B.Sc. (H) PHYSICS

THREE YEAR FULL TIME PROGRAMME

(Six – Semester Course)

Under

CHOICE BASED CREDIT SYSTEM

COURSE CONTENTS

(A draft approved by the BOS for implementing from 2020-21 Session)

Department of Physics
Oriental College (Autonomous)
Takyel, Imphal

AFFILIATED TO MANIPUR UNIVERSITY, CANCHIPUR

Learning Outcomes-based Curriculum Framework (LOCF) for under graduate programme for the Department of Physics, Oriental College (Autonomous), Takyel, Imphal.

I. AIM OF THE COURSE

The objectives of the B.Sc. Honours Physics programme under the Choice Based Credit System (CBCS) starts with conveying students with an exhaustive knowledge and understanding through the core courses which form the basis of Physics namely, Mechanics, Thermodynamics and Kinetic theory of gases, Mathematical Physics, Electricity & Magnetism, Optics, Atomic Physics, Nuclear Physics, Electronic, Advanced Mathematical Physics, Solid State Physics and Quantum Mechanics. In addition to these core papers there are skill papers like Basic Instrumentation skills, Basic application of luminescence and dating, Radiation safety, Atmospheric Physics, Experimental techniques, basic idea of Astrophysics, etc, to give additional knowledge to the students for further study and also to impart knowledge of the application of physics.

This syllabus also aimed to the creative thinking and problem-solving capabilities to the students. It also designed for more specialized and interdisciplinary content to train students with a broader knowledge base. The experiments included in this syllabus are designed to develop an appreciation for the fundamental concepts and working of devices used in everyday life employing scientific methods and tools of physics. The project work in both theory and experimental stream are expected to give a hint of research work for the further study.

II. COURSE LEVEL OUTCOMES

The student graduating with the B. Sc. Physics should be able to acquire the following knowledge and ideas.

i) The fundamental understanding of the academic field of Physics and applications in basic Physics like Mechanics, Special theory of relativity, Thermal Physics, Optics, Electricity, Magnetism, Atomic Physics, Nuclear Physics, Classical Mechanics, Electronics, Mathematical Physics, Physics of Material, Quantum Mechanics, Nano-particle, application in dating and radiation physics.

ii) Technical knowledge that creates different types of professionals related subject area of Physics, including involvement of research work and teaching to government and public service.

iii) Establish the ability to use skills in Physics and its related areas of technology for formulating and attempting wide range of related problems in physics.

iv) Exploratory skills, including skills of independent investigation of Physics related issues, problems analyse and interpret data or information collected using appropriate methods relevant to the theories of Physics.

v) Development of communication skills involving the ability to read texts throughout and research papers and present their ideas in a more concise manner to the audiences of technical group.

vi) Personal skills such as the ability to work both independently and in a group in the group discussion and project presentation and seminar presentation.

vii) Understanding the basic concepts and application of physics in different topics and the observation of the involvement of physics in nature logically with mathematical reasoning.

viii) Learn to carry out experiments in the areas of Optics, Electronics, Nuclear Physics, Electricity, Magnetism, Sound, etc.

Course Structure for Honours Students

Course Type ⇒	Core	DSE	GE	SEC	AECC
Credits ⇒	14 x 6= 84	4 x 6 = 24	4 x 6 = 24	2x 4 = 8	2 x 4 = 8
Semester ⇓	Paper	Paper	Paper	Paper	Paper
1	**PHY-HC 1016** **PHY-HC 1026**		**PHY-HG 1016**		**GEN-AE 1014/ MAN-AE 1014**
2	**PHY-HC 2016** **PHY-HC 2026**		**PHY-HG 2016**		**EVS-AE 2014**
3	**PHY-HC 3016** **PHY-HC 3026** **PHY-HC 3036**		**PHY-HG 3026**	**PHY-SE 3014/ PHY-SE 3024**	
4	**PHY-HC 4016** **PHY-HC 4026** **PHY-HC 4036**		**PHY-HG 4016/ PHY-HG 4026/**	**PHY-SE 4014/ PHY-SE 4024**	
5	**PHY-HC 5016** **PHY-HC 5026**	**PHY-HE 5016** **PHY-HE 5026/ PHY-HE 5036/ PHY-HE 5046/ PHY-HE 5056**			
6	**PHY-HC 6016** **PHY-HC 6026**	**PHY-HE 6016** **PHY-HE 6026/ PHY-HE 6036/ PHY-HE 6046/ PHY-HE 6056**			
TOTAL:	**26 Papers & 148 Credits**				

Abbreviation:

HC – Honours Core course (14 papers of 6 credits each)
DSE – Discipline specific elective course (4 papers of 6 credits each)
GE – Generic elective course (4 papers of 6 credits each)
SEC – Skill enhancement course (2 papers of 4 credits each)
AECC – Ability enhancement compulsory course (2 papers of 4 credits each)

Note: A student opting Physics as Honours course may take Generic Elective Papers from any other disciplines available in the college other than Physics.

Semester –wise course and credit details

	Course	Course Code	Title	Credits	Remarks
1	Core	**PHY-HC 1016**	Mechanics-I (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 1026	Mechanics-II (Theo+Pract)	4+2=6	
	Generic Elective #	**PHY-HG 1016**	Mechanics –I (Theo+Pract)	4+2=6	It can be choose from other disciplines other than Physics available in the college
	Ability Enhancement	**ENG-AE 1014/ MAN-AE 1014**	English Communication/ MAN	4	Compulsory
2	Core	**PHY-HC 2016**	Thermodynamics & Kinetic theory of gases (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 2026	Optics & Quantum Optics (Theo+Pract)	4+2=6	
	Generic Elective #	**PHY-HG 2016**	Thermodynamics & Kinetic theory of gases (Theo+Pract)	4+2=6	It can be choose from other disciplines other than Physics available in the college
	Ability Enhancement	**ENV-AE 2014**	Environmental Science	4	Compulsory
3	Core	**PHY-HC 3016**	Mathematical Physics (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 3026	Electricity (Theo+Pract)	4+2=6	
		PHY-HC 3036	Magnetism and Maxwell equation (Theo+Pract)	4+2=6	
	Generic Elective #	**PHY-HG 3026**	Electricity (Theo+Pract)	4+2=6	It can be choose from other disciplines other than Physics available in the college
	Skill Enhancement	**PHY-SE 3014**	Renewable Energy	4	Compulsory (Choose any one)
		PHY-SE 3024	Basic instrumentation skills	4	
4	Core	**PHY-HC 4016**	Introduction to Atomic Physics (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 4026	Elements of Nuclear Physics (Theo+Pract)	4+2=6	
		PHY-HC 4036	Radiation Physics (Theo+Pract)	4+2=6	

	Generic Elective #	**(Choose any one)** **PHY-HG 4016** **PHY-HG 4026**	Introduction to Atomic Physics Elements of Nuclear Physics	4+2=6	It can be choose from other disciplines other than Physics available in the college
	Skill Enhancement	**PHY-SE 4014** **PHY-SE 4024**	Basic application of luminescence and dating Radiation Safety	4	Compulsory (Choose any one)
5	Core	**PHY-HC 5016**	Elements of Electronics (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 5026	Advanced Mathematical Physics (Theo+Pract)	4+2=6	
	Discipline Specific Elective	**PHY-HE 5016**	Digital systems and application (Theo+Pract)	4+2=6	
		PHY-HE 5026 **PHY-HE 5036** **PHY-HE 5046** **PHY-HE 5056**	(Theory + Practical) Radiation sources and Hazards Basic idea of Astrophysics Atmospheric Physics Physics of Earth	4+2=6	Compulsory (Choose any one)
6	Core	**PHY-HC 6016**	Classical Mechanics (Theo+Pract)	4+2=6	Compulsory
		PHY-HC 6026	Quantum Mechanics (Theo+Pract)	4+2=6	
	Discipline Specific Elective	**PHY-HE 6016**	Solid State Physics (Theo+Pract)	4+2=6	
		PHY-HE 6026 **PHY-HE 6036** **PHY-HE 6046** **PHY-HE 6056**	(Theory + Practical) Statistical Mechanics Physics of low dimension Experimental Techniques Electromagnetic theory	4+2=6	Compulsory (Choose any one)

 # This paper (Generic Elective) is only for the students of other disciplines other than Physics

COURSE CONTENT DETAILS

PART-1: HONOURS CORE PAPERS
Compulsory 14 papers of 6 credits each

1. PHY-HC 1016: Mechanics – I
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the mechanics of a particle for linear and rotational motion.*
- *Provides the conservation laws and different properties of matter*.

Course Outcome:

- Students will learn about the different motion both linear and rotational.
- Learn about the different properties processed by a body in different states of matter.

THEORY CREDIT- 4

Unit I: Fundamentals of Dynamics

Dynamics of a single particle, Dynamics of a system of particles, Centre of mass, Equation of motion, Conservation of linear and angular momentum, Idea of conservation of momentum from Newton's third law, Impulse, Momentum of variable mass system; Motion of rocket, single stage and multi stage rockets; Work- energy theorem, Potential energy, Energy diagram, Stable and unstable equilibrium.

Unit II: Conservative and non- conservative forces

Conservative and non-conservative forces, Force fields, Force as gradient of potential energy, Motion in a uniform field, Components of velocity and acceleration in different co-ordinate systems, Uniformly rotating frame, Centripetal acceleration, Centrifugal force, Coriolis force, fictitious force and their application.

Unit III: Rotational Dynamics

Rigid body motion, Rotational motion- Rotation about a fixed axis, Kinetic energy of rotation, Moment of inertia, Radius of Gyration, Physical interpretation of Moment of Inertia, Parallel axis theorem, Perpendicular axis theorem, calculation of moment of inertia of rigid bodies of regular shapes - rectangular, spherical and cylindrical bodies; Torque and work, torque and angular acceleration, Relation between angular momentum and moment of inertia.

