Scalar and vector fields. Derivatives of vector functions (physical examples - velocity, centripetal acceleration of a point in circular motion). Directional derivative. Gradient of a scalar field (example of Newton's gravitational force as gradient of a scalar potential). Gradient as normal vector to a surface. Divergence and curl of a vector field- solenoidal and irrotational vector fields. Laplacian operator (physical problems –Laplacian of gravitational potential, divergence of central force). Vector identities.

Vector integration- Line integral (physical example- work done by a force, path dependence/independence and concept of conservative force). Surface and volume integrals. Concept of vector flux. Gauss's divergence theorem and Stokes's theorem (statement only).

Unit– II: Curvilinear coordinates (L=5)

Introduction to curvilinear coordinates. Orthogonal curvilinear coordinates. Examples of spherical, cylindrical and plane polar coordinates. Line element- transformation from Cartesian to curvilinear coordinates (spherical and cylindrical). Gradient, divergence and curl in spherical and cylindrical coordinates.

Unit – III: Dirac delta function (L=2)

Definition and properties of Dirac delta function. Representation of delta function by Gaussian function, rectangular function and Laplacian of 1/r . 3 Dimensional delta function.

Part B
Mechanics (Credit=2; Lectures=30)

Unit–I: Reference frames (L=4)

Inertial frames. Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications.

Unit –II: Gravitation and central force motion (L=7)

Motion under central force. Two-body problem and its reduction to one body problem. Kepler's laws, Gravitational potential and fields due to spherical body. Gauss's law and Poisson's equation for gravitational field.

Unit –III: Conservation laws (L=4)

Dynamics of a system of particles. Centre of mass. Principle of conservation of momentum. Torque. Impulse.

Elastic and inelastic collisions between particles. Centre of mass and laboratory frames.

Unit–IV: Dynamics of rigid bodies (L=6)

Rigid body motion. Rotational motion. Moment of inertia of rectangular lamina, disc, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

Unit–V: Work and energy (L=3)

Work and kinetic energy theorem. Conservative and non-conservative forces. Potential energy. Force as gradient of potential energy. Work and potential energy. Work done by non-conservative forces.

Unit –VI: Oscillations (L=2)

Oscillation - differential equation of simple harmonic motion and its solution. Total energy of oscillation.

Unit –VII: Properties of matter (L=4)

Relation between elastic constants. Twisting torque on a cylinder or wire. Cantilever. Kinematics of moving fluids: Poiseuille's equation for flow of a liquid through a capillary tube.

Laboratory (Credit =1)

1. To study the motion of spring and calculate (a) spring constant and (b) rigidity modulus.
2. To determine the moment of inertia of a cylinder about two different axes of symmetry by torsional oscillation method.
3. To determine coefficient of viscosity of water by capillary flow method (Poiseuille's method).
4. To determine the Young's modulus of the material of a wire by Searle's apparatus.
5. To determine the modulus of rigidity of a wire (static method).
6. To determine the value of g using bar pendulum.
7. To determine the value of g using Kater's pendulum.
8. To determine the height of a building using a sextant.
9. To determine g and velocity for a freely falling body using digital timing technique.

References:

Essential Mathematical Methods for the Physical Sciences; K.F. Riley and M.P. Hobson, Cambridge University Press.

Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York).

Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.

Mathematical Physics-I, K. K Pathak and S. Parasher, Vishal Publication, Jalandhar (Delhi).

Theoretical Mechanics, M. R. Spiegel, Tata McGraw Hill.

Mechanics; D. S. Mathur, S. Chand & Company Limited.

An Introduction to Mechanics, D. Kleppner and R. J. Kolenkow, Tata McGraw-Hill.

Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al., Tata McGraw-Hill.

Physics, R. Resnick, D. Halliday and J. Walker, John Wiley & Sons.

Analytical Mechanics, G. R. Fowles and G. L. Cassiday, Cengage Learning.

Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton and M. Sands, Pearson Education.

University Physics, F. W. Sears, M. W. Zemansky and H.D Young, Addison Wesley

Physics for Scientists and Engineers with Modern Phys., J. W. Jewett and R. A. Serway, Cengage Learning.

Mechanics, D. Sarma and K. K Pathak, Vishal Publications, Jalandhar (Delhi).

Four Year Undergraduate Course in Physics
Semester - II
Paper Name: Mathematical Physics & Electricity and Magnetism
Paper Code: PHY0200104
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course outcome:

CO1: Recall fundamental concepts of differential equations, matrix properties, electric and magnetic fields, and electrical circuits, including key definitions, laws, and theorems.

CO2: Explain the physical principles behind differential equations, matrix applications, electrostatics, magnetostatics, and AC circuits with practical examples.

CO3: Solve problems related to the behaviour of systems governed by differential equations, electric and magnetic fields, and circuit theorems using appropriate mathematical tools.

CO4: Examine and differentiate the characteristics of physical systems such as LCR circuits, magnetic materials, and dielectric properties under varying conditions.

CO5: Design and perform laboratory experiments to measure physical quantities, verify theoretical principles, and interpret results to draw meaningful conclusions about electromagnetic systems and circuits

Part A
Mathematical Physics (Theory)
Credit = 1

Unit - I: Differential equations (Lectures - 10)

First and second order ordinary differential equations (ODE). Homogeneous and inhomogeneous differential equations. Solutions of first order ODE – integrating factors (physical examples – radioactive decay, Newton's law of cooling, particle falling under gravity through a resistive medium). Concept of initial/boundary conditions. Solutions of second order ODE with constant coefficients- complementary function and particular integral (physical examples- simple harmonic oscillation, forced vibration). Wronskian- definition and its use to check linear independence of 2^{nd} order homogeneous linear differential equation.

Partial differential equations (PDE) (physical examples – wave equation, diffusion equation, Laplace and Poisson equation – introduction only). Exact and inexact differentials. Concept of variable separation in a PDE.

Unit - II: Matrices (Lectures - 5)

Properties of matrices. Determinant and rank. Transpose and complex conjugate of matrices. Hermitian and anti-Hermitian matrices. Unitary and orthogonal matrices. Representation of linear homogeneous and inhomogeneous equations through matrix equation. Inverse of a matrix. Eigen values and eigen-vectors. Cayley-Hamilton Theorem (statement only), Diagonalisation of simple matrices.

Part B
Electricity and Magnetism (Theory)
Credit = 2

Unit - I: Electric field and electric potential (Lectures - 13)

Electrostatic field, electric flux. Gauss's law. Application of Gauss's law to charge distributions with planar, spherical and cylindrical symmetries. Conservative nature of electrostatic field. Electrostatic potential. Electrostatic energy of a system of charges. Electrostatic boundary conditions. Laplace's and Poisson's equations. Uniqueness theorem. Application of Laplace's equation involving planar, spherical and cylindrical symmetries. Potential and electric field of a dipole. Force and torque on a dipole. Capacitance of a system of charged conductors. Parallel plate capacitor. Capacitance on an isolated conductor.

Unit - II: Dielectric properties of matter (Lectures - 4)

Electric field in matter. Polarisation, polarisation charges. Electrical susceptibility and dielectric constant. Capacitor (parallel plate, spherical and cylindrical) filled with dielectric. Displacement vector, $\vec{D}$. Relation between $\vec{E}$, $\vec{P}$ and $\vec{D}$. Gauss's law in dielectrics.

Unit - III: Magnetic field (Lectures - 6)

Magnetic force on a point charge, definition and properties of magnetic field $\vec{B}$. Curl and divergence. Vector potential, $\vec{A}$. Magnetic scaler potential. Magnetic force on (i) a current carrying wire and (ii) between two elements. Torque on a current loop in a uniform magnetic field. Biot-Savart's law and its simple application: straight wire and circular loop. Current loop as a magnetic dipole and its dipole moment (analogy with electric dipole). Ampere's circuital law and its application to (i) solenoid and (ii) torus.

Unit - IV: Magnetic properties of matter (Lectures - 2)

Magnetization vector, $\vec{M}$. Magnetic intensity, $\vec{H}$. Magnetic susceptibility and permeability. Relation between $\vec{B}$, $\vec{H}$ and $\vec{M}$. Ferromagnetism. B-H curve and hysteresis.

Unit - V: Electrical circuits (Lectures - 5)

AC circuits: Kirchhoff's laws for AC circuits. Complex reactance and inductance. Series LCR circuits and parallel LCR circuits: (i) phasor diagram, (ii) resonance, (iii) power dissipation, (iv) quality factor, and (v) band width. Ideal constant-voltage and constant-current sources. Thevenin theorem and Norton theorem (only statements and solving of related problems).

Part C
Laboratory
Credit = 1

The students are required to perform at least four experiments from the following list of experiments.

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De' Sauty's bridge.
6. Measurement of field strength $\vec{B}$ and its variation in a solenoid (determine $\frac{dB}{dx}$).
7. To verify the Thevenin and Norton Theorems.
8. To verify the superposition and maximum power transfer theorems.
9. To determine the self-inductance of a coil by Anderson's bridge.
10. To study the response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine the self-inductance of a coil by Rayleigh's method.
15. To determine the mutual inductance of two coils by the Absolute method.

Reference books:

[1] Essential Mathematical Methods for the Physical Sciences; K. F. Riley and M. P. Hobson, Cambridge University Press.

[2] Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York)

[3] Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier

[4] Mathematical Physics-I; Krishna K. Pathak and Sangeeta Prasher, Vishal Publishing Co, Jalalandhar (Delhi).

[5] Mathematical Physics, H. K. Dass and Dr. Rama Verma, S. Chand Publication.

[6] Introduction to Electrodynamics, D. J. Griffiths.

[7] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.

[8] Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and S. R. Choudhury, 2012, Tata Mcgraw.

[9] Schaum's outline of Theory and Problems of Electromagnetics, J. A. Edminister.

[10] Electromagnetics, B. B. Laud, New Age International Publishers.

[11] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.

[12] Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.

[13] Elements of Electromagnetics, M. N. O. Sadiku, 2008. Pearson Education.

[14] Electricity and Magnetism, J. W. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

Four Year Undergraduate Course in Physics
Semester - III
Paper Name: Wave and Optics
Paper Code: PHY0300104
Total Number of Lectures = 45
Total Credits = 4 (Theory 3+ Laboratory 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcome:

CO1: Understand the superposition of harmonic waves, oscillations, types of wave motions, standing waves, and wave velocity in different media.

CO2: Apply physical concepts to explain the behaviour and propagation of light waves.

CO3: Analyse optical phenomena such as interference, diffraction, and polarization using the wave model.

CO4: Evaluate and explain the principles and applications of optical instruments like biprism, interferometer, and diffraction grating.

PART A
Wave and Optics (Theory)
Total Credits = 3

Unit - I: Superposition of harmonic oscillations (Lectures - 4)

Superposition of waves: Linearity and Superposition principle, Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats), Lissajous figures and their use.

Unit - II: Wave motion (Lectures - 4)

Waves: Progressive (Travelling) Waves, wave equation, plane wave and spherical wave, Longitudinal and Transverse Waves, dispersion, group velocity, phase velocity, Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave.

Unit - III: Velocity of waves (Lectures - 4)

Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton’s Formula for Velocity of Sound. Laplace’s Correction.

Unit - IV: Superposition of two harmonic waves *(Lectures - 9)*

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes.

Unit - V: Wave optics *(Lectures - 4)*

Wave optics: Electromagnetic nature of light, definition and properties of wave front. Huygens principle. Temporal and Spatial coherence.

Unit - VI: Interference *(Lectures - 8)*

Division of wavefront and amplitude, intensity distribution in an interference pattern, Young's double slit experiment, Fresnel's Biprism. Phase change on reflection: Stokes' treatment, Interference in Thin Films: parallel and wedge-shaped films, Newton's Rings: Measurement of wavelength and refractive index, Michelson interferometer.

Unit - VII: Diffraction *(Lectures - 7)*

Fresnel and Fraunhofer diffraction. Fresnel's Half-Period Zones for Plane Wave. Fresnel diffraction pattern of a straight edge and at a circular aperture. Fraunhofer diffraction: Single slit. Double slit. Diffraction grating. Resolving power of grating.

Unit - VII: Polarization *(Lectures - 5)*

Polarized light and its mathematical representation, Production of polarized light by reflection, refraction and scattering. Polarization by double refraction and Huygen's theory, Nicol prism, Production and analysis of circularly and elliptically polarized light.

PART B
Wave and Optics (Laboratory)
Credit = 1

The students are required to perform at least four experiments from the following list of experiments.

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2-T law.

2. Study of Lissajous Figure of two different waves using CRO and find out the unknown frequency of an electrical signal.
3. Familiarization with: Schuster's focusing, determination of angle of prism.
4. To determine refractive index of the Material of a prism using sodium source.
5. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
6. To determine wavelength of sodium light using Fresnel Biprism.
7. To determine wavelength of sodium light using Newton's Rings.
8. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
9. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
10. To determine dispersive power and resolving power of a plane diffraction grating.

Reference books:

[1] Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
[2] The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
[3] Vibrations and Waves in Physics, 2nd edition, I. G. Main, 1984, Cambridge University Press.
[4] A Textbook of Sound, 3rd Edition, A. B. Wood, 1955, Bell & Sons.
[5] The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
[6] Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill
[7] Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
[8] Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
[9] Principles of Optics, B. K. Mathur and T. P. Pandya, 1981, Tata McGraw-Hill International.
[10] Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.

Four Year Undergraduate Course
Subject: Physics
Semester-III
Paper: Electromagnetic Theory
Paper Code: PHY0300204
Total number of lectures: 45
Total credits: 4 (Theory 3 +Laboratory 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course outcomes:

CO1: Extend the ideas of electricity and magnetism to formulate the Maxwell's equations.
CO2: Illustrate the behaviour of electromagnetic waves as it propagates through vacuum and other media.
CO3: Analyze the various effects that occur as electromagnetic waves propagate from one medium to another one.
CO4: Outline the basic concepts of waveguides and fibre optics.
CO5: Explain different aspects of electromagnetic wave polarization.

Theory (Credits=3)

Unit - I: Maxwell's equations *(Lectures -09)*

Maxwell's equations, Displacement Current, Vector and Scaler Potentials, Gauge Transformations: Coulomb and Lorentz Gauge, Boundary Conditions at Interface between Different Media, Poynting Theorem and Poynting Vector.

Unit - II: EM Wave Propagation in Unbounded Media *(Lectures - 09)*

Plane EM Waves through Vacuum and Isotropic Dielectric Medium, Transverse Nature of Plane EM Waves, Refractive Index and Dielectric Constant, Propagation though Conducting Media, Relaxation Time, Skin Depth. Wave Propagation through Dilute Plasma (Basic Concepts).

Unit - III: EM wave in Bounded Media *(Lectures - 09)*

Reflection and Refraction of Plane EM Waves at Plane Interface between two Dielectric Media – Laws of Reflection and Refraction, Fresnels's Formula for Perpendicular Polarization Case, Brewster's Law, Reflection and Transmission Co-efficients, Waveguides: Basic Concepts and Propagation of EM Waves in a Rectangular Waveguide.

Unit - IV: Polarization of Electromagnetic Waves *(Lectures - 11)*

Description of Linear, Circular and Elliptical Polarization, Propagation of EM Waves in Anisotropic Media, Symmetric Nature of Dielectric Tensor, Fresnel's Formula, Uniaxial and Biaxial Crystals, Light Propagation in Uniaxial Crystal, Double Refraction, Polarization by Double Refraction, Nicol Prism; Ordinary & Extraordinary Refractive Indices, Production & Detection of Plane, Circularly and Elliptically Polarized Light; Phase Retardation Plates: Quarter-Wave and Half-Wave Plates, Babinet Compensator and its Uses, Analysis of Polarized Light.

Unit - V: Rotary Polarization *(Lectures - 04)*

Optical Rotation, Biot's Laws for Rotatory Polarization, Fresnel's Theory of Optical Rotation, Calculation of Angle of Rotation, Experimental Verification of Fresnel's Theory, Specific rotation, Laurent's Half-shade Polarimeter.

Unit - VI: Optical Fibres *(Lectures - 03)*

Numerical Aperture, Step and Graded Indices (Definitions Only), Single and Multiple Mode Fibres (Concept and Definition Only).

Laboratory (Credit=1)

The students are required to perform at least four experiments from the following list of experiments.

1. To verify the law of Malus for plane polarised light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarised light by using Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection and refraction of microwaves.
7. To study polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarisation of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan's law of radiation and to determine Stefan's constant.
12. To determine the Boltzmann constant using V-I characteristic of pn junction diode.

Reference books:

[1] Introduction to Electrodynamics, D. J. Griffiths.
[2] Electromagnetics, B. B. Laud, New Age International Publishers.
[3] Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
[4] Introduction to Electromagnetic Theory, T. L. Chow, 2006, Jones & Bartlett Learning.
[5] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
[6] Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill.
[7] Electromagnetic Field Theory, R. S. Kshetrimayun, 2012, McGraw Hill.
[8] Engineering Electromagnetic, Willian H. Hayt, 2012, McGraw Hill.
[9] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.

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Four Year Undergraduate Course
Subject: Physics
Semester-IV
Paper: Classical Mechanics
Paper Code: PHY0400104
Total Lectures: 60 (45 Theory; 15 tutorials)
Total Marks 100: Internal-40+External-60

Credits: 4 (Theory -03; Tutorial – 01)

Course Outcomes:

CO 1: Recognise the physical concepts required for classical mechanics
CO 2: **Classify** different formalisms of classical mechanics
CO 3: **Solve** problems in physics by using formalisms of classical mechanics
CO 4: **Organise** the concepts to learn new aspects
CO 5: **Test** the applicability of classical mechanics

Unit –I: Mechanics of point particles-the Lagrangian approach
(Lectures 12)

Review of Newtonian mechanics; system of particles and constrained motion with types of constraints; degrees of freedom, generalised coordinates and velocities; principle of virtual work and D'Alembert's principle; Lagrange's (Euler-Lagrange, EL) equation; physical problems– simple and compound pendulums, simple harmonic oscillation, Lagrange's equations for a particle in spherical and cylindrical coordinate systems, falling body in uniform gravitational field, Lagrangian in central force problem.

Unit-II: Mechanics of point particles – the Hamiltonian approach
(Lectures 11)

Generalised momenta; Legendre transformation; Hamilton's canonical equations; Hamiltonian from the Lagrangian; conservation of energy and momentum; physical problems – Hamiltonian for simple pendulum, canonical equations for a particle moving in central force field (gravitational potential).

Unit – III: Small oscillation **(Lectures 07)**

Minimum of potential energy and concept of stable equilibrium; expansion of potential energy around a minimum; kinetic and potential energy matrices; equation of motion of small oscillation.

Unit-IV: Special theory of relativity **(Lectures 15)**

Inadequacy of Galilean transformation; postulates of special relativity; Lorentz transformation; simultaneity and order of events; length contraction and time dilation; relativistic addition of velocities; variation of mass with velocity and mass-energy equivalence. Lorentz transformation as a rotation in spacetime; relation between proper time and coordinate time; relativistic kinematics:energy-momentum relation.

Suggested text books:

(1) Classical Mechanics, H. Goldstein, C.P. Poole and J.L. Safko (Pearson Education)
(2) Theoretical Mechanics, M. R. Spiegel (McGraw Hill Book Company)
(3) Classical Mechanics, P.S. Joag and N.C Rana (McGraw Hill Book Company)
(4) Mathematical Physics, B. S. Rajput (Pragati Prakashan)

Suggested reference books:

(1) Classical Mechanics, T.W.B. Kibble and F.H. Berkshire (Imperial College Press)
(2) Mechanics: Courses in Theoretical Physics (Vol. 1), L.D. Landau and E.M. Lifshitz (Butterworth-Heinemann) (3rd Edn.)
(3) Classical Mechanics: With introduction to non-linear oscillations and chaos, V.B. Bhatia (Narosa Publishing House)

Four Year Undergraduate Course in Physics
Semester IV
Paper Name - Quantum mechanics I
Paper Code - PHY0400204
Total Lectures: 45, Credits: 4 (Theory: 03, Lab: 01)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcome:

CO 1: Recall key quantum theory concepts (blackbody radiation, photoelectric effect, wave-particle duality).

CO 2: Explain principles of uncertainty, matter waves, and Schrödinger's equations.

CO 3: Solve problems involving operators, eigenvalues, and the uncertainty principle.

CO 4: Analyze quantum systems (infinite potential well, harmonic oscillator) for energy levels and probability distributions.

CO 5: Model and predict quantum phenomena like tunnelling and particle in a spherically symmetric potential.

Theory :

Unit I: Origin of Quantum Theory (Lectures= 3)
Failure of classical theories, Explanation of blackbody radiation, Photoelectric effect, Compton effect, particle nature of radiation, Bohr's correspondence principle.

Unit II: Dynamical Variables as Operators and Uncertainty Principle (Lectures=10)
Dynamical variables as operators, definition of an operator, different types of operators and their properties, position, energy and momentum operator; commutation relations; introduction to Hilbert space, Dirac notation, eigenvalue and eigenfunctions; expectation value of an operator, e.g. position, momentum operator etc, orthonormality condition, Ehrenfest's theorem.

Simultaneous measurement and uncertainty principle; general statement of Heisenberg's uncertainty principle (for any two non commutating operators), different uncertainty relations involving canonical pair of variables; applications of the position momentum uncertainty principle, application of energy time uncertainty principle to virtual particles and range of an interaction.

