DEPARTMENT OF PHYSICS

COURSE STURUCTURE [2020-2021 onwards]

SEMESTER	CORE		ELECTIVE				
I	PHY-I.C-1 Introduction to Mathematical Physics	PHY-I.C-2 Mechanics-I	-------	-------	-------	-------	-------
II	PHY-II.C-3 Heat and Thermodynamics	PHY-II.C-4 Electricity and Magnetism	-------	-------	-------	-------	-------
III	PHY-III.C-5 Electromagnetic Theory-I	-------	PHY-E1 *Optics	PHY-E2 Modern Physics	PHY-E3 Oscillations, Waves and Sound	PHY-E17 Introduction to Astronomy and Astrophysics	PHY-E8 Instrumentation
IV	PHY-IV.C-6 Quantum Mechanics	-------	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.

COURSES FOR STUDENTS OPTING PHYSICS AS MINOR SUBJECT

[2020-2021 onwards]

Semester	Course
I	Mechanics-I
II	Electricity and Magnetism Or Heat and Thermodynamics
III	Modern Physics Or Electromagnetic theory -I
IV	Computational Physics Or Quantum Mechanics
V	Thermodynamics and Statistical Mechanics Or Electromagnetic theory -II
VI	Mechanics II Or Introduction to Materials Science

COURSES OFFERED AS GENERIC ELECTIVE COURSES

[2020-2021 onwards]

Semester	Course Title	Course code when offered as Generic Elective Course
I	Mechanics I	PHY-GEC-1
II	Heat and Thermodynamics	PHY-GEC-2
III	Oscillations, Waves and Sound	PHY-GEC-3
IV	Properties of Matter and Acoustics	PHY-GEC-4

Parvatibai Chowgule College of Arts and Science (Autonomous)
Margao, Goa

Syllabus

for the undergraduate degree courses

in

Physics

(2020-2021)

SEMESTER-I

Course Title : **Introduction to Mathematical Physics**

Course Code : **PHY-I.C-1**

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

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

Course Objectives : To develop basic competence in certain areas of mathematics required for understanding several important topics in physics.

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

CLO1: Have a good understanding of vector analysis and its application in physics.

CLO2: Have a good grasp on various tests used to test the convergence and divergence of different kinds of series and learn how to expand a function in power series.

CLO3: Understand the basics of complex numbers.

CLO4: Have an understanding of matrix operations and properties of matrices.

CLO5: Learn basics of partial differentiation and its application in physics.

CLO6: Be able to solve ordinary first and second order differential equations important in the physical sciences,

CLO7: familiarize with spherical and cylindrical coordinate systems.

CLO8: Use mathematical techniques to solve several problems in physics and enhance problem solving skills.

Theory:

Unit I: **[15 h]**

1. **Infinite Series and Power Series** **[8 h]**
   Geometric Series and other infinite series. Convergent and Divergent Series. Testing series for convergence. Power series. Expanding functions in power series. Techniques for obtaining power series expansion.
   [Boas 1.1-1.7, 1.10-1.13]

2. **Complex Numbers** **[4 h]**
   Real and imaginary Parts of a complex number. Complex plane. Complex algebra. Euler's formula. Powers and roots of complex numbers. Exponential and trigonometric functions.
   [Boas 2.1-2.5, 2.9-2.11]

3. **Coordinate Systems** **[3 h]**
   Plane polar coordinates. Cylindrical and Spherical polar coordinates.
   [Harper 1.6.6, Riley 8.9]

Unit II **[15 h]**

1. **Vector Algebra** **[5 h]**
   Scalars and vectors. Basis vectors and components. Multiplication of Vectors. Equation of lines and planes. Using vectors to find distances.
   [Boas 3.4-3.5]

2. **Vector Analysis** **[10 h]**
   Application of vector multiplication. Triple products. Differentiation of vectors. Gradient, divergence and curl of a vector. Line integrals. Divergence theorem. Curl and Stokes theorem.
   [Boas 6.1-6.11]