Unit IV: Properties of Matter

Hooke's law, Elastic constants and inter-relation amongst them, Surface tension, Surface energy and their relation, Excess pressure on a curved liquid surface, Capillarity and Jurin's law, Streamline and Turbulent flow, Critical velocity and Reynolds number, Equation of continuity, Bernoulli's theorem, Viscosity, Stoke's law, Terminal velocity, Poiseuille's law.

PRACTICAL CREDIT- 2

1. To study the random error in observations.
2. Determination of moment of inertia of a body by using a Torsion Pendulum.
3. Determination of frequency of a Tuning fork by means of a Sonometer.
4. Determination of surface tension of a given liquid by capillary rise method and verification of Jurin's law.
5. Determination of co-efficient of viscosity of water by Poiseuille's method.
6. To determine the Moment of Inertia of a Flywheel.

SUGGESTED READINGS

1. An introduction to mechanics by Daniel Kleppner, Robert J. Kolenkow (McGraw-Hill, 1973)
2. Mechanics Berkeley Physics Course Vol. 1 by Charles Kittel, Walter Knight, Malvin
3. Introduction to Mechanics-Mahendra K.Verma (University Press)
4. Mechanics by D.S. Mathur (S. Chand and Company Limited, 2000)
5. The properties of matter by D.S. Mathur (S. Chand and Company Limited)
6. Theoretical Mechanics by M.R. Spiegel, Schaum's outline series.
7. A Textbook of Applied Mechanics by Khurmi R. S.
8. Fundamental Laws Of Mechanics , IE Irodov
9. Introduction to Mechanics, Mahendra K. Verma
10. Mechanics, P Duraipandian, Laxmi Duraipandian, Muthamizh Jayapragasam

2. PHY-HC 1026: Mechanics – II

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the gravitational field and energy along with the motion under central force.*
- *Provides the detail idea of the oscillatory motion as well as about the special theory of relativity.*

Course Outcome:

- *Students will learn about the gravitational field and the energy. The motion of planetary motion of the solar system.*
- *Learn about the different types of oscillatory motion and superposition of the motion*
- *Lean about the famous special theory of relativity.*

THEORY CREDIT- 4

Unit I: Central Force Motion

Central force, Motion of a particle under central force field, one body problem, two body problem and its reduction to one body problem and its solution. Motion under an inverse square law.

Unit II: Gravitation

Gravitation and Gravitational force, Newton's Law of gravitation, Inertial and Gravitational mass and their equivalence. Kepler's laws and motion of satellite in circular orbit and application. Gravitational potential and field, Potential energy due to a spherical shell and solid sphere, gravitational self-energy.

Unit III: Oscillatory Motion

Motion of Simple, Compound pendulum and Loaded spring, Energy considerations, Time average of energy, Damped harmonic oscillator, Resonance in a lightly damped system, Free oscillations of system with one degree of freedom, Linearity and Superposition Principle, Superposition of (i) two and (ii) N-collinear harmonic oscillations; beats.

Unit IV: Special theory of relativity

Michelson-Morley experiment and its outcome, Postulates of special theory of relativity, Lorentz transformations, Lorentz contraction and Time dilation-twin paradox, Velocity Addition Theorem; variation of mass with velocity; mass energy equivalence. Relativistic Doppler Effect; Transformation of energy and momentum.

PRACTICAL CREDIT- 2

1. Determination of 'g' by using a Compound Pendulum (bar with holes).
2. Determination of 'g' by Kater's Pendulum.
3. To determine g and velocity for a freely falling body using Digital Timing Technique
4. Verification of Stoke's law and determination of coefficient of viscosity of a liquid.
5. Determination of Young's modulus by Searle's method.

SUGGESTED READINGS

1. The Physics of waves and oscillations by N.K. Bajaj (Tata McGraw-Hill, 1998)
2. Berkeley Physics Course Vol. 3 Waves by Franks Crawford (Tata McGraw-Hill , 2007)
3. Introduction to Special Relativity by R. Resnick (Wiley India Pvt. Ltd)
4. Theoretical Mechanics by M.R. Spiegel, Schaum's outline series.
5. Mechanics part I & II by Naryanamoorthy, S. Chand Publication.
6. Mechanics 3rd Edition by Keith R Symon, Pearson
7. Physics for Degree Students B.Sc.First Year, by C.L. Arora
8. Modern Classical Physics – Optics, Fluids, Plasmas , Elasticity, Relativity, and Statistical Physics by Kip Thorne, Roger Blandford.
9. Foundations of Classical Mechanics by P. C. Deshmukh

3. PHY-HC 2016: Thermodynamics and Kinetic theory of gases
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the laws of thermodynamics and their applications.*
- *Provides the detail idea of the kinetic theory of gases and difference between real and idea gases.*

Course Outcome:

- Students will learn about the application of thermodynamics laws.
- Make learn about the heat engine and thermodynamics scale of temperature.
- Learn about the real gases and their different from ideal gases.

THEORY CREDIT- 4

Unit I: Laws of Thermodynamics

Zeroth and First Law of Thermodynamics, Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth law of thermodynamics and concept of temperature; First law and its differential form, internal energy, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient Isothermal.

Second law of thermodynamics, Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Unit II: Entropy and Thermodynamics Potential

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of

Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their definitions, Properties and Applications. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations

Unit III: Kinetic theory of gases

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). Specific heat of gases.

Unit IV: Molecular Collisions and Real gases

Mean Free Path. Estimation of the molecular diameter and Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion, Dependence on temperature and pressure, their relationship. Brownian motion and its Significance.

Behavior of Real Gases: Deviations from the Ideal Gas Equation. Virial Equation. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States.

PRACTICAL CREDIT- 2

1. To construct a thermocouple with the elements supplied and to determine the melting point of the given substance and the thermoelectric power.
2. Determination of J by Callender and Barne's method.
3. Determination of co-efficient of linear expansion of a metallic rod by optical lever method
4. Verification of Newton's law of cooling.
5. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
6. Determination of thermal conductivity of a metallic rod by Searle's method.
7. Determination of apparent expansion of a liquid by weight thermometer method.
8. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.

SUGGESTED READINGS

1. Heat, Thermodynamics & Statistical Physics: J.P. Agarwal, Satya Prakash: Pragati Prakashan.
2. A treatise on heat: including Kinetic theory of gases, Thermodynamics and recent advances in Statistical thermodynamics : Meghanad Saha, B.N. Srivastava (Indian Press, 1958)
3. Heat and Thermodynamics: Zemansky (McGraw Hill)s
4. Thermal physics: P.K. Chakrabarti, New Central Book Agency 2006, Kolkata
5. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
6. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa
7. Thermodynamics 2013 Edition by Dr Prasanna Kumar, PEARSON INDIA
8. Thermodynamics, C.P. Arora
9. An Introduction to Thermodynamics , Rao Y. V. C.)
10. Principles of Thermodynamics, Ansermet Jean-Philippe

4. PHY-HC 2026: Wave Optics & Quantum Optics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about wave optics and different phenomenon of light in wave form.*
- *Provides the detail idea of principle of laser.*

Course Outcome:

- Students will learn about the different phenomenon of wave optic.
- Learn about the working principle of laser

THEORY CREDIT- 4

Unit I: Wave Optics & Interference

Theories of Light, Electromagnetic Nature of Light, Definition of a Wave Front. Propagation of a Wave Front. Huygens Principle of Secondary Wavelets.

Division of Amplitude and Division of Wavefront, Interference in thin films: Parallel and Wedge-shaped Films. Fringes of equal thickness and equal inclinations, Theory of Newton's ring: Measurement of Wavelength and Refractive Index. Michelson's interferometer: measurements of wavelength, refractive index and visibility of Fringes, thickness of a thin transparent sheet.

Unit II: Coherence and Diffraction

Coherence :- Temporal and Spatial Coherence. Theory of Partial Coherence. Coherence Time and Coherence Length. Purity of a Spectrum Line.

Difference between interference and diffraction, Theory of plane diffraction grating, Resolving power and dispersive power of a plane diffraction grating. Fresnel's integrals, Cornu's spiral, Fresnel diffraction pattern at a straight edge.

Unit III: Polarization

Polarization by reflection, double refraction, wave surfaces as uniaxial crystal, production and detection of elliptically and circularly polarised light, Babinet's compensator- theory and uses, optical activity and polarimeter.

Unit IV: Elements of Quantum Optics

Stimulated emission, Population inversion, Mechanism of population inversion, Spontaneous and Stimulated emission, Einstein's coefficients, and Threshold condition for laser action, Ruby laser, application of lasers, Elements of second harmonic generation.

PRACTICAL CREDIT- 2

1. Determination of the refractive index of the given liquid with the help of a plane mirror, convex and a spherometer.
2. Determination of the refractive index of a given liquid by travelling microscope method.
3. To study the variation of refractive index of the Material of a prism with wavelengths and hence the Cauchy constants using mercury/helium source
4. To determine wavelength of sodium light using Fresnel Biprism.

SUGGESTED READINGS

1. Fundamentals of optics: Francis Arthur Jenkins and Harvey Elliott White (McGraw Hill, 1981)
2. Optics: Ajoy Ghatak (Tata McGraw Hill, 2008)
3. A text book of light: B. Ghosh and K. G. Mazumdar, (5^{th} edition) Sreedhar publishers, Kolkata
4. A text book of Optics: N. Subrahmanyam, Brij Lal: S. Chand & Company LTD (2006).
5. Optics: P.K. Srivastava, CBS publications and Distributors.
6. Optics By Eugene Hecht and A R Ganesan (Pearson Education, 2002)
7. Light and Optics: Principles and Practices by Abdul Al-Azzawi (CRC Press, 2007)
8. Introduction to Optics 3rd Edition (English, Paperback, Frank L. Pedrotti, Leno M. Pedrotti, Leno S. Pedrotti)
9. Theory and Practice of Optics And Refraction 4th Edition 2018 By AK Khurana
10. Agarwal's Principles of Optics & Refraction , Agarwal L.P.