Unit III : Matter Wave and Wave-Particle Duality (Lectures = 8)

Wave-particle duality and de Broglie wavelength, particle as a matter wave, wave description of particles by wave packets; phase and group velocity; Experimental verification of matter wave, Davisson and Germer experiment; linearity and superposition principle, two slit experiments with electrons and photons; Uncertainty principle from wave packet description, Gaussian wave packet.

Unit IV : Schrödinger Equation and it's applications (Lectures =24)
Time dependent Schrödinger Equation, Time independent Schrödinger Equation; Physical interpretation and properties of wave function, continuity of a wave function, boundary conditions and emergence of discrete and continuous energy levels; probabilities and normalization in three and one dimension; equation of continuity, current density in both one and three dimensions.

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent Schrödinger equation in terms of linear combinations of stationary states, discrete and continuous spectrum, wave function of a free particle, spread of Gaussian wave function in one dimension, Fourier transforms and momentum space wave function.

Applications of Time independent Schrödinger Equation in different problems like : (i) particle in a one dimensional infinite potential well (quantum dot as an example) (ii) particle in a one dimensional finite square potential well (iii) barrier penetration problems – potential step and rectangular potential barrier (tunnelling effect) (iv) linear harmonic oscillator (v) spherically symmetric potential for hydrogen atom- radial solution, spherical harmonics, angular momentum operator and different quantum numbers, radial distribution function and shapes of the probability densities for ground & first excited states; degeneracy of states : s, p, d states.

Laboratory :

***A minimum of four experiments to be done*.**
1. Measurement of Planck's constant using blackbody radiation and photo-detector.
2. Photo-electric effect: Photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H_α emission line of hydrogen atom.
6. To determine the ionisation potential of mercury.
7. To determine the absorption lines in the rotational spectrum of iodine vapour.
8. To determine the value of e/m by (a) magnetic focusing or (b) bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunnelling effect in tunnel diode using I-V characteristics.
11. To determine the wavelength of laser source using diffraction from single slit.
12. To determine the wavelength of laser source using diffraction from double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.

Suggested Books

1. N. Zettili, Quantum Mechanics, John Wiley & Sons (2001).

2. J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics, Cambridge Univ. Press, 2020.
3. Y. R.Waghmare, Fundamentals of Quantum Mechanics, Wheeler publishing (2014).
4. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson Education 2nd Ed. (2004).
5. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson Education (2005).
6. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2002).
7. A. Bieser, Concepts of Modern Physics, McGraw Hill (2002).
8. H. C. Verma, Quantum Mechanics, TBS publications (2019).

Analog Electronics

(Semester IV)

Credits 4: (Theory: 3 + Practical: 1)

Paper Code: PHY0400304

Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Total Lectures: 45

Course Outcomes:

CO1: Recall the basic theory of PN Junction Diode.

CO2: Explain the working of different electronic components like diodes, transistors, and Op-Amps.

CO3: Classify various electronic circuits like rectifiers, amplifiers and oscillators.

CO4: Design different circuits related to Op-Amp (IC 741).

CO5: Interpret the basic use of CRO

Unit I: Semiconductor Diodes (Lectures 07)

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width, and Current for Step Junction.

Unit II: Two-terminal Devices and their Applications (Lectures 05)

Rectifier Diode: Half- wave Rectifiers. Centre-tapped and Bridge type Full-wave Rectifiers. Calculation of Ripple Factor and Rectification Efficiency. C-filter. Zener Diode and Voltage Regulation. Power supply without filter circuit and with C-filter circuit. Principle LEDs, Photodiode, and Solar Cell (Basic concept).

Unit III: Bipolar Junction Transistors (Lectures 05)

n-p-n and p-n-p Transistors. Characteristics of CB, CE, and CC Configurations. Current gains α and β. Relations between α and β. Load line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and Saturation Regions.

Unit IV: Amplifiers (Lectures 07)

Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as a 2-port Network. h-parameter. Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage, and Power Gains. Classification of Class A, B & C Amplifiers. Differential amplifiers.

Unit V: Coupled Amplifier (Lectures 02)

Two-stage RC-coupled amplifier and its frequency response.

Unit VI: Feedback in Amplifiers (Lectures 04)

Effects of Positive and Negative Feedback on Input Impedance. Output Impedance. Gain. Stability. Distortion and Noise.

Unit VII: Sinusoidal Oscillators (Lectures 05)

Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. Determination of Frequency. Colpitt's oscillator.

Unit VIII: Operational Amplifiers (Black Box approach) (Lectures 03)

Characteristics of an Ideal and Practical Op-Amp (IC 741). Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and Concept of Virtual Ground.

Unit IX: Applications of Op-Amps (Lectures 04)

Inverting and non-inverting amplifiers. Adder. Subtractor. Differentiator. Integrator. Log and Anti Log amplifier. Zero crossing detector. Wein bridge oscillator. Comparator.

Unit X: Introduction to CRO (Lectures 03)

Block Diagram of CRO. Electron Gun, Deflection System, and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.

Laboratory

A minimum of four experiments are to be done.

1. To study V-I characteristics of PN junction diode, and light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as a voltage regulator.
3. Study of V-I and power curves of solar cells, and find maximum power point and efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the various biasing configurations of BJT for normal Class A operation.
6. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
7. To study the frequency response of voltage gain of an RC-coupled transistor amplifier.
8. Using an Op-amp, design a Wien bridge oscillator for a given frequency.
9. To design a phase shift oscillator of given specifications using BJT.
10. To design and study Colpitt's oscillator.
11. To design an inverting amplifier using Op-amp for the DC voltage of a given gain.
12. To design inverting amplifier using Op-amp and study its frequency response.
13. To design a non-inverting amplifier using Op-amp and study its frequency response.
14. To study the zero-crossing detector and comparator.
15. To add two DC voltages using Op-amp in inverting and non-inverting modes.
16. To design a precision Differential amplifier of given I/O specification using Op-amp.
17. To investigate the use of an Op-amp as an Integrator.
18. To investigate the use of an Op-amp as a Differentiator.
19. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO. Construct a series LR circuit. Display the two waveforms on the CRO and measure the phase differences between the voltages across R and L.
20. To test a Diode and Transistor using a Multimeter. Draw the forward bias characteristic of the diode. Using only the base-emitter junction of the transistor draw a characteristic curve and show that it behaves as a forward-biased diode.

Note: All students will have to do an electronic project on the circuits, for example, the power supply, the AM detector, etc. to get acquainted.

Suggested Books

1. Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall.
3. Solid State Electronic Devices, B. G. Streetman & S. K. Banerjee, 6th Edn.,2009, PHI Learning
4. Electronic Devices & circuits, S. Salivahanan & N. S. Kumar, 3rd Ed., 2012, Tata McGraw Hill
5. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
6. Microelectronic circuits, A. S. Sedra, K.C. Smith, A. N. Chandorkar, 2014, 6th Edn., Oxford University Press.
7. Electronic circuits: Handbook of design & applications, U. Tietze, C. Schenk,2008, Springer
8. Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd Ed., 2002, Wiley India
9. Microelectronic Circuits, M. H. Rashid, 2nd Edition, Cengage Learning
10. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India
11. Electronics Fundamentals and Applications, D. Chattopadhyay and P. C. Rakshit, 17^{th} Ed, 2023, New Age International Publishers

Four Year Undergraduate Course in Physics
Semester - IV
Paper Name: Mathematical Physics
Paper Code: PHY0400404
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcome:

CO1: Recall and identify key concepts of partial differential equations, Fourier series, complex analysis, tensor algebra, and probability distributions.
CO2: Explain the principles and methodologies used in solving partial differential equations, expanding periodic functions into Fourier series, and analyzing complex variables.
CO3: Solve problems involving partial differential equations, Fourier series, and tensor algebra in physical and mathematical contexts.
CO4: Analyze the behaviour of complex functions, their singularities, and the properties of tensors and probability distributions in theoretical and applied scenarios.
CO5: Design and implement computational solutions to mathematical problems using programming tools such as C/C++, Scilab, FORTRAN, Mathematica, Matlab, or Python.

Theory

Unit I: Partial Differential Equations ***(Lectures 10)***

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

Unit II: Fourier Series ***(Lectures 07)***

Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Application to square and triangular waves.

Unit III: Complex Analysis ***(Lectures 17)***

Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity. Integration of functions with complex variable. Cauchy's Integral theorem and Cauchy's Integral formula. Simply and multiply connected regions. Laurent and Taylor's series expansions. Residue Theorem with application.

Unit IV: Tensor Algebra ***(Lectures 06)***

Introduction to tensor, Transformation of co-ordinates, Einsteins summation convention. Contravariant, covariant and mixed tensors. Symmetric and antisymmetric tensors, Kronecker delta, LeviCivita tensor. Quotient law of tensors. Rules of combination of tensors: addition, subtraction, outer multiplication, contraction and inner multiplication.

Unit V: Introduction to Probability ***(Lectures 05)***

Independent random variables: Probability distribution functions; binomial, Gaussian and Poisson, with examples. Mean and variance.

Laboratory

(Use C/C++/Scilab/FORTRAN/Mathematica/ Matlab/ Python to solve the following problems.)

1. Solve the differential equations

$$\frac{dy}{dx} = e^x \text{ with } y = 0 \text{ for } x = 0$$

$$\frac{dy}{dx} + e^{-x}y = x^2$$

$$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} = -y$$

$$\frac{d^2y}{dx^2} + e^{-x}\frac{dy}{dx} = -y$$

2. Perform the multiplication of two 3×3 matrices.
3. Compute the eigenvalues and eigenvectors of the following matrices.

$$\begin{bmatrix} 4 & 3 & 7 \\ 1 & 2 & 7 \\ 2 & 0 & 4 \end{bmatrix}, \begin{bmatrix} 1 & -i & 3+4i \\ i & 2 & 4 \\ 3-4i & 4 & 3 \end{bmatrix}, \begin{bmatrix} 2 & -i & 2i \\ i & 4 & 3 \\ -2i & 3 & 5 \end{bmatrix}$$

4. Using random number compute the areas of circle, square, volume of sphere and value of pi (π).
5. Evaluate trigonometric functions e.g. *sin θ; cosθ; tanθ* etc. using Interpolation by Newton Gregory Forward and Backward difference formula.
6. Find the solution of Partial Differential Equations: (a) Wave equation (b) Heat equation.
7. Evaluate the integral *I*,where,

   $I = \frac{1}{\sqrt{2\pi\sigma^2}} \int exp\left[\frac{(x-2)^2}{2\sigma^2}\right](x+3)dx$ for $\sigma = 1.0, 0.1, 0.01$ and show that $I \to 5$
8. Compute the *n*th roots of unity for *n* = 2, 3, and 4.
9. Find the two square roots of 5 + 12*i*.

References

1. Mathematical Physics; H K Dass and R Verma, S Chand and Company limited.
2. Mathematical methods for Physics and Engineering; K. F Riley, M. P Hobson, S.J Bence, Cambridge University Press.
3. Graduate Mathematical Physics (With Mathematica Supplement); J J Kelly, Willey-VCH Verlag GmbH and Co. KGaA.
4. Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.
5. Ordinary and Partial Differential equations; M. D Raisinghania, S. Chand and Company Ltd.
6. Complex Variables; M R Spiegel,S Lipschutz, J J Schiller and D Spellman, Schaum's Outline Series, McGraw Hill Education.
7. Complex variables Demystified (A self teaching guide); D McMahan, McGraw Hill Education.
8. A Student's Guide to vectors and Tensors; D A Fleisch, Cambridge University Press.
9. Vector analysis and an introduction to Tensor analysis; S Lipschutz, D Spellman, M R Spiegel, Schaum's Outline Series, McGraw Hill Education.
10. Tensors and applications with Scilab Programs; N D Soni, I.K International Publishing House Pvt. Limited.
11. Probability and Statistics; M R Spiegel, J J Schiller and R A Srinivasan, Schaum's Outline Series, McGraw Hill Education.

Four Year Undergraduate Course in Physics

Semester V

Paper Name: Atomic and Molecular Physics

Paper Code: PHY0500104

Total Number of Lectures = 60, Total Credits = 4

Total Marks 100: Internal-40+External-60

Course Outcome:

CO1: Explain the Bohr model and Sommerfeld's relativistic atom model, and fine structure of hydrogen atom lines and the limitations of both models.

CO2: Apply the concept of orbital magnetic dipole moment, Bohr magneton, and gyromagnetic ratio to explain the spin-orbit interaction and coupling schemes such as L-S and j-j coupling.

CO3: Analyze the Stern-Gerlach experiment and its conclusions, and interpret the results in the context of space quantization and electron spin.

CO4: Illustrate the principles of X-ray diffraction, the characteristic X-ray spectra, and the Compton effect, and describe their significance in atomic and molecular physics.

CO5: Outline the quantum theory of the Raman effect, its characteristics, and the complementary relationship between Raman and infrared spectra.

Unit I: Atom Model: (Lectures 20)

The Bohr model of the hydrogen-like atom, Sommerfeld Relativistic Atom Model: Elliptical orbits, explanation of fine structure of H alpha line in Balmer series of hydrogen atom. Limitation of Sommerfeld atom model.

Orbital magnetic dipole moment: Bohr Magneton, Gyromagnetic Ratio, Larmor precession, Space Quantization, Electron Spin, quantum numbers associated with vector atom model, spin-orbit interaction, Coupling Schemes: L-S Coupling and j-j Coupling, Spectroscopic term and their notation, Stern-Gerlach experiment and its conclusion.

Normal and Anomalous Zeeman Effect.

Paschen Back and Stark Effect (Qualitative Discussion only).

Unit II: X-rays: **(Lectures 08)**

Ionizing Power, X-ray Diffraction, Bragg's Law, X-ray Spectra: Continuous and characteristic X-rays Mosley's law, Compton effect.

Unit III: Multi electron atoms: **(Lectures 10)**

Hund's rule, Periodic table: Pauli's exclusion principle, explanation of the periodic classification of the elements, Building up or Aufbau Principle, Broad features of Alkali atom (Na etc.) spectra and its explanation

Unit IV: Molecular Spectra: **(Lectures 15)**

Rotational Energy levels, Selection Rules and Pure Rotational Spectra of a diatomic Molecule. Vibrational Energy Levels, Selection Rules and Vibration Spectra of a diatomic Molecule. Rotation-Vibration Energy Levels, Selection Rules and Rotation-Vibration Spectra. Determination of Internuclear Distance.

Unit V: Raman Effect: **(Lectures 07)**

Quantum Theory of Raman Effect. Characteristics of Raman Lines. Stoke's and Anti-Stoke's Lines. Complimentary Character of Raman and infrared Spectra.

Suggested Books:

1. Introduction to Atomic spectra, H. E. White, Tata McGraw Hill (1934)
2. Atomic and Molecular Spectra, Raj Kumar
3. Concepts of Modern Physics, Arthur Beiser (McGraw-Hill Book Company, 1987)
4. Atomic physics, J. B. Rajam & foreword by Louis De Broglie (S. Chand & Co., 2007)
5. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachein.
6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash

Semester:V

Course Name: Condensed Matter Physics

Credits: 4 (Theory: 03, Lab: 01) **Paper Code - PHY0500204**

Total Lectures: **45 (Theory)**

Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcome:

CO1: Describe the fundamental concepts of crystalline structure, lattice dynamics, nanomaterials, thin film and soft matter

CO2: Illustrate the dielectric, ferroelectric, magnetic properties in solids and basic concept in superconductivity.

CO3: Apply the mathematical and theoretical concepts to analyse and solve problems related to crystalline solids, lattice dynamics.

CO4: Analyse theoretical models to interpret physical phenomena such Transport properties of material and magnetic behaviour.

CO5: Determine parameters related to crytallinity, electrical, magnetic and other properties of condensed matter.

Unit I: Crystal Structure and Bonding in solids (Lectures 09)

Amorphous, crystalline and polycrystalline materials, lattice translation vectors, unit cell, types of crystal lattice, Bravais Lattice, Miller Indices, inter planer spacing.

Ionic, covalent, metallic, van-der-waal and hydrogen bondings, cohesive energy of ionic crystal, Madelung constant.

Unit II: Elementary Lattice Dynamics (Lectures: 04)

Basic idea of lattice vibration and phonon. Dulong and Petit's Law. Einstein and Debye theories of specific heat of solids, T^3 law.

Unit III: Dielectric and Ferroelectric Properties of Materials (Lectures 10)

Polarization. local electric field at an Atom, depolarization field, electric susceptibility, polarizability. Clausius Mosotti equation, classical theory of electric polarizability, normal and anomalous dispersion, Cauchy and Sellmeir relations, Langevin-Debye equation.

Piezoelectric effect, pyroelectric effect, ferroelectric effect, electrostrictive effect, Curie-Weiss Law.

Unit IV: Transport properties of materials (Lectures 09)

Free electron theory of metals, electrical and thermal conductivity of metals, Wiedemann-Franz law, drawback of classical theory and modification with quantum theory, preliminary idea of band theory, band gap, conductor, semiconductor (*p* and *n* type) and insulator, conductivity of semiconductor, mobility, measurement of conductivity (2-probe & 4-probe resistivity measurement method), Hall Effect (Qualitative idea).

Unit V: Nanophysics and soft matter (Lectures 03)

Basic idea about nanomaterials, thin film physics and soft matter.

Unit VI: Magnetic Properties of Matter (Lectures 07)

Dia, para, ferri, ferro and anti ferromagnetic materials, classical Langevin Theory of dia and paramagnetism, Curie's law, Weiss' theory of ferromagnetic domains, discussion of $B - H$ Curve, hysteresis and energy Loss.

Unit VII: Superconductivity (Lectures 03)

Basic idea of superconductivity, critical temperature, critical magnetic field, Meissner effect. Type I and type II Super- conductors, isotope effect.

Lab:

A minimum of four experiments to be done.

1. Indexing of powder X-Ray diffraction data of cubic crystalline materials and determination of lattice parameters including inter planner spacing (XRD data needs to arrange by the department).
2. Measurement of susceptibility of a paramagnetic solution (Quinck's Tube Method).
3. To measure the magnetic susceptibility of solids.
4. To determine the Coupling Coefficient of a piezoelectric crystal.
5. To measure the Dielectric Constant of a dielectric materials with frequency.
6. To study the *P-E* Hysteresis loop of a Ferroelectric Crystal.
7. To draw the B − H curve of Fe using Solenoid & determine energy loss from Hysteresis.
8. To measure the variation of resistivity of a semiconductor with temperature by four-probe method and to determine its band gap.
9. To determine the Hall coefficient of a semiconductor sample.

Suggested Books

1. *Introduction to Solid State Physics*, C Kittel
2. *Lattice Dynamics*, A K Ghatak and L S Kothari
3. *Solid State Physics*, A J Dekker.
4. *Introductory Solid State Physics*, H P Myers.
5. *Solid State Physics*, N W Ashcroft and N D Mermin
6. *Magnetism in solids*, D H Martin
7. *Physics of Magnetism,* S Chikazumi.
8. *Solid State Physics, S O Pillai*
9. *Introduction to Nanotechnology*, C. P. Poole, J. F. J. Owens

Semester-V

Paper Name: Heat & Thermodynamics

Course Code - PHY0500304

Total Lectures: 45, Lab: 30 h; Credit: 04 (03+01)

Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))

Course Outcome:

CO 1: Recognize the basic framework of kinetic theory of gases and thermodynamics.
CO 2: Interpret the behaviour of real gases.
CO 3: Apply the principles of thermodynamics to understand properties of thermodynamic systems.
CO 4: Analyze changes of entropy in reversible and irreversible processes.
CO 5: Estimate the thermodynamic potentials and their significance.

Theory

Unit I: ***Distribution of Velocities and Molecular Collisions*** **(Lectures 9)**

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required).

Mean Free Path. Collision Probability. Transport Phenomenon in Ideal Gases: (1) Viscosity, and (2) Thermal Conductivity. Brownian Motion (qualitative idea only).

Unit II: ***Real Gases*** **(Lectures 08)**

Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapor and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. Joule- Thomson Porous Plug Experiment. Joule- Thomson Effect, Joule-Kelvin coefficient for Ideal and Van der Waal Gases. Temperature of Inversion.

Unit III: ***Principles of Thermodynamics*** **(Lectures 16)**

Thermodynamic preliminaries: Extensive and intensive properties, Thermodynamic

Variables, Thermodynamic Equilibrium, P-V indicator diagram. Work done in terms of P and V, Zeroth Law of Thermodynamics & Concept of Temperature, Internal energy and First Law of Thermodynamics, Applications of First Law: General Relation between C_P and C_V.

Reversible and Irreversible process with examples. Heat & work, state function, Conversion of heat into work and vice versa, Work Done during Isothermal and Adiabatic Processes, Heat Engines, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence, Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Unit IV: ***Entropy*** **(Lectures 06)**

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics.

Unit V: ***Thermodynamic Potentials and Thermodynamic Relations*** **(Lectures 06)**

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, Surface Films and Variation of Surface Tension with Temperature, Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Energy equations, (5) Change of Temperature during Adiabatic Process.

Lab *(at least four experiments to be performed)*

1. To determine mechanical equivalent of heat, J, by Callender and Barne's constant flow method
2. To determine the mechanical equivalent of heat, J using calorimeter
3. To determine specific heat of a liquid using calorimeter
4. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
5. To determine the coefficient of thermal conductivity of an insulator by Lee and Charlton's disc method.
6. To determine the temperature coefficient of resistance by Platinum Resistance Thermometer (PRT).
7. To study the variation of thermo-emf of a thermocouple with difference of temperature of its two junctions.
8. To determine the change of entropy of universe for an AC circuit consists of a thermally insulated resistor.
9. To calibrate a thermocouple to measure temperature in a specified range using (1) Null method, (2) Direct measurement using OPAMP and to determine neutral temperature.

