Parvatibai Chowgule College of Arts and Science
(Autonomous)
Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

DEPARTMENT OF PHYSICS

SYLLABUS FOR

A.Y. 2023-24 under CBCS Autonomy (Sem III to VI)

COURSE STRUCTURE

SEMESTER	MAJOR CORE	MINOR/ VOCATIONAL	MULTI-DISCIPLINARY COURSE (MDC)	SKILL ENHANCEMENT COURSE (SEC)
III	**PHY-III.C-5** Electromagnetic Theory-I			**PHY-SEC.1** Basics of Visualization and Scientific word processing
	PHY-E1 *Optics			
	PHY-E2 Modern Physics			
	PHY-E3 Oscillations, Waves and Sound			
	PHY-E17 Introduction to Astronomy and Astrophysics			
IV	**PHY-IV.C-6** Quantum Mechanics			**PHY-SEC.2** Instrumentation
	PHY-E5 *Electronics-I			
	PHY-E18 Introduction to Error Analysis			
	PHY-E4 Properties of Matter and Acoustics			
	PHY-E7 Computational Physics			
V	**PHY-V.C-7** Electromagnetic Theory-II			
	PHY-E9 *Solid State Physics			
	PHY-E10 Thermodynamics and Statistical Mechanics			
	PHY-E11 Electronics-II			
	PHY-E12 Mathematical Physics			
	PHY-E6 Solid State Devices			
VI	**PHY-VI.C-8** Atomic and Molecular Physics			
	PHY-E13 *Mechanics II			
	PHY-E14 Nuclear and Elementary Particle Physics			

	PHY-E15 Introduction to Special Theory of Relativity			
	PHY-E16 Introduction to Material Science			

* BoS Physics recommends these elective courses to be taken by students as a prerequisite to the M.Sc. (Physics) Program.

SEMESTER III

Course Title **: Electromagnetic Theory – I**

Course Code **: PHY-III.C-5**

Marks **: 75 (Theory) + 25 (Practical)**

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

Pre-requisite **:** Electricity and Magnetism (PHY-II.C-4) and Introduction to Mathematical Physics (PHY-I.C-1)

Course Objectives **:** To acquaint students with fundamental principles of Electrostatics part of the Electromagnetic Theory.

Course Learning Outcomes: At the end of this course students will be able to:

CLO1: Apply vector calculus to understand concepts in electrostatics.

CLO2: Comprehend the interaction between charges in vacuum as well as in medium.

CLO3: Calculate the electric field and electrical potential for discrete charges and continuous distribution of charge.

CLO4: Apply suitable techniques to solve various electrostatic problems.

CLO5: Understand how ferroelectric materials can be used as memory devices.

Theory:

UNIT I: Vector Analysis **[10 h]**

1. **Vector Analysis** **[10 h]**

   Review of Vector Operations and Vector Algebra

   Position, Displacement and Separation Vectors, Differential Calculus: Ordinary Derivatives, Gradient, The Operator $\vec{\nabla}$, The Divergence and Curl, Product Rules, Second Derivatives, Integral Calculus: Line, Surface and Volume Integrals, The fundamental Theorem for Divergences, The fundamental Theorem for Curls, Different Co-ordinate Systems: Cartesian Co-ordinate System, Cylindrical Co- ordinate System, Spherical Co-ordinate System, Some Useful Vector Identities with Proofs.

   [Griffiths pp. 1 – 8, 13 – 22, 28] [Harper pp. 20, 26 30-31, 36]

UNIT II: Electrostatics and Techniques to Solve Electrostatic Problems [20 h]

1. **Electrostatics [12 h]**

   The Electric Field: Coulomb's Law, The Electric Field, Continuous Charge Distributions, Divergence and Curl of Electrostatic Fields: Field Lines, Flux and Gauss's Law, The Divergence of E, Applications of Gauss's Law, The Curl of E, Electric Potential: Introduction to Potential, Poisson's Equation and Laplace's Equation, Potential of a Localized Charged Distribution, Summary: Electrostatic Boundary Condition, Work and Energy in Electrostatics: Work Done to Move a Charge, The Energy of a Point Charge Distribution, The Energy of a Continuous Charge Distribution, Comments on Electrostatic Energy, Conductors: Basic Properties of Conductor, Induced Charges, Surface Charge and the Force on a Conductor, Capacitors.

   [Griffiths, pp. 58 – 103]

2. **Techniques to Solve Electrostatic Problems [8 h]**

   Poisson's Equation, Laplace's Equation: Laplace's Equation in One Dimension, Laplace's Equation in Two Dimensions, Laplace's Equation in Rectangular Co-ordinates, Solution to Laplace's Equation in Spherical Co-ordinates (Zonal Harmonics), Conducting Sphere in Uniform Electric Field, Electrostatic Images: Point Charge and Conducting Sphere, Line Charge and Line Images.

   [Griffiths, pp. 51 – 67]

UNIT III: Electrostatic Field in Matter and Microscopic Theory of Dielectrics [15 h]

1. **Electrostatic Field in Matter [8 h]**

   Polarization, Gauss's Law in a Dielectric, Electric Displacement Vector, Electric Susceptibility and Dielectric Constant, Boundary Conditions on the Field Vectors, Boundary Value Problems Involving Dielectric, Dielectric Sphere in a Uniform Electric Field

   [Reitz, pp. 75 – 93]

2. **Microscopic Theory of Dielectrics [7 h]**

   Molecular field in a dielectric: Clausius Mossotti Relation, Polar and Non-Polar Molecules, Induced Dipoles, Langevin's Debye Formula, Permanent Polarization, Ferroelectricity.

   [Reitz, pp. 101 – 109]

Experiments: (Minimum Six)

1. Van-de-graff Generator. [Demonstration]
2. Measurement of dielectric constant and susceptibility of liquid using parallel metal plates.
3. Measurement of dielectric constant and susceptibility of liquid using coaxial metal tubes.
4. Measurement and Study of variation of dielectric constant of BaTiO3 ferroelectric and determination of its Curie temperature.
5. E and D measurement for a parallel plate capacitor and calculation of dielectric constant.
6. Law of Capacitance using Dielectric Constant Measurement Kit.
7. Absolute capacity by ballistic galvanometer.
8. C1/C2 by De-Sauty's method using ballistic galvanometer.
9. Dipole Moment and Polarizability of Benzene.

References:

1. Griffiths D. J., 2011, *Introduction to Electrodynamics,* 3rd Ed., Prentice Hall of India, New Delhi
2. Harper Charlie, 1993, *Introduction to Mathematical Physics*, Prentice Hall of India, New Delhi
3. Reitz J. R., Milford F. J., Christy R. W., 1979, *Foundations of Electromagnetic Theory,* 3rd Ed. Addison-Wesley Publishing Company

Additional Reference:

1. Mukherji U., 2008, *Electromagnetic Field Theory and Wave Propagation*, Narosa Publishing House.

Web References:

1. https://nptel.ac.in/courses/115101005/
2. https://swayam.gov.in/nd1_noc19_ph08/preview
3. https://ocw.mit.edu/courses/physics/8-07-electromagnetism-ii-fall-2012/lecture-notes/
4. https://www.feynmanlectures.caltech.edu/II_10.html
5. https://www.iiserkol.ac.in/~ph324/ExptManuals/DielectricConstant.pdf

Course Title : **Optics**

Course Code : **PHY-E1**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite :**Nil**.

Course Objective: The course aims to enable the students to develop an understanding towards the properties of light, its nature, its propagation and the different phenomena exhibited by light. The whole branch is divided into: (1) Geometrical Optics involving geometrical consideration of image –formation based on the rectilinear propagation of light and (2) Physical Optics considering the wave nature of light, then explaining the optical phenomena such as Interference, Diffraction and Polarization exhibited by light using suitable theories. The primary aim of this course is to emphasize the different fundamental principles and the techniques used for different optical phenomena.

Course Learning Outcomes: On completion of this course, the students will be able to:
CLO1: Understand and apply cardinal points technique and aberration to study the image formation in optical systems and solve numerical problems based on aberration and cardinal points.
CLO2: Apply division by wave front and division by amplitude techniques to study interference patterns and solve numerical problems based on interference in thin films.
CLO3: Derive conditions for Fresnel class diffraction and Fraunhofer class diffraction, and solve numerical problems based on diffraction grating, resolving power of telescope and prism.
CLO4: Apply Huygen's theory of double refraction to study the types of crystal.
CLO5: Analyze the types of polarized light with help of Nicol Prism and retardation plate.
CLO6: Determine optical rotation of sugar solution using Polarimeters.

Theory:

Unit I: Geometrical Optics **[15 h]**

1. **Fundamentals of Reflection and Refraction** **[6 h]**
   Refractive index and optical path, Fermat's Principle of least time, Derivation of the laws of reflection and refraction using Fermat's Principle.
   Lenses: thin and thick lenses, Lens equation, Lens maker's formula, Cardinal points of an optical system, Combination of coaxially placed two thin lenses (equivalent lenses) (including derivation for focal length and cardinal points).
   [Subramanyam; Chapter.1: 1.6, 1.7; Sing; Chapter.1: 1.2, 1.3, 1.4; Subramanyam; Chapter.4: 4.8, 4.9, 4.10, 4.11, 4.12, 4.15, 4.17; Chapter.5: 5.2, 5.2.1, 5.2.2, 5.2.3, 5.3, 5.10, Chapter.6: 6.1, 6.2]

2. **Lens Aberrations** **[5 h]**
   Introduction, Types of aberrations: monochromatic and chromatic aberration, Monochromatic aberration and its reduction: Spherical aberration, Types of chromatic aberration: Achromatism (lenses in contact and separated by finite distance).
   [Subramanyam; Chapter.9: 9.1, 9.2, 9.5, 9.5.1, 9.10, 9.11, 9.12, 9.13]

3. **Optical Instruments[4 h]**
   Objective and Eyepiece, Huygen's eyepiece, Ramsden's eyepiece, Telescopes, Refracting and Reflecting type of telescopes and Spectrometer.
   [Subramanyam; Chapter.10: 10.8, 10.10, 10.10.1, 10.11, 10.11.1,10.12, 10.15, 10.15.1, 10.16, 10.16.1,10.17]

Unit II: Interference and Diffraction [20 h]

1. **Introduction to Interference and Interference in Thin Films [6 h]**
   Superposition of waves, Interference, Coherence, Conditions for Interference, Techniques of obtaining Interference, Young's Double Slit Experiment, Phase Change on reflection: Stoke's law.
   [Subramanyam: Chapter.14: 14.3, 14.4, 14.4.2, 14.4.4, 14.6, 14.7, 14.8 and Singh Ref.2: Chapter6: 6.3]

   Thin Film, Interference due to reflected and transmitted lights in thin films: Plane Parallel Film, Wedge-shaped Film, Newton's Rings, Types of fringes.
   [Subramanyam: Chapter.15: 15.1, 15.2, 15.2.1 - 15.2.5, 15.3, 15.4, 15.5, 15.5.1 - 15.5.4, 15.6, 15.6.1 - 15.6.9]

2. **Interferometry [3 h]**
   Michelson's Interferometer: Principle, Construction, Working, Circular Fringes, Localised Fringes, White Light Fringes, Application of Michelson's Interferometer: Measurement of Wavelength and Determination of the difference in the wavelength of two waves.
   [Subramanyam; Chapter.15: 15.7, 15.7.1 - 15.7.5, 15.8, 15.8.1, 15.8.2]

3. **Introduction to Diffraction and Fresnel Class Diffraction [5 h]**
   Difference between Interference and Diffraction, Types of diffraction: Fresnel Class and Fraunhoffer Class.
   [Subramanyam; Chapter.17: 17.6, 17.7 and Sing: Chapter7: 7.5, 7.6]
   Diffraction of Light (Fresnel Class): Division of cylindrical wave-front into Fresnel's half period strips, Diffraction at straight edge, Diffraction at a narrow wire.
   [Singh: Chapter.7: 7.9, 7.10, 7.11]

4. **Fraunhoffer Class Diffraction and Resolving Power of optical Instruments [6 h]**
   Diffraction at a single slit (Central maximum, Secondary maxima and Secondary minima), Diffraction at double slit, Distinction between single slit and double slit diffraction patterns, Missing orders in a double slit diffraction pattern, Diffraction at N slits(only conceptual), Determination of wavelength of a spectral line using Plane Transmission Grating. Resolving Power, Rayleigh's criterion, Resolving power of telescope and Resolving Power of Prism.
   [Subramanyam: Chapter.18: 18.2, 18.2.1, pg.431 to 433, 18.4, 18.4.1, 18.4.2, 18.4.3, 18.7, 18.7.1, 18.7.2, 18.7.6 and Chapter.19: 19.1, 19.2, 19.6, 19.7, 19.11]

Unit III: Polarization [10 h]

1. **Production and Analysis of Polarized lights [7 h]**
   Polarized Light, Natural Light, Production of Linearly Polarised Light, Anisotropic Crystal, Calcite Crystal, Huygens Theory of Double Refraction in Uniaxial crystal, Nicol prism- its fabrication, working and use, Types of Polarized Light, Retardation plates - Quarter wave plate and Half wave plate, Production of Elliptically and Circularly Polarized Lights, Detection of plane, circularly, elliptically polarized lights, Analysis of polarized light.
2. **Polarimeter [3 h]**
   Optical activity, Specific rotation, Simple Polarimeter, Laurent's Half-Shade Polarimeter.
   [Subramanyam: Chapter.20: 20.3, 20.4, 20.5, 20.5.1 to 20.5.5, 20.7, 20.8, 20.8.1 to 20.8.3, 20.9, 20.9.1, 20.9.2, 20.6.1, 20.6.3, 20.15, 20.17.1, 20.17.2, 20.18, 20.18.1, 20.19, 20.19.1, 20.20, 20.24, 20.24.1, 20.25, 20.26]

Experiments: (Minimum six)

1. Cardinals points of Two lenses
2. Prism Spectrometer: Optical levelling, Angle of Prism
3. Dispersive power of prism
4. Newton's Rings
5. Wedge shaped air film
6. Single Slit Diffraction using LASER/Sodium source.
7. Diffraction Grating using LASER/Sodium source.
8. Malus's Law using LASER source.
9. Brewster's Law using LASER source.
10. Polarimeter (Demonstration)
11. Lloyd's Mirror/Biprism (Demonstration)
12. Cylindrical Obstacle (Demonstration)

References:

1. Subramanyam N., Lal Brij, Avadhanulu M. N., 2006, *A Text book of Optics*, First multicolour Edition, S. Chand & Company Ltd., New Delhi
2. Singh S. P., Agarwal J. P., 2001, *Optics*, 8th Edition, Pragati Prakashan, Meerut

Additional References:

1. Mathur B. K., *Principles of Optics*, New Global Printing Press, Kanpur.
2. GhatakA., 1977, *Optics*, Tata McGraw-Hill Publishing Company Ltd., New Delhi
3. Jenkins F. A., White H. E., 1981, *Fundamentals of Optics*, Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Web References:

1. https://ocw.mit.edu/courses/mechanical-engineering/2-71-optics-spring-2009/video-lectures/
2. https://www.youtube.com/playlist?list=PLkzOLGQfSuu0L7NRVSxXrMd73NDc48ILb
3. https://www.youtube.com/playlist?list=PL9jo2wQj1WCP2eeRb8UacmKJy850Y9DYQ
4. https://www.youtube.com/playlist?list=PLX2gX-ftPVXWA5TjEhVQSQQzZ-5_5Nui8
5. https://www.youtube.com/watch?v=htSPI7YHnP4&list=PLD707C7AF1A0BC358
6. https://www.youtube.com/watch?v=v1U38n52h9A&list=PLA435953DF9CC6BB9

Course Title : **Modern Physics**

Course Code : **PHY-E2**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite :**Nil**.