5. PHY-HC 3016: Mathematical Physics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about different between vector and scalar fields.*
- *Provides the detail about the curvilinear coordinate and special integrals.*

Course Outcome:

- Students will learn about the vector and scalar fields and there derivatives.
- Learn about the special integral and about the beta and gamma functions.

THEORY CREDIT- 4

Unit I: Vector and Scalar fields

Fields - Scalar and Vector fields. Ordinary and Partial Derivative of a Vector w.r.t. Coordinates. Directional derivative and gradient of a vector field and its Geometrical Interpretation. Divergence of a vector field, Curl of a vector field, Algebra of the Del operator and Laplacian operator.

Unit II: Vector Integration

Ordinary Integral of Vectors. Line, Surface and Volume Integrals. Flux of a Vector Field. Gauss' Divergence Theorem, Green's Theorem and Stokes Theorem.

Unit III: Co-ordinate systems

Cartesian, Spherical and Cylindrical Co-ordinate system, Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Unit IV: Some Special Integrals and theory of errors

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.

PRACTICAL CREDIT- 2

1. Determination of rigidity modulus by Statical method.
2. Determination of frequency of a tuning fork by Melde's method
3. To determine wavelength of sodium light/radius of plano convex lens using Newton's Rings
4. Determination of refractive index of a prism by using a spectrometer.

SUGGESTED READINGS

1. Schaum's Outline of Vector Analysis, 2nd Edn. By Murray Spiegel, Seymour Lipschutz (McGraw-Hill, 2009)
2. Vector Analysis and Cartesian Tensors, 3ed By D. E. Bourne, P C Kendall (Chapman & Hall, 1992)
3. Schaum's Outline of Theory and Problems of Fourier Analysis By Murray R. Spiegel (McGraw-Hill, 1974)
4. Advanced Engineering Mathematics by Erwin Kreyszig (Wiley Eastern Limited,1985)
5. Introduction to Mathematical Physics by Charlie Harper. (P.H.I., 1995).
6. Higher Engineering Mathematics by B S Grewal, Khanna Publishers (2000).
7. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd
8. A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
9. Elementary Numerical Analysis, K.E. Atkinson,3 r d E d n . , 2 0 0 7 , Wiley India Edition.
10. Computational Physics, Darren Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.

6. PHY-HC 3026: Electricity

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the electric field, electric potential and potential energy.*
- *Provides the detail idea of the electromagnetic induction and electric circuit.*

Course Outcome:

- Students will learn about detail idea of electric field, potential and electrostatic energy.
- Learn about the different electric circuits

THEORY CREDIT- 4

Unit I: Electric field

Electric Field and Lines, Electric Field E due to a Ring of Charge. Electric Flux. Gauss's law. Gauss's law in Differential form. Applications of Gauss's Law : E due to an Infinite Line of Charge, a Charged Cylindrical Conductor, an Infinite Sheet of Charge and Two Parallel Charged Sheets, a Charged Spherical Shell, a Charged Conducting Sphere, (6) a Uniformly Charged Sphere, Two Charged Concentric Spherical Shells and a Charged Conductor. Force on the Surface of a Charged Conductor and Electrostatic Energy in the Medium surrounding a Charged Conductor.

Unit II: Electric Potential

Line Integral of Electric Field, Electric Potential Difference and Electric Potential. Conservative Nature of Electrostatic Field. Electrostatic Potential Energy of a System of Charges. Electric potential, multi-pole moments and multi-pole expansions, force, torque and energy of a dipole in an external electric field, Poisson's and Laplace's equations. Uniqueness theorem, solutions to Laplace's equations in spherical coordinates

Unit III: Electrostatic Energy

Electrostatic energy of a System of Point Charges, a Uniform Sphere, and a Capacitor. Electrostatic energy of system of point charges, system of continuous charge distribution, Spherically symmetric charge distribution, Dielectric properties of matter, polarization, electric field caused by polarised matter, Gauss's law in a dielectric, boundary conditions on E and D, capacitors filled with dielectric, dielectric sphere in a uniform electric field, Clausius - Mossoti equation.

Unit IV: Electromagnetic induction and electric circuit

Faraday's laws of induction, curl E, self and mutual inductance, reciprocity theorem, energy stored in a coil.

Alternating current and transient phenomena, A.C. circuit, Mean value of current and voltage, Skin effect, power factor, A.C. in L-R, C-R, L-C-R circuits, Series and Parallel resonance, transient growth and decay of currents in L-R, C-R, L-C-R circuits; Oscillatory discharge.

PRACTICAL CREDIT- 2

1. Determination of self-inductance by Rayleigh's method.
2. Determination of frequency of the A.C. mains with the help of Sonometer.
3. Determination of capacitance by de Sauty's bridge.
4. Determination of ECE of copper.
5. To study 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.
6. To study the response curve of a parallel LCR circuit and determine its (a) Antiresonant frequency and (b) Quality factor Q.
7. Determination of internal resistance of a cell using a potentiometer.
8. To measure current in an external circuit with the help of a potentiometer

SUGGESTED READINGS

1. Introduction to Electrodynamics: David J. Griffiths, 3rd edition (Benjamin Cummings, 1998)
2. Electricity and magnetism: D.C. Tayal (Himalaya Publishing House)
3. Electricity and magnetism: D. Chattopadhyay and P. Rakshit

4. Electromagnetism: B.B. Laud, Wiley Publication
5. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
6. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
7. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
8. Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol.I, 1991, Oxford Univ. Press.
9. Electricity & Magnetism by Mahajan, McGraw Hill
10. Text Book of Electricity, D.K. Jha

7. PHY-HC 3036: Magnetism and Maxwell equation
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the magnetic field and magnetic properties of matter.*
- *Provides the detail about the Ballistic galvanometer and about the Maxwell equation.*

Course Outcome:

- Students will learn about the magnetic produced by the different sources.
- Learn about the different Maxwell's equations and Ballistic Galvanometer.

THEORY CREDIT- 4

Unit I: Magnetic field

Magnetic field, Magnetic force between currents and definition of B-magnetic field vector, Biot-Savart's Law and its simple applications: straight wire and circular loop. Divergence and Curl of B, Ampere's circuital law and its application to a straight wire, a circular loop and a solenoid, Magnetic scalar and vector potentials. Field of a magnetic dipole, force, torque and energy of a dipole in an external field, torque on current loop, magnetic dipole moment, angular momentum, gyro magnetic ratio, Lorentz force, magnetic field energy.

Unit II: Magnetic properties of matte
r:

Magnetization vector, Magnetic Intensity. Magnetic Susceptibility and permeability. Relation between B, H, M. Ampere's law in a magnetised matter, boundary conditions on B and H; Magnetic shell, magnetic circuits, hysteresis and B-H curve.

Unit III: Ballistic Galvanometer

Potential Energy of a Current Loop. Ballistic Galvanometer: Current and Charge sensitivity. Electromagnetic Damping. Logarithmic Damping. CDR

Unit IV: Maxwell equation

Maxwell's equations, their physical meaning and respective laws, Equation of continuity; Wave equations for E and B, plane wave solutions, transverse nature of electromagnetic wave, flow of electromagnetic power and the Poynting theorem.

PRACTICAL CREDIT- 2

1. Determination of the Horizontal component of earth's magnetic field and the magnetic moment of the magnet with the help of a deflection magnetometer.
2. Determination of capacitance by using ballistic galvanometer.
3. To convert a given galvanometer into an ammeter calibrates it with the help of copper Voltameter.
4. Measurement of charge and current sensitivity and CDR of BallisticGalvanometer
5. Determine a high resistance by leakage method using Ballistic Galvanometer.
6. Measurement of field strength B and its variation in a solenoid (determine dB/dx)

SUGGESTED READINGS

1. Electrodynamics: Robert M. Wald, University of Chicago Press.
2. Introduction to Electrodynamics: David J. Griffiths, 3rd edition (Benjamin Cummings, 1998)
3. Elements of electromagnetic: Mathew N. O. Sadiku (Oxford University Press)
4. Electricity and magnetism: D.C. Tayal (Himalaya Publishing House)
5. New College Electricity and Magnetism , by R.P Chauhan, Dr. Mahabir Nain
6. Electricity Magnetism & Electromagnetic Theory by Mahajan, McGraw Hill
7. Electricity & Magnetism by Tewari K.K.
8. Handbook of Magnetism and Advanced Magnetic Materials: 5 Volume Set Hardcover by Helmut Kronmüller, Stuart Parkin
9. Classical Electrodynamics, by Puri S P
10. Electricity, Magnetism and Electromagnetic Theory,by Shobhit Mahajan , S Rai Choudhary

8. PHY-HC 4016: Introduction to Atomic Physics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the effects of the atoms in the electric and magnetic field.*
- *Provides the detail idea of the mass spectrometer and about Raman effect.*

Course Outcome:

- Students will learn about the splitting of the electronic orbit in the magnetic field.

- Learn about the different types coupling and origin of Raman effect.

THEORY CREDIT- 4

Unit I: Atoms in Electric and Magnetic Fields

Electron Angular Momentum. Space Quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only).

Unit II: Many electron atoms

Pauli's Exclusion Principle. Symmetric and Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total Angular Momentum. Vector Model. L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

Unit III: Mass spectrograph and X- ray

Atomic masses: Bainbridge and Aston's mass spectrograph, X- rays: Continuous and Characteristic X-rays, Mosley's law, Absorption of X- rays and absorption spectra, X-ray Diffraction and Bragg's law, measurement of wave length of X -ray.

Unit IV: Raman Effect

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

PRACTICAL CREDIT- 2

1. To determine the value of e/m by (a) Magnetic Focussing or (b) Bar Magnet.
2. To determine the wavelengths of Hydrogen spectrum and hence to determine the value of Rydberg's Constant.
3. Determination of dispersive power of a prism for sodium light using a spectrometer.
4. Determination of wavelength of sodium light using a plane transmission grating.
5. To determine the Wavelength of H-alpha Emission Line of Hydrogen Atom.
6. To determine the Absorption Lines in the Rotational Spectrum of Iodine Vapour.