Suggested Books

[1] Heat and Thermodynamics, M. Zemansky, R. Dittman, McGraw-Hill Education, 2017.

[2] A Treatise on Heat, Meghnad Saha and B. N. Srivastava, Indian Press, 1973.

[3] Thermal Physics: Kinetic Theory, Thermodynamics and Statistical Mechanics, S. C. Garg, R. M. Bansal and C. K. Ghosh, Tata McGraw Hill Education Pvt Ltd, 2013.

[4] Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F. W. Sears & G. L. Salinger, Narosa Publishing House, 1998.

[5] Thermal and Statistical Physics, R. B. Singh, New Academic Science, 2011.

[6] Theory and Experiment on Thermal physics, P K. Chakrabarti, New Central Book Agency (P) Ltd, 2011.

SEMESTER - VI

NUCLEAR & PARTICLE PHYSICS

Course Code - PHY0600104

Credit : 04 (Theory-03, Tutorial-01) **(Total Marks 100: Internal-40+External-60)**

Theory : 45 Hours Tutorial : 15 Hour

Course Outcomes:

CO1: On successful completion of the course, the students shall be able to discuss the basic structure and properties of a nucleus and their stability line.

CO2: Students can demonstrate the properties of strong nuclear force that keeps the nuclei bound and classify the radioactive decays, penetration and transformation.

CO3: Students get upgrade the knowledge on the construction and working principles of various particle accelerators, nuclear instrumentation and detector development.

CO4: Students can compare the merits and demerits of fusion and fission energy, their related technological development for generation of energy and control environment.

CO5: Students will enable to formulate the world of particle physics-types and interactions.

Unit – I: Basic Properties of Nuclei: **(No. of lecture = 8)**

Constituents of a nucleus: proton-electron hypothesis -Thompson atom model, failure of proton-electron hypothesis, discovery of neutrons, **Rutherford gold foil experiment** (qualitative) and atom model- mass, radius, volume, matter density of nuclei and their units. Binding energy, binding energy per nucleon, stability of a nucleus- neutron to proton ratio, stability line, stability limit against beta decays.

Unit – II: Radioactivity and Radioactive Laws: **(No. of lecture = 10)**

Types of Radioactivity – alpha, beta, and gamma decay. Laws of radioactive decay, disintegration constant, half-life and mean life. Activity of a radioactive source, units of radioactivity.
Alpha decay: range, ionization and stopping power, range-energy relation, **Geiger-Nuttall law**, Fine structure of alpha energy spectrum.
Beta decays: types of beta decays, essential conditions of beta decays, beta ray spectra, end-point energy, Pauli's neutrino hypothesis.
Gamma decay: origin of gamma radiation, its property, attenuation of gamma radiation in matter.

Unit III: Nuclear Instrumentation **(No. of lecture = 10)**

Detectors: Interaction of Radiation with Matter: Energy loss by a charged particle due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Interaction of photon with matter – Photoelectric effect, Compton effect, and Pair production, .

Gas filled detectors: Ionization chamber, proportional counter, and GM counter – construction and working principle

Charged particle accelerators: Need of charged particle accelerators, Linear accelerator (LINAC) – Construction and working principle.

Unit IV: Fission and Fusion **(No. of lecture = 10)**

Energy consideration in Nuclear Reaction, Mass defect and Q-value of a nuclear reaction, Einstein's mass-energy equivalence principle and generation of nuclear energy. Nuclear Fission: Spontaneous and induced fission – definition and examples, Fission chain reactions and nuclear reactor: peaceful use of fission energy.

Fusion and thermonuclear reactions: Energy production in stars (brief qualitative discussions).

Unit V: Elementary Particles **(No. of lecture = 7)**

Classification of elementary particles and their quantum numbers, conservation laws, Allowed and forbidden reactions, Types of interactions – strong, electro-magnetic and weak interactions.

Reference Books:

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999. 87
2. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
6. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
7. Concept of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.
8. Nuclear Radiation Detector by S S Kapoor and V S Ramamurthy , 1st edition, New Age international publisher.

Digital Electronics

(Semester VI)

Course Code - PHY0600204

Credits 4: (Theory: 3 + Practical: 1)
Total Marks=100 (45 (Th)+25 (Lab)+30 (Int))
Total Lectures: 45

Course Outcomes:

CO1: Recall the basics of digital electronics.

CO2: Discuss the working of logic gates.

CO3: Explain the theory related to Boolean algebra and K-Map.

CO4: Design different digital circuits like multi vibrators, flip flops and registers

CO5: Interpret the use of memory device.

Unit I: Integrated Circuits (qualitative treatment only) (Lectures 03)

Active & Passive Components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. The scale of integration: SSI, MSI, LSI, and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital ICs.

Unit II: Digital Circuits (Lectures 10)

Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal, and Hexadecimal numbers. AND, OR, and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates.

Unit III: Boolean Algebra (Lectures 10)

De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. The idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

Unit IV: Arithmetic Circuits (Lectures 05)

Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.

Unit V: Timers: IC 555 (Lectures 03)

Block diagram and applications: Astable multivibrator and Monostable multivibrator.

Unit VI: Sequential Circuits (Lectures 04)
SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race- around conditions in JK Flip-Flop. M/S JK Flip-Flop.

Unit VII: Shift Registers (Lectures 04)

Serial-in-Serial-out. Serial-in-Parallel-out. Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

Unit VIII: Computer Organization (Lectures 06)

Input/Output Devices. Data storage (the idea of RAM and ROM). Computer memory. Memory organization & addressing.

Laboratory

A minimum of four experiments are to be done.

1. To design a switch (NOT gate) using (i) a PNP transistor and (ii) an NPN transistor.
2. To verify and design AND, OR, NOT, and XOR gates using NAND gates.
3. To design a combinational logic system for a specified Truth Table.
4. To convert a Boolean expression into a logic circuit and design it using logic gate ICs.
5. To design a Half Adder and Full Adder
6. To design a 4-bit binary Adder.
7. To design Half Subtractor and Full Subtractor
8. To design Adder-Subtractor using Full Adder IC.
9. To design an astable multivibrator of given specifications using 555 Timer.
10. To design a monostable multivibrator of given specifications using 555 Timer.
11. To build a D flip-flop circuit using NAND gates.
12. To build a JK flip-flop circuit using NAND gates.
13. To build JK Master-slave flip-flop using flip-flop ICs.
14. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
15. To build SR flip-flop circuit using NAND gates

Suggested Books

1. Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw
2. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Electronics G. K. Kharate ,2010, Oxford University Press
5. Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning
6. Logic circuit design, Shimon P. Vingron, 2012, Springer.
7. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
8. Digital Electronics, S. K. Mandal, 2010, 1st edition, McGraw Hill
9. Electronics Fundamentals and Applications, D. Chattopadhyay and P. C. Rakshit, 17th Ed, 2023, New Age International Publishers

Four Year Undergraduate Course
Subject: Physics
Semester-VI
Paper: Astronomy & Astrophysics
Paper Code- PHY0600304
Total Lectures: 60 (Theory 45; Tutorial 15)
Credits: 4 (Theory -03; Tutorial – 01)
Total Marks 100: Internal-40+External-60

Course Outcomes:

CO1:**Recognise** the basic concepts of physics required for astronomy and astrophysics
CO2: **Interpret** the results of basic observations in astronomy
CO3: **Implement** laws of physics to understand stellar structure and evolution
CO4: **Integrate** the concepts to understand formation of solar system and galaxies.
CO5: **Test** the applicability of basic astronomy concepts in learning origin and evolution of large scale structure of the universe.

Unit –I: Fundamentals of astronomy (Lectures 8)

Basic components of the universe – stars, planets and galaxies; celestial sphere and celestial coordinates system - altitude-azimuth (Alt-Az) and right ascension-declination (RA-DEC); Introduction to constellations through sky observation and Stellarium; concept of time – universal time, solar and mean solar time, sidereal time, local sidereal time, Julian day; flux and luminosity of celestial objects; stellar magnitude scale – apparent and absolute magnitude; measurement of stellar distances – trigonometric parallax; introduction to HIPPARCOS and GAIA.

Unit- II : Astronomical techniques (Lectures 8)

Telescopes –size and light gathering power; resolving power; different types of optical telescopes (reflecting and refracting); space telescopes; concept of virtual observatory; virtual observatory tools in astronomy – SIMBAD, Aladin; SDSS, AAVSO, Sky-View; introduction to photometry; CCD –an introduction; spectroscopy and polarimetry.

Unit – III: Stellar astrophysics (Lectures 12)

Star formation from interstellar medium (introduction only); stellar properties- mass, luminosity, radius and effective surface temperature and their relationships; variable stars-cepheids; star clusters – open and globular, their ages (introduction only).

Gravity and thermodynamics – hydrostatic equilibrium of stars; virial theorem; internal temperature and pressure of stars; spectral classification – HR diagram; stellar evolution- idea of nucleosynthesis in main sequence phase- pp and CNO cycle; evolution of Sun-like stars off the main sequence -red giants and white dwarfs- Chandrasekhar mass limit (introduction only); evolution of massive stars – neutron stars and black holes (introduction only).

Unit-IV: The solar system (Lectures 5)

The Sun and its structure; Formation of the solar system – Kant-Laplace nebular hypothesis; asteroid belt and meteorites; Distances and atmospheres of planets; Pluto and dwarf planets; comets – Kuiper belt and Oort cloud; extra-solar planets – transit method of detection (introduction only).

Unit- V : Galaxies and cosmology (Lectures 12)

The Milky Way and its structure; classification of galaxies –Hubble's tuning fork diagram; types of galaxies – spirals, elliptical and lenticular and their differences.

Large scale structure of the universe – galaxies, clusters, superclusters, filaments, walls and voids; Cosmological Principle; Hubble's law; Newtonian cosmology and derivation of Friedman equation; closed and oscillating universe, flat and open universe; the Hot Big Bang model; Cosmic Microwave Background (CMB); steady state universe (introduction only); flat rotation curves in galaxies and evidence of dark matter; dark energy (introduction only).

Suggested text books:

(1) Astrophysics for physicists, A. Rai Choudhuri, Cambridge University Press.
(2) An introduction to the theory of stellar structure and evolution, D. Prialnik, Cambridge University Press.
(3) Astrophysics- Stars and galaxies, K. D. Abhyankar, Tata McGraw Hill Pub.
(4) Textbook of astronomy and astrophysics with elements of cosmology, V. B. Bhatia, Narosa Pub.
(5) Astronomy Methods - A Physical Approach to Astronomical Observations, Hale Bradt, Cambridge University Press.
(6) Introduction to astrophysics, H.L. Duorah and K. Duorah, Mani Manik Prakash (Guwahati).

Suggested reference books

(1) The physical universe – An introduction to astronomy, F. H. Shu, University of Science Books.
(2) The structure of the universe, J.V. Narlikar, Oxford University Press.
(3) Introduction to cosmology, B. Ryden, Cambridge University Press.

Semester-VI

Paper Name: Statistical Mechanics

Course Code - PHY0600404

Total Lectures: 60 (45 L + 15 T); Credit: 04
Total Marks 100: Internal-40+External-60

Course Outcome:

CO 1: Recall classical and quantum theories of radiation.

CO 2: Discuss basic concepts of statistical mechanics.

CO 3: Apply ensemble theories and evaluate partition functions.

CO 4: Differentiate classical and quantum statistics.

CO5: Interpret Bose-Einstein and Fermi-Dirac statistics and understand characteristic differences of quantum systems.

Unit I: Classical Statistics (Lectures 15)

Microstate and macrostate, distributions of particles in compartments, principle of equal a priori probability. Phase space, volume of phase space. Elementary concept of ensembles, Types of ensembles. Ergodic hypothesis. Entropy and thermodynamic probability, Stirling's approximation, Maxwell-Boltzmann distribution function, Partition functions. Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to specific heat and its limitations. Thermodynamic parameters (internal energy, entropy, free energy, enthalpy) using partition functions.

Unit II: Classical and Quantum Theory of Radiation (Lectures 12)

Properties of thermal radiation. Blackbody radiation. Spectral distribution of Blackbody radiation, Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation pressure (for Normal and diffused case). Wien's Displacement law. Wien's Distribution Law. Saha's ionization formula. Rayleigh-Jean's Law (with proof). Ultraviolet catastrophe. Need of quantum statistics. Planck's quantum postulates. Planck's law of blackbody radiation: Experimental verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan- Boltzmann Law, (4) Wien's Displacement law from Planck's blackbody radiation formula.

Unit III: Bose-Einstein Statistics (Lectures 8)

Bose-Einstein (BE) distribution, Pressure of a Bose gas, Bose Einstein Condensation (qualitative description only), Properties of liquid Helium (qualitative discussion only), Radiation as a photon gas and Bose's derivation of Planck's blackbody radiation formula, Thermodynamic functions of photon gas – energy, entropy, and free energy.

Unit IV: Fermi-Dirac Statistics (Lectures 10)

Fermi-Dirac (FD) distribution, FD function and Fermi Energy, Degenerate Fermi gas, strongly degenerate case (qualitative discussion only), Thermodynamic functions - energy and pressure of a completely degenerate Fermi gas, Heat capacity at low temperature, Free electron gas in metals and electronic specific heat, Relativistic Fermi gas, thermodynamics of white dwarf star (qualitative discussion only).

Suggested books

[1] Statistical Mechanics, R K Pathria and P D Beale, Elsevier Science, 2021.

[2] Statistical Physics, F. Reif, McGraw-Hill Education India, 2008.

[3] Statistical and Thermal Physics, S. Lokanathan and R. S. Gambhir, PHI Learning, 1991.

[4] Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, Springer, 2009.

[5] An Introduction to Statistical Mechanics & Thermodynamics, R. H. Swendsen, Oxford University Press, 2012.

[6] A Primer of Statistical Mechanics, R. B. Singh, New Age International Publishers, 2006.

Course Title: Basic Workshop Skills in Physics and Electronics

Course Outcomes (COs)

CO1: Identify and understand the functions of basic electronic components.

CO2: Test and evaluate components for their functionality.

CO3: Simulate circuit layouts using software tools.

CO4: Design PCB layouts.

CO5: Develop, test, and validate electronic circuits.

Program Specific outcome:

Students will gain practical abilities in soldering, de-soldering, assembling, testing, and other areas of electrical components and circuits through this course. These skills will be highly beneficial for projects, other coursework, and the workplace. Apart from this students will also get exposure to advanced fabrication techniques and sophisticated analytical tools.

Unit 1: Introduction to Electronic components

Identification of basic electronic components: Resistors, Capacitors, Diodes, Transistors, Integrated circuits (ICs), study datasheets and specifications.

Unit 2: Component Testing and electronic soldering

Tools for component testing: multimeter, CRO, DSO, etc., testing passive and active components, soldering and de-soldering techniques.

Unit 3: Hands on skill

Basics of PCB design, introduction to software tools, PCB fabrication techniques, design and simulate electronic circuits on breadboard and general purpose PCB.

Unit 4: Introduction to advanced electronic techniques

Basics of fabrication technology: semiconductor devices, printed electronics, and flexible devices, demonstration of sophisticated analytical tools and techniques, use of 3D printing tool and software.

Semester VII

FYUGP with Honours

Course: Classical Mechanics – II (Theory)
Paper Code: PHY0700104
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)

Credits: 4 (Theory- 03, Tutorial - 01)

CO 1: Reproduce the basic results of classical mechanics through general formalisms.

CO 2: Demonstrate the utility of the mathematical structure of mechanics in understanding large varieties of motion in Nature.

CO 3: Apply the mathematical structures to astronomical problems of orbits.

CO 4: Develop the methods to address various periodic motions in physics.

CO 5: Assess the power of generalized formalisms of classical mechanics in understanding foundation of physics as a whole.

Unit-I: Formalism of Classical Mechanics

Review of generalized coordinates, Lagrangian and Hamiltonian; Phase space; Variational principle and Euler-Lagrange equations; Noether's theorem, symmetries & conservation laws; Gauge transformation of the Lagrangian; Lagrangian of the Kepler problem; Analysis of effective potential energy diagram and classification of orbits; Quadrature; Condition for closed orbits-Bertrand's theorem; Poisson bracket formalism; Special theory of relativity- Minkowski spacetime and four-vectors; Lagrangian and Hamiltonian for relativistic particles; Relativistic energy – momentum relation in terms of four vectors; Introduction to classical field theory; Euler-Lagrange equation of classical fields.

Unit-II: Rigid Body Dynamics

Rigid body dynamics; moment of inertia tensor; non-inertial frames and pseudo forces; Principal axes and principal moments of inertia; Euler's equation of motion; Symmetric top motion and Foucault's pendulum.

Unit-III: Canonical transformation and Hamilton-Jacobi theory

Canonical transformations and generating function; Application to simple harmonic oscillator; Hamilton's Jacobi theory and its application to harmonic oscillator problem; Action–angle variables and application to planetary motion- orbital degeneracy.

Unit-IV: Theory of small oscillations

Equilibrium and small oscillations; potential and kinetic energy matrices; normal coordinates; normal modes; coupled oscillations; diatomic and triatomic molecules.

Unit-V: Nonlinear dynamics

Introduction to nonlinear systems; concept of catastrophe; bifurcation; chaos and strange attractors; fractals; physical examples.

Suggested Books and References

1. Classical Mechanics,H.Goldstein
2. Classical Mechanics, N C Rana and P S Joag
3. Mechanics, L D Landau and E M Lifshitz
4. Classical Mechanics, V.B.Bhatia
5. Classical Mechanics, A.K. Raychaudhury
6. Classical Mechanics of Particles and Rigid Bodies, K.C.Gupta
7. Introduction to Mathematical Physics-Methods and Concepts, C.W. Wong
8. Chaos and Nonlinear Dynamics, S Strogatz

Semester - VII
Paper Name: Mathematical Physics-II
Paper Code: PHY0700204
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course Outcome:

CO 1: Outline the concepts of linear vector spaces.

CO 2: Use of Laplace and Fourier transforms to solve differential equations.

CO 3: Solve physical problems using special function.

CO 4: Apply group theories to understand physical problems.

CO 5: Utilize tensor calculus in problems associated with mechanics, relativity, curved spaces and electromagnetism.

Unit-I:Linear Vector Spaces ***(Lectures 15)***

N-dimensional linear vector space, orthonormal basis, Inner product, Hilbert space, Gram-Schmidt orthonormalisation, Outerproduct. Linearoperatorsandtheiralgebra, Matrix representation of operators, Similarity transformation, Diagonalisation of Hermitian, Symmetric, Complex and Complex symmetric matrices, Cayley-Hamilton theorem.

Unit-II: Tensor Calculus ***(Lectures 15)***

Differentiable manifolds and coordinate systems; Transformation of coordinates: Galilean and Lorentz transformations in tensorial language; Tangent vectors and gradients; Metric tensor in different curved spaces. Four vectors and physical examples from special relativity and electrodynamics; Inertia tensors and energy-momentum tensor; Covariant derivatives and parallel transport; Geodesics. Idea of curvature.

Unit-III: Special Functions and Integral Transformations ***(Lectures 15)***

Legendre polynomials, Spherical Harmonics, Hermite polynomials, Bessel functions, Laguerre polynomials; Gamma and Beta functions; Green's function.

Laplace transform and inverse Laplace transform. Fourier transform. Shifting theorem and convolution. Solution of differential equations with the help of Laplace and Fourier transform.

Unit-IV: GroupTheory ***(Lectures 15)***

Group axioms, permutation groups (S2and S3) and symmetry operations of equilateral triangle, multiplication table, subgroup, classes, finite groups (Zn), direct and semi-direct products, block diagonalisation - reducible and irreducible representation. Infinite group, generators and their algebra, spin/Isospininvariance and SU(2) group, SO(3) group and its generators, Isomorphism.

Suggested Books

1. Mathematical methods for physicists, Arfkenand Weber

2. Mathematical Physics, PK Chattopadhyay

4. Matrices and tensorsin Physics, AW Joshi

5. Mathematical methods in the Physical Sciences, Mary L Boas

6. Mathematics for physicists, P Dennery and A Krzywick

7. Partial differential equations of Mathematical Physics, AG Webster

8. Differential equations and the applications, Zafar Ahsan

9. Mathematical Physics, AG Ghatak, IC Goyal and SJ Chua

Semester - VII
Paper Name:Quantum Mechanics-II
Paper Code: PHY0700304
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course outcome

CO 1: Interpret and apply the concepts of superposition of states, Bra and Ket vectors algebra, and orthonormal conditions in quantum mechanics.
CO 2: Apply perturbation theory, variational method, and time-dependent perturbation theory to analyze quantum systems and evaluate their limitations.
CO 3: Illustrate space and time translations, rotational invariance, and angular momentum operators.
CO 4: Analyze combinations of wave functions, exchange degeneracy, and quantum statistics for systems of identical particles.
CO 5: Examine and conclude the act of measurement and quantum harmonic oscillator.

Contents

Unit-I: Matrix formulation of quantum mechanics (16 L + 6 T)
Quantum states and linear algebra, superposition of states, act of measurement, Bra-Ket vectors and applications, orthonormal and completeness conditions, Hermitian operators, simultaneous eigen states, expectation values, change of basis, linear harmonic oscillator. Heisenberg's uncertainty principle in matrix mechanics. Heisenberg's equation of motion and physical equivalence of Schrödinger & Heisenberg picture.