Unit III **[15 h]**

1. **Partial Differentiation** **[6 h]**
   Definition of the partial derivative. Total differentials. Exact and inexact differentials. Theorems of partial differentiation. Chain rule. Thermodynamic relations. Differentiation of Integrals.
   [Riley 4.1-4.5, 4.10-4.11]

2. **Ordinary Differential Equation** **[9 h]**
   Introduction. Linear differential equation of the first order. Homogenous and inhomogeneous linear differential equation of the second order.
   [Boas 8.1-8.6 and Harper 5.1-5.2]

Experiments: (Minimum Six)

1. Introduction Error Analysis: Propagation of Errors
2. Statistical Analysis of Random measurement
3. Simulation of Radioactive Decay using Rolling of Dice
4. Plotting of various algebraic and trigonometric functions using Excel.
5. Curve fitting using Excel.
6. Interpretation of graphs.
7. Solving Integration, Ordinary Differential Equation and Matrices using Mathematica.
8. Tutorial on vector analysis
9. Tutorial on infinite series
10. Tutorial on differential equations
11. Tutorial on matrices and partial differentiation

References:

1. Riley K. F., Hobson M. P., Bence S. J., 1998, *Mathematical Methods for Physics and Engineering*, Cambridge University Press, UK
2. Mary L. Boas, *Mathematical Methods in Physical Sciences* 3rd Edition, John Wiley and Sons, USA
3. Charlie Harper, *Introduction to Mathematical Physics*, Prentice Hall of India, New Delhi

Additional References:

1. B. D. Gupta, 2004. *Mathematical Physics,* Vikas Publishing House, Noida
2. M. Spiegel, S. Lipschutz, D. Spellman, 2009, *Schaum's Outline of Vector Analysis,* Mc-Graw Hill Education

Web References:

1. https://ocw.mit.edu/resources/res-18-007-calculus-revisited-multivariable-calculus-fall-2011/
2. https://nptel.ac.in/courses/111108081/
3. https://www.math.upenn.edu/~deturck/m104/notes/week6.pdf
4. http://tutorial.math.lamar.edu/Classes/CalcIII/CalcIII.aspx
5. http://home.iitk.ac.in/~peeyush/102A/Lecture-notes.pdf
6. http://www.jimahoffman.com/MathB30/Matrices/Matrix1.pdf

Course Title : **Mechanics I**

Course Code : **PHY-I.C-2**

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

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

Course Objectives : This course provides an introduction to topics in mechanics, which are essential for advanced work in physics. An objective of this course is to train students to think about some of the physical phenomenon in mathematical terms.

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

CLO1: develop qualitative and quantitative understanding of Newtonian mechanics in one and two dimensions and solve the Newton equations for simple configurations.
CLO2: understand the Law of Conservation of Linear Momentum and Angular Momentum and apply these laws to understand elastic and inelastic collision, motion of a rocket and Kepler's law.
CLO3: demonstrate the knowledge of work and energy in kinetics
CLO4: understand the Principle of Conservation of Mechanical Energy (for conservative forces) and apply this law to problems of objects moving under the influence of conservative forces.
CLO5: develop ideas of Newtons Law of gravity, gravitational field and potential energy by solving various problems.

Theory:

Unit I: Newton's Laws of Motion, Projectiles and Charged Particles [20 h]

1. **Newton's Laws of Motion [10 h]**
   Brief description of classical view of Space and Time (vector operations). The concept of Mass and Force. Newton's First and Second Laws; Inertial frames. Equations of motion. Interpretation of Newton's third Law as Conservation of Momentum. Newton's Second Law in Cartesian coordinates and in two dimensional Polar coordinates. Applications of Newtons Laws: Atwood Machine, Free fall near surface of the earth, simple harmonic motion and time dependent force.
   [Taylor 1.1-1.7, Kleppner 2.4]