Course Objectives:

Modern Physics involves the study of radiation and matter at atomic levels and velocities close to the speed of light. This course will focus on the early development of the theory of atomic structure, wave particle duality, mass spectrographs, accelerators and Lasers. Lectures will help you clarify concepts of modern physics through various conceptual questions and problems.

Course Learning Outcomes: At the end of this course students will be able to:

CLO1: Understand constituents of an atom and atomic structure.
CLO2: Understand and interpret experiments that reveal the particle properties of waves and wavelike properties of particle.
CLO3: Apply uncertainty principle to solve numerical problems related to subatomic physics
CLO4: Understand the working of mass spectrographs and accelerators
CLO5: Understand the basic operating principle of the laser and the optical fibre.

Theory:

Unit I: **[15 h]**

1. **Electrons, Nucleus and Atoms:** **[4 h]**
   Determination of e/m for cathode rays. Thomson's model of the atom and qualitative discussion of alpha scattering experiment. Rutherford's model of the atom. Determining upper limit to nuclear dimension. Electron orbits. Failure of Classical Physics.
   [Rajam: Pages 33-36, 44-50, Beiser: 5.1, 5.3, 5.5-5.7]

2. **Brief review of Atomic models:** **[6 h]**
   Atomic Spectra. Frank-Hertz experiment. The Bohr Atom: Quantization of energy. Bohr-Sommerfeld model. Nuclear motion and reduced mass. Bohr's Correspondence Principle.
   [**Beiser: 6.1, 6.3-6.8]**

3. **Particle Properties of waves:** **[5h]**
   Concepts of Blackbody radiation. The Photoelectric effect. Compton Effect. Experimental verification of the Photoelectric effect.
   [Singh: 1.1-1.3, Beiser: 3.1,3.2, 3.5, Muregeshan: 8.5]

Unit II: **[15 h]**

1. **De Broglie's Postulate - Wavelike properties of Particles:** **[9 h]**
    a. **Dual nature of matter:** Experiments with bullets, waves and electrons. The interference of electron waves. Watching the electrons.
    [Feynman: 1.1-1.6]
    b. Matter Waves: De Broglie's postulate. Davisson and Germer experiment. Electron diffraction experiment of G. P. Thomson. Review of the Bohr's postulate about stationary states in the light of De Broglie's concepts.
    [Eisberg: 3.1], [Singh: 2.8]
    c. Properties of Matter waves: Wave and group velocities. Relation between the group velocity and phase velocity. Velocity of De Broglie wave. Wave packet and its motion in one dimension.
    [Singh: 2.3-2.5, 2.9]

2. **Heisenberg's Uncertainty Principle:** **[6 h]**
    Uncertainty principle. Elementary proof of Heisenberg's uncertainty relation between position and momentum. Elementary proof of Heisenberg's uncertainty relation between energy and time. Illustration of Heisenberg's uncertainty principle with thought-experiments. Consequences of the uncertainty relation.

    [Singh: 3.1-3.5]

Unit III: **[15 h]**

1. **Measurement of Mass and accelerators** **[6 h]**
    Measurement of Mass: Thomson's positive ray analysis, Dempster's Mass spectrometer, Bainbridge Mass spectrograph.
    Linear accelerator and Cyclotron.
    [**Rajam: pg. 227-233, 240-244, Muregeshan: 30.3, 30.4]**

2. **Lasers:** **[9 h]**
    Attenuation of light in an optical media. Thermal Equilibrium. Interaction of light with matter. Einstein's A and B coefficients and their relations. Population inversion. Principal pumping schemes. Ruby Laser, He-Ne Laser and Semiconductor laser. Applications of Laser.
    Optical fibres: Optical fibre, Total internal reflection, Propagation of light through optical fibre, Losses in optical fibre.
    [Subrahmanyam: 22.1-22.11,22.15, 22.16.1, 22.16.3, 22.7, 24.1-24.4, 24.15]

Experiments: (Minimum Six)

1. Determination of e/m of electrons using Thomson's method.
2. Measurement of k/e.
3. Measurement of diameter of Lycopodium powder.
4. To determine wavelength of Laser source by diffraction of single slit.
5. To determine wavelength of Laser source by diffraction of double slit.
6. Frank Hertz Experiment.

7. Photoelectric effect.
8. IV Characteristics of LASER
9. Optical fibre: Numerical aperture
10. Bending loss in optical fibre

References:

1. Beiser, A. 1969, *Perspectives of Modern Physics,* McGraw-Hill Book Company, Singapore.
2. Feynman, R. 2012, *Feynman Lectures on Physics: Quantum Mechanics (Volume - 3)*, Pearson Education, India.
3. Murugeshan, R 2009, *Modern Physics*, S. Chand and Company limited, New Delhi.
4. Rajam, J. 2000, *Atomic Physics*, S. Chand and Company limited, New Delhi.
5. Subramanyam, N., Lal, B. and Avadhanulu, M. 2004, *A Textbook of Optics*, S. Chand and Company limited, New Delhi.
6. Singh, K. And Singh, S. 2013, *Elements of Quantum Mechanics,* S. Chand, New Delhi.

Additional References:

1. Ghatak 2012, *Optics,*McGraw Hill Education, India.
2. Richtmyer, F., Kennard, E., Cooper, J. 2001, *Introduction to Modern Physics*, 6th ed. McGraw-Hill Book Company, New Delhi.
3. Tipler, P. 2012, *Modern Physics*, WH Freeman, New York.

Web References:

1. https://hcverma.in/QuantumMechanics
2. https://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state-chemistry-fall-2010/
3. https://ocw.mit.edu/courses/physics/8-04-quantum-physics-i-spring-2016/
4. https://www.youtube.com/watch?v=VLU4dntonhE&list=PLLUpvzaZLf3LeHh3JgGDSfkLQX02BsDK1
5. https://phet.colorado.edu/en/simulations/category/physics

Course Title : **Oscillations, Waves and Sound**

Course Code : **PHY-E3**

Marks : **75 (Theory) + 25 (Practical)**

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

Prerequisite : **Nil**

Course Objectives **:**Simple harmonic motion is one of the fundamental types of motion that exists in nature. The objective of this course is to cover the fundamental physical concepts of Simple harmonic motion, waves and sound.

Course Learning Outcomes: After successful completion of this course, students will be able to:
CLO1: Set up an equation of motion for simple harmonic motion and obtain its solution.
CLO2: Explain how superposition of waves leads to different Lissajous figures.
CLO3: Set and solve the equation of motion for damped and driven damped harmonic oscillators and analyse the nature of oscillations.
CLO4: Understand the dependence of velocity of sound waves on various factors like temperature, pressure, density, humidity.
CLO5: Solve problems for different cases of Doppler effect.

Theory:

Unit I: Undamped free oscillation **[15 h]**

1. **Undamped free oscillation** **[15 h]**
   Different type of equilibria (Stable, unstable and neutral equilibrium). Periodic oscillations and potential well.
   [Mathur: 5.9]
   Differential equation for simple harmonic oscillator and its solutions. Energy of the harmonic oscillator.
   [Taylor: 5.1-5.2]
   Examples of simple harmonic oscillations: spring and mass system, simple and compound pendulum, torsional pendulum, bifilar oscillations, Helmholtz resonator.
   [Mathur: 7.7.1-7.7.5]
   Superposition of two simple harmonic motions of the same frequency along the same line. Superposition of two mutually perpendicular simple harmonic vibrations of the same frequency. Superposition of two mutually perpendicular simple harmonic vibrations and having time periods in the ratio 1:2. Uses of Lissajous' figures.
   [Subrahmanyam: 2.1, 2.2, 2.4, 2.6, 2.9]

Unit II: Damped Oscillations and Driven Damped Oscillations [15 h]

1. **Damped Oscillations [5 h]**
   Introduction. Differential equation of damped harmonic oscillator and its solution, discussion of different cases (Strong, weak and Critical damping).Logarithmic decrement. Energy equation of damped oscillations. Power dissipation. Quality factor.
   [Taylor: 5.4 and Mathur: 8.2-8.4]

2. **Driven Damped Oscillations [5 h]**
   Introduction, Differential equation of forced oscillation and its solution (transient and steady state). Resonance. Width of the resonance; the Q factor. The phase at resonance. Velocity resonance.
   [Taylor: 5.5-5.6 and Mathur: 8.9]

3. **Coupled Oscillations [5 h]**
   Coupled oscillations. Normal Coordinates. Energy of coupled oscillations.

Unit III: Waves and Sound and Doppler Effect [15 h]

1. **Waves and Sound [10 h]**
   Transverse vibrations in strings. Velocity of longitudinal waves in gases. Newton's formula for velocity of sound. Velocity in a homogeneous medium. Laplace's correction. Kundt's tube-determination of velocity of sound in a gas and in solids. Intensity level and Bel and Decibel.
   Production and detection of Ultrasonic waves and its applications
   [Khanna 4.2, 5.3-5.5, 11.1, 11.3, 12.1-12.4, 19.6 and Subrah.: 11.23 11.25,11.27]

2. **Doppler Effect: [5 h]**
   Explanation of Doppler effect in sound. Observer in rest and source in motion. Source at rest and observer in motion. When both source and observer are in motion. Effect of wind velocity. Doppler effect in light. Applications of Doppler effect.
   [Subrahmanyam: 8.1-8.6]

Experiments: (Minimum Six)

1. To determine the equivalent length of the Kater's pendulum and the acceleration due to gravity using a resonance pendulum.
2. To determine the damping constant using Damped harmonic oscillator
3. To determine the velocity of Sound using Helmholtz resonator
4. To determine the value of acceleration due to gravity using a bar pendulum.
5. To determine the frequency of AC mains using Sonometer.
6. Bifilar suspension: Dependence of the time period on the geometry of non-parallel bifilar suspension.
7. Log Decrement.
8. Velocity of Sound using CRO.
9. Lissajous Figures (Demonstration).

References:

1. Khanna, D., Bedi, R. 1992, *A Textbook of Sound*, Atma Ram and sons, Delhi.
2. Mathur, D. 2012, *Mechanics*, S. Chand, New Delhi.
3. Taylor, J. 2005, *Classical Mechanics,* University Science Books, USA
4. Subrahmanyam, N. and Lal, B. 1994, Waves and Oscillation, Vikas Publishing House, Noida

Additional References:

1. French, AP 2003, Vibration and Waves, CBS Publisher, India.
2. Halliday, D., Resnick, R. and Walker, J. 2003, Fundamentals of Physics, 6th edition, John Wiley and Sons, USA.
3. Pain, J. 2005, *The Physics of Vibration and Waves,* 6th Edition, Wiley.

Web References:

1. https://nptel.ac.in/courses/115/106/115106119/
2. https://nptel.ac.in/courses/115/106/115106090/
3. https://ocw.mit.edu/courses/physics/8-03sc-physics-iii-vibrations-and-waves-fall-2016/part-i-mechanical-vibrations-and-waves/
4. http://galileo.phys.virginia.edu/classes/152.mf1i.spring02/OscWavesIndex.htm
5. http://www.qrg.northwestern.edu/projects/vss/docs/communications/3-what-is-the-doppler-effect.html

Course Title: Introduction to Astronomy and Astrophysics

Course Code: PHY-E17

Marks: 75 (Theory) + 25 (Practical)

Credits: 3 (Theory) + 1 (Practical)

Prerequisites: Classical Mechanics, Optics, Modern Physics, Quantum Mechanics, Electromagnetic Theory - I

Course Objectives: The course aims to introduce the students to the Exciting World of Extragalactic Universe.

Course Learning Outcomes: At the end of the course, students will be able:

CLO1: Understand the various Extra-galactic objects.

CLO2: Understand the construction, working and mounting of modern telescopes.

CLO3: Understand co-ordinate system of Celestial Objects.

CLO4: Understand different spectral classes of stars, galaxies and the very early universe.

CLO5: Locate objects in the sky using coordinate systems.