Unit-II: Identical particles (6 L + 2 T)
Indistinguishability, combinations of wave functions for a system of particles, symmetric and antisymmetric wave functions, spin-statistics connection, evolution of quantum statistics, exchange symmetry and exchange degeneracy.

Unit-III: Symmetry, invariance principle, and conservation (9 L + 3 T)
Space and time translations, rotational invariance under infinitesimal and finite rotations. Angular momentum operators, ladder operators, addition of angular momenta - Clebsch-Gordan coefficients, Wigner-Eckart theorem, time evolution.

Unit-IV: Approximation methods in quantum mechanics (14 L + 4 T)
Time independent perturbation theory, Stark and Zeeman effects, variational method and its applications, WKB approximation, time dependent perturbation theory, transition to continuum states, Fermi's Golden rule, adiabatic and sudden approximation.

Suggested Books

1. Quantum Mechanics, L I Schiff
2. Quantum Mechanics, S N Biswas
3. Quantum Mechanics, A K Ghatak and S Lokanathan
4. Introductory Quantum Mechanics, R L Liboff
5. Principles of Quantum Mechanics, R Shankar
6. Quantum Mechanics: concepts and applications, N Zettili

Semester - VII
Paper Name: Experimental Techniques
Paper Code: PHY0700404
Total Marks: 100 (Internal - 40 + External - 60)
Credit: 04 (0L+0T+4P)

Course Outcome:

CO 1: Demonstrate experiments related to electronics, optics, electricity, and nuclear physics.

CO 2: Interrelate the concepts and theories underlying each experiment.

CO 3: Apply mathematical formulae, experimental techniques, and principles to perform calculations and analyze data collected from experiments.

CO 4: Determine the effectiveness of experimental methods, assess the accuracy of results, and compare theoretical predictions with experimental outcomes.

CO 5: Analyze the experimental data, interpret results, and draw conclusions based on observations and measurements.

<u>Contents</u>

The students need to complete at least eight experiments from the given set of practicals and the tentative list of experiments is mentioned below.

Expt.1. *Design a RC phase shift oscillator using OPAMP. Compare the practical and theoretical frequency of oscillation for different values of circuit components.*

Expt. 2. *Design adder and subtractor circuit using OPAMP*

Expt.3. *Design logarithmic and anti-logarithmic amplifier using OPAMP.*

Expt. 4. *Determine the track spacing and pattern of the tracks of a CD.*

Expt. 5. *Determine the Young's modulus of the material of a rod by Newton's ring method.*

Expt. 6. *Verify Malus Law of polarization: To identify the relationship between the intensity of light transmitted through the analyzer and the angle 'θ' between axes of polarizer and analyzer.*

Expt. 7. *Verify the Heisenberg's uncertainty principle using He-Ne laser.*

Expt. 8 *Measure the resistivity and hence the band gap of a semiconductor using four-probe method.*

Expt. 9. *Perform the Hall Effect experiment by recording the Hall voltage at different sample currents under different magnetic field strengths. Plot suitable graph and hence determine Hall coefficients. Identify conductivity type of the semiconductor.*

Expt. 10. *Determine the plateau of the given GM counter and its percentage slope. Hence, study the statistical fluctuation (with beta source).*

Expt. 11. *Study the absorption of beta rays passing through different thickness of Al and determine the linear absorption coefficient.*

Expt.12. *To determine the beta particle range and maximum energy by half thickness method*

Expt.13. *Verify inverse square law for gamma rays using a GM tube.*

Semester-VII
Paper: Research Methodology-I
Paper Code: PHY0700504
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course Outcomes

CO 1: Develop a research plan, and formulate the objectives

CO 2: Use internet, and carry out a survey of literature

CO 3: Examine data by statistical approach

CO 4: Present the findings as a research paper, or a powerpoint/poster presentation

CO 5: Infer on plagiarism

Contents

Introduction to Research

Research: meaning, characteristics and types. Paper, article, workshop, seminar, conference and symposium.

Defining each major concept in operational terms: an overall description of approach, clearly stating any assumptions. Details of techniques. Expected outcome. Methodology to be adopted, planning of experiments for achieving the aims and objectives. Reproducibility of research work. Literature survey of the previous works. Review of an article in the relevant field and preparation of a short report.

Use of internet networks in research activities in searching material, paper downloading.

Sources, acquisition and interpretation of data. Quantitative and qualitative data. Graphical representation and mapping of data.

Statistical analysis

Error analysis and propagation. Types of data, Representation of data: tabular and diagrammatic methods, Inference from data: averages and higher moments. Scatter plots: Correlation tests.

Conditional probability, Bayes theorem, probability distributions, likelihood estimation.

Data-fitting (regression), types of errors, hypothesis testing and confidence limits.

Research Presentation and Academic Integrity

Steps of scientific writing: flow method, organisation of material and style. Types of report: research paper, thesis/dissertation. Drawing figures, graphs, tables, footnotes, references etc. in a research paper.

Preparation in power point for oral, and for poster presentation in scientific seminar. Development of communication skill in presentation of scientific seminars: eye to eye contact, facing to audience, question & answer sessions etc.

Plagiarism: meaning, why and how to avoid it, self-plagiarism.

Suggested Books

1. Research Methodology: Methods and Techniques, by C. R. Kothari and Gaurav Garg, New Age International Publishers.
2. Research Methodology and Techniques in Physics, by Anil Kumar Singh, Anmol Publishers.
3. Research Methods: The Basics, by Nicholas Walliman, Taylor and Francis.
4. Data Reduction and Error Analysis for Physical Sciences, by Philip R. Bevington and D. Keith Robinson, McGraw-Hill Education.
5. The Ethics of Teaching and Scientific Research, Edited by Sidney Hook, Paul Kurtz and Miro Todorovich, Prometheus Books, 1977.

Semester-VIII
Paper: Electrodynamics
Paper Code: PHY0800104
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course outcomes:

CO1: Describe behaviour of charged particles using Maxwell's equations.

CO2: Solve electrostatics problems using Laplace's and Poisson's equations.

CO3: Illustrate propagation and scattering of electromagnetic waves in unbounded and bounded media.

CO4: Develop the electromagnetic theories related to plasma.

CO5: Formulate the electromagnetic theories for power radiated by charged particles.

Unit-I: Boundary value problems and electromagnetic wave propagation (Lectures: 10)

Laplace's and Poisson's equations, solution of problems involving Laplace's equation in spherical, cylindrical and Cartesian coordinates, solutions of problems involving Poisson's equation in Cartesian coordinate and use of Green's function approximation. Review of propagation of electromagnetic waves in matter, reflection of electromagnetic waves from a metal surface, electromagnetic waves in metal-dielectric interface, electromagnetic waves in bounded media, rectangular wave guides, cylindrical waveguides, co-axial cables.

Unit-II: Electromagnetic radiation (Lectures: 10)

Review of Maxwell's equations, electromagnetic potentials, gauge transformation, Lorentz and Coulomb gauges, gauge invariance, retarded potential, Jefimenko's equations, radiation from oscillatory electric and magnetic dipoles, Lienard-Wiechart potential, fields of a point charge in motion, power radiated by a point charge, Larmor formula, Bremsstrahlung.

Unit-III: Electromagnetic scattering and dispersion (Lectures: 04)

Scattering of electromagnetic waves due to free electrons, Thomson scattering, scattering from bound electrons, Rayleigh scattering, dispersion – normal and anomalous.

Unit-IV: Motion of charged particles (Lectures: 07)

Non-relativistic motion of a charged particle in uniform constant fields and slowly varying field; gradient drift, magnetic mirror.

Unit-V: Covariant form of Maxwell's equations (Lectures: 06)

Four dimensional Lorentz transformation, covariance of Maxwell’s equations, electromagnetic field tensor.

Unit-VI: Basics of plasma **(Lectures: 08)**

Plasma as a fourth state of matter, Debye shielding, fluid equations in plasma, electrostatic oscillations and waves in plasma, single-fluid equations and MHD waves.

Suggested Books

1. Introduction to Electrodynamics, D. J. Griffiths
2. Foundation of Electromagnetic Theory, J. R. Reitz, F. J. Milford and R. W. Christy
3. Electricity and Magnetism, M. H. Nayfeh and M. K. Brussel
4. Classical Electrodynamics, J. D. Jackson
5. The Feynman Lectures on Physics (Vol II), R. P. Feynman
6. Introduction to Plasma Physics, F. F. Chen
7. Plasma Physics, R. J. Goldstone and P. H. Rutherford
8. Plasmonics: Fundamentals and Applications, S. A. Maier

Semester: VIII

Paper name: Atomic and Molecular Physics

Paper Code: PHY0800204

Total Lectures: 60 (45 Theories; 15 Practical)

(Total Marks 100: Internal-30+External-70)

Credits 4: (Theory: 3 + Practical: 1)

Course Outcome:

CO 1: Explain the Pauli exclusion principle, LS and j-j coupling, and the basics of spectral terms in atomic physics.
CO2: Use selection rules to analyze rotational, vibrational, and Raman spectra of diatomic molecules, demonstrating comprehension of molecular physics.
CO 3: Outline the basic elements of a laser system, and distinguish between temporal and spatial coherence properties of the laser.
CO 4: Apply Einstein's relations to explain light amplification and determine the threshold condition for oscillation, and obtain the necessary condition for achieving population inversion in two-, three- and four-level laser systems.
CO 5: Understand laser cavity modes, explain ammonia maser and different lasers with applications in holography and optical communication.

Contents:

Unit-I: Atomic Physics

Pauli exclusion principle: spectral terms from two equivalent electrons, Vector model for three or more valence electrons and spectral terms, branching rule, Landé interval rule, LS and j-j coupling schemes, energy levels, selection rules, spectra of oxygen, nitrogen and manganese atoms; Zeeman effect, Paschen- Back effect, Stark effect in hydrogen, hyperfine structure, determination of nuclear spin and nuclear gfactors, Breadth of spectrum lines: natural broadening, Doppler broadening, collision broadening, and Stark broadening.

Unit-II: Molecular Physics

IR spectra - rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determination of rotational constants. Electronic spectra: Born-Oppenheimer approximation, vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck Condon principle. Raman spectra: Classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and anti-Stokes lines, Rotational Raman spectrum, selection rule.

Unit-III: Lasers

Basic elements of a laser, properties of laser light; spontaneous and stimulated emission: Einstein
coefficients, light amplification, population inversion and threshold condition for laser oscillations, optical resonator modes of a rectangular cavity, rate equations: two-level, three-level and four-level systems; ammonia maser, ruby laser, He-Ne laser, CO2 lasers, laser applications: holography and optical communication.

List of Practical:

Expt. 1. *To determine the thickness of a given mica sheet by using Jamin's interferometer*

Expt. 2. *To find out the separation between the sodium D-lines using a grating and hence to determine the minimum number of lines required in the given grating to resolve sodium D-lines in the first and second order.*

Expt.3. *Determine wavelength of a given light source using the Michelson interferometer*

Expt.4. *Determination of the grating element of the double slit by observing interference and using lamp and scale method*

Suggested Books

1. *Introduction to Atomic Spectra*, H E White.
2. *Physics of Atoms and Molecules*, B H Bransden and C J Joachain
3. *Fundamentals of Molecular Spectroscopy*, C N Banwell and E M McCash.
4. *Spectra of Diatomic Molecules (Vol. 1)*, G Herzberg.
5. *Lasers and Nonlinear Optics*, B B Laud.
6. *Lasers : Theory and Applications*, K Thyagarajan and A K Ghatak

Semester: VIII
Paper name: Astrophysics & Cosmology
Paper Code: PHY0800304
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course outcomes:

CO 1: Identify the physical laws governing structure and evolution of celestial objects and the universe at large.

CO 2: Demonstrate the validity of physical principles in stellar and larger celestial systems.

CO 3: Apply the formalisms and working principle of the tools to understand and measure structure, scales and evolution of the universe.

CO 4: Analyze the models of stars and cosmological evolution to understand how matter in the universe has evolved.

CO 5: Assess and summarize various techniques and theoretical models used to describe the physical systems in question.

Unit I: Stellar astrophysics

Star formation and Jeans criterion; Stellar populations in the universe; Salpeter initial mass function; Mass-luminosity relation and stellar ages; Stability of stars; Polytropes and Lane-Emden theory of stars; Mass-radius relation; Gaseous and radiative stars; Stellar evolution and origin of elements; White dwarfs, neutron stars and black holes.

Unit II: Basic astronomy

Standard photometric system; Astronomical filters; Colour index; Spectral classifications of stars; Luminosity classification of stars and HR diagram; Astronomical coordinate system; Measurement of distance using distance modulus and standard candles: Cepheids, Type-Ia Supernovae; Super Chandrasekhar mass; Hubble's law and Hubble flow.

Unit III: Observational techniques

Optical/NIR telescopes and their different properties; Formation of image in an Optical/NIR telescope; Rayleigh criterion; Resolution enhancement techniques; CCD and their characteristics; Multi-messenger astronomy; Concept of photometry; Spectroscopy and Polarimetry; Space telescopes: WMAP, HST, PLANCK and JWST; Weak gravitational lensing.

Unit IV: Cosmology

Galaxies and supermassive black holes; Large scale structure of the universe; Hubble-Lemaitre parameter (H_0) and scales of cosmology; Cosmological principle and cosmic expansion; Mass-to-light ratio of galaxies; Dark matter; Cosmic Microwave Background (CMB) and the Hot Big Bang Model; Friedmann models of the universe (Newtonian treatments); CMB anisotropy, Planck mission and galaxy formation; Cosmic reionization – the Pop III stars; Dark energy; The H_0 problem; The high redshift universe of HST and JWST (introduction only).

Books & suggested references:

(1) Introduction to the theory of stellar structure and evolution, D. Prialnik, Cambridge University Press.

(2) Astrophysics for physicists, A. Rai Choudhuri, Cambridge University Press.

(3) B^2FH, the CMB & Cosmology, G. Burbidge, arXiv:0806.1065 (Review article).

(3) Introduction to cosmology, J. V. Narlikar, Cambridge University Press.

(4) Introduction to cosmology, B. Ryden, Cambridge University Press.

(5) The Physical Universe: An Introduction to Astronomy, Frank H. Shu, University Science Books.

(6) Extragalactic Astronomy and Cosmology, Peter Schneider, Springer.

(7) Telescopes and Techniques, C. R. Kitchin, Springer.

(8) Spherical Astronomy, W. M. Smart, Cambridge University Press.

Semester: VIII

Paper name: Nuclear Physics

Paper Code: PHY0800404

Total Lectures: 60 (Theory : 45 Hours , Practical : 30 Hours)

Total Marks 100: (Internal-30+External-70)

Credit : 04 (Theory-03, Practical-01)

Course Objective: The objective of this course is to impart the basic understanding of the nucleus, different representation of nuclear models, nuclear reactions and other sub atomic particles and their properties. It will emphasize to gain knowledge about the different nuclear techniques and their applications in different branches of Physics and society. The course will focus on the developments of problem based skills at the nuclear scale.

Course learning outcome:

- The course describes the structure of nuclei and interactions between the nucleons and nuclei.
- Discuss about the construction and working principles of accelerators and detectors
- Learners would be able to distinguish strong nuclear interaction with other fundamental interactions of the nature and learn about nuclear instrumentation.

1. **Nuclear Structure: Models of Nuclei:**
   Liquid drop model (LDM): Evidences in support of LDM, Establishment of Semi-empirical mass formula, its applications in – (i) estimating the energy released in fission of heavy nuclei, (ii) in predicting the most stable member of an isobaric family against beta decay. Success and Limitations of LDM.
   Shell Model: Evidences in favour of Shell model, Labelling of Shell model states to obtain shell closure at magic numbers, Spin and parity of various nuclei in the light of Single Particle Shell Model.
2. **Forces Between Nucleons**: Characteristics of nucleon-nucleon interactions with examples, Neutron-proton bound system: Deuteron – its binding energy, spin and parity, magnetic dipole moment, electric quadrupole moment, Quantum mechanical approach to estimate deuteron potential.
3. **Nuclear Reactions**: Concept of two body nuclear reactions for fixed target experiment – concept of flux, fluence, pnA, solid angle, and cross-section.
   Classification of nuclear reactions, kinematics of two body nuclear reaction – LAB and CM coordinate system, Rutherford alpha particle scattering experiment – corrections for extended object, QM and relativistic effects. Concept compound nuclear reaction – Bohr compound nucleus hypothesis, Ghosal experiment.
4. **Accelerators and Radiation Detectors:**
   Accelerators: Limitations of liner accelerators, Concept of Cyclic accelerator: Cyclotron – its working principle and construction, limitation of Cyclotron, Synchrotron (only concept).
   Detectors: Photon detectors – Scintillator detectors – Working principle of NaI(Tl) scintillator detector, PMT and its construction and working principle, Ge(Li) detector (introduction only).
   Charged particle detector: Si Surface Barrier detector (SSB) – construction and working principles, Resistive Plate Detector (RPC) – an introduction, SSNTD.

Reference Books:

1. Introductory Nuclear Physics – Kenneth S Krane
2. Introduction to Nuclear Reactions – G R Satchler
3. Nuclear Physics: Theory and Experiment – R R Roy and B P Nigam
4. Radiation Detection and Measurement – G F Knoll
5. Techniques for Nuclear and Particle Physics Experiments - W R Leo

Experiments (for 1 credit)

1. To draw the plateau curve for a given GM counter and hence to find the operating voltage and percentage slope the drawn plateau curve. Also, to find the statistical fluctuation in the count rate for a given beta source. Fit the obtained frequency distribution diagram with Gaussian distribution to draw conclusion on the nature of beta radioactive decay.
2. To find the operating voltage of a given GM counter and the maximum range of beta particles in aluminium using half-absorption method.

Reference Books:

1. Laboratory Manual
2. Radiation Detection and Measurement – G F Knoll
3. Techniques for Nuclear and Particle Physics Experiments - W R Leo

Semester VIII
Paper: Advanced Electronics
Paper Code: PHY0800504
Total Lectures: 60 (45 Theories; 15 Practical)
(Total Marks 100: Internal-30+External-70)
Credits 4: (Theory: 3 + Practical: 1)

Course Outcome:

CO1: Recall the basic principle of electronics.
CO2: Explain the working of different electronic circuits and components.
CO3: Operate on the various electronic circuits and components.
CO4: Relate different components of electronic systems.
CO5: Summarize the use of electronic circuits for various applications.

Theory:

Unit I: Electronic Devices and applications (Lecture 07)

Carrier concentrations in semiconductors; direct and indirect band gap semiconductors, Band structure of p-n junction; Homo and hetero-junction devices; SCR. UJT. Diac. Triac. JFET. MOSFET. CMOS. Tunnel diode. GUNN diode. IMPATT diode and their characteristics graphs.
Application of UJT: Relaxation oscillator, Application of SCR**:** Saw tooth generator. Application of JFET: Amplifier, AC equivalent circuit, and voltage gain. Application of CMOS: as NOR gate and NAND gate operation.

Unit II: Optoelectronics (Lecture 06)

Working principle of LED. Relation between forbidden energygap and emitted wavelength. Power and quantum efficiency of LED. Types of LED (Surface emitter SLED, Edge emitter ELED, and Super Luminescent SLED). Drive circuit for LED (Single common emitter and emitter follower).
Photodetector materials. The basic principle for optical detection. P-N junction photodiode and its disadvantage. The p-i-n photodiode, expression for current, quantum efficiency, and responsivity of a photodiode. Noise optical devices. Noise Equivalent Power(NEP). Photo Transistor, its structure, and operation.

Unit: III: Filters (Lecture 03)

General diagram of active filter. Critical frequency and roll-off rate. Low Pass, High Pass, Band Pass, and Band Reject filter. 1st order and 2nd order filters. Sallen Key (Voltage Controlled Voltage Source).

Unit IV: Special purpose Op-Amps (Lecture 04)

Instrumentation amplifier. AD622 instrumentation amplifier with IC pin numbers. Operational Transconductance Amplifier (OTA) and basic OTA circuit.

Unit V: Data Processing Circuits (Lectures 04)
The basic idea of Multiplexers. De-multiplexers. Decoders. Encoders.

Unit VI: Counters (4 bits) (Lectures 04)
Ring Counter. Asynchronous counters. Decade Counter. Synchronous Counter.

Unit VII: Conversion of Analog and Digital Voltages (Lectures 03)
Digital to analog conversion (DAC): Resistive network (Weighted and R – 2R Ladder). Analog to digital conversion (ADC): Basic block diagram. Nyquist theorem. Counter type ADC. Successive approximation method. Accuracy and Resolution of ADC.

Unit VIII: Intel 8085 Microprocessor Architecture (Lectures 07)
Basics of a microprocessor. Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry.

Unit IX: Introduction to Assembly Language (Lectures 04)
1-byte, 2 bytes, &3-byte instructions

Unit X: Nanoelectronics (Lectures 03)
Introduction to the quantum view of bulk solids: key ideas in electronic properties. Review of basicsemiconductor device physics with a broad survey of modern device technology. Introduction tonanomaterials and their special features in electronics. Overview of nanoelectronics devices and materials requirement. Introduction to nanolithography process with an overview of photolithography.

Practical Lab:

A minimum of ***four*** experiments are to be done.

1. Draw the V-I characteristic curve of a tunnel diode.
2. Draw the V-I characteristic curve of a Gunn diode.
3. To study transfer and output characteristics of an n-channel Junction field effect Transistor (JFET) in Common-source configuration.
4. Determine the value of the Planck Constant using LED.
5. To design a digital-to-analog converter (DAC) of given specifications.
6. To study the analog-to-digitalconverter (ADC) IC.
7. Design high and low pass filters using OPAMPs. Estimate the cutoff frequency and roll-off rate.
8. Design bandpass filters using OPAMPs
9. Design band reject filters using OPAMPs
10. Design and study the gain of an Instrumentation Amplifier.
11. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.