SUGGESTED READINGS

1. Concepts of Modern Physics: A Beiser
2. Atomic and Nuclear Physics: Gopalakrishnan (McMillan)
3. Atomic Physics: J. Rajam, S. Chand & Co (pvt) LTD.

4. Theory and problem of Modern physics: Ronald Gautreau, W. Savin, Schaum's outline series, Mc Graw-Hill
5. Concepts of Modern Physics by Arthur Beiser (McGraw-Hill Book Company, 1987)
6. Atomic Physics by J.H.Fewkes & John Yarwood. Vol. II (Oxford Univ. Press, 1991).
7. Physics of Atoms and Molecules, Bransden and Joachein.

9. PHY-HC 4026: Elements of Nuclear Physics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the different nuclear properties and nuclear reaction and radioactivity.*
- *Provides the basic idea of the elementary particles.*

Course Outcome:

- Students will learn about different properties of nucleons and nuclear model.
- Learn about the nuclear reaction and energy released in a nuclear reaction.
- Lean about the elementary particles that are the building block of matter.

THEORY CREDIT- 4

Unit I: Nuclei and their properties

Rutherford's theory of alpha particle scattering and its experimental verification, Charge, Mass, Size, Constituents, Spin and Parity of nuclei; Nuclear stability and binding energy; Nuclear moments- electric dipole moment, Electric quadrupole moment and magnetic moment, Nuclear forces.

Unit II: Nuclear models and Nuclear reaction

Liquid drop model, Semi-empirical mass formula and its applications, Shell model.

Q- value of a reaction, kinematics of nuclear reactions, types of nuclear reactions, Cross sections for nuclear reactions; Nuclear fission- elementary theory of nuclear fission, Energy and mass distribution of fission fragments, fission neutrons, four factor formula, Nuclear reactor and its types, Breeder reactor; Nuclear fusion reaction in the Sun, Controlled nuclear fusion.

Unit III: Radioactivity

Law of radioactive decay and half life period, Radioactive series, Theory of successive transformations, Secular and Transient equilibrium, Carbon dating, Artificial radioactivity, Radio isotopes and their uses, Radiation hazards, Theory of alpha decay, Beta decay and Neutrino hypothesis, Gamma decay.

Unit IV: Elementary Particles (Qualitative Discussion Only) :- Fundamental Interactions. Classification of Elementary Particles. Particles and Antiparticles. Baryons, Hyperons, Leptons, and Mesons. Elementary Particle Quantum Numbers : Baryon Number, Lepton Number, Strangeness, Electric Charge, Hypercharge and Isospin. Conservation Laws and Symmetry. Elementary ideas of quarks and gluons

PRACTICAL CREDIT- 2

1 To draw (i-D) curve for a prism using a spectrometer and to find the minimum deviation using sodium light.
2 To draw (i-D) curve for a prism using a spectrometer and to find the refractive index of the prism using sodium light (angle of prism is given).
3 Determination of radius of curvature of a convex lens by Newton's ring method.
4 Determination of e/m of electrons by using bar magnet.

SUGGESTED READINGS

1. Concepts of Nuclear Physics: Bernard L Cohen
2. Nuclear Physics: S N Ghosal
3. Nuclear Physics: D C Tayal
4. Nuclear Physics – Kalpan
5. Theory and problem of Modern physics: Ronald Gautreau, W. Savin, Schaum's outline series, Mc Graw-Hill.
6. Nuclear Physics 2014 Edition by Prasad, PEARSON INDIA
7. Nuclear Physics: Problem-Based Approach Including Matlab, Hari M Agrawal
8. New College Nuclear Physics B.Sc. Sem-VI , Jaivir Singh, Meenu Rani, Amar Singh

10. PHY-HC 4036: Radiation Physics

Credit 6 (Theory 4+ Practical 2)

Course objectives:

➢ *The students will acquire*

- knowledge of the fundamental principles for radiation protection

- knowledge of the organisation of the university and division of responsibility within the radiation protection

- knowledge of the organisation of the own workplace and division of responsibility within the radiation protection

- basic knowledge of the origin of radiation, properties and biological impact

- knowledge of risks when working with radiation and how these risks relate to other risks in the society

- basic knowledge of working method and measures to be taken when working with

radiation sources

- basic knowledge and skills in using simple radiation protection instruments

Course Outcome:

- Students will learn about the Interaction of matter with radiation.
- Learn about the different types of radiation doses that affect our body.

THEORY CREDIT- 4

Unit I: Interaction of radiation with matter

Passage of heavy charged particles through matter : Energy loss by collision, maximum energy loss in a single collision, range energy relation, Bragg curve, Specific ionization, mean excitation energies, Bethe-Bloch formula collision stopping power, radiation stopping power.

Interaction of neutrons: Neutron sources, General properties, energy classification, elastic and inelastic scattering, nuclear reaction, neutron activation and induced activity, radioisotope production, Nuclear fission.

Unit II: Radiation detectors

Characteristics of organic and inorganic scintillation counters, Resolving time, Semiconductor devices - physics of semiconductors, diffused junction, surface barrier and ion-implanted detectors, Examples, Semiconductor spectrometer, Analysis of pulse height of spectra, superheated drop detectors. Neutron detectors: BF_3 counters, fission chambers, activation methods, Neutron time of flight method.

Preamplifier circuits, noise, linear pulse amplifier, pulse shaping, pulse stretching, operation amplifier, Pulse discriminators, coincidence and anti-coincidence circuits. Scalers, single and multichannel analyser, charge sensitive amplifier. Principles of measurement (collimation shielding, geometry, calibration),Radiation survey instruments.

Unit III: Radiation exposure and dose

Radiation units exposure, absorbed dose, units: rad, gray, relative biological effectiveness, effective dose- Rem & Sievert, inverse square law. Interaction of radiation with matter Compton & photoelectric effect, linear attenuation coefficient. Radiation Detectors: ionization (Thimble chamber, condenser chamber), chamber. Geiger Muller counter, Scintillation counters and Solid State detectors

Unit IV Internal and external dosimetry

Biological half-life, effective half-life, selectivity of organs, beta particle dosimetry. Calculation of integral dose due to internal deposition, specific effective energy, annual limit on intake, derived air concentration. Dosimeters: Primary and secondary dosimeters. Pocket dosimeters, films, TLDs. Chemical and calorimetric devices.

PRACTICAL CREDIT- 2

1. Correction of Myopia (short sightedness) using a combination of lenses on an optical bench/breadboard.
2. Correction of Hypermetropia/Hyperopia (long sightedness) using a combination of lenses on an optical bench/breadboard.
3. To learn working of Thermoluminescent dosimeter (TLD) badges and measure the background radiation.
4. Familiarization with Geiger-Muller (GM) Counter & to measure background radiation
5. Familiarization with Radiation meter and to measure background radiation.

SUGGESTED READINGS

1. Radiation Protection (Adam Hilger Ltd. International Publishers Services, 1985), Ronald L. Kathren,
2. Environmental Radioactivity (Academic Press, Orlando, 1987), Merril Eisenbud,
3. Atoms, Radiation & Radiation Protection (Pergamon Press, 1986), James E Turner,
4. Physics for Radiation Protection, Third Edition, James E. Martin
5. Physics for Radiation Protection, a Handbook, 2nd Edition, Vaziri, Kamran
6. Introduction to Health Physics, 5th Edition, Harris, Jason T
7. Radiation protection and dosimetry, Michael G. Stabin

11. PHY-HC 5016: Elements of Electronics

Credit 6 (Theory 4+ Practical 2)

Course objectives:

This paper deals with

- *The basic concept of physics of semiconductors.*
- *Basic principles of biasing and transistor amplifiers.*
- *The construction of Oscillators.*
- *Fundamental concepts of digital electronics.*
- *Working of special diodes and transistors.*

Course Outcome:

- Students will learn about the diodes as well as about the transistor.
- Learn about the amplifier and oscillator.

THEORY CREDIT- 4

Unit I: Basic circuit analysis and Semiconductor diodes

Passive elements, Active Elements, Star and Delta Connection, Voltage and current divider riles, Principle of superposition, Thevenin's theorem and Norton's theorems, Two port analysis of an electrical network.

p-n junction diode, I-V characteristics, application in rectifiers, clippers and limiters, Zener diodes and its application.

Unit II: Bi-polar junction transistors (BJT)

p-n-p and n-p-n structures, active and saturation regions, characteristics of BJT, common emitter configuration, input and output characteristics, z and h parameters, common base configuration, output characteristics, two-port analysis of a transistor using Z and h parameters, load line concept.

Derivation of current gain, input resistance, voltage gain and output resistance of the CB, CE amplifier configurations (for small signals), the CE configuration with an ammeter resistor (also for small signals), bypassing of the emitter resistor with a bypass capacitor.

Unit III: Amplifiers

Resistance-capacitance and transformer coupled amplifiers, power amplifiers- class A, B, AB, and C operations, concept of negative and positive feedback, representation of a single loop negative feedback amplifier, transfer gain with feedback, merits and demerits of negative feedback,

Differential amplifiers, principles of operational amplifiers, transfer characteristics, offset parameters, differential gain, CMR, inverting and non-inverting operational amplifier, operational amplifier adder, differentiator, integrator, applications of operational amplifier.

Unit IV: Field effect transistor (FET) and Oscillator

Classification of various types of FETS, constructional details of junction field effect transistor, drain characteristics of JFET, biasing of JFET, operating regions, pinch off voltage, idea of metal- oxide-semiconductor-field-effect-transistor (MOSFET).

Wave – form generators, Barkhausen criterion, RC oscillator, Wien Bridge oscillator, phase shift oscillator.

PRACTICAL CREDIT- 2

1. To draw the input and output characteristics of a transistor in CE configurations.
2. To draw the characteristics of a Zener diode and to study its use as a voltage regulator.
3. To plot the frequency response of an RC coupled amplifier i) without feedback and ii) with negative feedback and to determine the bandwidth in each case

4. To study solid state half wave and full wave rectifiers and to determine the ripple factor and p.c. of regulation and different types of filters.
5. To determine the refractive index of a dielectric using SPR technique.
6. To study the PE Hysteresis loop of a Ferroelectric Crystal.