Theory:

UNIT I: FUNDAMENTALS OF ASTRONOMY [15 h]

1. The Celestial Sphere and Mechanics: [7 h]

The Greek tradition: The geocentric universe; The Copernican revolution: Bringing Order to the Planets; Positions on the Celestial Sphere: The Altitude- Azimuth Coordinate system, The Equatorial Coordinate System, Precession, Measurement of time

Elliptical orbits: Kepler's Laws of Planetary Motion, Geometry of Elliptical Motion

[**Carroll & Ostlie: Chapter 1: 1.1-1.3; Chapter 2: 2.1]**

2. Continuous Spectrum of Light [8 h]

Stellar Parallax; The Magnitude Scale: Apparent Magnitude, Flux, Luminosity and Inverse Square Law, Absolute Magnitude, Distance Modulus; Blackbody Radiation: Connection between color and temperature, Stefan Boltzmann Equation; Planck function and Astrophysics; Color Index: UBV Wavelength filters, Color indices and the Bolometric Correction, The Color-Color diagram;

Interaction of Light and Matter: Spectral lines, Kirchoff's laws, Applications of Stellar Spectra Data, Spectrographs

[**Carroll & Ostlie: Chapter 3: 3.1-3.2, 3.4-3.6; Chapter 5: 5.1]**

UNIT II: ASTRONOMICAL TOOLS, THE SOLAR SYSTEM AND THE NATURE OF STARS [15 h]

1. Astronomical Instruments: [4 h]

Optical telescopes: Refracting and reflecting telescopes, Telescope mounts, Large Aperture telescopes, Adaptive optics, Space based observatories, Electronic detectors; Radio telescopes: Spectral flux density, Improving resolution – Large apertures and Interferometry

[**Carroll & Ostlie: Chapter 6: 6.2-6.3]**

2. The Solar Sytem: [6 h]

Brief survey: General characteristics of the planets, Moons of the planets, Asteroid belt, Comets and Kuiper belt objects, Meteorites, Solar system formation – a brief overview; Tidal forces: Physics of tides, Effects of tides, Synchronous rotation, Additional tidal effects from the sun, Roche limit

[**Carroll & Ostlie: Chapter 19: 19.1-19.2]**

3. Classification of Stellar Spectra: [5 h]

Formation of spectral lines: Spectral types of stars, The Maxwell Boltzmann velocity distribution, The Boltzmann equation, Saha equation; The Hertzsprung Russell Diagram: An enormous range in stellar radii

[**Carroll & Ostlie: Chapter 8: 8.1-8.2]**

UNIT III: STAR FORMATION, GALAXIES AND THE UNIVERSE [15 h]

1. Star formation [6 h]

Formation of protostars- Jeans criterion; Pre-Main Sequence- Formation of Brown Dwarfs, The Zero Age Main Sequence (ZAMS); Evolution of the Main Sequence- Schönberg-Chandrsekhar limit; Late Stages of Stellar Evolution- Subgiant branch, Red Giant branch, Horizontal branch; Stellar Clusters- Globular and Galactic clusters

[**Carroll & Ostlie: Chapter 12: 12.2-12.3, Chapter 13: 13.1-13.3]**

2. The Milky Way and the Nature of Galaxies [5 h]

Morphology of the Milky Way Galaxy; Galactic Center; The Hubble Sequence: Classification of galaxies

[**Carroll & Ostlie: Chapter 24: 24.2, 24.4, Chapter 25: 25.1]**

3. The Early Universe **[4 h]**

Fundamental particles, Hot and Cold Dark matter, Planck's limits on time, mass and length, Unification and spontaneous symmetry breaking, Problems with the standard theory of the Big Bang, Inflation

[**Carroll & Ostlie: Chapter 30: 30.1]**

Experiments: (Minimum six)

1. Resolving power of telescope
2. Study of scattering of light (Diameter of Lycopodium powder)
3. To find radius of curvature of a convex lens using optical lever
4. Measurement of the solar constant
5. Draw constellation map of a) Orion b) Auriga c) Taurus d) Ursa Major (Big Dipper) marking of pole star.
6. To determine the elements in sun using Frauhoffer spectra
7. To estimate Astronomical Unit using Venus transit data by parallax method
8. Determine the period of revolution of sun using virtual laboratory
9. To become familiar with the astronomical objects visible to naked eye in the night sky using the software Stellarium
10. To become familiar with the Constellations in the night sky using the software Stellarium
11. To identify the retrograde motion of Mars with respect to the Background stars using Stellarium
12. To identify some of the prominent spectral lines in the spectrum of our sun
13. To get familiar with the spectra of different stars using Stellarium
14. To extract coordinates of a star assuming a telescope in equatorial mount using Stellarium
15. To measure astronomical distances using Cepheid variables using Stellarium
16. To measure the Proper Motion of Barnard's Star using Stellarium
17. To identify a Circumpolar Star using Stellarium
18. To determine the distance and age of cluster using Colour Magnitude Diagram using Stellarium
19. To determine orbital inclination of the planet Mars using Stellarium
20. To measure planetary distances using Stellarium
21. To measure distance to Moon using Stellarium
22. To determine observer's location by means of the stars using Stellarium

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1. Abhyankar K.D., 2001, *Astrophysics - Stars and Galaxies*, Tata McGraw Hill, New Delhi
2. Sule, A., 2013. *A Problem Book in Astronomy and Astrophysics.* [Online]
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Course Title : Basics of Visualization and Scientific word processing

Course Code : PHY-SEC.1

Marks : 100

Credits : 4

Course Objectives : To develop basic competence in Linux environment, Data visualization, scientific word processing and Crystal visualization.

Course Outcomes : At the end of this course students will be able to:

CLO1: Familiarize with the Linux environment

CLO2: Design crystal structures using crystal visualizers

CLO3: Understand basic mechanisms of Latex and prepare high quality type setting.

CLO4: Plot and visualize data to explore data sets graphically or create high quality graphs for presentation and publication purpose.

Unit I **[20 h]**

Introduction to Linux Environment:

- Installation of Virtual Box.
- Navigation: Current working directory, Listing the Contents of a Directory. Changing the Current Working Directory.
- Exploring the system: Determining A File's Type With file. Viewing File Contents With less.
- Manipulating files and directories: Creating, deleting, copying and moving of directories and files.
- Filters: grep, head/tail, tee, awk, sed, more, less.
- Vi Editor: Appending text. Deleting text. Cutting, Copying, And Pasting Text. Saving work.
- Simple bash scripting: Introduction and executable permissions, if-then-else, do-while and for loops.

[Shotts: Chapter 2, 3 (pg.13-19), **4, 6** (pg. 59-66), **12** (pg. 136-147, 154-155), **24** (Pg:354-358), **27** (pg. 381-389), **29** (pg. 409-413)**, 33** (pg. 450-452)**]**

Unit II **[10 h]**

Crystalline and molecular structure visualisation

Introduction to crystal structures. Installing Vesta. designing crystal structures. Simulate XRD pattern. visualizing lattice planes and drawing lattice vectors. creating supercell.

Unit III **[20 h]**

Scientific word processing:

- **Introduction to LaTeX**: Preparing a basic LaTeX file. Input Files and File structure.

- **Typesetting Text**: The structure of text and language, Line breaking and page breaking. Readymade strings. Special characters and symbols. Titles, chapters and symbols. Cross references, Foot notes, emphasised words.
- **Environments**: Itemize, enumerate and description. Flushleft, Flushright, and Centre. Tabular
- **Typesetting mathematical formulae:** General. Grouping in math mode. Building blocks of a mathematical formula. Math spacing. Vertically aligned material.
- **Graphics and Bibliography:** EPS graphics, Bibliography and Indexing.
- **Creating Presentations:** Introduction to Beamer. Setting up a beamer document. Enhance a beamer presentation.

[Oetikar: 1.1-1.3, 2.1-2.4, 2.7-2.11, 3.1-3.5, 4.1-4.3][Binder: 11.1-11.5]

Unit IV

Data Visualization: **[10 h]**
Introduction to gnuplot. Simple plots, plotting data from a file, abbreviations and defaults. Saving commands and exporting graphs. Plotting functions and data. Math with gnuplot. multiple data sets per file. Different plot styles. Multiple axis. Plot range. Tic marks.
[Janert: 1.3, 2.1-2.2, 3.1,3.2, 4.1- 4.2, 6.1-6.3.1, 8.1-8.3.4.]

References:

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4. Donald Binder and Martin Erickson, 2011, *A students guide to the study practice and tools of Modern Mathematics*, CRC Press, USA

5. Phillip Janert, 2016, *Gnuplot in Action: Understanding data with graphs* 2nd Edition, Manning Publications, US

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3. https://www.youtube.com/playlist?list=PL1D4EAB31D3EBC449
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SEMESTER IV

Course Title : **Quantum Mechanics**

Course Code : **PHY-IV.C-6**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Nil**

Course Objectives **:** The objective of this course is to provide an introduction to quantum mechanics and its application.

Course Learning Outcomes: At the end of this course students will be able to:
CLO1: understand the principles in quantum mechanics, such as the Schrödinger equation, the wave function and its statistical interpretation.
CLO2: solve the Schrödinger equation for potentials in one and three dimension and interpretate the solutions.
CLO3: grasp the concepts of angular momentum and spin.
CLO4: have an insight into fundamental issues in quantum mechanics like the EPR paradox, Bells theorem and Schrödinger's cat
CLO5: develop an understanding of why both analytic and numerical solutions are important in quantum mechanics.
CLO6: use numerical tools and software to solve the Schrodinger equation for complex problems.

Theory:
Unit I: Schrödinger's Theory of Quantum Mechanics **[10 h]**

Plausibility argument leading to Schrödinger equation, Born interpretation of wave functions, Operators in quantum mechanics: position, momentum, kinetic energy and Hamiltonian, Expectation values, The time independent Schrödinger equation, Required properties of Eigen functions, Energy quantization in the Schrödinger theory. Postulates of quantum mechanics.

[Eisberg: 5.1- 5.8][Singh: 4.6]

Unit II: Applications of Schrödinger's Steady state equation **[20h]**

Free particle.
One dimensional infinite rectangular potential well (Particle in a one-dimensional box).
Stationary states, Concept of parity, parity operator and its eigen values.
Particle in a three-dimensional rigid box. Degree of degeneracy.
One dimensional step potential of finite height (Energy less than step height and energy greater than step height)
One dimensional potential barrier. Qualitative discussion of alpha decay,

One dimensional finite rectangular potential well (placed symmetric to origin). Parity and parity operators.
One dimensional harmonic oscillator (Algebraic method using raising and lowering operators and analytical method.)
[Eisberg: 6.2 – 6.6], [Griffiths: 2.1-2.3, 2.6]

Unit III: [15 h]

1. **Angular momentum and Spin [11 h]**
   Angular momentum operators, Angular momentum Eigenvalues and Eigenfunctions. Spin 1/2, Spinors, Pauli spin matrices, Eigenvalues and Eigenspinors of Spin. Electron in a Magnetic field,
   [Griffiths: 4.3, 4.4.1, 4.4.2]
2. **Fundamental issues in quantum mechanics [4 h]**

   EPR paradox, Bell's Theorem and Schrödinger's cat.

   [Griffiths: 12.1, 12.2, 12.4]

Experiments:

1. Introduction to Numerov method.
2. Numerically solving the Time Independent Schrödinger equation for the case of Infinite potential well. / Tutorial.
3. Numerically solving the Time Independent Schrödinger equation for the case of finite potential well. / Tutorial.
4. Numerically solving the Time Independent Schrödinger equation for the case of Infinite potential well with a cosine bump. / Tutorial.
5. Numerically solving the Time Independent Schrödinger equation for the case of Step potential. / Tutorial
6. Numerically solving the Time Independent Schrödinger equation for the case of Sloping potential well. / Tutorial.
7. Numerically solving the Time Independent Schrödinger equation for the case of Potential barrier. / Tutorial.
8. Tunnel Diode.

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2. Griffiths, D. 2015, *Introduction to Quantum Mechanics*, Pearson Education, India.
3. Singh, K. And Singh, S. 2013, *Elements of Quantum Mechanics,* S. Chand, New Delhi.

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2. Flugge, S. 2008, *Practical Quantum Mechanics*, Springer (SIE).

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4. Richtmyer, F., Kennard, E., Cooper, J. 2001, *Introduction to Modern Physics*, 6^{th} ed. Tata McGraw-Hill Book Company, New Delhi.
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3. PhET Interactive Simulations, University of Colorado Boulder, https://phet.colorado.edu/
4. Adams, A. (2013). Retrieved from MIT OpenCourseWare: https://ocw.mit.edu/courses/physics/8-04-quantum-physics-i-spring-2013/
5. Greensite, J. (2003). Retrieved from http://stanford.edu/~oas/SI/QM/papers/QMGreensite.pdf

Course Title : **Electronics-I**

Course Code : **PHY-E5**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Nil**

Course Objectives : The general goal of this course is to allow the students to understand the fundamentals of semiconductor behavior and the operation of basic semiconductor devices. This course lays the foundations for the understanding of more advanced semiconductor devices such as those covered in more advanced courses.

Course Learning Outcomes: At the end of the course, students will be able to:

CLO1: Understand the fundamentals of semiconductor behaviour and the operation of basic semiconductor devices.

CLO2: Understand basic circuit laws; semiconductor based analog circuits.

CLO3: Use this knowledge to describe bipolar transistors and its applications.

CLO4: Understand and apply the concept of feedback in operational amplifier and sinusoidal oscillators.

Theory:

Unit I: **[15 h]**

1. **Basic concepts and resistor circuits** **[7 h]**
   Basics of current and voltages in a circuit, C**onstant** voltage and Constant current source, Conversion of voltage source into current source, Maximum power transfer theorem, Kirchoff's Current and voltage Law, Thevenin's theorem and Norton's theorem, Techniques for solving circuit problems.
   [Eggleston: section1.1, 1.2.1.3, 1.2.3, Mehta:section 1.8-1.16]

2. **Semiconductor Diodes** **[8 h]**
   Semiconductor materials- intrinsic and extrinsic types, Ideal Diode, Terminal characteristics of diodes: p-n junction under open circuit condition, p-n junction under forward bias and reverse bias conditions, Diode I-V characteristic and load line for a simple diode circuit, Diode applications: Voltage dropper, Diode limiter, Variable diode clipper, Diode clamp, Rectification-working of Half wave and Full wave – calculation of efficiency, nature of rectifier output, comparison of rectifiers, Power supply filters (capacitor filter)
   [Eggleston: section 3.1.3, 3.1.4, 3.2.1-3.2.4, Mehta: section 5.8-5.18,6.7-6.21]

Unit II: **[20 h]**

1. **Bipolar Junction Transistors (BJTs)** **[12 h]**
   Physical structure and operation modes, Transistor action, Transistor as an amplifier, Basic BJT amplifier configuration: common emitter, common base and common collector connections and their characteristics, comparison of transistor connections, Transistor as an amplifier in C-E mode, Active region operation of transistor, D.C. analysis of transistor circuits, performance of transistor amplifier, cut off and saturation points, power rating of transistor. Biasing the BJT: fixed bias, emitter feedback bias, collector feedback bias and voltage divider bias.
   [Mehta: section 8.1- 8.23, 9.1-9.12, Eggleston:section 4.1-4.4]
2. **Sinusoidal oscillators** **[8 h]**
   Positive and negative feedback, Voltage and current feedback, series and shunt feedback, Effect of negative feedback on gain, frequency response, input and output resistance and distortion, Positive feedback, Barkhausen criterion for oscillations, Phase shift oscillator, Wein bridge oscillator, Hartley oscillator and Colpitt's oscillator.
   [Mehta: section13.1-13.13 ,14.1-14.14, Eggleston: section 7.3-7.3.4.1]