12. Write the following programs using 8085 Microprocessor
    (a) Addition and subtraction of numbers using direct addressing mode
    (b) Addition and subtraction of numbers using indirect addressing mode
    (c) Multiplication by repeated addition
    (d) Division by repeated subtraction
    (e) Handling of 16-bit Numbers

Note: Students **can** use electronic simulation software to test the circuit/program before implementing it in hardware.

Suggested Books

1. Electronic Devices and Circuit Theory, R L Boylestad
2. Electronic Devices and Circuits, T Bogart, J S Beasley and G Rico
3. Electronic Devices, T L Floyd
4. Modern Digital Electronics, R P Jain
5. Optoelectronics and Fiber Optics Communication, C K Sarkar and D C Sarkar
6. OPAMPS and Linear Integrated Circuits, Ramakant A Gayakwad.
7. Operational Amplifier and Linear Integrated Circuits, R F Coughlin and F F Driscoll.
8. Modern Digital and Analog Communication Systems, B P Lathi.
9. Electronic Communication System, George Kennedy. 6. Communication Systems, Simon Haykin
10. Microprocessor Architecture Programming & applications with 8085, 2002, R. S. Goankar, Prentice Hall.

Semester VIII
Course Name: Advanced Condensed Matter Physics
Paper Code: PHY0800604
Total Lectures: 60 (45 Theories; 15 Practical)
Total Marks 100: (Internal-30+External-70)
Credits 4: (Theory: 3 + Practical: 1)

Course Outcome:

CO 1: Describe the fundamental concepts of matter in condensed state, crystalline structure and lattice dynamics

CO 2: Illustrate the structural, electrical, and magnetic properties such as band theory in solids, superconductivity, dielectric and ferroelectric Properties

CO 3: Apply the mathematical and theoretical concepts to analyse and solve problems related to crystalline solids, lattice dynamics, semiconductor, and magnetic properties.

CO 4: Analyse theoretical models to interpret physical phenomena such as phonons, dielectric relaxation, energy band structures, and magnetic behaviour.

CO 5: Determine parameters related to crytallinity, electrical, magnetic and other properties of condensed matter.

Content:

Unit-I: Crystalline Solids (Lectures 11)

Symmetry operations, point groups and space groups, X-ray diffraction, Bragg's law, reciprocal lattice, atomic scattering factor, geometrical structure factor, quasicrystals, defects in crystals.

Unit-II: Lattice Dynamics (Lectures 06)

Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Dispersion relations in monoatomic and diatomic linear lattices, normal modes.

Unit-III: Dielectric and Ferroelectric Properties (Lectures 08)

Complex dielectric constant and dielectric loss, dielectric relaxation, Debye equations, optical phenomena, dipole theory of ferroelectric domains, P-E hysteresis loop, structural phase transition, anti-ferroelectricity.

Unit-IV: Energy Bands in Solids (Lectures 08)

Bloch function, Kronig-Penney model, Brillouin zones, effective mass of charge carriers, tight binding approximation and Wigner Seitz method.

Unit-V: Nanophysics and Soft Matter (Lectures 04)

Understanding of nanomaterials (0-D, 1-D, 2-D & 3-D) and their synthesis procedures. Basic characterization techniques of nanomaterials: XRD (X-Ray Diffraction), UV-VIS-NIR spectrophotoscopy, TEM (Transmission Electron Microscopy), SEM (Scanning Electron Microscopy), AFM (Atomic Force Microscopy). Brief idea about thin film technology (synthesis and characterization), Soft Matter.

Unit-VI: Semiconductors (Lectures 08)

Number density of carriers in intrinsic and extrinsic semiconductors, expression for Fermi levels, recombination processes, photoconductivity, Hall effect in metals and semiconductors.

Unit-VI: Magnetic Properties (Lectures 09)

Quantum theory of diamagnetism and paramagnetism, diamagnetic and paramagnetic susceptibilities of free electrons, molecular field theory of ferromagnetism, anti- ferromagnetism and ferrimagnetism, anisotropic energy, Electron paramagnetic resonance and nuclear magnetic resonance.

Unit-VII: Superconductivity (Lectures 06)

Thermodynamics of superconducting state, London equations, penetration depth, coherence length, idea of BCS theory.

Lab:

Course Outcome:

CO 1: Demonstrate the experiments in the field of electrical and optical transport, transport in magnetic field, dielectric phenomena and spin resonance

CO 2: Interrelate the experiments with theoretical advanced topic of condensed matter physics

CO 3: Develop the skill to solve the experimental problems

CO 4: Analyse the experimental data collected from each experiment and interpret the results.

CO 5: Rearrange and design research grade devise on the basis of experience of handling advanced equipment in context of Advanced Condensed Matter Physics

Contents

The students need to complete at least four experiments from the given set of practicals and the tentative list of experiments is mentioned below.

Expt 1: *To study the dispersion relation for the monoatomic and diatomic lattice*

Expt 2: *Determine the coercivity, retentivity, and saturation magnetization of a given ferromagnetic specimen using B–H loop curve.*

Expt 3: *Measurement of magnetoresistance of the supplied material*

Expt 4: *Study of temperature dependent Hall effect of the supplied semiconductor*

E**xpt 5**: *Determination of Plank's constant by photoelectric effect*

Expt 6: *Determination of transition temperature of the supplied ferroelectric sample*

Suggested Books

1. *Introduction to Solid State Physics*, C Kittel
2. *Lattice Dynamics*, A K Ghatak and L S Kothari
3. *Solid State Physics*, A J Dekker.
4. *Introductory Solid State Physics*, H P Myers.
5. *Solid State Physics*, N W Ashcroft and N D Mermin
6. *Magnetism in solids*, D H Martin
7. *Physics of Magnetism*, S Chikazumi.
8. *Solid State Physics, S O Pillai*
9. *Introduction to Nanotechnology*, C. P. Poole, J. F. J. Owens

Semester: VIII
Paper name: Particle Physics
Paper Code: PHY0800704
Total lectures: 60 (45 Theory; 15 Tutorials)
Total Marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory- 03, Tutorial - 01)

Course Outcome:
CO 1: Recall fundamental particles and interactions
CO 2: Explain Relativistic wave equation and Feynman diagrams
CO 3: Utilize Feynman rules to calculate cross sections
CO 4: Assess accelerator operation and experimental data.
CO 5: Appraise different dimensions of high energy physics
Content

Unit I - Introduction to Particle Physics **(15 L+ 5 T)**

Classification of Elementary Particles and fundamental forces, Parity, Elementary ideas of U(1), SU(2) and SU(3) symmetry, groups and hadron classification; Charge Conjugation and Time Reversal, spin and parity determination of pions and strange particles, parity violation in weak interactions, CP violation; Gell-Mann Nishijima scheme; Properties of quarks and their classification, Concept of quark model, eightfold way, colour quantum number, gluons; Introduction to the standard model, Electroweak interaction - W & Z Bosons, Higgs Boson; Quark mixing; Natural unit system and conversion factors.

Unit II - Basics of Scattering & Decays **(15 L + 5 T)**

Relativistic wave equations, Klein-Gordon equation, Dirac equation, Gamma matrices and traces of their products, particle and antiparticle spinors, Golden rule for scattering and decays, Feynman rules for QED processes; cross section of different processes, like Mott scattering, Compton scattering, muon decay, hadron production in $e^{-}e^{+}$collisions, resonance and decay widths.

Unit III - Recent trends in High Energy Physics **(6 L + 2 T)**

Elements of Neutrino physics, grand unified theories, supersymmetry, dark matter, baryon asymmetry of the universe, string theories.

Unit IV - Fundamentals of Particle Accelerators & Detectors **(9 L + 3T)**

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron & VECC, Synchrotrons (Principal, construction, working, advantages and disadvantages); LHC dipole magnets, Colliders and fixed target accelerators, Luminosity.

Particle detectors: Qualitative idea of Interaction of radiation with matter, Basics of solid state detectors, Scintillation and gas detectors for particle and electromagnetic radiation detection, Idea of Calorimeter, Hybrid detectors and arrays, Photo Multiplier Tube, detection via Cerenkov radiation.

Books

1. Introduction to Elementary particles, D Griffiths, Willey VCH
2. Particle Physics, B R Martin, G Shaw, John Willey and Sons
3. Particle Physics in the LHC Era, G. Barr, R. Devenish, R Walczak, T. Weidberg, Oxford University Press.
4. Modern Particle Physics, Mark Thomson, Cambridge University Press.
5. An Introduction to Particle Physics and the Standard Model, Robert Mann, CRC Press, A Taylor and Francis Book
6. An Introductory course of Particle Physics, P B Pal, Taylor and Francis group.
7. Physics and Engineering of Radiation Detection by Syed Naeem Ahmed (Academic Press 2007).
8. An Introduction To Quantum Field Theory, M E Peskin and D V Schroeder
9. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, Inc.3rd Ed., 2000)

Semester-VIII

Paper: Nanophysics
Paper Code: PHY0800804
Total lectures: 60 (45 Theory, 15 Tutorials)
Total marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course outcomes:

CO1: Recognize the importance of nanoscale dimension in physics.
CO2: Give examples of natural occurrence, ancient use and modern synthesis methods of nano-objects.
CO3: Illustrate basic techniques to gather information of nanomaterials.
CO4: Construct quantum mechanical framework to study nanoscale phenomena.
CO5: Explain the role of surface atoms at nanoscale.

Contents:

Unit I: Introductory idea (Lectures: 14)

Original scientific idea, natural occurrence, ancient use of nano-objects, top-down and bottom-up approaches, synthesis of nanomaterials: solution based, solid state based and vapour based methods, characterization of nanomaterials: X-ray diffractometry for phase identification and crystallite size determination, transmission electron microscopy for imaging nanocrystals and microstructure, UV-visible absorption spectroscopy, scope and challenges of nanotechnology.

Unit II: Quantum effects in nanostructures (Lectures: 12)

Low dimensional structures (2D, 1D, 0D) and density of states, ε-k diagram, band gap engineering, compositional variation and quantum confined structure, quantum wells, multiple quantum wells and superlattice, quantum dots (introductory concepts), solutions of Schrödinger equation for infinite spherical barrier and nanocrystals.

Unit III: Surface effects (Lectures: 08)

Increased surface area-to-volume ratio, melting point suppression, increased reactivity, catalysis, superhydrophobicity

Unit IV: Nanocomposites (Lectures: 11)

Natural nanocomposites, biomimetic and bioinspired nanocomposites, metal/ceramic nanocomposites, polymer-based nanocomposites, dispersion of nanophase, mechanical properties of CNT/polymer composites, nanocomposites for optoelectronic applications.

Suggested Books:

1. Nanophysics and Nanotechnology, E. L. Wolf

2. Elements of X-ray Diffraction, B. D. Cullity, S. R. Stock
3. Nano: The Essentials, Understanding Nanoscience and Nanotechnology, T. Pradeep
4. Nanotechnology: Principles and Fundamentals, G. Schmid
5. Introduction to Nanotechnology, C. P. Poole, J. F. J. Owens
6. Nanostructures and Nanomaterials, G. Cao, Y. Wang
7. Fundamental of Nanoelectronics, G. W. Hanson
8. Nanocomposite Science and Technology, P. M. Ajayan, L. S. Schadler, P. V. Braun
9. Introduction to Nanoscience and Nanotechnology, K. K. Chattopadhyay, A. N. Banerjee

Semester VIII

Paper (Course): Plasma Physics I

Paper Code: PHY0800904
Total lectures: 60 (45 Theory, 15 Tutorials)
Total marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Objectives: • To introduce the subject of plasma physics, which has emerged, in recent decades, as one major branch of study and research in physics. • To provide the the student with the fundamental knowledge of plasma physics. • To provide the student with a comprehensive initial knowledge of plasma physics, so that one can plan for future career in plasma physics

Course Outcomes:

CO1: Unit I Define and describe the subject.

CO2: Unit II Illustrate the foundations of the subject.

CO3: Unit II Explain the necessary theoretical background.

CO4: Unit III Analyse the outcome of the previous sections and utilise the knowledge to broaden the perspective of the subject.

CO5: Unit IV Determine the implications of the previous analysis and combine advanced ideas.

Prerequisites : None

Unit I What is plasma? (5 Lectures)

Definition of plasma. Plasma as another state of matter, key differences of properties of matter in plasma state. Plasma production and plasma in nature. Concept of temperature. Classification of plasmas. CMA diagram. The concept of Debye shielding (no derivation) and criteria for plasmas. Concept of quasi-neutrality. Introduction to applications of plasma physics.

Unit II Particle orbit theory (20 Lectures)

Motion of individual charge particles in a uniform electric and magnetic fields. Concept of Lorentz force and its effect on charged particles. Concept of guiding centre drift. Motion of individual charged particles in a nonuniform magnetic field (i.e. magnetic field with spatial gradients). Concept of polarisation of charged particles due to drift motion (secondary drift motion). Electric drift, gradient of B drift, curvature drift, and drift due to gravity. Concept of conserved quantities for charged particles in a magnetic field. Adiabatic invariants and magnetic mirror. Radial and longitudinal confinements in a magnetic mirror. Motion of individual charged particles in a nonuniform electric field, time-varying electric and timevarying magnetic fields. The concept of adiabatic heating in a mirror.

Unit III Plasma as a fluid (8 Lectures)

Concept of fluid element and collective motion. Debye shielding (with derivation). Incorporation of fluid equations to describe plasma as a fluid. Fluid model of plasma (Continuity, momentum equations, and equation of state). Two-fluid model of plasma.

Unit IV Plasma waves : application of fluid model (electrostatic wave) (10 Lectures)

Application of fluid model of plasma in analysing waves in plasmas. Concept of electrostatic and electromagnetic waves. High and low frequency electrostatic waves. Various approximations in fluid model and plasma approximation. Electron plasma oscillation and wave. Consequence of Debye shielding in electron plasma wave. Ion-acoustic wave. Comparison of electron and ion waves.

1-year PG Programme:

A. Research:

B. Course Work

Semester IX

Paper: Quantum Mechanics-III
Paper Code: PHY0900104
Total lectures: 60 (45 Theory, 15 Tutorials)
Total marks: 100 (Internal - 40 + External - 60)

Credits: 4 (Theory – 03; Tutorial - 01)

Course Outcome:
CO 1: Recall the key principles of relativistic mechanics and quantum mechanics.

CO 2: Illustrate the process of quantum mechanical interaction with matter.

CO 3: Apply the concepts to explain experimental results and to realize new developments in technology.

CO 4: Analyze the formalisms to explain different components and problems of quantum mechanical interactions.

CO 5: Assess the implications of quantum mechanical interactions in dealing with deeper problems in quantum mechanics.

Content
Unit-I: Relativistic Quantum Mechanics (15 L+ 5T)
Concept of four vectors, Minkowski space; Natural units; Klein Gordon (KG) equation, Problem with KG equation; Feynman-Stuckelberg interpretation and antiparticle, Covariant formulation of Dirac equation, Plane wave solution of Dirac equation, Negative energy and vacuum, Non-relativistic limit of Dirac equation, Prediction of spin of electron, Transformation of spinor; Dirac bilinear, Traces of product of Dirac gamma matrices, helicity and chirality.

Unit-II: Scattering Theory (10L +3T)
Introduction to scattering cross section and differential cross section, Scattering by a potential,Lippman Schwinger equation, Green function solution; Transition matrix; Born series and Born approximation; Scattering cross section for delta function, Yukawa, Coulomb and square-well potential; Resonance scattering, Breit–Weigner formula; Partial wave analysis- scattering by square-well and hard sphere.

Unit-III: Interaction of Radiation with Matter (10L+ 3T)
Electromagnetic field and its interaction with single electron atom; Harmonic perturbation and transition rates; Spontaneous and stimulated emission; Absorption; Einstein A and B coefficients; Selection rules.

Unit- IV: Advanced topics in Quantum Mechanics (11 L+3 T)
EPR paradox, Bell's inequality and entanglement; Schrodinger's cat paradox – Copenhagen interpretation and Many World Hypothesis; Basics of Quantum computation - Qubits, Quantum algorithms, models of Quantum computation, Quantum cryptography.

Suggested Books and References:

1. Relativistic Quantum Mechanics, J D Bjorken and S D Drell
2. Quantum Mechanics, B H Bransden and C J Joachain
3. Advanced Quantum Mechanics, J J Sakurai
4. Quantum Mechanics, Eugene Merzbacher
5. Quantum Mechanics, L I Schiff and J Bandhyopadhyay
6. Quantum Mechanics, A Ghatak
7. Principles of Quantum Mechanics, R Shankar
8. Feynman's Thesis: A New Approach to Quantum Theory, R P Feynman and L M Brown
9. Introduction to Quantum Mechanics, D Griffiths.
10. Quantum Computation and Quantum Information, M A Nielsen and I Chuang, Cambridge University Press (2013).
11. Quantum Computing, A Gentle Introduction , E G. Rieffel and W H. Polak, MIT press (2014)
12. Quantum Computing for Everyone, C Bernhardt,, The MIT Press, Cambridge, 2020

Semester-IX

Paper: Statistical Mechanics-II
Paper Code: PHY0900204
Total lectures: 60 (45 Theory, 15 Tutorials)
Total marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course outcome:

CO 1: Recall and summarize statistical mechanics concepts.

CO 2: Interpret theories of fluctuations like Einstein–Smoluchowski theory and Onsager relations.

CO 3: Apply statistical mechanics concepts to solve problems and analyze phenomena.

CO 4: Analyze various models of phase transitions.

CO 5: Summarize phase transitions in various systems using Ising model.

Contents

Unit-I: Classical statistical mechanics *(11 L, 4 T)*

Review of classical statistics, systems in canonical ensemble, partition functions, energy fluctuations in canonical ensemble, harmonic oscillators, paramagnetism, thermodynamics of magnetic systems, negative temperatures. Grand canonical ensemble, system in grand canonical ensemble, grand partition function, fluctuations in grand canonical ensemble, equivalence to other ensembles.

Unit-II: Quantum statistical mechanics *(15 L, 5T)*

Framework of quantum statistics, density matrix for various systems, postulates of quantum statistical mechanics, quantum mechanical ensembles. Review of Fermi systems, thermodynamics of Fermi gas, Pauli paramagnetism, Landau diamagnetism. Review of Bose systems, thermodynamics of Bose gas, Bose-Einstein condensation (BEC) and phase transitions, magneto-optical trap and experimental evidences of BEC, photon and phonon gas model, photon counting.

Unit-III: Phase transitions *(11 L, 4 T)*

Phase equilibrium, mean field theory, Van der Waals equation of state and phase transitions, Ising model, lattice gas and binary alloy, spontaneous magnetization, Bragg-Williams and Bethe-Peierls approximation, two-dimensional Ising model.

Unit-IV: Fluctuations *(8 L, 2 T)*

Brownian motion, Einstein–Smoluchowski theory, Langevin theory, approach to equilibrium: Fokker–Planck equation, Wiener-Khintchine theorem, Onsager relations.

Suggested Books

1. *Statistical Mechanics*, R K Pathria and P D Beale
2. *Statistical Mechanics*, K Huang
3. *Introduction to Statistical Physics*, S R A Salinas
4. *Thermodynamics and Statistical Mechanics*, W. Greiner, L Neise, H Stöcker
5. *Statistical Physics*, L D Landau and E M Lifshitz

Semester IX
Paper: Computational Physics
Paper Code: PHY0900304
Total Lectures: 60 (30 Theories; 30 Practical)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 2 + Practical: 2)

Course Outcome:

CO1: Outline of basic computer programming and O/S. Need for computational physics.
CO2: Illustrate FORTRAN 90/95 and Python programming examples.
CO3: Discuss fundamental techniques of computation of solution of transcendental equations. Solution of algebraic equations. Solution of differential equations. Concept of numerical integration. Partial differential equations.
CO4: Manipulate matrix. Solution of linear equations.
CO5: Construct advanced computational techniques like generating pseudo random numbers. Monte-Carlo integration

Theory:

Unit-I: Introduction to Computer Programming **(2 Lectures)**
Programming languages – high level languages, low level languages. Concepts of file structure, directories, compilers and debuggers in relation to GNU Linux O/S. Algorithms and flowcharts. Basic commands in GNU Linux. Graphical utilities-e.g., gnuplot.

Unit-II: Programming in FORTRAN /Python **(7 Lectures)**
Introduction to FORTRAN/Python as a programming language. Basic concept in FORTRAN/Python – variables, numbers, operators. Data structures. Concept of input-output statements, conditional statements, logical expression and control statements, use of loops in program. Concept of subprograms, concept of modules. Computation with external packages.

Unit-III: Introduction to Numerical Methods **(2 Lecture)**
Need of numerical analysis and its limitations. Concept of errors with examples.

Unit-IV: Solution of Linear System Ax = b **(2 Lectures)**
Gauss elimination and Gauss-Jordan elimination.

Unit-V: Solution of Nonlinear Equations **(3 Lectures)**
General method of solving transcendental equations- solution by Newton-Raphson method and bisection method, comparison of their limitations, propagation of errors.

Unit-VI: Solution of ordinary differential equations (ODEs) **(4 Lectures)**
Concept of finite differencing. Solution of a first order ODE with Euler's method and its limitations. Need for a higher-order method - solution of a first order ODE with Runge-Kutta method. Solving higher order ODE- coupled ODEs.