2. **Projectiles and Charged Particles [10 h]**
   Motion of projectile in air resistance/drag (function of velocity.) Linear Air Resistance. Horizontal and vertical motion with linear drag, Trajectory and Range in a Linear Medium. Quadratic Air Resistance. Horizontal motion with quadratic drag (ignoring gravity), Motion of a charged particle with a velocity perpendicular to the direction of a uniform constant (1) electric field, (2) magnetic field and (3) electric and magnetic field (crossed) in mutually perpendicular directions. Lorentz force.
   [Taylor 2.1 - 2.7, Symon 3.17]

Unit II: Momentum, Angular Momentum, Gravitation Field and potentials [15 h]

1. **Momentum and Angular Momentum [7 h]**

   Principle of conservation of momentum (Elastic and Inelastic collision), Analysis of Rocket motion. The Centre of Mass, Angular Momentum for a Single Particle. Kepler's second law as a consequence of conservation of angular momentum.
   [Taylor 3.1-3.5]

2. **Gravitation Field and potentials [8 h]**
   Newton's Law of Gravitation. Gravitational field. Gravitational potential energy. Equipotential surface. Gravitational potential and field due to a (1) thin spherical shell, (2) uniform hollow sphere and (3) thin circular plate.

Unit III: Work and Energy [10 h]

1. **Work and Energy [10 h]**
   Kinetic Energy and Work: Work energy theorem. Potential Energy and Conservative Forces. Force as a Gradient of Potential Energy, Time dependent potential energy (one dimension). Energy for Linear One-Dimensional Systems. Curvilinear one-dimensional systems. Energy of interaction of two particles in one dimension.
   [Taylor 4.1-4.3, 4.5-4.7, 4.9]

Experiments: (Minimum Six)

1. Dimensions of different solid body
2. Moment of Inertia of a flywheel
3. Atwood Machine
4. Verification of Newton's Second Law using Air Track
5. Conservation of linear momentum using Air Track
6. Spring Mass System: Determining the Spring Constant
7. Simple Pendulum
8. Determining "**g**" using time of flight method using Python

References:

1. Taylor J. R., 2005, *Classical Mechanics*, University Science Books, USA
2. Kleppner, Kolenkow, 2013, *Introduction to Mechanics*, Cambridge University Press, UK
3. Symon K. R., 1971, *Mechanics*, Addison Wesley, New York
4. Brij Lal and N. Subramanyam, 2005, *Mechanics and Electrodynamics*, S. Chand and Company Ltd., New Delhi

Additional References:

1. Kittle, Knight, 2011, *Mechanics,* Berkeley Physics Course, Vol. 1, McGraw Hill Education,
2. .Mathur D. S, 2005, *Mechanics,* S. Chand & Co., New Delhi
3. Takwale R. G., and Puranik P. S., 1997, *Introduction to Classical Mechanics*, Tata Mc-Graw Hill, New Delhi

4. Javier E. Hasbun, 2010, *Classical Mechanics,* Jones and Bartlett India Pvt. Ltd.
5. Atam Arya, 1997, *Introduction to Newtonian Mechanics,* Addison-Wesley

Web References:

1. https://nptel.ac.in/courses/122106027/
2. https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2016/
3. https://www.khanacademy.org/science/ap-physics-1/
4. https://www.feynmanlectures.caltech.edu/I_13.html
5. http://hep.physics.wayne.edu/~harr/courses/5200/f07/lecture06.htm

SEMESTER-II

Course Title	**: Heat and Thermodynamics**
Course Code	**: PHY-II.C-3**
Marks	**: 75 (Theory) + 25 (Practical)**
Credits	**: 3 (Theory) + 1 (Practical)**
Course Objectives	**:** To acquaint students with fundamental concepts of Thermal Physics and explain the usefulness of these concepts for wide range of applications that include heat engines, refrigerators and air conditioners.