Unit III: **[10 h]**

1. **Operation Amplifier (Op-amps)** **[10 h]**
   Ideal Op-amp, operation of differential amplifier, differential and common mode signals, common mode rejection ratio (CMRR), d.c. analysis of differential amplifier , parameters of differential amplifier due to mismatch of transistors, bandwidth of an Op-amp, Slew rate limiting, Frequency response, Practical op-amp circuits: inverting amplifier, non –inverting amplifier, integrator, differentiator.
   [Mehta: section 25.1-25.5,25.9,25.11,25.15,25.19,25.21,25.23,25.35,25.37, Eggleston: section 6.1,6.3,6.4]

Experiments: (Minimum Six)

1. Half wave rectifier using Junction Diode
2. Full wave rectifier using Junction Diode
3. Bridge rectifier with capacitor filter- Ripple factor using CRO.
4. C.E. Amplifier: Gain v/s Load
5. C.E. Amplifier:Input and Output Impedance
6. C.E. Amplifier. Frequency response. Calculation of Gain Bandwidth product
7. OP-Amp: Characteristics Input and Output impedance
8. OP-Amp: Inverting and Non-inverting amplifier
9. Colpitt's Oscillator
10. Wein's Bridge Oscillator

References:

1. Eggleston D. L., 2011, *Basic Electronics for Scientists and Engineers*, 1stedition Cambridge University Press.
2. Mehta V. K., Rohit Mehta, *Principles of Electronics*, S. Chand and Co. Ltd. New Delhi

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1. Kal Saantiram 2006, *Basic Electronics: Devices, Circuits and IT fundamentals*, PHI, New Delhi
2. Malvino A. P, Bates D. J. 2006, *Electronic Principles*, Tata McGraw- Hill, New Delhi
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4. Bhargava N. N., Kulshrestha D. C., Gupta S. C., 2017, *Basic Electronics and Linear Circuits*, 2nd Edition, Tata McGraw Hill, New Delhi
5. Gayakwad R. A., 2015, *Op-Amps and Linear Integrated Circuits*, 4th Edition, Pearson Education, Delhi

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3. https://www.elprocus.com/different-types-rectifiers-working/
4. https://www.pitt.edu/~qiw4/Academic/ME2082/Transistor%20Basics.pdf
5. https://nptel.ac.in/courses/115/102/115102014/
6. https://www.electronics-tutorials.ws/oscillator/oscillators.html

Course Title : Introduction to Error Analysis

Course Code : PHY-E18

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1 (Practical)

Course Objectives: The objective of this course is that the students will be able to comprehend some of the important methods used in estimate uncertainties and should be able to use these methods in estimating uncertainty in laboratory experiments.

Course Learning Outcomes: After successful completion of this course, the students will be able to understand

CLO1: the techniques involved in analysing measurement data and the errors associated with the measurement system used.
CLO2: the importance of knowing the uncertainty and nature of uncertainty that occurs during measurements
CLO3: the method of propagation of errors and applying it to estimate uncertainties.
CLO4: the method of statistical analysis in applying it to estimate uncertainties.
CLO5: several probability distribution functions like Gaussian distribution, Binomial distribution, and Poisson distribution.
CLO6: plotting of graphs and estimate the best fit lines through the data points.

Theory:
Unit I: [20 h]

1. **Preliminary description [7 h]**
   Errors as uncertainty and its inevitability. Importance of knowing the uncertainties. Estimating uncertainties. Significant figures. Discrepancy. Comparison of measures and accepted values. Comparison of two measured numbers. Checking relationship with graphs. Fractional uncertainties. Multiplying two measured numbers.
   [Taylor: 1.1-1.6, 2.1-2.9]

2. **Propagation of uncertainties [7h]**
   Uncertainties in direct measurements. The square root rule for a counting experiment. Sums and differences; product and quotient. Arbitrary functions of one variable. General formula for error propagation.
   [Taylor: 2.1-2.9]

3. **Statistical analysis of random uncertainties [6 h]**
   Random and systematic errors. The mean and standard deviation. The standard deviation as the uncertainty in the single measurement. The standard deviation of the mean. Systematic errors.
   [Taylor: 4.1- 4.6]

Unit II: [15 h]

1. **The Normal Distribution** **[9 h]**
   Histograms and Distributions, Limiting distributions. The normal distribution. The standard deviation as 68% confidence limit. Justification of the mean as the best estimate. Justification of addition in quadrature. Standard deviation of the mean. Acceptability of the measured answer.
   [Taylor: 5.1-5.8]

2. **Least-Squares fitting** **[6 h]**
   Data that should fit a straight line. Calculation of slope and intercept. Uncertainty in the slope and intercept. Least-squares fit to other curves.
   [Taylor: 8.1-8.6]

UnitIII: [10 h]

1. **The Binomial Distribution** **[6 h]**
   Distributions. Probability in dice throwing. Definition of binomial distribution. Properties of binomial distribution. The Gauss distribution for random errors. Application: testing of hypothesis
   [Taylor: 10.1-10.6]

2. **The Poisson Distribution** **[4 h]**
   Definition of Poisson distribution. Properties of Poisson distribution. Applications. Subtracting a background.
   [Taylor: 11.1-11.4]

Experiments: (Minimum Six)

1. Tutorial on Propagation of uncertainties
2. Tutorial on Statistical Analysis of Random measurement
3. Tutorial on Normal Distribution
4. Tutorial on Binomial distribution
5. Tutorial on Poisson Distribution
6. Application of Error Analysis based on experimental data.
7. Application of Error analysis based on experimental data.
8. Application of Error analysis based on experimental data.

Reference:

1. Taylor J, 1997, *An Introduction to Error analysis*, University Science Books.

Additional References:

1. Drosg M. 2007, *Dealing with Uncertainties: A guide to error analysis*, Springer.

2. Hughes, I. G., Hase, T. P. 2010, *Measurements and their Uncertainties A practical guide to modern error analysis.* New York: Oxford University Press Inc.

3. Young, H. D. 1962, *Statistical Treatment of Experimental Data.* New York: McGraw-Hill Book Company, Inc.

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3. https://www.youtube.com/watch?v=5XIybCGh4ck&list=RDCMUCCDzHkpuIuD1ZC0wsCXUuPQ&index=1
4. http://web.pas.rochester.edu/~physlabs/manuals/L2C-StatisticsForWeb-AB5-short.pdf
5. https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-621-experimental-projects-i-spring-2003/lecture-notes/10_errors03.pdf

Course Title : **Properties of Matter and Acoustics**

Course Code : **PHY-E4**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Oscillations, Waves and Sound**

Course Objectives : This course provides an introduction to dynamics of rigid bodies and calculation of moment of inertia, properties of matter and acoustics of rooms. An objective of this course is to build up an understanding of fundamental physical principles which are required for most of other physical sciences.

Course Learning Outcomes: At the end of this course students will be able to:

CLO1: Gain an introductory knowledge of dynamics of rigid bodies, and its applications to basic physical problems.

CLO2: Familiarize with of acoustics of rooms and musical scales.

CLO3: Explain the concept of elasticity, including its various types and its applications.

CLO4: Explain the concept of surface tension, analyse and explain the role of surface tension in various natural phenomena such as capillary action.

CLO5: Interpret the concept of viscosity and its applications, describe the properties of fluids that determine their viscosity.

Theory:

Unit I: **[15 h]**

1. **Dynamics of Rigid bodies:** **[15 h]**

   Rigid bodies, Rotational Kinetic energy, Moment of inertia and its physical significance, Angular acceleration, angular moment, law of conservation of momentum, Analogy between translatory and rotatory motion, Theorem of perpendicular axis, Theorem of parallel axis, Moment of inertia of thin uniform bar, Moment of Inertia of a bar about an axis passing through one end and perpendicular to its length, Moment of Inertia of a bar about an axis perpendicular to its at a distance 'a' from one end, Moment of inertia of rectangular lamina, Moment of inertia of solid uniform bar of rectangular cross section, Moment of inertia of ring, Moment of inertia of disc, ,Moment of inertia of Annular disc, Moment of inertia of hollow cylinder, Moment of inertia of solid sphere, Moment of inertia of hollow sphere, Moment of inertia of spherical shell, ,Moment of inertia of a uniform elliptical lamina, Moment of inertia of a uniform triangular lamina, Moment of inertia of a solid cone.

   [Brij Lal: Section 3.1-3.25]

Unit II: [15 h]

1. **Elasticity: [10 h]**

   Moduli of elasticity, Poisson's ratio and relationship between them. Bending of beams-bending moment, flexural rigidity. Cantilever (rectangular bar). Depression of a beam supported at the ends and loaded at the center. A vibrating cantilever. Torsion in a string-couple per unit twist, Torsional Pendulum.

   [Mathur: Section 8.8, 8.9, 8.12, 8.13, 8.14, 8.15, 8.16, 8.17, 8.18, 8.22, 8.26, 8.29, 8.30(a(i)), 8.32, 8.33(i)]

2. **Surface Tension: [5 h]**

   Brief review of molecular theory of surface tension. Relation between surface tension and surface energy. Excess pressure inside a spherical Liquid drop, difference of pressure across a curved surface, Angle of contact. Capillarity-rise of liquid in a capillary tube.

   [Mathur: Section 14.1, 14.2, 14.3, 14.4 14.6, 14.8, 14.14, 14.15 and 14.17]

   [Brij Lal: section 8.7 -8.9]

Unit III: [15 h]

1. **Viscosity [9 h]**

   Equation of continuity: Euler's equation for liquid flow, Bernoulli's theorem and its applications. Streamline flow, Turbulent flow, Critical velocity, Coefficient of viscosity, Poiseuille's formula for flow of liquid through a capillary tube. Criticism of Poiseuille's equation

   [Mathur: Section 12.1 - 12.12 (12.8 upto equation b)]

2. **Acoustics of Rooms and Musical Scales [6 h]**

   Reverberation of Sound, Reverberation time, Absorption coefficient, Sabine's formula for reverberation time (discussions only) , Acoustic requirements of an auditorium. Musical interval, harmony, melody. Diatonic scale. Tempered scale. (only concepts)

   [Khanna: Section: 23.1-23.17, Section:17.1-17.12]

Experiments: (Minimum Six)

1. Cantilever: Determination of Young's modulus by vertical vibrations of a cantilever.
2. Torsional Pendulum: Determination of Rigidity Modulus of the material of a wire.
3. Jagger's Method: Determination of Surface Tension
4. Viscosity of a liquid by Poiseuilles method
5. Bending of beams: determination of Young's modulus
6. Capillarity: determination of Surface tension
7. Flat Spiral Spring: determination of elastic constants by vertical and torsional oscillations of a loaded spring
8. Young's Modulus of Brass by Flexural Vibrations of Bar.

9. Rigidity Modulus of Brass.

References:

1. Brij Lal, Subramanyam N., 1999,*Properties of matter*, Eurasia Publishing House New Delhi
2. Mathur D. S., 2010, *Elements of Properties of Matter*, S. Chand and Company, New Delhi.
3. Bedi R.S.,Khanna D. R.,1994, *Text book of Sound*. Atma Ram, New Delhi

Additional References:

1. Mee F. G., 1967, *Sound*. Heinemann Ltd., London
2. Newman, Searle, 1957, *General properties of Matter,* 5thedition,Hodder & Stoughton Educational, UK
3. Smith C. J., 2011, *Properties of Matter,* 2nd edition, Edward Arnold, UK

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1. https://www.youtube.com/watch?v=ZFEExw-qUSk&list=PLVFqK_9GOGXnSnuU-x2qgX68mWyBqn6O8
2. https://www.youtube.com/watch?v=47bEFVyczLk&list=PLwdnzlV3ogoV-ATGY2ptuLS9mwLFOJoDw
3. https://www.youtube.com/watch?v=fa0zHI6nLUo&list=PLbMVogVj5nJTZJHsH6uLCO00I-ffGyBEm
4. https://www.youtube.com/watch?v=yyqhgnc5cWI&list=PLbRMhDVUMngeGSqPVkrc8G_kApltxEEos
5. https://www.youtube.com/watch?v=CIws3dZEHMU&list=PL546CD09EA2399DAB&index=7

Course Title **: Computational Physics**

Course Code **: PHY-E7**

Marks **: 75 (Theory) + 25 (Practical)**

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

Pre-requisite **:Nil**

Course Objectives **:** The course aims to enable the students to solve problems in Physics which involves numerical methods by using FORTRAN as a programming language.

Course Learning Outcomes: At the end of this course students will be able to:
CLO1: Understand various numerical methods

CLO2: Use FORTRAN language for numerical calculations.

CLO3: Understand various concepts of Physics using numerical methods using FORTRAN as a programming language.

CLO4: Understand least square fitting using computation.

Theory:

Unit I: Concepts of programming: **[5 h]**

Definition and Properties of algorithms, Algorithm development, Flow charts- symbols and simple flowcharts.

Unit II: FORTRAN Programming **[20 h]**

Evolution of Fortran.

Simple Fortran Programs:

Writing a Program, Input statements, Some Fortran program examples.

Numerical Constants and Variables:

Constants, Scalar Variables, Declaring Variable Names, Implicit Declaration, Named Constants.

Arithmetic Expressions:

Arithmetic Operators and Modes of Expression, Integer Expressions, Real Expressions, Precedence of Operations in Expressions, Assignment Statements, Defining Variables, Some problems due to rounding of real numbers, mixed mode expressions, Intrinsic functions, Examples of Use of Functions.

Input-Output Statements:

List-directed input statements, List-directed output statements.

Conditional Statements:

Relational Operators, The block IF construct, Example programs Using IF structure.

Implementing Loops in Program:

The block DO loop, count control DO loop, Rules to be followed in writing DO loops.

Logical expressions and More Control statements:

Introduction, Logical constants, variables and expressions, precedence rules for logical operators, Some examples of use of Logical expressions, The case statements.

Functions and subroutines:

Introduction, function subprogram, syntax rules for function subprograms, Generic functions, Subroutines, Internal Procedures.

Defining and Manipulating Arrays:

Arrays Variables, Use of multiple subscripts, Do type notation for Input/Output Statements, Initializing arrays, Terminology used for multidimensional arrays, use of arrays in DO loops, whole array operations.

[Rajaraman (Ref. 1): Chapter-1 to Chapter-10]

Unit III: Computational Physics: [20 h]

Errors in Computation:

Inherent errors in storing, Numbers due to finite bit representation to use in Computer, Truncation error, round off errors (Explain with the help of examples)

Iterative methods:

Discussion of algorithm and flowcharts and writing FORTRAN programs for finding single root of equation using bi-section method, Newton-Raphson method.