Unit-VII: Numerical integration **(4 Lectures)**

Numerical integration as quadrature (area under the curve), integration through Lagrange's polynomial interpolation (i.e. Newton-Cotes formulae: trapezoidal and Simpson's rule), simple applications with composite trapezoidal and Simpson's rule, Gaussian quadrature.

Unit-VIII: Interpolation and curve fitting **(4 Lectures)**

Polynomial interpolation by Lagrange's method. Construction of Newton-Gregory forward difference and backward difference tables. Estimation of errors in these methods, least square curve fitting.

Unit-IX: Random numbers in numerical analysis **(2 Lectures)**

The concept of random numbers - pseudo random numbers and their generators. Application - Monte-Carlo integration. Examples from Physics to be given.

Practical Lab:

From the following list, any ***eight*** practicals should be performed.

1. Simple Programs like - solution of a Quadratic equation, sine/cosine value using Taylor series expansion, matrix operation.
2. Least square fitting.
3. Numerical Interpolation.
4. Numerical solution of non linear equation with bisection method.
5. Numerical solution of a non linear algebraic equation with Newton-Raphson method.
6. Solution of differential equation with Euler’s method.
7. Solution of differential equation with Runge Kutta method.
8. Solution of a definite integral with trapezoidal method.
9. Numerical integration using Simpson’s Method.
10. Monte Carlo Simulation programs using random numbers.

Suggested Books:

1. Scientific Computing in Python, 2nd Edition, Abhijit Kar Gupta
2. Fortran 90 Handbook, J C Adams, W S Brainerd, J T Martin, B T Smith, J L Wagener
3. Computer Programming in FORTRAN 90 and 95, V, Rajaraman, Prentice-Hall of India, New Delhi, 1997.
4. Introduction to FORTRAN 90/95, S. J. Chapman, McGraw-Hill Book Co., Singapore, 1998.
5. Numerical Recipes, S A Teukolsky, W T Vetterling, B P Flannery, W H Press.
6. Numerical Methods for Mathematics, Science and Engineering, J. H. Mathews, Prentice-Hall of India, New Delhi, 1998.

IX Semester
Paper: Quantum Field Theory and Gauge Theories
Paper Code: PHY0900404
Total lectures: 60 (45 Theory, 15 Tutorials)
Total marks: 100 (Internal - 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Outcome

CO 1: Recall the fundamentals of Relativistic Quantum Mechanics and Quantum Field Theory.

CO 2: Discuss the scalar, vector and spinor fields and the transformation properties of the Fields.

CO 3: Apply the Covariant Perturbation Theory and Feynman rules to calculate the cross-sections of scattering processes.

CO 4: Analyze the implications of Global and local gauge symmetries, spontaneous symmetry breaking and Higgs mechanism in particle physics.

CO 5: Develop innovative strategies to address challenges related to the mass generation in gauge theories.

Content

Unit-I: Introduction to Quantum Field Theory **(15 L+5 T)**
Quantization of free electromagnetic wave: infinite harmonic oscillators, creation and annihilation operators, idea of photon, vacuum fluctuation, number operators and Fock space; Classical fields as generalized coordinates, Euler-Lagrange equation, Canonical quantization of a one-dimensional classical system; Second quantization: Klein-Gordon field, Dirac Field and Electromagnetic field; Conservation of energy, momentum and charge of the field, C, P, T transformation of scalar field; photon propagator, fermion propagator.

Unit-II: Covariant Perturbation Theory **(6L +2T)**
Interaction Hamiltonian, S matrix expansion; Wick's Theorem, Time ordering and Normal Ordering, Feynman diagrams in configuration space and momentum space, Spin Sums, Photon polarization sums, Bhabha scattering, Radiative correction, photon self-energy. Renormalization.

Unit-III: Gauge Symmetries **(15 L+ 5 T)**
The Aharonov–Bohm effect, Different gauges associated with Maxwell's field, Proca equation; Global gauge transformation and Noether's theorem: conserved currents, Lie algebra and Charge algebra; Dirac bilinear, chirality, vector and Axial vector fields, Local Gauge transformation, Gauge fields and their transformation, Abelian and Nonabelian models based on U(1) (QED), SU(2) groups (Yang-Mills Theory); The need for a $SU(2)_L \otimes U(1)_Y$ framework (For first generation of leptons) and Electroweak force.

Unit-V: Symmetry Breaking **(9L+3T)**
Spontaneous symmetry breaking for Z_2, $U(1)$, $SO(2)$ and $SU(2)$, Mexican hat potential, Goldstone's theorem, Mass matrix and choice of ground states, Useful parametrization of U(1) and SU(2) models, Unitary gauge and Higgs mechanism (in the context of SU(2)), Conservation of degrees of freedom, Mass generation of matter and gauge fields, Yukawa term.

Prerequisite: Particle Physics in Semester VIII

Suggested Books

1. An Introduction To Quantum Field Theory, M E Peskin and D V Schroeder
2. The Quantum Theory of Fields, Steven Weinberg
3. Quantum Field Theory, F Mandal and G Shaw
4. Field Quantization, W Greiner and J Reinhardt
5. Gauge Theory of Elementary Particle Physics, T P Cheng and L F Li
6. Quantum Electrodynamics, W Greiner and J Reinhardt
7. The Physics of Standard Model and Beyond, T Morii, C S Lim and S N Mukherjee

Semester IX
Paper: Electronics-I
Paper Code: PHY0900504
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Outcome:

CO1: Recognize various aspects of advanced electronics.
CO2: Generalize the various components of communication, filters, microprocessors, microcontrollers, and Nano-electronics.
CO3: Use knowledge of the components of advanced electronics.
CO4: Design an electronic system that correlates different components of advanced electronics.
CO5: Develop an electronic system to meet any needs of any experimental physics.

Unit-I: Communication Systems (Lectures 15)

Analog and digital Communication: Review of analog communication. Necessity of digital communication. Coherent and Non-coherent modulation. ASK, FSK, PSK, Differential PSK, MSK. QPSK; M-ary signalling. Error Control Code. Spread Spectrum modulation. Multiplexing. PCM. Differential PCM. Delta Modulation.

Information theory: Information channel and fundamental limits on performance. Random signal, Uncertainty. Entropy. Source encoding theorem. Shanon's encoding theorem. Shanon-Hartley theorem and Channel capacity. Shannons Limit.

Fibre Optic Communication: Propagation of optical signal through fibre.Single mode. Step index. Graded fibre. Optical fibre performance. Optoelectronic communication circuits.

Satellite communications: Orbital and Geostationary satellites. Orbital patterns. GPS.

Radar: Radar block diagram. Radar performance: range equation, noise. Radar frequencies. Pulse system.antenna and scanning.display.

Antenna: Parabolic antenna. Horn Antenna. Lens antenna: single surface dielectric, stepped lenses and metal plate lens antenna, aperture and field, Microstrip antenna: cavity model, impedance, radiation pattern, smart antenna: switched beam, adaptive array, SDMA; Overview of mobile adhoc network.

Transmission Line: Types of transmission lines, Cable parameters, Open and Short circuited transmission lines, Half wave and Full wave transmission line, Smith Chart.

Unit-II: OP-AMPS and Linear Integrated Circuits (Lectures 7)

Butterworth Filters. Chebyshev Filters. Bessel filters. Frequency transformation. OPAMPs as voltage regulators. waveform generators. Voltage Controlled Oscillators. Phase Locked Loop. Analog Computation.

Unit-III: Microprocessor and Microcontrollers-I (Lectures 15)

Microprocessor as a CPU, Organization of Microprocessor based systems, 8085 Architecture, operations and pin diagram, 8085 programming model: Registers, Flags, Program counter and Stack pointer, Bus organization, Microprocessor communication and Bus Timing, 8085 programming: Addressing Modes, Instruction Set, Stack and Subroutine, Introduction to 8051 Microcontroller.

Unit-IV: Nanoelectronics-I (Lectures 8)

Microscopy Techniques: Scanning Electron Microscopy (SEM), Transmission electron Microscopy (SEM), Atomic Force Microscopy (AFM), Fabrication techniques for nanostructures and nanodevices, Nanolithography: Photolithography and e-beam lithography, Fabrication of nanoelectromechanical systems (NEMS).
Introduction to advanced 2D materials: Graphene

Suggested Books

1. *Communication Systems*, Simon Haykin
2. *Modern Analog and Digital Communication*, B P Lathi
3. *Microprocesors, Architecture, Programming and Applications with the 8085*, Ramesh Gaonkar
4. *Electronic Communication Systems*, George Kennedy
5. *Introduction to Nanoelectronics*, V. Mitin, V. Kochelap,
6. *Fundamentals of Nanoelectronics*, George W. Hanson.

Semester IX
Paper: Laser and Spectroscopy-I
Paper Code: PHY0900604
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Outcome:
CO1: Explain the concepts of atomic, molecular, and fluorescence spectra, including Zeeman and Paschen-Back effects, and the fundamentals of X-ray spectra.
CO2: Analyze fluorescence spectra using the Jablonski diagram to interpret fluorescence lifetimes, quantum yields, and steady-state and time-resolved fluorescence.
CO3: Combine understanding of atomic and molecular spectra to create models for molecular transitions, applying concepts like rotational constants and band origins to propose applications in scientific research.
CO4: Explain modes, and determine stability of the laser cavity.
CO5: Comprehend generation of high-intensity and ultra-short pulses, and discuss different types of lasers and their applications.

Contents:

Unit-I: Atomic, Molecular and Fluorescence Spectra

Part A: Atomic Spectra – Intensity relations, Relative intensities of multiplet lines; Zeeman and Paschen- Back effects in complex spectra; Zeeman effect and Goudsmit effect in hfs; X-ray spectra: X-ray emission and absorption spectra, X-ray doublet laws; Isoelectronic sequences.
Part B: Electronic spectra of diatomic molecules – Fine structure of electronic transitions: rotational analysis, combination relations with and without Q branches, determination of rotational constants, internuclear distance and moment of inertia, determination of band origins; Wave mechanical formulation of Franck Condon principle: overlap integral, band intensities in emission and absorption, vibrational sum rule and vibrational temperature. Intensity distribution in rotational structure: rotational temperature, intensity distribution in homonuclear molecules. NMR & ESR spectra: Magnetic properties of nuclei, nuclear resonance, Spin-spin & spin-lattice interaction, chemical shift, nuclear coupling.
Part C: Fluorescence spectra – Luminescence: fluorescence and phosphorescence, Jablonski diagram, Characteristics of fluorescence emission, Fluorescence lifetimes and Quantum Yields, Fluorescence anisotropy, Resonance energy transfer, Steady state and Time-resolved fluorescence, Molecular information from fluorescence.

Unit-II: Lasers Fundamentals and Applications Resonators – Modes of a resonant cavity:

longitudinal & transverse laser modes; stability condition; properties of Gaussian beams; single and multimode oscillations; Q switching; mode locking. Types of lasers – Nd:YAG laser, Semiconductor laser, Dye laser, Titanium sapphire laser, He : Cd laser, and Excimer laser.
Selected applications of lasers – Laser-induced fluorescence of vegetation and other biological materials.

Suggested Books

1. Laser Fundamentals, W T Silfvast
2. Principles of Fluorescence Spectroscopy, J R Lakowicz
3. Essentials of Laser and Nonlinear Optics, G D Baruah
4. Molecular Spectra and Molecular Structure (Vol. 2), G Herzberg

Semester IX
Paper (Course) : Plasma Physics II
Paper Code: PHY0900704
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Objectives: • Provide a comprehensive knowledge of plasma physics

Course Outcomes:

CO1: Unit I Describe the next phase of application of theory.

CO2: Unit II Explain the necessity of refinement of theory.

CO3: Unit III Use the new theory and compare the earlier results.

CO4: Unit IV Illustrate the need for stability analysis.

CO5: Unit IV Explain the techniques with examples.

Prerequisites : Plasma Physics I

Unit I Plasma waves : application of fluid model (electromagnetic wave) (12 Lectures)
Approximation of fluid model of plasma for low-frequency oscillations and single-fluid model. Concept of collisions and generalised Ohm's law. Introduction to diffusion, ambipolar diffusion. MHD (magnetohydrodynamics) model of plasma and ideal MHD approximation. Application of single-fluid model to describe electrostatic and electromagnetic waves. Hydromagnetic or Alfvén wave. Concept of magnetic pressure and frozen-in-fluid condition. Electrostatic electron and ion waves in presence of magnetic field. Lower and upper hybrid waves.

Unit II Kinetic theory of plasma (10 Lectures)

Description of plasma as collection of thermal particles and built up to the kinetic theory. The concept of velocity distribution function, specifically Maxwellian distribution. Kinetic theory of plasma and Vlasov equation. Fluid model of plasma as an approximation of the kinetic model. Derivation of fluid equations from Vlasov equation. Concept of moment.

Unit III Application of kinetic theory of plasma (8 Lectures)

Electron plasma wave in the framework of kinetic theory. Landau damping (collision-less damping) and wave-particle resonance.

Unit IV Plasma stability (8 Lectures)

Instabilities in plasma. Introduction to instability analysis in plasma. The concept of energy principle. Normal mode analysis for stability analysis. Two-stream instability.

Semester-IX

Nuclear Physics - I
Paper Code: PHY0900804
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Objective: This course focuses on the deep knowledge of nuclear structure and spectroscopy. The course also includes some advanced topics on Nuclear Reactions studies and nuclear data acquisition system. Standard Model and properties of strong interaction as well as the concept of QGP have also been introduced. The course is designed in such a way that with this advanced knowledge on Nuclear Physics one can pursue research in any field of Nuclear Physics.

Course Outcome:

- The course outlines an advanced course in Nuclear Physics
- Advance topics on nuclear structure, nuclear reactions, nuclear DAQ and elementary particles will be discussed
- Learners will be able to apply this knowledge while pursuing research in the field or using nuclear instruments for applied purposes.

Unit-I: Nuclear Models

Applications of SPSM: Magnetic dipole moments of nucleon and nuclei in the light of SPSM - C-N Catastrophe, Schmidt's one nucleon model of total angular momentum and total magnetic moment.

Electric quadrupole moments of various nuclei with single particle and many particles outside the closed shell.

(ii) **Collective Models** : Failure of shell model in understanding the excited states of odd A and even-even nuclei, Evidences in favour of collective motion of nucleons, dynamics of collective motion, vibrational modes-volume and shape vibrations, EOS of a vibrating nuclei, states of vibrational model. Rotational model and rotational energy states of a deformed nucleus.

Unit-II: Electromagnetic Interaction with Nuclei

Multipole expansion of Radiation field, multipolarity, gamma-ray transition probability, Angular momentum and Parity selection rules. Comparison with experiments, Nuclear Isomerism, Internal Conversion of gamma-rays, Angular distribution of gamma-rays, Angular correlation in gamma-gamma-cascade.

Unit-III: Nuclear Reactions

(i) **Optical Model of Nuclear Reaction**: General concept of optical model (OM) for elastic scattering, Optical potential for N-N scattering, OM parameters, imaginary part of OM and absorption - interpretation in scattering experiment results.

(ii) **Compound Nuclear Model**: Difference between a Direct and Compound Nuclear (CN) reactions, Compound nucleus processes - a) cross section for discrete levels of CN , b) cross section for overlapping CN levels. Statistical theory of CN, Dependence of nuclear entropy and energy on nuclear temperature and Evaporation theory of nuclear reaction.

(iii) **Transfer and inelastic scattering**: Definitions of transfer and inelastic scattering with examples, Born amplitude and Distorted Wave Born approximation (DWBA) for rearrangement reaction.

(iv) **Compound Nucleus Resonance**: Concept of cross section in terms of scattering and reaction. Nuclear cross sections in terms of phase shift (or nuclear radius), Breit-Wigner formula in the neighbourhood of a single isolated resonance level i.e. l=0 (s-wave) and all values of l.

Unit-IV: Nuclear Data Acquisition (DAQ) System:

Components of a data acquisition system, Pulse Signals in Nuclear Electronics, The Frequency Domain, Bandwidth, Pre-amplifiers, Main Amplifiers, Discriminators, Single-Channel Analyzer, ADC, TDC, MCA, Coincidence Units.

Introduction to Counting statistics.

Unit-V: Elementary Particles:

Introduction to Standard Model, Properties of quarks and their classification, Coloured quarks and gluons, Hadron properties in terms their quark content.

Strong Interaction potential, Running coupling constant of strong interaction– Confinement and asymptotic properties of strong interaction- QGP.

Suggested Books

1. *Introductory Nuclear Physics*, Kenneth S Krane
2. *Nuclear Physics: Theory and Experiment*, Roy and Nigam

3. *Introduction to Nuclear Reactions*, G R Satchle
4. *Nuclear & Particle Physics*, W E Burcham, M Jobes
5. *Nuclear Physics - Principles & Applications*, John Lilley
6. *Radiation Detection and Measurement*, G F Knoll
7. Concept of Nuclear Physics - B L Cohen
8. *Techniques for Nuclear and Particle Physics Experiments*, W R Leo
9. *Nuclear Radiation Detector*, S S Kapoor and V S Ramamurthy
10. *Introduction to Nuclear & Particle Physics*, A Das & T Ferbel.

Semester IX
Course Name: Condensed Matter Physics I
Paper Code: PHY0900904
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Prerequisite: Advanced Condensed Matter Physics in semester VIII
Course Outcome:

CO 1: Illustrate the principles underlying phonon scattering, optical properties of solids, superconductivity, semiconductor devices, and magnetic phenomena in solids.

CO 2: Apply the theoretical knowledge and principles to analyse and solve problems related to phonon-phonon scattering, optical absorption, superconductivity theories, semiconductor device characteristics, and magnetic phenomena

CO 3: Develop ideas for some semiconductor device fabrication

CO 4: Analyse theoretical models, and complex phenomena such as inelastic scattering, optical emission processes, superconducting behaviours, semiconductor device characteristics, and magnetic phenomena in solids

CO 5: Transform the ideas and critically assess the implications and applications of these concepts in research application

Contents:

Unit-I: Phonon Spectrum
Phonon creation and annihilation operators, elastic scattering of electrons by phonon, inelastic scattering of photons by phonons, inelastic scattering of neutrons by phonons, inelastic phonon- phonon scattering, normal and umklapp processes.

Unit-II: Optical Properties of Solids
Optical constants, dispersion relation of optical constants from Maxwell's equations, Kramers-Kronig relations, optical absorption and emission in semiconductors, exciton absorption, impurity and interband transitions, luminescence, activators, Frank-Condon principle, photoluminescence and thermoluminescence.

Unit-III: Superconductivity
Isotope effect, Frohlich interaction, electron-phonon interaction and BCS theory of superconductivity (extensive), superconducting quantum interference device (SQUID), Ginsburg-Landau theory of the type II superconductivity, high temperature superconductivity and superconducting magnets.

Unit-IV: Semiconductor Devices

Metal-semiconductor junctions, Semiconductor homo and heterojunctios, I-V characteristics of junctions, some optoelectronic devices, photogeneration at p-n junction, photovoltaic effect.

Unit-V: Magnetic Phenomena in Solids

Magnetoconductivity, cyclotron resonance, Landau levels and Landau cylinders, de Haas-van Alphen effect, Fermi surface studies. Exchange interaction and exchange integral for two-electron system, Heisenberg Hamiltonian for exchange interaction, relationship between exchange energy and molecular field, ferromagnetic spin waves and their dispersion relations, magnons.

Suggested Books

1. *Lattice Dynamics*, A K Ghatak and L S Kothari
2. *Theory of Superconductivity*, J R Schriffer
3. *Solid State Physics*, A J Dekker
4. *Fundamentals of Solid State Physics*, J R Christman
5. *Introduction to Solid State Physic*, C Kittel
6. *Solid State Theory*, W. Harrison
7. *Intermediate Quantum Theory of Crystalline Solids*, A O E Animalu

Semester-IX
Paper: Nanophysics I
Paper Code: PHY0901004
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course outcomes:

CO1: Identify various phenomena occurring at nanoscale.
CO2: Demonstrate techniques to produce nanostructures and gather information about them.
CO3: Discuss synthesis and properties of carbon nanostructures, graphene and 2D metal chalcogenides.
CO4: Explain the nucleation and growth of nanocrystals through theoretical frameworks.
CO5: Develop quantum mechanical theories to understand nanoscale phenomena.

Contents:

Unit I: Nucleation and growth (Lectures: 08)
Classical nucleation theory, critical nuclei size, homogeneous and heterogeneous nucleation, growth of nanocrystals in solution, Ostwald ripening, LaMer's mechanism of nucleation, supersaturation and monodispersity, LSW theory, limited Ostwald ripening.

Unit II: Nanostructure synthesis and characterization (Lectures: 15)
Chemical methods (chemical co-precipitation, hydrothermal, solvothermal, sol-gel, green synthesis), chemical vapour deposition, magnetron sputtering, pulsed laser deposition, molecular beam epitaxy, electro spinning, electrodeposition, lithography, mechanical alloying, crystallization of amorphous precursors, nanomanipulation. X-ray diffraction, crystallite size and lattice strain, X-ray line profile analysis – size and strain broadening, Williamson-Hall method, electron microscopy, atomic probe microscopy, magnetometry, absorbance and luminescence spectroscopy, X-ray photoelectron spectroscopy.

Unit III: Quantum effects in nanosized semiconductors (Lectures: 12)
Quantum island, shrinking to quantum dot (QD), energy gap of semiconductor quantum dot, shape effect, exciton Bohr radius and excitation binding energy, strong and weak confinement, core-shell QD and light emitting device, sub-nm QD and challenges.