SUGGESTED READINGS

1. Digital principles and applications: Donald P. Leach and Albert Paul Malvino (Glencoe, 1995)
2. Basic electronics and linear circuits: N.N. Bhargava, D.C. Kulshreshtha and S.C.Gupta (Tata McGraw Hill, 2006)
3. Integrated Electronics: Millman and Halkias
4. Electronics: D. Chattopadhyay and P.C. Rakshit
5. Principal of electronics: V.K. Mehta, Rohit Mehta, S. Chand & Company.
6. Elements of electronics: M.K. Bagde, S.P. Singh: S.Chand & Company (Pvt) Ltd.
7. Electronic Devices and Circuits by VENKATA RAO, McGraw Hill
8. Electric Circuits, 11/e by James W. Nilsson, PEARSON INDIA
9. Electronics Paper-II (Electronic Devices) B.Sc I-Year II-Sem (O.U) As Per The CBCS Syllabus, Latest 2020 Edition (Paperback, SIA)

12. PHY-HC 5026: Advanced Mathematical Physics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- This paper deals with various Mathematical techniques which are very useful in the study of physics and engineering application.
- Function of Complex variable and Fourier analysis occur frequently in all branches of physics.
- Special functions and partial differential equations deals in details in this paper.

Course Outcome:

- Students will learn about complex variable and solving problem about the complex variable.
- Learn about the different types special functions and Fourier series.

THEORY CREDIT- 4

Unit I: Complex variables and functions of a complex variable

Complex numbers and their representation, modulus and argument of a complex number, function of a complex variable, continuity and derivative, Cauchy- Riemann condition, analytic functions, integration of a function of a complex variable, Cauchy's theorem, Cauchy's integral formula, Taylor's series for an analytic function, Laurent series, Singularities and their classification, residue and the residue theorem, evaluation of definite integrals.

Unit II: Special Functions

Gamma functions, recurrence relations, Beta function and recurrence relations, relation between gamma and beta function.
Legendre, Hermite and Laguerre Polynomials, associated Legendre functions, differential equations and series solutions, generating functions, recurrence relations, Orthogonality relations. Bessel Differential equation, generating functions, recurrence relations, zeros of the Bessel function, orthogonality relations, series expansion of a function in terms of a complete set of orthogonal functions.

Unit III: Partial differential equations

Vibrations of stretched string, derivation of the equation and its solution under various initial conditions, vibration of rectangular and circular membranes, heat conduction, derivation of the equation, solution for the temperature in a finite rod, semi- infinite rod, the classical wave equation and the Laplace equation.

Unit IV: Fourier series

Orthogonality of the sine and cosine functions, Fourier series of a function, Fourier series expansion of a periodic function, Parseval's theorem, sine and cosine series. Application of Fourier series.

PRACTICAL CREDIT- 2

1. Estimation of relative humidity using wet and dry bulb thermometer.
2. Estimation of height from the given pressure data.
3. Characteristics of a photo cell-determination of stopping potential.
4. To determine value of Planck's constant using LEDs of at least 4 different colours.
5. To draw the (μ- lambda) curve for the material of a prism by using a Spectrometer and to determine the wave length of the given source.

SUGGESTED READINGS

1 Advanced Engineering Mathematics : Erwin Kreyzig
2 Mathematical methods for Physicists: G. Arfken and Weber
3 Mathematical Physics: A.K.Ghatak ,I.Goyal and Chu
4 Applied mathematics for Engineers and Physicists: L.A. Pipes and L.R. Harvell
5 Complex variables (Schaum series): M. Spiegel
6 Complex variables and applications: R.V. Churchill, J.W. Brown, R.F. Verhey, McGraw-Hill, Kogakusha, LTD
7 Mathematical Physics (English, Hardcover, Hari Prasad Gupta)
8 Fundamentals of Mathematical Physics First Edition (English, Paperback, Tarasankar Nag)

13. PHY-HC 6016: Classical Mechanics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the Lagrangian and Hamiltonian formulation*
- *Provides the detail idea of central force and about four vector.*

Course Outcome:

- Students will learn about the Lagrangian and Hamiltonian.
- Learn about the problem of the central force about the four vector.

THEORY CREDIT- 4

Unit 1: Lagrangian formulation

Conservative force, potential and the Langrangian function. Recasting of Newton's equation of motion in the Eular- Lanrange form (in Cartesian co-ordinates), Constraints and its classification with examples

Generalised co-ordinates, Generalised velocities and Generalised momenta, Principles of virtual work, D' Alembert's principle and its derivation, Langrangian and Langrange's equation of motion, Hamilton's principle, derivation of Langrange's equation of motion from Hamilton's principle, generalised momenta, conservation laws, special velocity potential, the generalised potential; Lagrangian of a charged particle in an electromagnetic field, Rayleigh dissipation function.

Unit II: Hamiltonian formulation

Concept of phase space, Principle of variation, deduction of Hamilton's canonical equations from variational principle. The Hamiltonian function and its physical interpretation, Legendre transformation and the Hamilton's equation of motion, deduction of Hamilton's principle from D' Alembert's principle, Poisson bracket (P.B), equations of motion in P.B., constants of motion; Fundamental Poisson Bracket, Poisson Bracket algebra of angular momentum.

Unit III: Central Force Motion

Central force and its example, central potential, particle in a central potential, angular momentum and energy conservation, Langrangian of a particle under central force, reduced mass, two bodies central force problem, equation of motion, and 1^{st} integrals (differential equation of motion of a particle and its solution to inverse square force field), Kepler problem, equivalent one dimensional problem for the radial motion, qualitative discussion on the nature of the orbits, the orbit equation (differential and integral forms), the, inverse square law of force, Kepler's laws of planetary motion, and its deduction.

Unit IV: Four-vectors

Space-like, time-like and light-like. Four-velocity and acceleration. Metric and alternating tensors. Four-momentum and energy-momentum relation. Doppler effect from a four vector

perspective. Concept of four-force. Conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle.

PRACTICAL CREDIT- 2

1. Determination of wave length of monochromatic light by using Fresnel's biprism.
2. To draw the (μ- lambda) curve for the material of a prism by using spectrometer and verification of dispersion formula.
3. To draw the (D- lambda) curve for a given spectrometer and hence to determine the wave length of the unknown source.
4. To determine the wavelength of H-alpha emission line of Hydrogen atom.

SUGGESTED READINGS

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rdEdn. 2002, Pearson Education.
2. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
3. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
4. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press
5. Classical Mechanics-J. C.Upadhyay (Himalaya Publication) 2014
6. Classical Dynamics of Particles and Systems – S. T. Thornton (Cengage Learning) 2012
7. Introduction to Classical Mechanics-R.K.Takwale,S.Puranik-(Tata Mc Graw Hill)
8. Classical Mechanics-M. Das, P.K.Jena, M. Bhuyan, R.N.Mishra (Srikrishna Prakashan)
9. Classical Mechanics – B.D. Gupta and Satya Prakash
10. Introduction to Classical Mechanics – R.G. Takwale and P.S. Puranik

14. PHY-HC 6026: Quantum Mechanics

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This paper is a powerful tool of modern physicist and most of the experimentally observed phenomena in Modern Physics are explained only by Quantum Mechanics.*
- *One cannot imagine now, to do research in Physics, without understanding Quantum mechanics.*
- *This paper will deals with the origin of Quantum theory and its formalism.*
- *The concept of commutator, eigen value, eigen function and Hydrogen energy spectrum etc will be deals in detail.*

Course Outcome:

- Students will learn about the origin of quantum theory and development of quantum mechanics.
- Learn about the problem of particle in a box and about the hydrogen atom.

THEORY CREDIT- 4

Unit I: Origin of the Quantum theory

Failure of classical physics to explain the phenomena such as Black body radiation spectrum and Planck's hypothesis, Planck's radiation law, Einstein's idea and the photo electric effect, Compton Effect, Franck- Hertz experiment
Stability of the atom, Bohr's postulate of angular momentum quantization and the Bohr atom model, Bohr-Sommerfeld quantization rule, limitations of Bohr's theory

Wave particle duality, De Broglie hypothesis for matter waves, the concept of wave and group velocities, De Broglie's wave and wave particle duality, Davisson Germer experiment, electron diffraction and neutron diffraction

Unit II: Development of Quantum mechanics

Wave behaviour of matter, two slit experiment with electron (thought experiment), superposition, description in terms of probability and need for probability amplitude, Wave packet, Heisenberg's uncertainty principle (thought experiment and applications), Bohr's complimentary principle, Bohr's correspondence principle.

Schrodinger wave equation- time dependent and time independent equation, wave function as probability amplitude, normalization of wave function, probability conservation, conditions for physical acceptance of wave function, equation of continuity (differential probability conservation), dynamical variables as operators

Unit III: Eigen values and Eigen function

Eigen values and Eigen function of a dynamical variable, Hermiticity and reality of eigen values, physical meaning of eigen values of a dynamical variable, superposition of wave functions and the expansion postulate, expectation values and Ehrenfest's theorem, the quantum analogue of the classical equation of motion, constants of motion.

The Commutator: The fundamental Commutator and the Commutator algebra; precise definition of uncertainty and the uncertainty relation (statement).

Stationary states and energy Eigen states**,** time independent Schrodinger equation, the stationary state wave functions, free particle and plane wave

Unit IV: Particle in one dimensional box and oscillator

Particle in one dimensional box, Energy eigen values and eigen functions, graphical illustrations, nodes as the energy quantum number, calculation of the expectation values, qualitative estimation of the ground state energy from the uncertainty principle.

Linear harmonic oscillator: Solution of the Schrodinger equation for energy eigen values and eigen functions, Calculation of the expectation values and matrix elements, parity of eigen functions, the virial theorem.