Least Square Curve fitting:

Discussion of algorithm and flowcharts and writing FORTRAN program for straight line fit with example in physics.

Numerical Integration:

Discussion of algorithm and flowcharts and writing FORTRAN program for trapezoidal rule and Simpson's 1/3rd rule.

Solution of Differential equations:

Discussion of algorithm and flowcharts and writing FORTRAN program for Euler's method for finding solution of differential equation.

(*Derivation of formula is not expected for all the above numerical methods*)

[Rajaraman(Ref.2): Chapters - 2, 3, 6, 8 and 9]

Experiments:

Following programs may be discussed thoroughly in theory lectures and implemented in the practicals.

1. Sum of digits of an integer
2. To find factorial of a number
3. Checking and printing of prime numbers
4. Generation of Fibonacci numbers
5. To find sin(X), cos(X) using series method
6. Sorting of Numerical data - ascending, descending.
7. Matrix operations – addition, subtraction, multiplication
8. Graphics- line, circle, arc, bar, ellipse.
9. Root of equation-Bisection method, Newton Raphson method
10. Numerical integration- Trapezoidal, Simpson's 1/3rd rule.
11. Least square curve fitting- data for ohm's law.
12. Freely falling body and motion of falling body including air drag. (using Euler's method)
13. Electric field due to a point charge
14. Charging and Discharging of Capacitor in RC circuit/Growth and Decay of current in RL Circuit.

References:

1. Rajaraman V. 1987, *Computer Programming in Fortran 90 and 95*, 2nd Edition, Prentice-Hall of India, New Delhi,.
2. Rajaraman V. 1999, *Computer Oriented Numerical Methods*, Prentice-Hall of India, New Delhi.

Additional Reference:

1. Verma P. K. and Ahluwalia and Sharma K. C. 1999, *Computational Physics*, New Age International Publishers, India.

Web References:

1. https://nptel.ac.in/courses/115/106/115106118/
2. https://www.fortrantutorial.com/
3. https://web.stanford.edu/class/me200c/tutorial_77/
4. https://pages.mtu.edu/~shene/COURSES/cs201/NOTES/fortran.html
5. http://www.ibiblio.org/pub/languages/fortran/index.html

SEMESTER V

Course Title : **Electromagnetic Theory – II**

Course Code : **PHY-V.C-7**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Electromagnetic Theory – I (PHY-III.C-5)**

Course Objectives : To acquaint students with fundamental principles of Magnetostatics part of the Electromagnetic Theory.

Course Learning Outcomes: At the end of this course, students would be able to:
CLO1: Calculate magnetic field induction using Biot-Savart's law and Ampere's law.
CLO2: Interpret bound currents and calculate magnetic fields in matter.
CLO3: Comprehend microscopic theory magnetism.
CLO4: Relate electrostatics and magnetostatics using Maxwell's equations.
CLO5: Develop and solve the wave equation for propagation of electromagnetic waves through material media and vacuum at different angles of incidence.

Theory:

Unit I: Magnetostatics **[15 h]**

1. **Magnetostatics** **[15 h]**

   Lorentz force law: Magnetic fields, Magnetic forces, Currents, Biot-Savart law: Steady currents, Magnetic fields of a steady current, Divergence and Curl of **B**: Straight-line currents, divergence and curl of **B**, applications of Ampere's law, comparison of magnetostatics and electrostatics, Magnetic vector Potential: Vector potential, magnetostatic boundary conditions, multipole expansion of the vector potential.
   [Griffiths: 5.1: 5.1.1 – 5.1.3, 5.2: 5.2.1 – 5.2.2, 5.3: 5.3.1 – 5.3.4, 5.4: 5.4.1 – 5.4.3]

Unit II: Magnetic Fiels in Matter and Microscopic Theory of Magnetism **[15 h]**

1. **Magnetic Fields in Matter** **[11 h]**

   Magnetization: Diamagnets, paramagnets and ferromagnets, torques and forces on magnetic dipoles, effect of a magnetic field on atomic orbits, magnetization, the field of a magnetized object: Bound currents, physical interpretation of bound currents, magnetic field inside matter, The auxiliary field H: Ampere's law in magnetized materials, a deceptive parallel, boundary conditions, Linear and nonlinear media: Magnetic susceptibility and permeability, Energy in magnetic fields.
   [Griffiths: 6.1: 6.1.1 – 6.1.4, 6.2: 6.2.1 – 6.2.3, 6.3: 6.3.1 – 6.3.3, 6.4: 6.4.1 – 6.4.2, 7.2.4]

2. **Microscopic Theory of Magnetism** **[4 h]**

   Molecular field inside matter, origin of diamagnetism, origin of paramagnetism, theory of ferromagnetism, ferromagnetic domains, ferrites
   [Reitz: 10.1 – 10.2]

Unit III: Maxwell's Equations and Propagation of Electromagnetic Waves **[15 h]**

1. **Maxwell's Equations** **[5 h]**

   Generalization of Ampere's law, displacement current, Maxwell's equations and their empirical basis, electromagnetic energy, Poynting theorem.
   [Reitz: 16.1 – 16.3]

2. **Propagation of Electromagnetic Waves** **[10 h]**

   The wave equation, plane monochromatic waves in non-conducting media, polarization, plane monochromatic waves in conducting media, reflection and refraction at the boundary of two non-conducting media: normal incidence and oblique incidence, Brewster's angle, critical angle.
   [Reitz: 16.4, 17.1, 17.2, 17.4, 18.1, 18.2]

Experiments: (Minimum Six)

1. Hysteresis by magnetometer.
2. B-H curve in a hard magnetic material and in a soft ferrite.
3. Core losses and copper losses in a transformer.
4. Measurement of mutual inductance using ballistic galvanometer.
5. Calibration of lock-in-amplifier and determination of mutual inductance.
6. Determination of magnetic susceptibility of $FeCl_3$ by Quincke's method.
7. M/C using ballistic galvanometer
8. Helmholtz coils.

References:

1. Griffiths D. J., 2011, *Introduction to Electrodynamics,*3rd Ed., Prentice Hall of India, New Delhi
2. Reitz J. R., Milford F. J., Christy R. W., 1979, *Foundations of Electromagnetic Theory*,3rd Ed., Addison-Wesley Publishing Company.

Additional Reference:

1. Mukherji U., 2008, *Electromagnetic Field Theory and Wave Propagation*, Narosa Publishing House.

Web References:

1. https://nptel.ac.in/courses/115101005/
2. https://swayam.gov.in/nd1_noc19_ph08/preview
3. https://ocw.mit.edu/courses/physics/8-07-electromagnetism-ii-fall-2012/lecture-notes/
4. https://www.feynmanlectures.caltech.edu/II_toc.html
5. http://galileo.phys.virginia.edu/classes/109N/more_stuff/Maxwell_Eq.html

Course Title : **Solid State Physics**

Course Code : **PHY-E9**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisites : **Quantum Mechanics (PHY-IV.C-6)**

Course Objective: This course deals with crystalline solids and is intended to provide students with basic physical concepts and mathematical tools used to describe solids. The course broadly deals with the topics related to structural aspects and the various physical properties of crystalline solids.

Course Learning Outcomes: After completion of this course, students will be able to
CLO1: Identify bonding types in crystalline solids and correlate the nature of bonding of solid to some of the physical properties associated with it.
CLO2: Identify different crystal systems and determine structural parameters like unit cell of crystal lattices, translation vectors, atomic packing, crystal planes and directions with help of Miller Indices.
CLO3: Derive and apply Bragg's law to determine crystal structure.
CLO4: Derive and apply classical free electron theory of metals to study electrical conductivity
CLO5: Derive and apply density of energy states to estimate density of free electrons, Fermi energy and mean energy of electron gas at absolute zero
CLO6: Derive and apply Fermi Free electron gas model in 3 dimensions to study electrical properties of metals.
CLO7: Understand Bloch's theorem, Kronig-Penney Model and interpret energy band structures in solids, effective mass and energy-wavevector relationship.
CLO8: Distinguish materials with respect to their magnetic properties.
CLO9: Apply the knowledge gained to solve problems in solid state physics using relevant mathematical tools.

Theory:

Unit I: Bonding in Solids and Crystal Structures **[20 h]**

1. **Bonding in Solids** **[5h]**

   Introduction, Bonding in Solids, Cohesive energy, Ionic bonding, Calculation of Cohesive energy of ionic solids, Covalent bonding, Metallic bonding, Hydrogen bonding, Van der Waals (Molecular) bonding.
   [Pillai: Ch-3.I– 3.IX, 3.XII–3.XXIV]

2. **Crystal Structure** **[11h]**

   Introduction, Space Lattice, Unit cell, Lattice Parameter of unit cell, Bravais lattices, Crystal Symmetry, Stacking sequences in metallic crystal structure, SC, BCC, FCC and HCP structures, Crystal structures- NaCl, diamond, CsCl, ZnS, Directions in crystals, Planes in crystals- Miller indices, Distances of Separation between Successive (*hkl*) Planes.
   [Pillai: Ch-4.I – 4.VIII, 4.XIV – 4.XXII]

3. **Diffraction of X-rays by Crystals** **[4 h]**

   Introduction, Bragg's law, Bragg's X-ray Spectrometer, Powder Crystal method (Debye Scherrer method), Rotating Crystal method.
   [Pillai: Ch-5.VII – 5.XI]

Unit II: Electrical Properties of Metals **[20 h]**

Introduction, Classical Theory of Electric Conduction, Drawbacks of Classical theory, Revision of particle in a rectangular three-dimensional box, Fermi-Dirac Statistics and Electronic distribution in Solids, Fermi distribution function, Density of energy states and Fermi energy, Mean energy of electron gas at absolute zero, Electrical conductivity from Quantum mechanical consideration, Sources of electrical resistance in metals, Thermal conductivity in metals, Joule's law, Thermionic emission, Failure of Sommerfeld's free electron model, Band theory of Solids, Bloch's Theorem, Kronig-Penny model, Brillouin Zones, Motion of electrons in one- dimensional periodic potential, Distinction between metals, insulators and semiconductors.
[Pillai: Ch-6.II – IV, 6.XIV – 6.XVIII, 6.XX – 6.XXII, 6.XXV, 6.XXIX, 6.XXXI, 6.XXXV – 6.XXXXI]

Unit III: Magnetic Materials and Magnetic Properties **[5 h]**

Introduction, Classification of magnetic materials, The quantum numbers, Origin of magnetic moment, Ferromagnetism, Ferromagnetic domains, Hysteresis, Hard and soft materials.
[Palanisamy: 8.1, 8.2, 8.3, 8.4, 8.7, 8.7.3, 8.7.5, 8.7.6]

Experiments: (Minimum Six)

1. Energy band gap of a semiconductor using a diode.
2. Energy band gap of a semiconductor using LEDs
3. Energy band gap of a thermistor.
4. To determine value of Planck's constant using LEDs of at least 4 different colours.
5. Fermi energy of Copper
6. Measurement of Hysteresis loss using CRO
7. Calculation of lattice constant by of Copper – X-ray diffraction pattern is given and student calculates: d-spacing, miller indices and lattice constant.
8. To measure the resistivity of a semiconductor (Ge) crystal with temperature by four-probe method (room temperature to 150 °C) and to determine its band gap
9. Investigating crystal structure using Vesta software.

References:

1. Pillai S. O., 2018, *Solid State Physics,* 8th Multi Colour Edition, New Age International Publisher.
2. Palanisamy P. K., 2004, *Solid State Physics*, Scitech Publications (India) Pvt. Ltd.

Additional References:

1. Kittel C., 2004, *Introduction to Solid State Physics*, 8th Edition,John Wiley and Sons.
2. Dekker A. J., 1998, *Solid State Physics*, Macmillan India Ltd. Publisher.

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1. https://www.youtube.com/watch?v=RImqF8z91fU&list=PLtTPtV8SRcxi91n9Mni2xcQX4KhjX91xp
2. https://www.classcentral.com/course/swayam-introduction-to-solid-state-physics-13045
3. https://www.classcentral.com/course/swayam-solid-state-physics-14298
4. https://www.youtube.com/playlist?list=PLaNkJORnlhZnC6E3z1-i7WERkferhQDzq
5. https://www.youtube.com/playlist?list=PL0jxQTuSuktJd7Gbelcg9R0f3oYYeMbRs

Course Title : Thermodynamics and Statistical Mechanics

Course Code : PHY-E10

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1 (Practical)

Pre-requisite : Heat and Thermodynamics (PHY-II.C-3)

Course Objectives : This course will introduce kinetic theory, classical thermodynamics, probability and statistical methods.

Course Learning Outcomes: After completion of this course, students will be able to:
CLO1: Understand basics of kinetic theory of gases.
CLO2: Comprehend concepts of thermodynamic potentials and their physical interpretation.
CLO3: Understand Maxwell-Boltzmann distribution law and its application to classical gas.
CLO4: Learn Bose-Einstein statistics and derive classical radiation laws of black body radiation.
CLO5: Comprehend Fermi-Dirac statistics and its application to the electrons in metals
CLO6: Understand the concept of Fermi energy and electronic contribution to specific heat of metals.

Theory

Unit I: Kinetic theory of Gases and Thermodynamic Potentials. [15 h]

1. **Kinetic theory of Gases: [9 h]**
   Basic assumptions, Equation of State of an Ideal Gas, Collisions with a moving wall, the principle of equi-partition of energy, classical theory of specific heat capacity, specific heat capacity of a solid.
   [Sears and Salinger: 9.1, 9.2, 9.4 – 9.8]

2. **Thermodynamic Potentials [6 h]**
   The Helmholtz function and Gibbs function, Thermodynamic Potentials, Maxwell Relations.
   [Sears and Salinger: 7.1-7.3]

Unit II: Statistical Thermodynamics and Quantum Statistics [20 h]

1. **Statistical Thermodynamics [10 h]**
   Phase space, Probability of distribution, The most probable distribution, Maxwell Boltzmann Statistics. Molecular speeds: mean, most probable and r. m. s. speeds. Experimental verification of Maxwell Boltzmann statistics.
   [Beiser: 15.1 – 15.5]

2. **Quantum Statistics [10 h]**
   Bose Einstein statistics, Blackbody Radiation, Rayleigh Jeans formula, Plank radiation formula, Fermi Dirac statistics.
   [Beiser: 16.1 – 16.6]

Unit III: Specific Heats of Solids **[10 h]**

1. **Lattice Vibrations and Specific Heats of Solids** [10 h]
   Thermal Vibrations: Frequencies. Thermal Vibrations: Amplitudes. Normal Modes of a Lattice. Phonons. Specific Heats of Solids. The Einstein's theory. The Debye Theory. Fermi energy, Electron energy distribution.
   [Beiser: 19.1 – 19.7, Kachhava: 2.5, 2.6. 2.13]

Experiments: (Minimum Six)

1. Specific heat of Graphite
2. Study the temperature dependence of resistivity.
3. OPAMP as a bridge amplifier and its application in temperature measurement.
4. Determination of Boltzmann constant.
5. Study of Stefan's Law.
6. Determination of Stefan's constant
7. Thermal conductivity of poor conductor by LEE's method.
8. Tutorial on Maxwell Equation and Free energy
9. Tutorial on Statistical Thermodynamics
10. Tutorial on Statistical Thermodynamics

References:

1. Beiser A., 1995, *Perspectives of modern physics*, 5th edition, McGraw hill.
2. Sears F. and Salinger G., 1998, *Thermodynamics, Kinetic Theory and Statistical Thermodynamics*, 3rd Edition, Narosa.
3. Kachhava C. M., 2003, *Solid State Physics Solid State Devices and electronics*, New Age International (P) Limited.