Unit IV: Carbon nanostructures and 2D semiconductors (Lectures: 10)
Small carbon clusters; structure and properties of C_{60}; single walled and multiwalled carbon nanotubes; (n,m) naming scheme; synthesis, properties and applications of carbon nanotubes; carbon nanotube based nanocomposites; graphene: electronic structure, synthesis, properties and applications; graphene based nanocomposites; 2D transition metal dichalcogenides (TMDCs): electronic and optical properties, synthesis, properties, applications and 2D TMDC based nanocomposites.

Suggested Books:

1. Kinetic Processes, K. A. Jackson
2. Nanophysics and Nanotechnology, E. L. Wolf
3. Elements of X-ray Diffraction, B. D. Cullity, S. R. Stock
4. Nano: The Essentials, Understanding Nanoscience and Nanotechnology, T. Pradeep
5. Nanotechnology: Principles and Fundamentals, G. Schmid
6. Springer Handbook of Nanotechnology, B. Bhushan (Ed.)
7. Introduction to Nanotechnology, C. P. Poole, J. F. J. Owens
8. Fundamental of Nanoelectronics, G. W. Hanson
9. Introduction to Nanoscience and Nanotechnology, K. K. Chattopadhyay, A. N. Banerjee

Semester: IX
(Course Work)
Course Name: Astronomy & Astrophysics-I
Paper Code: PHY0901104
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

CO 1: Recall the basic principle of physics applied in stellar astrophysics and observational techniques.

CO 2: Explain the working of various observing tools for measuring stellar properties.

CO 3: Apply the physical principles for understanding stellar structure and evolution.

CO 4: Combine the principles to understand stars and large structures of galaxies.

CO 5: Assess various techniques and theoretical principles discussed.

Unit-I: Basic astronomy and coordinate system

Stellar magnitudes; Astronomical filters; Colour-index of stars; Stellar binaries - variable stars and types; Spectral classification of stars; Luminosity classification of stars and HR diagram; Star clusters; Astronomical co-ordinate systems; Measurement of distances to the nearby stars; Stellar positions and motions.

Unit-II: Observational techniques (Optical & Infra-red astronomy)

Details about the telescopes and their different properties; Telescope Mount; Adaptive and Active Optics; Detectors and their characteristics (Photodiode, PMT and CCD); spectrograph; concept of photometry; spectroscopy and polarimetry; Standard photometric system; Atmospheric extinction; Transformation equations for photometric standardization.

Unit-III: Star formation and radiation transport

Interstellar medium(ISM); Jeans theory of star formation; Theory of radiative transport; Stellar opacity; Saha’s ionisation equation and stellar spectra.

Unit-IV: Stellar structure and evolution

Hydrostatic equilibrium; Stellar mass, radii, luminosity and their relations; Stellar time scales; virial theorem for stars; Lane-Emden theory of polytropes; Mass –radius and pressure –density relations for polytropes; Eddington’s standard model of stars.

Evolution of low mass stars – white dwarfs and Chandrasekhar mass limit; Evolution of high mass stars –Type II supernovae, pulsars and stellar mass black holes.

<u>Unit-V: Galaxies</u>

Local and large scale distribution of stars and interstellar matter; The Milky Way and its centre; Rotation curves and dark matter.

Suggested Books & References

1. Astrophysics for Physicists, A Rai Chaudhuri.
2. An Introduction to the Theory of Stellar Structure and Evolution, Dina Prialnik.
3. Stellar Structure and Evolution, R Kippenhahn and A Weigert
4. Astronomy Method, Hale Bradt.
5. Hand book of CCD Astronomy, S B Howell.
6. Astrophysical Techniques, C R Kitchin
7. Telescopes and Techniques, C R Kitchin
8. Spherical Astronomy, W M Smart
9. Observational Astrophysics, Pierre Lena

Semester X

Paper: Research Methodology-II
Paper Code: PHY1000104
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Outcomes

CO 1: Develop the skill for writing a research paper

CO 2: Apply for patents, being informed of the patent laws

CO 3: Explain the basics of scientific ethics, and develop research integrity

CO 4: Identify research misconducts, and evaluate plagiarism

CO 5: Survey indexing and citation databases

Contents

Writing and Communicating a Research Paper

Components of a research paper: Title, Abstract, Introduction, Materials and Methods, Results and Discussion, Conclusion, References. Styles of writing a research paper, and formats of citing references in it. Graphical Presentation and Highlights of the paper.

Writing a cover letter, and uploading supplementary information.

Introduction to Patent laws

Patent laws, process of patenting a research finding, Copyright.

Scientific Ethics

Ethics with respect to science and research**.** Intellectual honesty and research integrity**.** Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP)**.** Redundant publications: duplicate and overlapping publications, salami slicing**.** Selective reporting and misrepresentation of data.

Publication ethics: definition, introduction and importance. Conflicts of interest. Best practices/standards setting initiatives and guidelines: Committee on Publication Ethics (COPE, WAME etc).

Publication Misconduct and Plagiarism-Remedy

Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types of publication misconduct. Violation of publication ethics, authorship and contributorship. Identification of publication misconduct, complaints and appeals. Predatory publishers and journals.

Plagiarism detection softwares: Turnitin, Urkund and other open source software tools. Ways to avoid plagiarism.

Databases

Indexing databases. Citation databases: Web of Science, Scopus etc.

Suggested Books

1. A Manual for Writers of Research Papers, Theses, and Dissertations, Kate L. Turabian, Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams and Joseph Bizup, The University of Chicago Press.
2. Research Ethics: A Psychological Approach, Edited by Barbara H. Stanley, Joan E. Sieber, Gary B. Melton, University of Nebraska Press.

Semester: X

Course: Interactions at High Energy
Paper Code: PHY1000204
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course Outcome

CO 1: Recall essentials of quark model to generate the hadron wave functions.

CO 2: Use the principles of symmetry to understand electroweak interaction.

CO 3: Examine Standard Model concepts to understand the experimental tests of electroweak theory.

CO 4: Assess the predictions of renormalisation

CO 5: Develop theoretical models in Neutrino Physics to contribute to ongoing research.

Content

Unit-I: Static quark model and elements of QCD **(15 L + 5 T)**
Flavour symmetry: πN scattering; pseudo scalars, pseudo vectors, G-parity, simple quark model: $SU(2)_{spin}$, $SU(3)_{Flavour}$ and $SU(3)_{colour}$: Hyper charge, shift operators, spin, flavour and colour wavefunctions of baryons: mass and magnetic moment of N, heavy $Q\bar{Q}$ system: charmonium, bottomonium, exotic hadrons; Partons and Bjroken scaling, neutrino quark scattering, QCD Lagrangian and the strength of colour force.

Unit-II: Electroweak interaction **(15 L + 5T)**
V-A current, parity violation, CP violation: neutral Kaon system, spontaneous breaking of $SU(2)_L \otimes U(1)_Y$ symmetry (first generation of leptons); charged and neutral current, comparison with effective Fermi's theory. quark mass matrix, quark lepton symmetry and quark mixing, GIM mechanism, Anomalies, Feynman rules for electroweak interaction, Experimental tests of electroweak theory: physics at e^+e^- collider, physics at LEP; Higgs discovery; $\gamma\gamma, ZZ^*, WW^*$ channels.

Unit-III: Elements of Renormalisation **(9 L +3 T)**
Virtual particles in loops and higher order corrections, concept of renormalisation, mass renormalisation, coupling constant renormalisation and RGE equations.

Unit-IV: Neutrino Physics **(6L + 2 T)**
Solar and atmospheric neutrino puzzles, theory of neutrino oscillations in vacuum and medium (MSW mechanism), neutrino masses and leptonic mixings, survey of various neutrino

oscillation experiments, seesaw mechanism for small neutrino masses. Theoretical and experimental challenges in neutrino physics.

Books

1. Quarks and Leptons: An Introductory Course in Modern Particle Physics, F Halzen and A.D Martin
2. Particle Physics, B R Martin and G Shaw
3. Introduction to Elementary Particles, D Griffiths
4. An Introduction To Quantum Field Theory, M E Peskin and D V Schroeder
5. Gauge Theory of Elementary Particle Physics, T P Cheng and L F Li
6. The Physics of Standard Model and Beyond, T Morii, C S Lim and S N Mukherjee
7. Particle Physics in the LHC Era, G Barr, R Devenish, R Walczak and T Weidberg
8. Quantum Mechanics: Symmetries, W Greiner and B M¨uller
9. Fundamentals of Neutrino Physics and Astrophysics, C Giunti and C W Kim

Semester: X
Paper: Electronics-II
Paper Code: PHY1000304
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Outcome:

CO1: Recall advanced topics of electronics
CO2: Explain various advanced topics of electronics related to the design, and analysis of electronic systems and signals.
CO3: Apply knowledge to solve the specific problem of the topic
CO4: Design a comprehensive system using the areas included.
CO5: Develop a new system using the knowledge gained that requires electronic tools in any real-world problem.

Unit-I: Digital Circuits (Continued) (10)

Simplification of boolean functions: Mapping and function minimization (SOP and POS) Sequential logic:RS, JK, D and T flip flop; shift register; synchronous and asynchronous counters; Memory Concepts. Faultdetection in digital circuits. Synthesis and design of sequential circuits: Analysis and synthesis ofsynchronous and asynchronous circuits, hazard free asynchronous circuits, sequential machine.FlashConverter; Successive Approximation ADCs; Counting and Integrating ADC Architectures. Implementation of digital circuits in VHDL and FPGA.

Unit-II: Digital Signal Processing (10)

Signals and systems, Impulse Response and Convolution sum, difference equation ,FIR and IIR systems , Stable and Unstable systems. z transform , delay operator, System function, Stability Criterion , Frequencyresponse of a system , Design of Digital Filters, discrete fourier transform, fast fourier transform, digitalsignal processor

Unit-III: Microprocessor and Microcontrollers-II (5)

8051 microcontroller Architecture, pin diagram, on chip peripherals, Instruction Set, SFR, Introduction to Arduino programming.

Unit-IV: Control Systems (5)

Open and close loop system, Mathematical Modeling of Physical Systems. First and Second order system with derivative &integral control, Servo motor and its simple control circuits.

Unit-V: Network Analysis (5)

Network functions; poles and zeros, zero input and zero state response; effect of position of poles and zeros on system response, Routh Array; frequency response analysis, Bode plot, Nyquist Criterion for stability, Nyquist path, Nyquist Path, Gain ,Margin, Phase Margin.

Unit-VI: Nanoelectronics-II (5)

Nanofabrication, Necessity for a clean room, different types of clean rooms, construction and maintenance of a clean room, basic steps in IC fabrication, Single Electron Transistor, Carbon nanotube transistor, Graphene transistor, Semiconductor Nanowire transistor, Quantum dot transistor.

Unit-VII: Waveguides (5)

Fundamental concepts of signal transmission through wave guide, relation between cut off frequency and waveguide dimension of rectangular waveguide.

Suggested Books

1. *Electronic Communication*, George Kennedy
2. *Digital Signal Processing*, J G Proakis and D Malonakis
3. *Network Analysis*, M V Valkenburg
4. *The 8051 Microcontroller and Embedded Systems*, Mazidi
5. *Introduction to Nanoelectronics,* V Mitin, V Kochelap, M Stroscio
6. *Fundamentals of Nanoelectronics,* G W Hanson

Semester: X
Paper: Laser and Spectroscopy-II
Paper Code: PHY1000404
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Outcome:

CO 1: Explain the basics of molecular spectroscopy, focusing on Hund's coupling cases, molecular orbital theory, and symmetry in point groups.
CO 2: Use spectroscopy principles to calculate molecular properties, such as dissociation energies, and predict infrared and Raman selection rules.
CO 3: Determine nuclear spin and statistics, and identify potential new applications of spectroscopy in science and technology.
CO : 4 Explain various nonlinear optical phenomena, and compare linear Raman and laser Raman spectra.
CO 5: Assess laser applications in a few selected areas.

Contents:

Unit-I: Spectroscopy
Part A: Spectra of diatomic molecules
Hund's coupling cases, symmetry properties of electronic states and rotational levels, selection rules, types of electronic transitions: $^1\Sigma$ - $^1\Sigma$, $^2\Sigma$ - $^2\Sigma$, $^1\Pi – ^1\Sigma$, $^2\Pi – ^2\Sigma$, Continuous and diffuse spectra: pre-dissociation, Auger effect, Heats of dissociation: determination of dissociation limits, band convergence, Birge-Sponer extrapolation.
Part B: Molecular orbital approximation
United and separated atom constructs, correlation of molecular orbitals, LCAO/MO theory, determination of terms and multiplicities from molecular orbitals.
Part C: Spectra of polyatomic molecules
Symmetry elements and symmetry operations of point group, Matrix representations of symmetry
elements of a point group, Reducible and irreducible representations, Character Tables for C_{2v} and C_{3v} point groups. Normal modes of vibration and their distribution into symmetry species of the molecule, Infrared and Raman Selection rules.
Part D: Applications of molecular spectroscopy
In nuclear physics: spin & statistics, In astrophysics: absorption and emission in earth's atmospheres, terrestrial Fraunhofer lines, planetary atmospheres, comets, stellar atmospheres and interstellar space.

Unit-II: Lasers
Part A: Nonlinear optics
Nonlinear susceptibility, second harmonic generation, phase matching, parametric oscillation, intensity dependent refractive index: self-focusing, phase conjugation: four wave mixing.
Part B: Laser spectroscopy
Preliminary ideas only: Laser Raman spectroscopy: experimental techniques, resonance Raman, stimulated Raman, hyper Raman and coherent anti Stokes Raman spectroscopy; Doppler limited spectroscopy: photoacoustic spectroscopy and laser-induced fluorescence;

Time-resolved spectroscopy: phase shift method, pulse excitation and quantum beat spectroscopy.

Part C: Selected applications of lasers in science and technology

Isotope separation, laser-induced fusion, Laser cooling of atoms, Applications in physical, chemical and biological systems: optical tweezers and chirped pulse amplification.

Suggested Books:

1. *Chemical Applications of Group Theory*, F A Cotton
2. *Introduction to Molecular Spectroscopy*, G M Barrow
3. *Modern Spectroscopy*, J M Hollas
4. *Laser Age in Optics*, V Tarasov
5. *The Principles of NonlinearOptics*, Y R Shen
6. *Laser Spectroscopy: Basic Concepts and Instrumentation*, W Demtröder

Semester X
Paper (Course) : Plasma Physics-III
Paper Code: PHY1000504
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Objectives: • Provide a comprehensive knowledge of advanced topics of plasma physics

Course Outcomes:

CO1: Unit I Identify the need for analysis of nonlinear plasma phenomena.

CO2: Unit I Explain different theoretical methods of investigation.

CO3: Unit I Use the knowledge to analyse the problem at hand.

CO4: Unit II Examine the need for studying complex plasmas.

CO5: Unit III Formulate the necessary concepts needed to study confined plasmas.

Prerequisites : Plasma Physics II

Unit I Foundations of nonlinear theory of plasma (15 Lectures)

Introduction to nonlinear phenomena in plasma. Plasma sheath as a nonlinear phenomenon and theory of plasma sheath. Concept of Mach number and Bohm criterion. Plasma sheath and plasma probe. Child-Langmuir law for plasma probe. Sheath equation and its relation to nonlinear plasma phenomena such as solitons. The concept of pseudo-potential (or Sagdeev potential) and ion-acoustic solitons. Equations of nonlinear plasma such Korteweg-de Vries (KdV) and Burger's equations. Introduction to stretched coordinates and reductive perturbation theory resulting KdV and Burger's equations. Interpretation of solutions of KdV and Burger's equations.

Unit II Introduction to dusty pasma (15 Lectures)

Impurities in plasma and dust particles in plasma. Essential properties of a dusty (or complex plasma) and dusty plasma versus dust in plasmas. Ubiquity of charged dust particles in plasmas. Parameters for dusty plasma. Dust charging. Orbit motion limited (OML) theory of dust charging. Dust-acoustic (DA) and dust-ion-acoustic (DIA) waves. Dust-charge as a dynamic variable in dusty plasma. Effect of dust-charge fluctuations on plasma waves.

Unit III Introduction to plasma confinement (10 Lectures)

Need for plasma confinement. Lawson criteria. Plasma confinement devices such as ITER, JET etc. Axisymmetric equilibria of plasmas in the framework of ideal MHD. 1-D equilibria and plasma pinch. 2-D equilibria and tokamak. Equation of axisymmetric plasma equilibrium and Grad-Shrfranov equation. The concept of flux surfaces in axisymmetric devices.

Semester X
Paper (Course) : Nuclear Physics-II

Coursework Component

Paper Code: PHY1000604
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Objective: This course focuses on the deep knowledge of neutron physics, fission, fusion processes, principles of energy production mechanism through nuclear processes, their merits and demerits. The synthesis of both light and heavy nuclei (by r and s processes) inside stars will be discussed. The various applications of nuclear techniques and radiation safety and dosimetry instruments for protection. It imparts all the basic skills to work in a nuclear reactor or needed by a radiation safety officer or any job dealing with radiation such as X-ray operators, jobs dealing with nuclear medicine: chemotherapists, operators of PET, MRI, CT scan, gamma camera etc.

Course Learning Outcomes: On successful completion of the course, the students shall be able to:

- The phenomena such as fission physics and nuclear reactor, fusion reactions and production of energy in stars and laboratory.
- Know about the units of radiations and their safety limits, the devices to detect and measure radiation.
- Learning radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards etc.
- Learning about the devices which apply radiations in nuclear medical sciences, such as X-ra y , CT-scan, PET, MRI etc.
- Physics of advanced detectors and data acquisition system with offline & online measurements.
- Advanced knowledge of elementary particle physics.

Unit-I: Neutron Physics, Nuclear Fission and Fission Reactors Lectures: 10

Classification, Production, and detection of neutrons. Slowing down of neutrons, Logarithmic decrement.

Spontaneous and induced fission, Q-value of fission, fission barrier, activation energy, condition for spontaneous fission. Characteristics of fission- energy distribution of fission product, mass distribution, no. of neutrons emitted in fission, fast and delayed neutrons, fission cross-section. Bohr-Wheeler theory of fission reaction. Fissionable materials, enriched uranium, Fission chain reaction, Neutron balance in a nuclear reactor – four factor formula and dimension of a reactor, Production of fission energy, India's peaceful 3 Phase nuclear programme.

Unit-II: Nuclear fusion in Steller and Laboratory Environments Lecture: 8

(i) Nuclear fusion and Nucleosynthesis: Basic fusion process, characteristics of fusion, Stages of evolution of universe – nuclear reaction era, thermonuclear fusion & Fusion hindrance, Nucleosynthesis - pp chain reactions & CNO cycle. Production of elements with mass A > 56 - s & r processes.

(ii) Controlled fusion reaction: plasma, Debye length, Confinement of plasma - magnetic confinement and Torodial confinement, Lawson criterion – Tokamak.

Unit III: Nuclear Scattering and Resonance scattering and fusion Lecture: 8

Optical model of elastic and quasi-elastic scattering, OM parameters & OM analysis of a experimental result, Born approximation and Distorted wave Born approximation(DWBA) for transfer reactions.

Compound Nucleus Resonance: Concept of cross section in terms of scattering and reaction. Nuclear cross sections in terms of phase shift (or nuclear radius), Breit-Wigner formula in the neighborhood of a single isolated resonance level i.e. l=0 (s-wave) and all values of l.

Wong's formula for fusion reaction, fusion couplings in sub-barrier energies and related deformation effect, neutron transfer etc.

Unit-IV: Radioactivity, Radiation safety and Nuclear Medicine Lecture: 10

(i)**Radioactivity and measurement**: Laws of successive transformation, Natural Radioactive series, Radioactive equilibrium. Units of radioactivity – Becqueral, Curie, Rutherford, Radiation doses and its unit – quality or weighting factor - equivalent dose, effective dose, committed effective dose, collective effective dose

(ii)**Radiation Safety** : Biological effect of radiation - Acute and chronic exposure, Effects and symptoms of exposure. Exposure limits. Exposure protection. AERB norm & protocol.

(ii)Nuclear Medicine: Application of radiation in medical science, basic principle of imaging techniques like X-rays,CT scan, PET, SPECT, MRI etc, Projection Imaging Gamma Camera, Radiation therapy), Commonly used radio-active sources in medical treatment and their characteristics, Production of radionuclides with accelerator for medical treatment.

(iv)**Dosimetry Instrument**: Quartz Fibre Electroscope, Film Badge dosimeter, Thermoluminescent dosimeter(TLD), Optically stimulated thermoluminescent dosimeter (OSLD), Track detector dosimeter

Reference Books:-

1. Introductory Nuclear Physics – K S Krane: John Wiley and Sons
2. Concept of Modern Physics – A Beiser: Tata McGraw Hill
3. Nuclear Physics – R R Roy and B P Nigam: New Age International (P) Ltd.
4. Nuclear and Particle Physics –W E Burcham and M Jobes: Addison Wesley Longman
5. Introduction to Nuclear Reaction – S R Satcher: Springer
6. Techniques of Nuclear and Particle Physics Experiments – W R Leo: Springer Verlag
7. Radiation detection and measurement by G F Knoll, 4th Edition, Wiley Publications, 2010.