One-dimensional potential barrier: One-dimensional finite potential step, stationary solutions, reflection and transmission coefficients, phenomenon of barrier penetration.

Hydrogen atom: Solution for the energy spectrum and the eigen functions, the quantum numbers n, *l*, m. Degeneracy, expectation values, the viral theorem

PRACTICAL CREDIT- 2

1. Determination of the grating constant by using sodium light and hence to determine the wave length of the unknown radiation.
2. To calibrate a Polarimeter and to determine the concentration of a given solution
3. Determination of electronic charge by Millikan's experiment.
4. Determination of e/m of electron by Thomson's method.
5. To determine Planck's constant using a photocell.

SUGGESTED READINGS

1. Quantum Mechanics: B.H. Bransden and C.J. Joachain(Pearson, 2008)
2. Quantum Mechanics: E. Merzbacher (John Wiley & Sons, Inc 1997)
3. Quantum Mechanics: Theory and Applications: A. Ghatak & S. Lokanathan (5th edition)
4. Quantum Mechanics: G. Aruldhas (Prentice Hall India)
5. Concepts of modern Physics: Arthur Beiser
6. Modern Physics: R. Murugeshan and K. SivaprasathS(S. Chand & Company Ltd)
7. Quantum Mechanics: L.I. Schiff (McGraw Hill Book Co., New York, 1968)
8. Quantum Mechanics: J.L.Powell & B. Crasemann (Addition-Wesley Pubs. Co., 1965)
9. Introduction to Quantum Mechanics: P.T. Matthews, Tata McGraw-Hill Publishing Company LTD.
10. Quantum Physics: R.G. Newton, Springer-Verlag, New York.

Part-2 :Discipline Specific Elective Papers (DSE)

4 Papers of 6 credits each to be opted
Two papers in 5th Semester and
Two papers in 6th Semester

1. PHY-HE 5016: Digital systems and application
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the CRO, digital circuits.*
- *Provides the detail idea of the Boolean algebra.*

Course Outcome:

- Students will learn about the working principle of the CRO, about the integrated circuit.
- Learn about the Boolean equation and about the digital circuit.

THEORY CREDIT- 4

Unit I: Introduction to CRO

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.

Unit II: Integrated Circuits (Qualitative treatment only)

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

Unit III: Boolean algebra

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

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

Unit IV: Digital Circuits

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 and application as Parity Checkers.

PRACTICAL CREDIT- 2

1. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.
2. Half Adder, Full Adder and 4-bit binary Adder
3. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
4. To verify and design AND, OR, NOT and XOR gates using NAND gates.
5. To design a combinational logic system for a specified Truth Table

SUGGESTED READINGS

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. Logic circuit design, Shimon P. Vingron, 2012, Springer.
6. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
7. Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
8. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.

Choose any one from PHY-HE 5026, PHY-HE 5036, PHY-HE 5046, PHY-HE 5056

2. PHY-HE 5026: Radiation Sources and Hazards
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the radiation sources.*
- *Provides the detail idea of the Hazard of radiation.*

Course Outcome:

- Students will learn about the different sources of radiation and biological effect of radiation.
- Learn about the different health hazard causes by the radiation.

THEORY CREDIT – 4

Unit I: Radiation sources

Radiation Sources, Gamma chamber, Particle Accelerators – DC accelerators, Linear accelerator, Cyclic accelerators, Synchrotron Radiation Sources. Accelerator as photon,

neutron and other particle sources. Accelerators in medical and industrial applications. Safety aspects of accelerators.

Unit II: Radiation biophysics

Radiation biophysics Basic aspects of cell biology and physiology. Mechanism of direct and indirect action of radiation at cellular level. Nature of radiation damage at molecular, subcellular and cellular level. Induction of chromosomal aberrations and its application in biological dosimetry of absorbed radiation. Cell killing and induction of mutations. Physical, chemical and biological modifiers of cellular response. Radiation effects on human beings – deterministic and stochastic effects, Dose limits.

Unit III: Radiation Hazard

Radiation hazard, evaluation, control and radiation protection Hazard evaluation by calculation, area monitoring, personal monitoring. Detection and measurement of contamination on work surface and person. Methods of decontamination. Planning of medical and industrial radiation installations. Radiation protection standards : Need for protection, philosophy of radiation protection. ALARA principle. Time, distance, shielding. External and internal exposure.

Unit IV: RADIATION PROTECTION

Principles of radiation protection ,protective materials-radiation effects, somatic, genetic stochastic and deterministic effect. Personal monitoring devices: TLD film badge, pocket dosimeter, OSL dosimeter. Radiation dosimeter. Natural radioactivity, Biological effects of radiation, Radiation monitors. Steps to reduce radiation to Patient, Staff and Public. Dose Limits for Occupational workers and Public.

SUGGESTED READINGS

1. Attix F H et al, „Radiation Dosimetry", Vol. I, II and III (Academic Press, NY, 1968)
2. Knoll G F, „Radiation Detection and Measurements" (Wiley, New York, 1989)
3. Erich J Hall, „Radiology for the Radiologists", III Edn. (J B Lippincott Company, New York, 1988)
4. Herman Cember, „Introduction to Health Physics" (Pergamon Press, 1983)
5. Radiation: Fundamentals, Applications, Risks, and Safety by Ilya Obodovski
6. Radiation Detection and Measurement, by Glenn F. Knoll
7. Radiobiology for the Radiologist, by Hall E J (Author)

3. PHY-HE 5036: Basic idea of Astrophysics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the astronomical scales and astronomical techniques.*
- *Provides the detail idea of the Sun, Milky Way and Galaxy.*

Course Outcome:

- Students will learn about the different astronomical scales and astronomical techniques.
- Learn about the Sun, Milky Way and Galaxy.

THEORY CREDIT – 4

Unit I: Astronomical Scales

Astronomical Distance, Mass and Time, Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Basic concepts of positional astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram.

Unit II: Astronomical techniques

Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes (Types of Detectors, detection Limits with Telescopes). Physical principles: Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium.

Unit III: The Sun

The sun (Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magneto-hydrodynamics. Helioseismology). The solar family (Solar System: Facts and Figures, Origin of the Solar System: The Nebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets. Stellar spectra and classification Structure

(Atomic Spectra Revisited, Stellar Spectra, Spectral Types and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification).

Unit IV: The Milky Way and Galaxies

Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus.

Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms.

SUGGESTED READING

a. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
b. The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
c. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
d. K.S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New Age International (p) Ltd, New Delhi,2002.
e. Baidyanath Basu, 'An introduction to Astro physics', Second printing, Prentice –

4. PHY-HE 5046: Atmospheric Physics
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the general features of the earth's atmosphere.*
- *Provides the detail idea of the motion of the atmospheric air, particle floating in the atmosphere.*

Course Outcome:

- Students will learn about the atmospheric air, the motion of the air.
- Learn about the different types of aerosols present in the atmosphere and their effect.

THEORY CREDITS – 4

Unit I: General features of Earth's atmosphere

Thermal structure of the Earth's Atmosphere, Ionosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect and effective temperature of Earth, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations, including RS/RW, meteorological processes and different systems, fronts, Cyclones and anticyclones, thunderstorms.

Unit II: Atmospheric Dynamics

Scale analysis, Fundamental forces, Basic conservation laws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semiannual oscillations, Mesoscale circulations, The general circulations, Tropical dynamics.

Unit III: Atmospheric Waves

Surface water waves, wave dispersion, acoustic waves, buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration

Unit IV: Atmospheric Radar and Lidar

Radar equation and return signal, Signal processing and detection, Various type of atmospheric radars, Application of radars to study atmospheric phenomena, Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques.

SUGGESTED READING

1. Fundamental of Atmospheric Physics – Murry L Salby; Academic Press, Vol 61, 1996.
2. The Physics of Atmosphere – John T. Houghton; Cambridge University press; 59 3rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014
5. Atmospheric Pressure : The Rise of the Resistance, by Aaron Frale
6. Air Pressure and Wind, Elizabeth Borngraber
7. Air and Water Pressure, Richard Spilsbury

5. PHY-HE 5056: Physics of Earth

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the Earth and universe*
- *Provides the detail idea of the structure of the earth and reorganisation for the existence of living organism.*

Course Outcome:

- Students will learn about the origin of universe and their constituents objects.
- Learn about the evolution of the earth.

THEORY CREDITS – 4

Unit I: The Earth and the Universe

Origin of universe, creation of elements and earth. A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences.

General characteristics and origin of the Universe. The Milky Way galaxy, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Meteorites & Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Energy and particle fluxes incident on the Earth. The Cosmic Microwave Background.

Unit II: Structure

The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?

The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.

The Atmosphere: variation of temperature, density and composition with altitude, clouds.

The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

The Biosphere: Plants and animals. Chemical composition, mass. Marine and land organisms.

Unit III: Dynamical Processes

The Solid Earth: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types products and distribution.

The Hydrosphere: Ocean circulations. Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend – air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

The Atmosphere: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones.
Climate:
i. Earth's temperature and greenhouse effect.
ii. Paleoclimate and recent climate changes.
iii. The Indian monsoon system.

Unit IV: Evolution

Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law of superposition and faunal succession. Introduction to the geology and geomorphology of Indian subcontinent.
1. Time line of major geological and biological events.
2. Origin of life on Earth.
3. Role of the biosphere in shaping the environment.
4. Future of evolution of the Earth and solar system: Death of the Earth.

SUGGESTED READING

1. Planetary Surface Processes, H. Jay Melosh, Cambridge University Press, 2011.
2. Consider a Spherical Cow: A course in environmental problem solving, John Harte. University Science Books
3. Holme's Principles of Physical Geology. 1992. Chapman & Hall.
4. Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

PRACTICAL-DSE CREDIT- 2

1. Program to glow the first four LEDs then next four using TIMER application.
2. To design a power supply using bridge rectifier and study effect of C-filter.
3. To study the output and transfer characteristics of a JFET.
4. Offline and online processing of radar data (a) VHF radar, (b) X-band radar, and (c) UHF radar
5. Handling of satellite data and plotting of atmospheric parameters using radio occultation technique
6. To design an Amplitude Modulator using Transistor
7. To determine the coupling coefficient of coupled pendulums.
8. Half adder, Full Adder using basic and derived gates
9. Design and simulation of a 4 bit Adder.
10. To design traffic light controller
11. To determine the environmental dose rate using Micro-R-Survey Meter.
12. To determine the back ground radiation of the different houses using Survey Meter.