Additional References:

1. Garg S., Bansal R.and Ghosh C., 1993, *Thermal Physics*, Tata McGraw Hill.
2. Zemansky M. and Ditman R., 1997, Heat *and Thermodynamics*, McGraw Hill.
3. Reif F., 1965, *Fundamentals of Statistical and Thermal Physics*, Mc Graw Hill
4. Brijlal, Subrahmanyam N., 2008, *Heat thermodynamics and Statistical Physics*, S Chand Company Ltd.
5. Laud B., 2003, *Introduction to Statistical Mechanics*, New Age International.
6. Saha M. and Shrivastava B., 1965, *Treatise on heat*, The Indian Press.

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1. https://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/
2. https://nptel.ac.in/courses/113106039/
3. https://www.youtube.com/watch?v=ef54OnrZBg4&list=PLclocfvsabE1j2OcBdWfVhzNJNnbQ3YM7
4. https://aptv.org/Education/khan/topic.php?topic=thermodynamics
5. https://www.youtube.com/watch?v=Th-LQz5bBJA

Course Title : Electronics-II

Course Code : PHY-E11

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1 (Practical)

Pre-requisite : Electronics-I (PHY-E5)

Course Objectives : This course aims at introducing students to analog and digital circuits.

Course Learning Outcomes: At the end of this course, students will be able to:
CLO1: Analyse AC circuits and apply the techniques in designing circuits.
CLO2: Generate different kinds of waves using OP-Amp.
CLO3: Understand the basic concepts of 555 timer.
CLO4: Apply binary operations to different digital circuits
CLO5: Understand the clocked digital electronics and its applications in different types of Counters

Theory
Unit I: [15 h]
1. **AC Models (BJT) [4 h]**
Base-Biased amplifier, Emitter-Biased amplifier, Small signal operation, analyzing an amplifier.
[Malvino: Article 9.1 to 9.7]

2. Transistor Multivibrators [4 h]
Transistor as a switch, switching times, Multivibrators – Astable, Monostable, Bistable and Schmitt Trigger.
[Mottershed: Article 18.1 to 18.5]

3. FET's and MOSFET's [7 h]
Basic structure of the JFET, Principles of operation, Characteristic curves and parameters, Common source amplifiers, Common gate amplifier, MOSFET: Depletion Mode and Enhancement mode, Dual-Gate MOSFET. FET Phase shift oscillator, FET as VVR and its applications in Attenuator, AGC and Voltmeter circuits.
[Malvino: Article 13.1 to 13.9, 14.1 to 14.5]

Unit II: [10 h]
1. OPAMP Applications [5 h]
Active diode circuits, Comparator, Window comparator, Schmitt Trigger, Waveform generator –Square wave, Triangular and Ramp Generator and monostable.
[Malvino: Article 22.7, 22.8]

2. Timers [5 h]
The 555 Timer, Basic concept, 555 block diagram, Monostable, Astable, Bistable, Schmitt Trigger and Voltage controlled oscillator (VCO) using 555 timer.
[Malvino: Article 23.7, 23.8]
[Malvino and Bates: 24.4, 24.5]

Unit III **[20 h]**

1. Digital Circuits **[10 h]**

Binary number system, Binary to Decimal and Decimal to Binary conversion, Basic logic gates, AND, OR, NOT(realization using Diodes and Transistor), NAND, NOR as universal building blocks in logic circuits, EX-OR and Ex-NOR gates. Boolean Algebra:De Morgan's Law's, Boolean Laws, NAND and NOR gates, Sum of Products methods and Product of Sum methods of representation of logical functions. Half adder and Full adder, Data Processing Circuits: Multiplexer and Demultiplexer, Encoders and decoders.
[Jain: Article 5.1 to 5.8.1, 6.1, and 6.2]

2. Sequential Circuits [10 h]

Basic RS FF, Clocked RS FF, JK FF, D-type and T-type FF, Master Slave Concept. Shift Registers:Serial-in-Serial-Out, Serial-in-Parallel-out, Parallel-in-Serial-out, Parallel-in-Parallel-out Shift registers (upto 4 bits), Counters: Applications of FF's in counters, binary ripple counter, Modulus of counter (3,5) BCD Decade Counter, Cascade BCD Decade counters.
[Jain: Article 7.1 to7.9, 8.1, 8.2, 8.4]

Experiments (Minimum Six):

1. Astable Multivibrator
2. Monostable Multivibrator
3. Bistable Multivibrator
4. Schmitt Trigger
5. F.E.T Characteristics
6. IC LM 317 Voltage Regulator
7. IC 555 Timer as Astable Multivibrator and its use as Voltage Controlled Oscillator
8. IC 555 Timer as Monostable Multivibrator
9. Digital Multiplexer
10. Verification of De Morgan's Theorems and Boolean Identities
11. NAND and NOR Gates as Universal Building Blocks
12. Binary Addition –Half Adder and Full Adder Using Gates
13. JFET as a common source amplifier.

References :

1. Malvino A.,1996, Electronic Principles, 5th edition,Tata McGraw Hill.
2. Jain R. P. 2003, Digital Electronics, 3rd edition, Tata McGraw Hill.
3. Mottershed A. 1997, Electronics Devices and Circuits an Introduction, PHI
4. Malvino A. and Bates D.J., 2007, Electronic Principles, 7th edition, Tata McGraw Hill

Additional References:

1. Malvino A. and Leach D. 1986, Digital Principles and Applications,4th edition Tata McGraw Hill.
2. Millman J. and Halkias C., 1972, Integrated Electronics, Tata McGraw Hill.
3. Millman J. and Halkais C., 1967, Electronic Devices and Circuits, Mc Graw Hill.
4. Mehta V.K., 2003, Principles of Electronics, 8th edition, S. Chand & Company.

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1. https://nptel.ac.in/courses/117/107/117107094/
2. https://www.electronics-tutorials.ws
3. https://www.electronicshub.org/
4. https://nptel.ac.in/courses/108/105/108105132/
5. https://www.khanacademy.org/science/electrical-engineering

Course Title : **Mathematical Physics**

Course Code : **PHY-E12**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Introduction to Mathematical Physics (PHY-I.C-1)**

Course Objectives : To acquaint students with mathematical skills which are required to study various concepts of Physics.

Course Learning Outcomes: At the end of this course, students will be able to:
CLO1: Comprehend the functions of complex variables.
CLO2: Apply mathematical techniques such as: calculus of residues to evaluate definite integrals.
CLO3: Apply solutions of Legendre, Bessel and Hermite equations in solving various Physics problems.
CLO4: Apply Fourier transforms of different functions in solving various Physics problems.

CLO5: Able to solve higher order problems in Physics**.**

Theory:

Unit I: Functions of a Complex Variables and Calculus of Residues [15 h]

1. **Functions of a Complex Variables [8 h]**

   Introduction, complex variables and representations: algebraic operations, Argand diagram: vector representation, complex conjugate, Euler's formula, De Moivre's theorem, the n^{th} root or power of a complex number, analytic functions of a complex variable: the derivative of f(z) and analyticity, harmonic functions, contour integrals, Cauchy's integral theorem, Cauchy's integral formula.
   [Harper: 3.1, 3.2: 3.2.1 – 3.2.6, 3.3: 3.3.1 – 3.3.5]

2. **Calculus of Residues [7 h]**

   Zeroes, isolated singular points, evaluation of residues: m^{th} order pole, simple pole, the Cauchy residue theorem, the Cauchy principal value, evaluation of some definite integrals.
   [Harper: 4.1 – 4.3: 4.3.1 – 4.3.2, 4.4 – 4.6: 4.6.1-4.6.4]

Unit II: Partial Differential Equations and Special Functions of Mathematical Physics [15 h]

1. **Partial Differential Equations and Special Functions of Mathematical Physics [15h]**

   Introduction, Some important partial differential equations in physics, an illustration of the method of direct integration, method of separation of variables, the Hermite

polynomials: basic equations of motion in mechanics, one-dimensional linear harmonic oscillator, solution of Hermite's differential equation, Legendre and associate Legendre polynomials: spherical harmonics, the azimuthal equation, Legendre polynomials, Bessel function: introduction: solution of Bessel's equation, analysis of various solutions of Bessel's equation, characteristics of Bessel functions.
[Harper: 6.1 – 6.5: 6.5.1 – 6.5.3, 6.5.8]

Unit III: Fourier Series and Fourier Transforms [15 h]

1. **Fourier Series** **[7 h]**

   Introduction: The Fourier cosine and sine series, change of interval, Fourier integral, complex form of Fourier series, generalized Fourier series and Dirac-delta function, summation of the Fourier series.
   [Harper: 7.1 – 7.3]

2. **Fourier Transforms** **[8 h]**

   Introduction, theory of Fourier transforms: formal development of the complex Fourier transform, cosine and sine transforms, multiple-dimensional Fourier transforms, the transforms of derivatives, the convolution theorem, Parseval's relation, the wave packet in quantum mechanics: origin of the problem - quantization of energy, the development of a new quantum theory, a wave equation for particles - the wave packet.
   [Harper: 8.1 – 8.3]

Experiments: (Minimum Six)

1. Generating and plotting Legendre Polynomials.
2. Generating and plotting Bessel function.
3. Generating and plotting Hermite Polynomials.
4. Using spherical polar co-ordinates obtain an expression for divergence and curl of a vector function, operate gradient and Laplacean operator on a scalar function.
5. Using cylindrical co-ordinates obtain an expression for divergence and curl of a vector function, operate gradient and Laplacean operator on a scalar function.
6. Fourier series: programme to sum:$\sum_{n=1}^{\infty}(0.2)^n$, and to evaluate Fourier co-efficients of a given periodic functions.
7. Compute the n^{th} roots of unity for n = 2, 3, and 4.

References:

1. Harper, C., 1993, *Introduction to Mathematical Physics,* 5th Ed., Prentice Hall of India
2. Arfken G., 2005, *Mathematical Methods for Physicists*, Elsevier.
3. Spiegel, M.R., 2004, *Fourier Analysis*, Tata McGraw-Hill.

Additional References:

1. Riley K. F., Hobson M. P., Bence S. J., 1998, *Mathematical Methods for Physics and Engineering,* Cambridge University Press
2. Boas M. L., 2013, *Mathematical Methods in Physical Sciences,* 3rd Ed., John Wiley and Sons
3. Lipschutz S., 1974, *Schaum Outline of Theory and Problems of Complex Variables*, Mc Graw Hill.

Web References:

1. https://nptel.ac.in/courses/115106086/
2. https://www.maths.ed.ac.uk/~jmf/Teaching/MT3/ComplexAnalysis.pdf
3. https://www-thphys.physics.ox.ac.uk/people/FrancescoHautmann/ComplexVariable/s1_12_sl8.pdf
4. https://nptel.ac.in/courses/111/106/111106100/
5. https://nptel.ac.in/courses/115/105/115105097/

Course Title : Solid State Devices

Course Code : PHY-E6

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1(Practical)

Pre-requisite : Nil

Course Objectives : The objectives are to provide a clear explanation of the operation of most commonly used solid state devices.

Course Learning Outcomes : At the end of this course, the students will be able to:
CLO1: Comprehend the p-n junction theory and analyse the effect of heat and light on the performance of the semiconductor devices.
CLO2: Understand different types of special diodes and their uses in various electronics applications.
CLO3: Understand different types of optoelectronic devices and their uses in various electronics applications.
CLO4: Design, construct and working of the circuits based on breakdown devices.
CLO5: Understand basic construction of FET, principle of operation of different types of FETs, and its applications.

Theory:

Unit I: Basic Semiconductor and pn-Junction Theory and Special Diodes [15 h]

1. **Basic Semiconductor and pn-Junction Theory [10 h]**

   The Atom, Electron Orbit and Energy Levels, Energy Bands, Conduction in Solids, Conventional Current and Electron Flow, Bonding Forces between Atoms, Classification of Solids, Intrinsic Semiconductor, Conduction of Electrons and Holes, *p*-Type and *n*-Type Semiconductors, Effect of Heat and Light, Drift Current and Diffusion Current, The *pn*-Junction, Reverse-biased Junction, Forward-biased Junction, Temperature Effect, Mobility and Conductivity, Hall Effect and Hall Coefficient.

   [Bell: Chapter 1 and Ref.2: Chapter 1: 1.8 and1.9]

2. **Special Diodes: [5 h]**

   Zener Diode, Use of Zener Diode as voltage regulator and as Peak Clipper, Meter Protection, Tunneling Effect, Tunnel Diode, Tunnel Diode as Oscillator, Varactor, PIN Diode, Schottky Diode, Step Recovery Diode.

   [Theraja: Chapter 15]

Unit II: Optoelectronic Devices and Industrial Devices [20 h]

1. **Optoelectronic Devices: [8 h]**

   Light Units, Photomultiplier tube, Photoconductive Cell, Photovoltaic Cell, Photodiode, Solar Cell, Phototransistor, PhotoFET, Spectral response of Human eye, Light Emitting Diode(LED), Liquid Crystal Display(LCD), Optoelectronic Couplers, Laser Diode, Light Dependent Resistor (LDR).