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

CLO1: Understand different types of temperature scales and relationship between different scales of temperature.
CLO2: Able to relate the effects of changes in temperature, pressure and volume on physical systems at macroscopic scale by analyzing collective motion of their particles.
CLO3: Able to comprehend the first law of thermodynamics to represent the relationship between heat and mechanical work.
CLO4: Able to comprehend the second law of thermodynamics to depict the manner in which thermodynamic changes take place.
CLO5: Explain the usefulness of these concepts for wide range of applications that include heat engines, refrigerators and air conditioners.
CLO6: Calculate change in entropy in matter during change in phase.

Theory:

Unit I: **[15 h]**

1. **Principle of Thermometry** **[6 h]**
   Review of concept of heat and temperature, Thermometry, Types of thermometers, Centrigrade, Fahrenheit, Rankine Scales and relations between them, Platinum resistance thermometer, Thermocouple (thermoelectric) thermometers.
   [Brij Lal: 13.1 – 13.5, 13.15, 13.23]

2. **Equations of State** **[9 h]**
   Equation of state, Andrew's experiment, Amagat's experiment, Van der Waal's equation of State, Critical constants, Reduced equation of state, Boyle temperature. Joule's Law for a perfect gas, expression for Joule's coefficient, Joule Thomson effect, Joule Thomson porous plug experiment, Joule-Kelvin effect-temperature of inversion.
   [Saha and Shriavastava: 10.1 -10.6], [Brij Lal: 2.6, 2.14, 2.17-2.21]

Unit II: **[15 h]**

1. **Laws of Thermodynamics** **[15 h]**
   Thermodynamic system, Thermodynamic variables, Thermodynamic equilibrium, and Thermodynamic processes, Zeroth law of thermodynamics, Concept of work and internal energy, First law of thermodynamics, Isothermal and adiabatic changes, Work done in isothermal and adiabatic changes, Relation between pressure, volume and temperature in adiabatic process, Reversible and irreversible processes, Carnot Heat engine, Carnot cycle for perfect gas, efficiency, Second law of thermodynamics (Kelvin – Planck Statement, Clausius Statement)
   [Brij Lal: 4.1, 4.4 – 4.7, 4.10.4, 4.11 - 4.13, 4.20 – 4.24, 4.28]

Unit III: **[15 h]**

1. **Applications of First and Second Law of Thermodynamics** **[9 h]**
   Otto cycle and Otto engine, Diesel cycle and Diesel engine, Efficiencies, Introduction to refrigeration, Principle and coefficient of performance, Principle of air conditioning, comfort chart A.C. machine, factors affecting size and capacity of A.C. machines.
   [Saha and Shriavastava: 4.16 – 4.19], [Brij Lal: 4.26, 4.27, Chapter 17]

2. **Concept of Entropy** **[6 h]**
   Changes of entropy during reversible and irreversible process, Temperature – Entropy diagram, Temperature – Entropy diagram of Carnot's cycle, Physical significance of Entropy, Entropy of a perfect gas, Principle of increase of entropy, Third Law of Thermodynamics.
   [Saha and Shriavastava: 6.9, 6.12], [Brij Lal: 5.1 – 5.8]

Experiments: (Minimum Six)

1. Latent heat of ice
2. Calibration of Si diode as a thermometer.
3. Constant volume air thermometer.
4. Constant pressure air thermometer.
5. Thermal conductivity by Lee's method.
6. Thermal conductivity of copper.
7. Temperature coefficient of resistance of copper.
8. Temperature coefficient of resistance of Platinum thermometer using PT-100.
9. Callender-Griffith Bridge.

References:

1. Brij Lal, Subramanyam N., Hemne P.S. 2007, *Heat Thermodynamics and Statistical Physics*, S. Chand & Company Ltd., New Delhi

2. Saha M.N., Shrivastava B.N. 1965, *Treatise on Heat*, 5th Ed., The Indian Press, Allahabad and Calcutta.

Additional References:

1. Roberts J. K., Miller A.R. 1960, *Thermodynamics*, E.L.B.S.

2. Zemansky M.W., Ditman R.H. 2013, *Heat and Thermodynamics*, 8^{th} Ed., McGraw Hill, New Delhi

Web References:

1. http://www.zytemp.com/infrared/thermometry_history.asp
2. https://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/video-lectures/lecture-1-state-of-a-system-0th-law-equation-of-state/
3. https://ocw.mit.edu/high-school/physics/exam-prep/kinetic-theory-thermodynamics/laws-of-thermodynamics/
4. https://www.texasgateway.org/resource/124-applications-thermodynamics-heat-engines-heat-pumps-and-refrigerators
5. https://web.mit.edu/2.972/www/reports/compression_refrigeration_system/compression_refrigeration_system.html
6. http://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node41.html
7. F., R. A Treatise on Heat. *Nature* 137, 554-556 (1936) https://doi.org/10.1038/137554a0

Course Title : **Electricity and Magnetism**

Course Code : **PHY-II.C-4**

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

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

Course Objectives : The objective of this course is to introduce fundamentals of electricity and magnetism to the students, which is an essential preparation for more advanced courses like Electromagnetic theory.

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

CLO1: Demonstrate Gauss law, Coulomb's law for the electric field, and apply it to systems of point charges as well as line, surface, and volume distributions of charges.

CLO2: Explain and differentiate the vector (electric fields, Coulomb's law) and scalar (electric potential, electric potential energy) formalisms of electrostatics.

CLO3: Apply Gauss's law of electrostatics to solve a variety of problems.

CLO4: Understand the dielectric properties, magnetic properties of materials and the phenomena of electromagnetic induction.

CLO5: Describe how self-inductance/mutual inductance is produced.

CLO6: Apply Kirchhoff's rules to analyse DC circuits consisting series combinations of voltage sources with resistors, capacitor and inductors.

CLO7: Apply j-operator method and vector diagram to analyse AC circuits consisting parallel/ series combinations of voltage sources with resistors, capacitor and inductors.

CLO8: Construct, understand the working and use of various AC bridges,

CLO9: In the laboratory course the student will learn about the construction and working of DC and AC circuits. The student will get an opportunity to use various measuring instruments.

Theory:

Unit I: **[15 h]**

1. **Electrostatics** **[10 h]**

   Coulomb's law: Statement, Vector form of Coulomb's law for like and unlike charges, Variation of force with distance (F.vs.r graph), Concept of electric field and Electric Field Lines: Electric field, Electric field due to (i) a Point Charge, (ii) an Electric Dipole, (iii) a Line of Charge and (iv) a Charged Disk, Concept of electric flux: Gauss' Law of electrostatics (Conceptual explanation), Applications of Gauss law: Coulomb's Law from Gauss' Law, Electric Field due to (i) an isolated uniformly charged sphere, (ii) an uniform distribution of charge throughout the sphere and (iii) an uniformly charged hollow cylinder, Electric Field near (i) a charged infinite cylindrical conductor or a cable and (ii) a plane of sheet charge, Concept of Electric Potential: Electric Potential Energy, Equipotential Surfaces, Calculating the Potential from the Field Potential due to (i) a Point Charge, (ii) a Group of Point Charges and (iii) an Electric Dipole Calculating the Field from the Potential

[Halliday: 22.4, 23.2-23.7, 24.1-24.5, 25.1-25.7, 25.9] [Vasudeva: 2.4(1-6)]

2. **Capacitors and Dielectrics** **[5 h]**

Capacitance: Calculation of capacitance of (i) a Parallel-Plate Capacitor, (ii) a Cylindrical Capacitor and (iii) a Spherical Capacitor; Energy stored in an electric field, Capacitor with a Dielectric, Dielectrics: An Atomic View, Dielectrics and Gauss' Law, Relation between three electric vectors (E, D and P)(Without derivation, qualitative discussion only)

[Halliday: 26.1- 26.3, 26.5-26.8]

Unit II: **[15 h]**

1. **Magnetostatics** **[6 h]**

Concept of magnetic field: Definition and properties of magnetic field Biot–Savart's law and its applications: (i) a long straight wire and (ii) a current carrying circular loop (for a point on the axis only) Ampere's circuital law and its applications: (i) Field of solenoid and (ii) Field of toroidal solenoid Magnetic Field lines and Magnetic flux; Gauss' law for magnetism