Semester X
Course Name: Condensed Matter Physics II
Paper Code: PHY1000704
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

Course Outcome:

CO 1: Define the properties of matter at microscopic level with reduction in size (thin films and nanomaterials)

CO 2: Recognise some unconventional condensed matter (soft matter) and their unusual properties

CO 3: Apply knowledge of thin film preparation methods, analytical techniques, and nanomaterial properties to design and fabricate nanomaterial-based devices

CO 4: Analyse the correlation between the size and the properties of matter in thin films and nanomaterials.

CO 5: Reorganise the significance of size effects and unusual phenomena of nanomaterials and soft matter and reconstruct the ideas for potential applications in research in condensed matter physics and material science

Contents
Unit-I: Physics of Thin Films

Definition of a thin film, different methods of film preparation: thermal evaporation, sputtering.
Film thickness measurement: optical interference methods and other methods, Analytical techniques for chemical, structural and surface studies. Nature of thin films: Theories of nucleation: the capillarity and the atomistic model, growth processes, epitaxial films and their growth.

Mechanical properties of thin films: Internal stress, stress and adhesion.
Electrical conduction in discontinuous and continuous metal and semiconducting films, theories of size effect, galvanomagnetic size effect.
Magnetism in thin metal films, ferromagnetic and antiferromagnetic properties of thin films, surfaces and interfaces of ferromagnetic metals, spin dependent current. QHE and GMR, some thin film devices.

Unit-II: Physics of Nanomaterials
Definition of nanomaterials, Types of nanomaterials: Metal, semiconductor (elemental and compound), methods of preparation. Quantum confinement: One, Two and Three-dimensional. Electrical, optical, and magnetic properties of nanomaterials. Applications (Electrical, optical, magnetic, electrical, and biological) of nanomaterials. Nanomaterial based devices: Electronic, photonics, spintronics.

Unit-III: Soft Condensed Matter Physics

Definition of soft matter, Different types of soft matter: Liquid Crystals, Polymers: high polymers and conducting polymers, Surfactants, Biological materials, Correlated and uncorrelated systems, Nonlinear dynamics in soft matter, Recent studies on soft condensed matter.

Suggested Books

1. *Materials Science of Thin Films*, M Ohring
2. *Handbook of Thin Films*, Maissel and Glang
3. *Thin Film Phenomena*, K L Chopra
4. *Thin Film*, Ashok Goswami
5. *Introduction to Nanotechnology*, C P Poole and F J Owens
6. *Soft Condensed Matter*, R A L Jones

Semester-X
Paper: Nanophysics-II
Paper Code: PHY1000804
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

Course outcomes:

CO1: Recall ideas of electrodynamics and quantum mechanics to explain properties of semiconductor and metallic nanostructures.
CO2: Discuss concepts of quantum confinement, plasmonics, nanomagnetism and transport at nanoscale.
CO3: Develop theories of Coulomb blockade and Ballistic transport, and explore their experimental evidences.
CO4: Examine phenomena such as superparamagnetism, quantization of electrical/thermal conductivity and surface plasmon resonance.
CO5: Produce advanced nanomaterials using nanostructures for applications in various fields.

Contents:

Unit I: Plasmonics **(Lectures: 14)**
Dielectric function of free electrons, Lorentz oscillator model and Drude theory, bulk plasmons, surface plasmon polaritons (SPPs) at plane interfaces, excitation of SPPs, localized surface plasmons (LSPs) in metal particles, scattering and absorption cross-sections, scattering and emission enhancements, plasmonic effect in metal-semiconductor nanostructures.

Unit II: Nanoscale magnetism **(Lectures: 08)**
Review of basic magnetism: exchange interaction, magnetocrystalline anisotropy, magnetic domains, particle size and surface effects on magnetic behaviour, superparamagnetism, ultrasoftmagnetism, magnetism in multilayers, dilute magnetic semiconductors, spintronics, ferrofluids, magnetic recording.

Unit III: Nanoscale transport **(Lectures: 12)**
Coulomb blockade transport: Coulomb blockade in a nanocapacitor and a quantum dot circuit, single electron transistors; Ballistic transport: review of classical theory of transport, ballistic transport model, quantum resistance; nanoscale thermal transport, magnetotransport.

Unit IV: Nanomaterials for energy, environmental and biological applications
(Lectures: 11)
Nanogenerators, quantum dot LEDs, solar cells, nanosensors, photovoltaics, catalytic elimination of pollutants (photocatalysis, piezocatalysis and pyrocatalysis), water splitting, CO_2 reduction, biological applications: antibacterial, antifungal and drug delivery, nanomaterials in forensics.

Suggested Books

1. Nanotechnology: Principles and Fundamentals, G. Schmid
2. Plasmonics: Fundamentals and Applications, S. A. Maier
3. Principles of Nanomagnetism, A. P. Guimaraes
4. Fundamental of Nanoelectronics, G. W. Hanson
5. Experimental Micro/Nanoscale Thermal Transport, X. Wang
6. Nanostructures and Nanomaterials, G. Cao, Y. Wang
7. Nano: The Essentials, Understanding Nanoscience and Nanotechnology, T. Pradeep

Semester: X
Course Name: Astronomy & Astrophysics-II

Paper Code: PHY1000904
Total Lectures: 60 (45 Theories; 15 Tutorials)
Total Marks 100: (Internal-40+External-60)
Credits 4: (Theory: 3 + Tutorial: 1)

CO 1: Outline the basic principles of general relativity, cosmology and extragalactic astronomy.

CO 2: Illustrate the techniques of multi-messenger astronomy to understand the exotic objects in the universe

CO 3: Calculate various observable parameters associated with predictions of the theoretical structures.

CO 4: Classify galactic and extragalactic objects based on the multi-messenger astronomy

CO 5: Assess the application of physical principles in understanding structure and evolution of the universe.

Unit-I: General relativity and astronomical tests

Principle of Equivalence (Weak Equivalence Principle and Einstein Equivalence Principle); Gravity as curvature of spacetime; Einstein's field equations; Linearisation of Einstein's equations and Gravitational Waves; Quadrupole formula and Gravitational Waves from binaries; Schwarzschild and Kerr black holes. Post-Newtonian and PPN formalism; application to solar system tests.

Unit-II: Observational techniques (Radio ,X ray and Gamma ray astronomy)

Radio signals and their emission mechanisms; Radio telescope; Single dish aperture; Interferometry; Radio observation's highlights: HI-21 cm-line, molecular lines; Radio galaxies; Mechanism of production of X ray and Gamma ray in astrophysics; Focusing optics and collimating optics; Wolter optics-I, II and III; X-ray telescopes and Gamma ray telescopes; X-ray and Gamma-ray sources in the sky; Space based X-ray and Gamma ray astronomy.

Unit-III: Extragalactic astronomy

Extragalactic astronomy-Distance measurements: Cepheids, RR-Lyrae, Type-Ia supernovae, Tully-Fisher relation; Hubble's observations and implications; Active galaxies: starburst galaxies, radio galaxies, Seyfert galaxies, blazer and quasar; Unified model of Active Galactic Nuclei.

Unit-IV: Basic cosmology

Large scale structure of the universe- galaxy clustering; Cosmological principle and FLRW metric; Hubble's law, luminosity distance and magnitude-redshift relation. Friedmann models and cosmological parameters; Equation of state; The Hot Big Bang model and Big Bang Nucleosynthesis (Helium synthesis); Recombination and Cosmic Microwave Background (CMB); CMB anisotropies; Formation of large scale structures (introduction); Intergalactic medium and cosmic reionisation.

Unit-V: Dark matter and dark energy

Mass-to-light ratio of galaxies, clusters and dark matter; mass density of dark matter; Idea of cosmic inflation; accelerated expansion, Lambda (Λ) Cold Dark Matter (CDM) model and dark energy.

Suggested Books & References

1. Gravity, JB Hartle
2. Introduction to Cosmology, J V Narlikar
3. Introduction to Cosmology, B. Ryden
4. Physical Universe, F. Shu
5. The Invisible Universe, Gerrit Verschuur
6. X-ray Astronomy, R Giacconi
7. Frontiers of X-ray Astronomy, A C Fabian
8. Gamma Ray Astronomy, Poolla V. Ramana Murthy, Arnold W. Wolfendale
9. Extragalactic Astronomy and Cosmology, Peter Schneider
10. The Formation of Stars, S. W. Stahler and F. Palla

Semester: X

Course: Mathematical Physics (In lieu of Laboratory elective A)

Paper Code: PHY1001004
Total lectures: 60 (45 Theory; 15 Tutorials)
Total marks: 100 (Internal – 40 + External - 60)
Credits: 4 (Theory – 03; Tutorial - 01)

CO 1: Recall and describe concepts used in physical applications of mathematical structures.

CO 2: Give examples where the mathematical structures are useful.

CO 3: Apply the mathematical concepts to understand working of the macroscopic world of gravitation and microscopic world of particles.

CO 4: Design and analyze the structures for explaining various parts of the physical reality.

CO 5: Assess and judge the range of applicability of the mathematical structures.

Unit-I: Spacetime and General Relativity

Events and light cone structure of spacetime, causality; Differentiable manifold and structures – coordinates and the metric; Gravitation and curvature; Geodesics; Riemann tensor and Bianchi identities; Einstein-Hilbert action and Einstein's field equations; Stress–energy tensor; Linearisation of Einstein's equations and gravitational waves.

Unit II: Mathematical theory of Black Holes:

Schwarzschild metric in different coordinate systems; Kerr metric and cosmic censorship hypothesis; Concept of event horizons; Reissner-Nordstrom metric; Black hole theorems; Raychaudhuri equation, singularities and Hawking-Penrose singularity theorem; Idea of quantum gravity (introductory ideas only).

Unit-III: Path Integral Approach

Action as functional; Functional derivative- Euler-Lagrange's equation; Path integration-Dirac's formulation; Propagator; Derivation of the Schrodinger's equation; Path integral foundation of Quantum Field Theory.

Unit-IV: Applications of Group Theory

Lie Groups and Lie Algebra; Orthogonal and special unitary groups; Generators in both matrix and differential operator form; Doublet and triplet representation; Conjugate representation; Charge algebra, current algebra; Goldstone's theorem in the context of spontaneous symmetry breaking; Young's tableaux, applications to simple quark model;

Family of baryons and mesons;

Discrete groups; Z_n, S_n and A_n; Representation theory; Schur's Lemma; Orthogonality theorem and other related useful theorems; Character table; Direct product representations; Irreducible representations; Formulation of the Lagrangian (specially Yukawa terms) symmetric under certain group or groups.

Suggested Books and References:

1. *Spacetime*, SM Carroll
2. *Gravity*, JB Hartle
3. *Lecture Notes on General Relativity*, SM Carroll
4. *Gravitation*, CW Misner, KS Thorne and JA Wheeler
5. *Feynman's Thesis: A new Approach to Quantum Theory*, RP Feynman and LM Brown
6. *Quantum Field Theory In a Nutshell*, A Zee
7. *Group Theory and its Application to Physical Problems*, M Hamermesh
8. *Unitary Symmetry and Elementary Particles*, DB Lightenberg
9. *Quantum Mechanics: Symmetries*, W Greiner and B Muller

Semester: X
Paper: Electronics-II Laboratory
Paper Code: PHY1001104
Total Marks 100: (Internal-40+External-60)
Credit:4 (0L+0T+4P)

Course Outcome:

CO1: Recognize different measuring devices and hardware used in electronics laboratory
CO2: Distinguish the measuring devices, and different software used in the electronic laboratory.
CO3: Operate the measuring devices and different hardware used in the electronics laboratory.
CO4: Utilize the various components of electronics laboratory
CO5: Formulate new electronic experiments to solve the associated problem of experimental physics.

List of Experiments (Any ***five*** experiments should be completed)

Exp 1: Design a Frequency modulation circuit using IC555 both in LTSpice and hardware. Observe the components of the FM modulated spectrum for different modulation index. Compare the same with the theoretical value. Estimate the bandwidth required for the FM modulated signal.

Exp 2: Design a FM demodulation circuit using PLL. Estimate the free running signal and the lock range. Use the circuit for demodulating a FM modulation system.

Exp 3: Use the 8085 microprocessor for controlling the speed and direction of a stepper motor.

Exp 4: Use an Optical Fibre for the following: (i) IV Characteristics (ii) analog transmission (iii) digital transmission, (iv) estimate the numerical aperture.

Exp 5: Study and analysis of the sampling theorem and reconstruction of the analog signal using MATLAB and hardware

Exp 6: Implementation of simple circuits and systems in FPGA and SoC

Exp 7: Use of hands-on test and measurement equipment: VNA and MSO, lock in amplifier

Exp 8: Use of virtual instrumentation for signal acquisition and analysis (Labview and DAQ)

Exp 9: Solution of differential equations using OPAMP using LTSpice simulator and hardware implementation.

Exp 10: Design and test digital filter implementation using Digital Signal Processor.

Exp 11: Experiments using microwave test bench

Exp 12: Measuring key transport properties of two probe, four probe and FET devices using Probe Station setup.

Semester: X

Paper: Laser and Spectroscopy Laboratory
Paper Code: PHY1001204
Total Marks 100: (Internal-40+External-60)
Credit:4 (0L+0T+4P)

Course Outcome:

CO 1: Use high-resolution spectrometry to measure the vibrational frequency and anharmonicity constant in an aluminium oxide molecule from its emission spectrum.

CO 2: Analyze how a magnetic field affects the length of a material using a Michelson Interferometer.

CO 3: Explain the Zeeman effect and use it to determine the Bohr Magneton.

CO 4: Evaluate the frequency response of a defocused optical imaging system to assess its optical performance.

CO 5: Describe the concept of quantum defect in a sodium source and its impact on atomic transitions.

List of Experiments

Exp 1: *Determine the vibrational frequency and anharmonicity constant of Aluminium oxide molecule by taking the emission spectrum of aluminium arc, using a high-resolution spectrometer.*

Exp 2: *Determine the variation of length of a material with magnetic field using Michelson Interferometer.*

Exp 3: *Determine the Bohr Magneton using Zeeman effect*

Exp 4: *Study the frequency response of a defocussed optical imaging system*

Exp 5: *Determine the heat of dissociation of iodine molecule in the ground state, taking absorption spectra.*

Exp 6: *Study the quantum defect in a sodium source*

Semester: X
Paper: Nuclear Physics Laboratory
Paper Code: PHY1001304
Total Marks 100: (Internal-40+External-60)
Credit:4 (0L+0T+4P)

Course Learning Objective: The course is designed in such a way that the students get an advance knowledge in experimental nuclear physics. They will be required to do hands-on activities in labs and learn how to handle various radioactive sources and nuclear radiation detectors.

Course outcome:

- Will demonstrate the various mechanisms of detection of both charged and neutral radiations.
- Learn from hands-on activities how to handle nuclear radioactive sources nd detectors.
- After completion of the course learner can join any laboratory of radiation safety or radiation research.

List of Experiments:

(Minimum four experiments need to be performed from the following):

1.To determine the half-life of an artificially produced In- beta radioactive Isotope- I^{116} using 241Am-Be neutron howitzer.

2. (i) To study the complete spectrum of different gamma sources and to locate the corresponding photo peak, Compton edge, Annihilation peak etc. using NaI(Tl) scintillation counter and single/Multi channel analyser and draw calibration curve. (ii) To find resolution of gamma spectrometer.

3. To count the number tracks produced per unit area of a Solid State Nuclear Track Detector (SSNTD) using an optical microscope.

4. To study the absorption of beta rays, emitted from different radioactive sources, in Al and hence to find the range-energy relation for beta particles, by Feather’s method.

5. Obtain a GM pulse using DSO, determine the dead time and recovery time from the obtained pulse. Also determine the dead time of a GM tube by taking counts for different paralysis time of a given GM counting system.

6. To draw the energy spectrum of alpha particles, emitted from a alpha radioactive source, using a SSB and hence to find the energy resolution of the detector.

7. SRIM/TRIM based experiments to study ion-matter interaction of heavy projectiles on heavy atoms. The range of investigations will be ZP = 6 to 92 on ZA = 16 to 92 (where ZP and ZA are atomic numbers of projectile and atoms respectively). Draw and infer appropriate Bragg Curves.

8. To find the efficiency of a GM counter for gamma rays.

Ref: 1. Laboratory Manuals

2. Techniques of Nuclear and Particle Physics Experiments – W R Leo

3. Nuclear Radiation Detector, S S Kapoor and V S Ramamurthy

4. Radiation Detection and Measurement, G F Knoll

Semester X

Course Name: Condensed Matter Physics Laboratory
Paper Code: PHY1001404
Total Marks 100: (Internal-40+External-60)
Credit: 4 (0L+0T+4P)

Course Outcome:

CO 1: Demonstrate the experiments in the field of electrical and optical transport, transport in magnetic field, dielectric phenomena and spin resonance

CO 2: Interrelate the experiments with theoretical advanced topic of condensed matter physics

CO 3: Develop the skill to solve the experimental problems

CO 4: Analyse the experimental data collected from each experiment and interpret the results.

CO 5: Rearrange and design research grade devise on the basis of experience of handling advanced equipment in context of Advanced Condensed Matter Physics

List of Experiments

Expt 1: *Determination of magnetic susceptibility of a given solid using Gouy's method*

Expt 2: *Determination of Landé g factor using the ESR set-up*

E**xpt 3**: *Study of photoconductivity of the CdS sample*

Expt 4: *Determination of solar cell characteristics using the supplied set up*

Expt 5: *To study thermoluminescence of a given KBr sample*

Expt 6:*Preparation of nanoparticles by chemical reduction method*

Expt 7: *To determine the absorption coeffiecient and band gap of a given thin film*

Suggested References
Lab Manual, Advanced Condensed Matter Physics Lab

Semester-X
Paper: Nanophysics Laboratory
Paper Code: PHY1001504
Marks: 100 (Internal – 40 + External - 60)
Credit: 4 (0L+0T+4P)

Course Outcome:

CO1: Prepare nanomaterials using chemical and physical methods.
CO2: Develop handling experience in techniques such as ball mill, magnetron sputtering, UV-visible spectrophotometer and spectrofluorometer.
CO3: Analyze X-ray diffraction patterns to gather microstructural information.
CO4: Interpret experimental results to understand phenomenon such as quantum confinement and surface plasmon resonance.
CO5: Organize experimental data to co-relate with the physical properties of nanostructures.

Contents

List of Experiments (All experiments including demo are compulsory)

Exp 1: Familiarization with ORIGIN Graphing and Analysis Software for analysis of absorption & photoluminescence spectra and X-ray diffraction patterns (Demo)

Exp 2: Production and measurement of low pressure using high vacuum pumping system (Demo)

Exp 3: Synthesize CdS nanostructures by the chemical co-precipitation method and record UV-visible absorption spectra. Examine the possible quantum confinement effect.

Exp 4: Obtain the powder diffraction pattern of a polycrystalline material using the Debye-Scherrer method. Analyze the results to determine the crystal structure.

Exp 5: Deposit Ag nanoparticles on glass substrate by magnetron sputtering. Record the absorption spectra and study surface plasmon resonance.

Exp 6: Prepare undoped ZnS and Mn-doped ZnS nanocrystals by chemical co-precipitation method. Record photoluminescence spectra and analyze your results.

Exp 7: Using the ball milling method, prepare nanocrystalline ZnO/MoO_3 powder. Record X-ray diffraction patterns of milled and unmilled powders. Index diffraction patterns and determine the crystallite size.

Suggested References

1. Lab Manual, Nanophysics Lab
2. Instruments operation manual

Semester-X
Paper: Astro Lab
Paper Code: PHY1001604
Marks: 100 (Internal – 40 + External - 60)
Credit: 4 (0L+0T+4P)

CO 1 Recall basic concepts in observational astronomy of stars and galaxies.

CO 2 Explain the procedures of performing the laboratory activities.

CO 3 Apply the procedure to perform the activities.

CO 4 Analyze the diagrams to understand how stars and galaxies evolve.

CO 5 Interpret the results of the experiments and outcomes of the procedures.

Note 1: The course contains laboratory exercises in Astronomy & Astrophysics and analysis of astrophysical phenomena by using publicly available databases and tools. Tools to be used are data reduction software like IRAF, planetarium software Stellarium, databases like SDSS, Skyview, SIMBAD, VizieR, Aladin and NED, AAVSO, and the available telescopes and instruments Any eight from the following lab exercises have to be completed with report writing in laboratory notebooks.

Note 2: Colleges/institutions which do not possess telescopes can opt all eight experiments from virtual observatory tools or databases (experiment (i) to (viii)).

Experiments:

(i) To study Virtual Observatory tools: method of collecting astronomical data and image visualization.

(ii) To generate HR diagrams of globular clusters by using SDSS Sky Server and determine turn-off point.

(iii) To draw light curves of variable stars and estimate period by using archival data and applying differential photometric technique.

(iv) To make a comparative analysis of HR diagrams of open clusters to determine distances and ages using archival data.

(v) To separate elliptical galaxies from spiral galaxies in the galaxy cluster Abell 2255 and estimate their percentage.

(vi) To determine the orbital period of the moons of Jupiter by using Stellarium.

(vii) To study galaxy spectra at various redshifts through SDSS Sky Server and study galaxy evolution.

(viii) To classify 300 galaxies through SDSS Sky Server and estimate percentage of irregular, spiral, elliptical and lenticular galaxies.

(ix) To determine plate scale of a telescope using some nearby terrestrial objects

(x) To determine heights of lunar mountains and size of lunar craters by imaging.
(xi) To obtain the period of the moons of Jupiter from imaging.
(xii) To measure the width of the Saturn's ring from imaging.
(xiii) To measure the rotation period of the Sun from sunspot measurements.