   [Bell: Chapter 19: 19-1 to 19-7, 19-9, 19-11, 19-12 and Theraja: 16.1 to 16.3]

2. **Industrial Devices: [12 h]**

   Silicon Controlled Rectifier(SCR), SCR Characteristic and Parameters, Simple applications of SCR: HWR, Battery-charging regulator and Temperature Controller, Silicon Controlled Switch (SCS), Gate Turn Off switch (GTO), Light Activated SCR (LASCR), Shockley Diode, The TRIAC and DIAC, Typical Diac-Triac Phase control circuit, The Unijunction Transistor(UJT), UJT Characteristics, UJT Parameter and Specification, UJT Relaxation Oscillator, UJT Control of SCR, Programmable Unijunction Transistor.

   [Bell: Chapter 18: 18-1, 18-2, 18-4, 18-6 to 18-11; Ref.4: Chapter 21: 21.6 to 21.10 and Mottershead: Chapter 28: 28-4]

Unit III: Field Effect Transistors [10 h]

1. **Field Effect Transistors: [10 h]**

   Advantage and Disadvantage of The FET, Basic Construction of JFET, Characteristics curves of The JFET, Principle of operation of The JFET, Effect of V_{DS} on Channel Conductivity, Channel Ohmic Region and Pinch-Off Region, Characteristic Parameters of The FET, Effect of Temperature on FET Parameters, The MOSFET, The Depletion MOSFET, The Enhancement MOSFET, The difference between JFETs and MOSFETs, Dual Gate MOSFET, FET used in Phase-Shift Oscillator Circuit, Applications of FET in its Channel Ohmic Region, FET as a VVR in Voltage controlled Attenuator and in an Automatic Gain Controlled Circuit, Field-Effect Diode and its use as CRD, Power MOSFETs.

   [Mottershead: Chapter 21: 21-1 to 21-8, Chapter 22: 22-1 to 22-5, 22-9, 22-10;

   Bell: Chapter 8: 8-9]

Experiments: **(Minimum six)**

1. Energy Gap of a Semiconductor
2. Energy Gap of a LED.
3. Zener Diode Characteristics and Voltage regulation
4. LDR Characteristics
5. LED VI Characteristics
6. Phototransistor
7. SCR characteristics and gate controlled ac half wave rectifier
8. UJT Characteristics and its use in relaxation oscillator

9. FET Characteristics
10. Solar Cell.
11. SCR, Diac, Triac Characteristics.

References:

1. Bell D. A.,2000, *Electronics Devices and Circuits*, 3rd Edition, Prentice-Hall of India Pvt. Ltd., New Delhi,
2. Singh K., Singh S. P., 2007, *Solid State Devices and Electronics*,1st Edition, S. Chand & Company Ltd., New Delhi,
3. Theraja B. L., 2005, *Basic Electronics (Solid State)*, 1stMulticolour Edition, S. Chand and Company Ltd., New Delhi,
4. Boylestad R., Nashelsky L., 2000, *Electronic Devices and Circuit Theory*, 6th Edition, Prentice-Hall of India Pvt. Ltd., New Delhi
5. Mottershead A., 2000, *Electronics Devices and Circuits An Introduction*, Prentice-Hall of India Pvt. Ltd., New Delhi

Web References:

1. https://nptel.ac.in/courses/117106091/
2. https://www.elprocus.com/types-of-diodes-and-applications/
3. https://www.electronicshub.org/types-of-diodes/
4. https://www.electronicshub.org/thyristor-basics/
5. https://gradeup.co/field-effect-transistor-study-notes-i-96d9d1d0-79ad-11e7-bf36-f08a68dca14c

SEMESTER VI

Course Title **: Atomic and Molecular Physics**

Course Code **: PHY-VI.C-8**

Marks **: 75 (Theory) + 25 (Practical)**

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

Pre-requisite **: Quantum Mechanics (PHY-IV.C-6)**

Course Objectives : Atomic and molecular physics is the study of dynamics and interactions of the basic building blocks of matter. The objective of this course is to study the behaviour of the electrons that surround the atomic nucleus which will help students to understand the dynamics atoms and molecules.

Course Learning Outcomes: After successful completion of this course, student will be able to:
CLO1: solve the case of the hydrogen atom using the three-dimension time-independent Schrödinger equation, identify atomic effect such as space quantization and interpret the wave functions and probability densities.
CLO2: become familiar with the orbital, spin and total angular momentum of many electron atoms.
CLO3: explain the observed dependence of atomic spectral lines on externally applied magnetic fields.
CLO4: grasp the physics of diatomic molecules, their electronic states, vibrations and rotations and their spectra.
CLO5: comprehend classical and quantum theory of Raman effect.
CLO6: develop analytical and computing skills through problem solving, and computer-based exercises, which involve quantum mechanical systems such as the Harmonic oscillator, Hydrogen atom and Morse potential.

Theory:

Unit I: **[15 h]**

1. **Quantum Theory of the Hydrogen Atom[7 h]**
   Schrodinger's equation for the H-atom. Separation of variables, Eigen values, Quantum numbers and Magnetic moment. Angular momentum, Electron Probability density.
   [Beiser 9.1-9.9]

2. **Many Electron Atoms:** **[8 h]**
   Electron Spin. Pauli Exclusion Principle and classification of elements in periodic table. Symmetric and Antisymmetric wave functions. Electron configuration. Hund's rule. Total angular momentum. L-S coupling. J-J coupling.
   [Beiser 10.1, 10.3- 10.9]

Unit II: **[15 h]**

1. **Atoms in a Magnetic Field:** **[7 h]**
   Effects of magnetic field on an atom. Larmor Precession. The Stern-Gerlach experiment. Spin Orbit Coupling. The Normal Zeeman effect, Lande 'g' factor. Zeeman pattern in a weak field (Anomalous Zeeman effect).
   [Eisberg 8.1-8.4, 10.6]

2. **Atomic Spectra:** **[4 h]**
   Origin of Spectral lines. Selection rules (derivation from transition probabilities). Alkali metal type spectra. Principal, Sharp, Diffused and Fundamental series, fine structure in alkali spectra.
   [Beiser 11.1-11.2, Mcgervey 9.1]

3. **X-ray Spectra:** **[4 h]**
   Characteristic spectrum. Moseley's law. Explanation of X-ray spectra on the basis of quantum mechanics. Energy levels and characteristic X-ray lines. X-ray absorption spectra. Fluorescence and Auger effect.
   [Richtmayer: 7.6, 7.7, 16.1-16.3, 16.5]

Unit III: **[15 h]**

1. **Spectra of Diatomic Molecules:** **[9 h]**
   Rotational energy levels. Rotational spectra. Vibrational energy levels. Vibration - Rotation spectra. Fortrat Parabolas and explanation of band structure on its basis. Electronic spectra.
   [Beiser 14.1, 14.3, 14.5, 14.7, 14.8 and Rajam 11.2]

2. **Raman Effect:** **[6 h]**
   Quantum theory of Raman effect. Classical theory of Raman effect. Pure rotational Raman spectra. Vibrational Raman spectra. Rotational fine structure. Experimental set up for Raman effect.
   [Banwell 4.1-4.3]

Experiments: (Minimum Six)

1. To find the wavelengths of Balmer series of visible emission lines and to determine the value of Rydberg constant.
2. Numerically solving the Time Independent Schrödinger equation for the case of Harmonic oscillator./Tutorial.
3. Numerically solving the Radial Schrödinger equation for the case of Hydrogen atom./Tutorial.
4. Numerically solving the Time Independent Schrödinger equation for the case of Morse potential./ Tutorial.
5. Absorption spectra of $KMnO_4$
6. X-ray Emission (characteristic lines of copper target)- Calculation of wavelength and Energy.
7. Resolving Sodium D-lines using grating.
8. Resolving Mercury lines using prism.
9. Determination of wavelength of Sodium light using Lloyd's Mirror.
10. Determination of wavelength of Sodium light using a cylindrical obstacle.

11. Double Refraction

References:

1. Beiser, A. 1969, *Perspectives of Modern Physics,* McGraw-Hill Book Company, Singapore.
2. Eisberg, R. And Resnick, R. 2010, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and particles*, 2nd Edition, Wiley India Pvt Ltd.
3. Mcgervey, J. 1983, *Introduction to Modern Physics*, Academic Press, USA.
4. Richtmyer, F., Kennard, E., Cooper, J. 2001, *Introduction to Modern Physics*, 6th ed. Tata McGraw-Hill Book Company, New Delhi.
5. Rajam, J. 2000, *Atomic Physics*, S. Chand and Company limited, New Delhi.
6. Banwell, C. 1994, *Fundamentals for Molecular Spectroscopy*, 4th Edition, McGraw-Hill Higher Education.

Additional Reference:

1. White, H. 1934, *Introduction to Atomic Spectra*, McGraw-Hill Inc., USA.

Web References:

1. Das, A.K. (2017). Retrieved from https://nptel.ac.in/courses/115/105/115105100/#
2. PhET Interactive Simulations, University of Colorado Boulder, https://phet.colorado.edu/en/simulation/legacy/stern-gerlach
3. Geva, E. (20120). Retrieved form https://demonstrations.wolfram.com/HydrogenAtomRadialFunctions/
4. Morse, P. M. (1929). Diatomic Molecules According to the Wave Mechanics. II. Vibrational Levels. *Physical Review, 34*(57).
5. Singh, R. (2002). C. V. Raman and the Discovery of the Raman Effect. *Physics in Perspective, 4*, 399-420.

Course Title **: Mechanics – II**

Course Code **: PHY-E13**

Marks **: 75 (Theory) + 25 (Practical)**

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

Pre-requisite **: Mechanics – I (PHY-I.C-2)**

Course Objectives **:** To acquaint students with a higher-level Mechanics which includes advanced concepts through topics like central force problems, mechanics in non-inertial frames, motion of rigid bodies, collision theory and Lagrangian formulation.

Course Learning Outcomes: At the end of this course, students will be able to:

CLO1: Analyze two body problem by separating into two equivalent single body problems

CLO2: Obtain equation of orbit for the motion under inverse square law force and study different types of orbits.

CLO3: Relate time derivative of a vector in a fixed frame of reference to that of moving frame of reference.

CLO4: Comprehend the occurrence of some pseudo forces such as Coriolis's force, centrifugal force due to relative motion of the particle in the fixed frame and rotating frames of reference.

CLO5: Derive and solve Euler's equations of motion to understand the motion of rigid bodies.

CLO6: Apply D'Alembert's principle to obtains LaGrange's equation of motion.

CLO7: Comprehend the advantages of Lagrangian formulation over Newtonian formulation by solving various mechanical problems.

Theory

Unit I: Motion Under a Central Force and Collisions of Particles **[15 h]**

Motion Under a Central Force **[10 h]**
Center of mass coordinate, equivalent one body problem, general features of motion in a central force field, motion in an inverse square law force field, equation of the orbit, nature of orbits, elliptical orbits: the Kepler problem, hyperbolic orbits, parabolic orbits.
Symon: 3.13, 3.14, 3.15, 3.16 [pg. 122-140]
Takwale: 5.1, 5.2, 5.3, 5.4, 5.5, 5.6 [pg. 133-153]

Collisions of Particles **[5 h]**
Elastic and inelastic cross section, scattering in a central force field, scattering cross section, Rutherford scattering cross-section.
Symon: 4.6 [pg. 175-182], 3.16 [pg. 137-140]
Takwale:7.5, 7.6 [pg. 202-211]

Unit II: Moving Coordinate Systems and The Rotation of a Rigid Body [20 h]

Moving Coordinate Systems [10 h]

Moving origin of coordinates, rotating coordinate system, laws of motion on rotating earth, effect of Corioli's force on freely falling particles, the Foucault pendulum.

Symon: 7.1, 7.2, 7.3, 7.4 [pg. 271-284]

Takwale:9.1, 9.2, 9.3, 9.4, 9.5 [pg. 246-257]

The Rotation of a Rigid Body [10 h]

Euler's theorem, angular momentum and kinetic energy, the inertia tensor, Motion of a rigid body in space, Euler's equations of motion for a rigid body, torque free motion, Euler's angles, qualitative discussion of the symmetric top.

Symon: 11.1, 11.2, 11.3\4, 11.5 [pg. 444-460]

Takwale: 10.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7 [pg. 262-283]

Unit III: Lagrangian Formulation [10 h]

Lagrangian Formulation [10 h]

Constraints, generalized coordinates, D'Alembert's principle, Lagrange's equations, a general expression for kinetic energy, symmetries and law of conservation, cyclic or ignorable coordinates.

Takwale: 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7 [pg. 217-238]

List of Experiments: (Minimum Six)

1. Study of Compound Pendulum as a Reversible Pendulum: Kater's Pendulum
2. Measurement of Moment of Inertia of Uniform Rigid Bodies: Bifilar Suspension
3. Principle of conservation of linear momentum using linear air track
4. Value of "g" by Rod pendulum
5. To Study the different oscillation modes of the coupled pendulum
6. To determine the moment of inertia of Gyroscope disc
7. Equation of Orbit (bounded orbit) simulation experiment
8. Equation of Orbit (unbounded orbit) simulation experiment

References:

1. Symon K. R., 1971, *Mechanics*, 3rd Edition, Pearson, India
2. Takwale R. G., and Puranik P. S., 1992, *Introduction to Classical Mechanics*, Tata Mc-Graw Hill, New Delhi

Additional Reference:

1. Taylor J. R., 2005, *Classical Mechanics*, University Science Books, USA

Web References:

1. http://www.dept.aoe.vt.edu/~lutze/AOE4134/4OrbitSolution.pdf
2. http://web.mit.edu/12.004/TheLastHandout/PastHandouts/Chap03.Orbital.Dynamics.pdf

3. http://twister.ou.edu/PM2000/Chapter7.pdf
4. http://www.southampton.ac.uk/~stefano/courses/PHYS2006/chapter4.pdf
5. https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2016/
6. https://nptel.ac.in/courses/115/105/115105098/

Course Title : Nuclear and Elementary Particle Physics

Course Code : PHY-E14

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1 (Practical)

Contact Hours : 45 (Theory) + 30 (Practical)

Pre-requisite : Quantum Mechanics (PHY-IV.C-6)

Course Objectives : The objective of this course is to introduce students to the fundamental principles and concepts governing nuclear and particle physics.

Course Learning Outcomes: After successful completion of this course, student will be able to:

CLO1: Learn the ground state properties of a nucleus.

CLO2: Gain knowledge on basic concept of nuclear force and Meson theory of nuclear force.

CLO3: Know about the liquid drop model and shell model to understand nuclear properties.

CLO4: Learn the basic aspects of nuclear reactions

CLO5: Learn about the principles and basic constructions of nuclear reactor.

CLO6: Gain knowledge on the basic aspects of particle Physics and the fundamental interactions.