[Halliday: 29.1, 29.2, 30.1, 30.3, 30.4, 32.2][Young:27.2, 27.3]

2. **Self and Mutual Inductance** **[9 h]**

Self induction; Calculation of self inductance of (i) a long solenoid, (ii) long parallel wires and (iii) a coaxial cable, Mutual inductance, Coefficient of coupling; Calculation of mutual inductance between two coaxial solenoids, Mutual inductance of two coils in series, Energy stored in a magnetic field and Energy density of a magnetic field

[Fewkes: 5.1, 5.2, 5.8, 5.9] [Halliday:31.8, 31.10, 31.11, 31.12]

Unit III: **[15 h]**

1. **Transient Circuits** **[6 h]**

   Transient currents, Growth and Decay of current in an inductive (L-R) circuit, Physical meaning of time constant, Charging and Discharging of a capacitor through resistor in C-R circuit, Physical meaning of time constant, Charging and Discharging of a capacitor through resistor and inductor in L-C-R circuit: Over damped, Critically damped and Under damped conditions of L-C-R circuit.

   [Fewkes:5.3, 5.4, 5.13, 5.14]

2. **Alternating Current Circuits** **[9 h]**

   Inductive and Capacitive reactance, Variation of inductive reactance and capacitance reactance with frequency Introduction to vector or phasor diagrams method and its application to A.C. circuits(Series L-R, Series C-R, Series L-C-R and Parallel L-C-R) Introduction to j-operator method and its application to A.C. circuits (Series L-C-R and Parallel L-C-R) Physical significance of Series resonance, Parallel resonance, Quality factor and Bandwidth, Graphical representation of resonance A.C. bridges: Maxwell's inductive bridge, Maxwell's L/C bridge, de Sauty's capacitance bridge, Wien's frequency bridge.

   [Vasudeva:22.3, 22.4, 22.6, 22.7, 22.8, 22.9, 22.10, 22.13, 22.14] [Vasudeva: 22.19, 22.20, 22.21(b), 22.22] [Fewkes:6.5, 6.6, 6.7(c), 6.9, 6.14, 6.20, 6.21, 6.22, 6.24]

Experiments: (Minimum Six)

1. Susceptibility measurement of a parallel plate capacitor in a dielectric medium
2. Step Response of RC circuit with DC emf.
3. Study of LR circuit to DC using Excel worksheet
4. LCR- Transient Response
5. Response of LR circuit to A.C. - phasor diagrams
6. Response of CR circuit to A.C. - phasor diagrams
7. LCR- Series resonance –Resonant frequency, Q value and Bandwidth
8. LCR- Parallel resonance –Resonant frequency, Q value and Bandwidth
9. de Sauty's bridge - comparison of capacitance
10. Maxwell's Inductive bridge - determination of mutual inductance

References:

1. Halliday David, Resnik Robert and Walker Jearl, 2003, *Fundamentals of Physics*, John Wiley & Sons, Inc., 6th Edition.

2. Vasudeva D. N., 1999, *Fundamentals of Magnetism and Electricity*, S. Chand & Company Ltd., 12th Revised Edition.
3. Young Hugh D., Freedman Roger A. and Ford A. Lewis, 2012, Sears and Zemansky's *University Physics with Modern Physics*, Addison-Wesley Publishers, 13th Edition (PDF).
4. Fewkes J. H. and Yarwood John,1991, *Electricity, Magnetism and Atomic Physics*, Volume I, Oxford University Press Ltd., 10th Impression.

Additional References:

1. Purcell Edward M., *Electricity and Magnetism-Berkeley Physics Course*, Volume 2, McGraw-Hill Book Company (PDF)
2. Brij Lal and Subramaniam, 1966, *Electricity and Magnetism*, Ratan Prakashan, New Delhi.
3. Thereja B.L., 1990, *Text Book of Electrical Technology*, S. Chand and Co Ltd. New Delhi.