6. PHY-HE 6016: Solid State Physics

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- The principles of Physics which are applied to study of solids, the relationship between structure and property is brought out in this paper.
- Details of magnetic properties are brought out in this topic also.

Course Outcome:

- Students will learn about the crystal structure of the matter, and their magnetic properties.
- Learn about the Ferroelectric Properties of Materials

THEORY CREDITS – 4

Unit I: Crystal structure

Crystalline and amorphous materials, lattice and unit cell, lattice translational vectors, lattice with a basis- central and non central unit cell, reciprocal lattice, Bravais lattice types, Brillouin zones of sc, bcc, fcc lattices, X-ray diffraction: Bragg's law, X-ray Scattering, atomic structure factor and geometric structure factor.

Van der Wall London interaction, repulsive interaction and cohesive energy, ionic crystals, Madelung energy, covalent, metallic and hydrogen bonded crystals.

Unit II: Elementary Lattice dynamics

Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T3 law.

Unit III: Electrical properties of Materials

Free electron model and its limitation, elementary band theory, Bloch theorem, Kronig Penney model, effective mass, concept of hole, band gaps, classification of solids, intrinsic and extrinsic semi conductor, p-type and n- type semiconductors, conductivity of semi conductors, concentration of charge carriers, Fermi level and its temperature dependence, classical Hall effect.

Unit IV: Magnetic properties of materials

Types of magnetic materials, classical theory of diamagnetism and Para magnetism, Curie law, Weiss's theory of ferromagnetism, magnetic domains, soft and hard magnetic materials.

Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

PRACTICAL CREDIT- 2

1. Determination of the band gap of a p-n junction diode (germanium)
2. To draw the input and output characteristics of a transistor in CB configurations
3. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
4. To measure the Magnetic susceptibility of Solids.
5. To determine the Coupling Coefficient of a Piezoelectric crystal.
6. To measure the Dielectric Constant of a dielectric Materials with frequency.
7. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR) technique.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature (up to 150o C) by four-probe method and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.

SUGGESTED READING

1 Solid state Physics: A.J. Dekker
2 Introduction to Solid state Physics: C. Kittel
3 Solid state Physics: A. R. Verma and O.N. Srivastava
4 Solid state Physics: Keer
5 Solid State Physics: S.O. Pillai, New Age International (P) LTD.
6 The crystal lattice: Arnold M.Kosovich: Wiley-Vch Verlag Gmbh & Co.K GaA

Choose any one from PHY-HE 6026, PHY-HE 6036, PHY-HE 5066, PHY-HE 5066

7. PHY-HE 6026: Statistical Mechanics

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the statistical physics and different types of related theory.*
- *Provides the detail idea of the different laws of quantum statistics.*

Course Outcome:

- Students will learn about the fundamental of statistical physics and calculation of the probabilities.
- Learn about the different types distribution laws both from the classical and quantum approach.

THEORY CREDITS – 4

Unit 1: **Fundamental ideas of Statistical Physics**

Distinguishable and indistinguishable particles, microscopic and macroscopic systems with examples, probability and thermodynamic probability, calculation of probabilities, ensembles, principle of equal a priori probability, most probable state, accessible and inaccessible states, probability distribution, Probability and entropy, Boltzmann entropy relation, statistical interpretation of second law of thermodynamics.

Unit II: Maxwell-Boltzmann (M-B) statistics or Classical statistics

Position space, momentum space, Phase space, Maxwell-Boltzmann (M-B) distribution law, Maxwell's law of velocity distribution, distinction between mean, r.m.s. and most probable speed values, molecular energy in an ideal gas.

Unit III: Bose – Einstein Statistics

Bose-Einstein Statistics, B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.

Unit IV: Fermi-Dirac Statistics

Fermi-Dirac Statistics, Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

M-B distribution as a limiting case of B-E and F-D distribution, comparison of the three distribution laws.

SUGGESTED READING

1. Statistical Mechanics- K.K. Huang
2. Thermodynamics, Statistical Physics and kinetics- Satya Prakash
3. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
4. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
5. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
6. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
7. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

8. PHY-HE 6036: Physics of low dimension

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the nano particles and their synthesis methods.*
- *Provides the detail idea of the characterization of the nanoparticles.*

Course Outcome:

- Students will learn about the nanoparticles and their properties.
- Learn about the characterisation of the nanoparticles and their applications.

THEORY CREDITS – 4

Unit I: Nanoscale Systems

Length scales in physics, Nanostructures: 1D, 2D and 3D nanostructures (nano dots, thin films, nanowires, nano rods), Band structure and density of states of materials at nanoscale, Size Effects in nano systems,

Unit II: Synthesis of Nanostructure Materials

Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD).Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods.MBE growth of quantum dots.

Unit III: Optical Properties and Characterization

Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons. Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons,

charging effects. Radiative processes: General formalization-absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures.

X-Ray Diffraction. Optical Microscopy. Scanning Electron Microscopy. Transmission Electron Microscopy.Atomic Force Microscopy.Scanning Tunneling Microscopy.

Unit IV: Applications

Carrier transport in nanostrcutures. Coulomb blockade effect, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects.

Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron transfer devices (no derivation). CNT based transistors.

SUGGESTED READING

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
2. S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company)
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (PHI Learning Private Limited).
4. V.V. Mitin, V.A. Kochelap and M.A. Stroscio, Introduction to Nanoelectronics, Cambridge University Press.
5. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).
6. Mahmood Aliofkhazraei. Handbook of Nanoparticles,
7. Günter Schmid , Nanoparticles: From Theory to Application
8. VD Hodoroaba, W Unger, A Shard, Characterization of Nanoparticles: Measurement Processes for Nanoparticles
9. Abdel Salam Hamdy Makhlouf Ahmed Barhoum, Fundamentals of Nanoparticles, Elsevier

9. PHY-HE 6046: Experimental Techniques

Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the different experimental techniques for physics applications.*
- *Provides the detail idea of the Shielding and Grounding*

Course Outcome:

- Students will learn about the different experimental techniques for the measurement.
- Learn about the uses of the different types of measuring instruments

THEORY CREDITS – 4

Unit I: Measurements

Accuracy and precision. Significant figures. Error and uncertainty analysis. Types of errors: Gross error, systematic error, random error. Statistical analysis of data (Arithmetic mean, deviation from mean, average deviation, standard deviation, chi-square) and curve fitting. Guassian distribution.

Unti II: Signals and Systems

Periodic and aperiodic signals. Impulse response, transfer function and frequency response of first and second order systems. Fluctuations and Noise in measurement system. S/N ratio and Noise figure. Noise in frequency domain. Sources of Noise: Inherent fluctuations, Thermal noise, Shot noise, 1/f noise.

Methods of safety grounding. Energy coupling. Grounding. Shielding: Electrostatic shielding. Electromagnetic Interference.

Unit III: Industrial instrumentation (working principle, efficiency, applications)

Static and dynamic characteristics of measurement Systems. Generalized performance of systems, Zero order first order, second order and higher order systems. Electrical, Thermal and Mechanical systems. Calibration. Transducers and sensors. Characteristics of Transducers. Transducers as electrical element and their signal conditioning. Temperature transducers: RTD, Thermistor, Thermocouples, Semiconductor type temperature sensors and signal conditioning. Linear Position transducer: Strain gauge, Piezoelectric. Inductance change transducer: Linear variable differential transformer (LVDT), Capacitance change transducers. Radiation Sensors: Principle of Gas filled detector, ionization chamber, scintillation detector.

Unit IV: Digital Multimeter and Vacuum Systems

Comparison of analog and digital instruments. Block diagram of digital multimeter, principle of measurement of I, V, C. Accuracy and resolution of measurement.

Characteristics of vacuum: Gas law, Mean free path. Application of vacuum. Vacuum system- Chamber, Mechanical pumps, Diffusion pump & Turbo Modular pump, Pumping speed, Pressure gauges (Pirani, Penning, ionization). (12 Lectures)

SUGGESTED READING

1. Experimental Methods for Engineers, J.P. Holman, McGraw Hill
2. Introduction to Measurements and Instrumentation, A.K. Ghosh, 3rd Edition, PHI Learning Pvt. Ltd. 40
3. Transducers and Instrumentation, D.V.S. Murty, 2nd Edition, PHI Learning Pvt. Ltd.

4. Instrumentation Devices and Systems, C.S. Rangan, G.R. Sarma, V.S.V. Mani, Tata McGraw Hill
5. Electronic circuits: Handbook of design & applications, U.Tietze, Ch.Schenk, Springer

10. PHY-HE 6056: Electromagnetic Theory
Credit 6 (Theory 4+ Practical 2)

Course objectives:

- *This topic gives details about the Maxwell's equation and EM waves.*
- *Provides the detail idea of the propagation of the wave in the bounded and unbounded media.*

Course Outcome:

- Students will learn about the electromagnetic wave and their energy transfer.
- Learn about the phenomenon of polarisation of the electromagnetic wave and basic idea of optical fibres.

THEORY CREDITS – 4

Unit I: Maxwell Equations

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density. Momentum Density and Angular Momentum Density.

Unit II: EM Wave Propagation in Unbounded Media

Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.