Theory:

Unit I: [20 h]

1. Basic Nuclear Properties [5 h]

Nomenclature, Nuclear Size (Electron scattering and Mirror Nuclei), Nuclear Charge, Nuclear Mass, Nuclear Density, Nuclear Spin, Nuclear Magnetic Moment, Nuclear Electric Quadrupole Moment, Parity, Binding Energy, Nuclear Stability, Packing Fraction

[Jain: 1.1, 1.2, 3.1-3.9]

2. Nuclear forces [3 h]

Main characteristics of Nuclear Forces, Meson theory of Nuclear forces, Estimation of the mass of a meson using Heisenberg's Uncertainty Principle, Yukawa potential

[Patel: 8.6] [Ilangovan: 1.9]

3. Liquid drop model of a nucleus [8 h]

Analogy between liquid drop and a nucleus, Assumptions of Liquid Drop Model, Wiezsacker Semi- Empirical Mass Formula, Equation for Mass Parabola for Isobaric Nuclei, Merit and Demerit of Semi-Empirical Mass Formula, Potential Barrier for Fission, Stability Limit against

Spontaneous Fission (Bohr and Wheeler Theory for Fission Process), Energetic of Symmetric Fission

[Jain: 4.1-4.4][Patel: 5.5]

4. Nuclear Shell Model [4 h]

Experimental basis of Shell Model, Single-Particle Shell Model, Shell Model with Spin-Orbit Coupling, Prediction of ground state spin and parity, Prediction of Magnetic Moment, Prediction of Quadruple moment,

[Jain: 5.1-5.6][Patel: 7.3]

Unit II: [15 h]

1. Nuclear Reactions [2 h]

Nuclear Reactions, The Balance of mass and energy in Nuclear Reactions(Q-Value), The Q-Equation.

[Patel: 3.2-3.4][Jain: 11.1,11.2]

2. Radioactive decay [10 h]

Alpha decay: Magnetic Spectrograph-Velocity and Energy of Alpha Particles, Bragg's Experiment-Range of Alpha Particles, Geiger Law, Geiger-Nuttal Law, Disintegration energy of Spontaneous Alpha-decay, The Alpha Spectra and Fine structure: Short Range and Long-Range Alpha Particles, Alpha Decay Paradox-Barrier Penetration(Qualitative treatment)

[Ilangovan: 3.1-3.1.7] [Patel: 4.2.1- 4.2.3]

Beta Decay: Magnetic Spectrograph-Velocity and Energy of Beta Particles, Origin of Continuous Beta –ray Spectrum and difficulties in understanding it, Pauli's Neutrino Hypothesis. Types of Beta decay, Energies of Beta -decays

[Ilangovan: 3.2.1, 3.2.5][Patel: 4.3.1- 4.3.3][Jain: 8.1]

Gamma Decay: Origin of Gamma Decay, Internal Conversion, Nuclear isomerism, The Absorption of Gamma Rays with Matter, Detection of Gamma rays using G. M. Counter

[Patel: 4.4.1- 4.4.3] [Ilangovan: 3.3.2, 3.3.3, 3.3.5, 3.3.6] [Jain:13.6]

3. Nuclear Energy [3h]

Neutron Induced Fission, Asymmetrical Fission-Mass Yield, Energy released in the fission of U-235, Fission Chain Reaction, Principle of a Nuclear Reactor, Neutron cycle in a Thermal Nuclear Reactor (The four factor formula), Principle of a Breeder Reactor.

[Patel: 6.1-6.5, 6.7-6.9]

Unit III: **[10 h]**

4. Elementary Particle Physics **[10 h]**

Classification of Elementary Particles, Particles and Antiparticles, Fundamental Interactions, Quantum Numbers, Conservation Laws, Gell-Mann-Nishijima Formula, Concept of Quark Model, Baryons and Mesons as Bound States of Quarks

[Ilangovan: 11.1, 11.5-11.8, 12.2-12.7][Jain: 15.1-15.3]

Practicals: (Minimum Six)

1. Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope etc.

2. Determination of Absorption Coefficient using GM counter

3. Verification of Inverse Square Law using GM counter

4. Tutorial on Basic Properties of the Nucleus

5. Tutorial on Liquid Drop Model and Nuclear Shell Model

6. Tutorial on Q-value of Nuclear Reaction, and Radioactive Decays

7. Tutorial on Nuclear Energy

8. Tutorial on Elementary Particle Physics

[Minimum of eight numerical problems to be given to students per tutorial]

References:

1. Jain, V. K., 2015, *Nuclear and Particle Physics*, Ane Books Pvt. Ltd., New Delhi.
2. Patel, S. 2011, *Nuclear Physics: An Introduction*, 2nd Edition. New Age International Limited, New Delhi.
3. Ilangovan, K. 2012, *Nuclear Physics*, MJP Publishers, Chennai.

Additional References:

1. Krane, K. 1987, *Introductory Nuclear Physics,* 3rd Edition. Wiley, New Jersey.
2. Kaplan, I. 1956, *Nuclear Physics,* 3rd Edition, Addison-Wesley, Boston.
3. Beiser, A. 1969, *Perspectives of Modern Physics,* McGraw-Hill Book Company, Singapore.
4.

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1. https://www.youtube.com/playlist?list=PLF15670EECA944A13
2. http://inside.mines.edu/~kleach/PHGN422/#
3. https://www.youtube.com/watch?v=josqjcH79PE&list=PLbMVogVj5nJRvq-w3zway7k3GzmUDte3a

4. https://www.youtube.com/playlist?list=PL9jo2wQj1WCNPlSEv-Yd3d13_fLiQhCyT
5. https://www.youtube.com/watch?v=2zZ1kv6vlq0
6. https://www.youtube.com/watch?v=kW6rR9H9Vu8
7. https://www.youtube.com/tTDHS64wJkk
8. https://www.youtube.com/F5fFVkYJ_Rs
9. https://www.youtube.com/eDCDrRzHGuE

Course Title : **Introduction to Special Theory of Relativity**

Course Code : **PHY-E15**

Marks : **75 (Theory) + 25 (Practical)**

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

Pre-requisite : **Electromagnetic Theory –I (PHY-III.C-5) and Electromagnetic Theory-II (PHY-V.C-7)**

Course Objectives : The objective of this course is to introduce students to Special Theory of Relativity.

Course Learning Outcomes: At the end of this course, students will be able to:

CLO1: Understand the limitations of Newtonian relativity at speeds close to the speed of light.
CLO2: Learn the postulates of special theory of relativity and understand the connection between space and time.
CLO3: Comprehend the concepts of relativistic velocity, relativistic mass and equivalence of energy and mass.
CLO4: Learn about the doppler effect in relativity.

Theory

Unit I: **[20 h]**

1. **Experimental Background:** **[10 h]**

   Galilean Transformation, Newtonian relativity, Electromagnetism and Newtonian relativity, Michelson Morley experiment, Lorentz-Fitzgerald contraction hypothesis, Ether Drag hypothesis, attempts to modify electrodynamics, postulates of the theory of special Relativity. Einstein and origin of relativity theory.
   [Resnick: Article 1.1to 1.10]

2. **Relativistic Kinematics** **[10 h]**
   Relativity of simultaneity, Derivation of Lorentz transformation equations, some consequences of Lorentz transformation equations, Relativistic addition of velocities, relativistic transformation of velocities and Doppler effect in Relativity.
   [Resnick: Article 2.1to 2.8]

Unit II: **[10 h]**

1. **Relativistic Mechanics** **[10 h]**
   Mechanics and Relativity, Redefining momentum, Relativistic momentum, Relativistic mass, Equivalence of mass and energy. The transformation properties of Momentum, Energy, Mass and Force.
   [Resnick: Article 3.1to 3.7]

Unit III: [15 h]

1. **Relativity and Electromagnetism [10 h]**
   Interdependence of electric and magnetic fields, Transformation for E and B, Field of a uniformly moving point charge, Forces and fields near a current carrying wire, Forces between moving charges, The invariance of Maxwell's equations, Limitations of special relativity.
   [Resnick: Article 4.1to 4.8]
2. **The Geometric Representation of Space –Time and Twin Paradox [5 h]**
   Space-Time Diagrams, Simultaneity, Contraction and Dilation, The time Order and Space Separation of events, The route dependence of proper time, space time diagram of the twin paradox, The experimental test.
   [Resnick: Article A1-A3 and B-1 to B-5]

Experiments: (Minimum Six)

1. Michelson Interferometer
2. Tutorial on Relativistic Kinematics
3. Tutorial on Relativistic Kinematics
4. Tutorial on Relativistic Mechanics
5. Tutorial on Relativistic Mechanics
6. Tutorial on Relativity and Electromagnetism
7. Tutorial on Relativity and Electromagnetism

[Minimum of eight numerical problems to be given to students per tutorial]

Reference:

1. Resnick R., 1965, *Introduction to Special Relativity*, John Wiley, New Jersey, USA

Additional References:

1. Ghatak A., 2009, *Special Theory of Relativity,* Sheth Publishers Pvt., Ltd., Mumbai
2. French A. P., 1968, *Special Relativity*, Chapman & Hall, London, UK.

Web References:

1. https://ocw.mit.edu/courses/physics/8-20-introduction-to-special-relativity-january-iap-2005/
2. http://edu.itp.phys.ethz.ch/hs10/ppp1/PPP1_2.pdf
3. https://cosmolearning.org/video-lectures/relativistic-kinematics/
4. https://arxiv.org/ftp/arxiv/papers/0910/0910.5847.pdf
5. https://arxiv.org/pdf/physics/0509161.pdf
6. https://nptel.ac.in/courses/115/101/115101011/
7. https://www.ibiblio.org/ebooks/Einstein/Einstein_Relativity.pdf
8. http://www.physics.iisc.ernet.in/~vasant/publications/popular/apr_05.pdf
9. http://physics.mq.edu.au/~jcresser/Phys378/LectureNotes/VectorsTensorsSR.pdf

Course Title **: Introduction to Materials Science**

Course Code **: PHY-E16**

Marks **: 75 (Theory) + 25 (Practical)**

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

Pre-requisite **: Quantum Mechanics (PHY-IV.C-6), Solid State Physics (PHY-E9)**

Course Objectives **:** To acquaint students with fundamentals of materials science and study the properties and applications of materials.

Course Learning Outcomes: At the end of this course, students will be able to:
CLO1: Describe the different types of crystal structures of solid materials.
CLO2: Identify and describe the defects and imperfections in solids and their effects on the properties of materials.
CLO3: Apply the knowledge of electrical properties of materials to solve problems related to their applications.
CLO4: Understand diffusion mechanism and apply it to solve problems related to materials processing and analysis.
CLO5: Identify and describe the different types of ceramics and their applications.
CLO6: Understand the concept of polymers and their importance in various applications.

Theory:

Unit I: **[15 h]**

1. **Structure of Crystalline Solids** **[8 h]**
   Introduction, metallic crystal structures: the face centered cubic crystal structure, the body centered cubic crystal structure, the hexagonal close-packed crystal structure, density computations, atomic arrangements, linear and planar densities, close-packed crystal structures, polymorphism and allotropy, ceramic crystal structures: radius ratio rules, AX-type crystal structures, A_MX_P-type crystal structures, $A_MB_NX_P$-type crystal structures, crystal structures from close packing of anions, ceramic density computations, silicate ceramics, carbon, polymer structures: polymer crystallinity, polymer crystals, x-ray diffraction: determination of crystal structures.
   [Callister: 4.1 – 4.20]

2. **Imperfections in Solids** **[7 h]**
   Introduction, point defects: vacancies and self-interstitials, impurities in solids, specification of composition, imperfections in ceramics, miscellaneous imperfections: dislocations-linear defects, interfacial defects, bulk or volume defects, atomic vibrations, defects in polymers, microscopic examination: microscopic techniques, grain size determination.

[Callister: 5.1 – 5.13]

Unit II: [15 h]

1. **Electrical properties of materials [7 h]**
   Thermoelectric effects, the Hall effect, Dielectric Materials, Ferroelectricity, Pyroelectricity, Piezoelectricity, Relationship between Ferro-, Piezo- and Pyroelectricity, Applications of Ferro-, Piezo- and Pyroelectrics.
   [West: 15.1 – 15.8]

2. **Diffusion [8 h]**
   Introduction, diffusion mechanisms, steady-state diffusion, nonsteady-state diffusion, factors that influence diffusion, diffusion in ionic materials, diffusion in polymeric materials.
   [Callister: 6.1 – 6.8]

Unit III: [15 h]

3. **Applications and Properties of Ceramics [8 h]**
   Introduction, types and applications of ceramics: glasses, Glass-ceramics, clay products, refractories, abrasives, cements, advanced ceramics, mechanical properties: brittle fracture of ceramics, stress-strain behavior, mechanism of plastic deformations, miscellaneous mechanical considerations, glass properties, heat treatment of glasses, heat treatment of glass ceramics.
   [Callister: 12.1 – 12.8, 12.10 – 12.16]
4. **Structures of Polymers [7 h]**
   Introduction, hydrocarbon molecules, polymer molecules, the chemistry of polymer molecules, molecular weight, molecular shape, molecular structure, molecular configurations, thermoplastic and thermosetting polymers, copolymers.
   [Callister: 13.1 –13.10]

Practicals: (Minimum Six)

1. Grain size estimation using XRD.
2. Determination of density of materials.
3. Analysis of surface morphology using SEM/TEM
4. Determination of compressibility of liquids using crystal oscillator.
5. To study the corrosion of metals with the help of galvanic cells.
6. Thermal diffusivity of brass.
7. Thermal conductivity of a poor conductor.
8. Specific heat of graphite.
9. Measurement of ionic conductivity of solutions as a function of temperature and concentration.

References:

1. Callister W. D., 2015, *Materials Science and Engineering* 2nd Ed., John Wiley and Sons, New Jersey, USA
2. West A. R.., 2014, *Solid State Chemistry and its Applications*, John Wiley and Sons, New Jersey, USA

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1. Kittel C., 2015, *Introduction to Solid State Physics,* 8th Edition, John Wiley and Sons, New Jersey, USA.

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2. http://kaizenha.com/wp-content/uploads/2016/04/Materials-Textbook-8th-Edition.pdf
3. https://www.edx.org/learn/materials-science
4. https://www.coursera.org/courses?query=material%20science
5. https://ocw.mit.edu/courses/materials-science-and-engineering/3-012-fundamentals-of-materials-science-fall-2005/lecture-notes/
6. http://www.nptelvideos.in/2012/11/materials-science.html
7. https://www.digimat.in/nptel/courses/video/113107078/L01.html