Unit III: EM Wave in Bounded Media

Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients.Total internal reflection, evanescent waves. Metallic reflection (normal Incidence)

Unit IV: Polarization of Electromagnetic Waves

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. 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

SUGGESTED READING

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
3. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
4. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
5. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
6. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
7. Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2015, Cambridge University Press

PRACTICAL-DSE CREDITS -2:

1. Synthesis of metal nanoparticles by chemical route.
2. Synthesis of semiconductor nanoparticles.
3. Surface Plasmon study of metal nanoparticles by UV-Visible spectrophotometer.
4. XRD pattern of nanomaterials and estimation of particle size.
5. To study the effect of size on color of nanomaterials.
6. To prepare composite of CNTs with other materials.
7. Growth of quantum dots by thermal evaporation.
8. Prepare a disc of ceramic of a compound using ball milling, pressing and sintering, and study its XRD.
9. Fabricate a thin film of nanoparticles by spin coating (or chemical route) and study transmittance spectra in UV-Visible region.
10. Prepare a thin film capacitor and measure capacitance as a function of temperature or frequency.
11. Fabricate a PN diode by diffusing Al over the surface of N-type Si and study its V-I characteristic.
12. Determine output characteristics of a LVDT & measure displacement using LVDT
13. Measurement of (a) Strain using Strain Gauge, (b) level using capacitive transducer. (c) distance using ultrasonic transducer
14. To study the characteristics of a Thermostat and determine its parameters.
15. Calibrate Semiconductor type temperature sensor (AD590, LM35, LM75) and Resistance Temperature Device (RTD).

16. Create vacuum in a small chamber using a mechanical (rotary) pump and measure the chamber pressure using a pressure gauge.
17. Comparison of pickup of noise in cables of different types (co-axial, single shielded, double shielded, without shielding) of 2m length, understanding of importance of grounding using function generator of mV level & an oscilloscope.
18. To design and study the Sample and Hold Circuit.
19. Design and analyze the Clippers and Clampers circuits using junction diode
20. To plot the frequency response of a microphone.

Part-3: Generic Elective Courses (HG)

(General Papers for the students of other discipline)
4 papers of 6 credits (Theory - 4 + Practical-2) each to be opted one each in 1st, 2nd, 3rd & 4th Semester

Course/ Paper No.	Title	Credit
PHY-HG 1016	Mechanics-I	6 Credit (Theo. 4 + Pract. 2)
PHY-HG 2016	Thermodynamics & Kinetic Theory of gases	-do-
PHY-HG 3026	Electricity	-do-
PHY-HG 4016	Introduction to Atomic Physics	-do-
PHY-HG 4026	Elements of Nuclear Physics	-do-

Part-4: Skill Enhancement courses (SEC)

2 papers of 4 credit each to be opted- one in Sem. 3 and one in Sem. 4

1. PHY-SE 3014: Renewable Energy : Credit - 4

Course objectives:
The aim of this course is not just to impart theoretical knowledge to the students but to provide them with exposure and hands-on learning wherever possible

- *This topic gives details about alternate sources of energy.*
- *Provides the detail idea of the solar energy, wind energy, ocean energy, geothermal energy.*

Course Outcome:

- Students will learn about the different types of renewable energy.
- Learn about the different types sources of renewable energy.

THEORY CREDIT – 4

Unit I: Fossil fuels and Alternate Sources of energy

Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.

Unit II: Solar energy

Solar energy, its importance, storage of solar energy, solar pond, non convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.

Unit III: Wind and Ocean Energy

Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies.

Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices.
Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass.

Unit IV: Geothermal Energy

Geothermal Resources, Geothermal Technologies. (2 Lectures) Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources.

Demonstrations

Demonstration of Training modules on Solar energy, wind energy, etc.

SUGGESTED READING

1 Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi
2 Solar energy - M P Agarwal - S Chand and Co. Ltd.
3 Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
4 Godfrey Boyle, "Renewable Energy, Power for a sustainable future", 2004, Oxford University Press, in association with The Open University.
5 Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009
6 J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).

2. PHY-SE 3024: Basic Instrumentation Skills : Credit - 4

Course objectives:

- This course is to get exposure with various aspects of instruments and their usage through hands-on mode

Course Outcome:

- Students will learn about the different types of electronic instruments and their working.

THEORY CREDIT – 4

Unit I: Basic of Measurement and Electronic Voltmeter

Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Multimeter: Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance.

Advantage over conventional multimeter for voltage measurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. AC millivoltmeter: Type of AC millivoltmeters. Block diagram ac millivoltmeter, specifications and their significance.

Unit II: Oscilloscope

Block diagram of basic CRO. CRT, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence. Time base operation, synchronization. Front panel controls. Specifications of CRO and their significance.

Use of CRO for the measurement of voltage (dc and ac), frequency and time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: principle of working.

Unit III: Signal and pulse Generators and Impedance Bridges

Block diagram, explanation and specifications of low frequency signal generator and pulse generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.

Block diagram of bridge. working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram and working principles of a Q- Meter. Digital LCR bridges.

Unit IV: Digital Instruments

Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.

Digital Multimeter: Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution.

The test of lab skills will be of the following test items:

1. Use of an oscilloscope
2. Oscilloscope as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment,
4. Use of Digital Multimeter/VTVM for measuring voltages
5. Circuit tracing of Laboratory electronic equipment,
6. Winding a coil / transformer.
7. Study the layout of receiver circuit.
8. Trouble shooting a circuit
9. Balancing of bridges

SUGGESTED READING

1. A text book in Electrical Technology - B L Theraja - S Chand and Co.
2. Performance and design of AC machines - M G Say ELBS Edn.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Logic circuit design, Shimon P. Vingron, 2012, Springer.
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
6. Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill

3. PHY-SE 4014: Basic application of luminescence and dating: Credit - 4

Course objectives:

- This course is to get exposure with various aspects of instruments and their usage through hands-on mode
- *The main objective of the topic is to understand the basic application of physics.*
- *The topic is study about the carbon dating and its application.*
- *Then the different types dating like luminescence and meteorite dating. .*

Course Outcome:

- Students will learn about the luminescence and its application.
- Learn about the different types of daing.

THEORY CREDIT – 4

Unit I: Luminescence and its application

Introduction of luminescence, mechanism of luminescence, glow curve, different luminescence phenomenon, fluorescence, applications of fluorescence (basic idea), phosphorescence, thermoluminescence (TL), basic application of thermoluminescence in Archaeology, Biology and Biochemistry, Forensic science, Geology , Quality control in Industry, Radiation Dosimetry, Application of TLD in Medicine, Radiotherapy Measurements, Environmental Monitoring, Personal monitoring, Personal monitoring

Unit II: Carbon Dating and its application

Dating, carbon dating, radioactive decay of Carbon, mechanism of carbon dating, ratio of Carbon-12 to Cabon-14 isotopes in plants, important of carbon dating, determination of the history of planet by carbon dating method, Physics of Carbon dating.

Unit III: Thermoluminescence Dating

Natural radioactivity and annual dose, gamma irradiation, beta irradiation, alpha irradiation, measurement of thermoluminescence (idea), basic thermoluminescence dating, age equation and evaluation.

Unit IV: Meteorite dating

Meteorite, Meteorite in history, determination of the age of the meteorite and its application to the determination of the age of the earth.

Demonstrations

Demonstration of Training modules on the measurement of Thermoluminescence glow curves

SUGGESTED READING

1. Thermoluminescence Dating, M. J. Aitken
2. Theory of thermoluminescence and related phenomena , R. Chen and S.W.S. McKeever
3. Radiocarbon dating, M.J. Aitken
4. Handbooks for Archaeologists: No. 3: Radiocarbon Dating. Strasbo. Mook, W.G.; Waterbolk, H.T. (1985).

4. PHY-SE 40214: Radiation Safety: Credit - 4

Course objectives:

- The aim of this course is for awareness and understanding regarding radiation hazards and safety.

Course Outcome:

- Students will learn about the radiation safety measurement.

THEORY CREDIT – 4

Unit I: Basics of Atomic and Nuclear Physics

Basic concept of atomic structure; X rays characteristic and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, mass number, isotopes of element, spin, binding energy, stable and unstable isotopes, law of radioactive decay, Mean life and half life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission.

Unit II: Interaction of Radiation with matter

Types of Radiation: Alpha, Beta, Gamma and Neutron and their sources, sealed and unsealed sources, Interaction of Photons - Photoelectric effect, Compton Scattering, Pair Production, Linear and Mass Attenuation Coefficients, Interaction of Charged Particles: Heavy charged particles - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling, Channeling and Cherenkov radiation. Beta Particles- Collision and Radiation loss (Bremsstrahlung), Interaction of Neutrons- Collision, slowing down and Moderation.

Unit III: Radiation detection and monitoring devices: Radiation Quantities and Units:

Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derived Air Concentration (DAC). Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Gieger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermoluminescent Dosimetry.

Unit IV: Radiation safety management

Biological effects of ionizing radiation, Operational limits and basics of radiation hazards evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, justification, optimization, limitation, introduction of safety and risk management of radiation. Nuclear waste and disposal management. Brief idea about Accelerator driven Sub-critical system (ADS) for waste management.

Demonstrations

Demonstration of Training modules on the background radiation levels using Radiation meter

SUGGESTED READING

1. W.E. Burcham and M. Jobes – Nuclear and Particle Physics – Longman (1995)
2. G.F.Knoll, Radiation detection and measurements
3. Thermoluninescense Dosimetry, Mcknlay, A.F., Bristol, Adam Hilger (Medical Physics Handbook 5)
4. W.J. Meredith and J.B. Massey, "Fundamental Physics of Radiology". John Wright and Sons, UK, 1989.
5. J.R. Greening, "Fundamentals of Radiation Dosimetry", Medical Physics Hand Book Series, No.6, Adam Hilger Ltd., Bristol 1981.
6. Practical Applications of Radioactivity and Nuclear Radiations, G.C. Lowental and P.L. Airey, Cambridge University Press, U.K., 2001
7. A. Martin and S.A. Harbisor, An Introduction to Radiation Protection, John Willey & Sons, Inc. New York, 1981.
8. NCRP, ICRP, ICRU, IAEA, AERB Publications.
9. W.R. Hendee, "Medical Radiation Physics", Year Book – Medical Publishers Inc. London, 1981