Web References:

1. https://youtu.be/T8bjzTsZyqE
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3. https://youtu.be/7jxUT5sIbxY
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8. https://physicscatalyst.com/elec/relation-between-electric-field-and-potential.php
9. https://physicscatalyst.com/elec/equipotential-surfaces.php
10. https://physicscatalyst.com/elec/electric-potential-dipole.php
11. https://physicscatalyst.com/elec/potential-energy-of-dipole.php
12. https://ocw.mit.edu/courses/physics/8-02t-electricity-and-magnetism-spring-2005/lecture-notes/

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]**

   Vector Algebra: Vector Operations, Vector Algebra: Component form, Triple Products, 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.

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1. https://nptel.ac.in/courses/115101005/
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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: Apply cardinal points technique and aberration to study the image formation in optical systems
CLO2: Solve numerical problems based on aberration and cardinal points
CLO3: Apply division by wave front and division by amplitude techniques to study interference patterns
CLO4: Solve numerical problems based on interference in thin films
CLO5: Derive conditions for Fresnel class diffraction and Fraunhofer class diffraction
CLO6: Solve numerical problems based on diffraction grating, resolving power of telescope and prism
CLO7: Apply Huygen's theory of double refraction to study the types of crystal
CLO8: Analyze the types of polarized light with help of Nicol Prism and retardation plate
CLO9: 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 Constant deviation 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

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1. Mathur B. K., *Principles of Optics*, New Global Printing Press, Kanpur.
2. Ghatak A., 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

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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: have an understanding of constituents of an atom and atomic structure.
CLO2: discuss and interpret experiments that reveal the wave properties of matter.
CLO3: discuss and interpret experiments that reveal the particle properties of waves and wavelike properties of particle.
CLO4: apply uncertainty principle to solve physics problems
CLO5: understand the working of mass spectrographs and accelerators
CLO6: understand the basic operating principle of the laser and the optical fiber.

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:** **[5 h]**
   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.

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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

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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.

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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)**

Course Objectives **:** The course aims to introduce the students to the Exciting World of Extra-galactic 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 types of stars and their life cycle.

Theory:

Unit I: Fundamentals of Astronomy and Astronomical Instruments **[20 h]**

1. **Fundamentals of Astronomy:** **[10 h]**
   Introduction: Components of the Universe; Stars, Planets, Asteroids, Meteors, Comets, Galaxies. Solar System: Age, Origin Basic measurements: Planetary orbits, distances, physical size, mass, density, temperature, rotation period determination, Kepler's laws, black body radiation and curves, Doppler effect.

   [Abhyankar: chapter1: 1.1-1.5, chapter 3: 3.1- 3.4]

2. **Astronomical Instruments:** **[10 h]**
   Optical telescopes, mounts, light gathering power, magnification, resolution. Spectroscopes, CCD camera, photometer, filters Radio telescopes, interferometry UV, IR, X-ray and Gamma ray telescopes. Modern telescopes: HST, Chandra.

   [Abhyankar: chapter19: 19.1-19.5, chapter20: 20.1-20.5]

Unit II: Star and Star Systems and Galaxies, Dark Matter and Dark Energy **[15 h]**

1. **Star and Star Systems** **[8 h]**
   Stars life cycle, Neutron stars, black holes, white dwarf, Chandrasekhar limit. Spectral classification of stars, O,B,A,F,G,K,M. Sytem of stars: Binaries / Cepheids / RR Lyrae, HR diagram, sun and solar system.

   [Abhyankar: chapter5: 5.1-5.7, chapter12:12.3, 12.4]

2. **Galaxies, Dark Matter and Dark Energy** **[7 h]**
   Galaxies, classification of galaxies, Hubble's tuning fork diagram, Open and Globular clusters, ISM.

   [Abhyankar: chapter16: 16.4, chapter 17:17.1-17.4]

UNIT III: Observational Astronomy **[10 h]**

1. **Observational Astronomy** **[10 h]**
   Co-ordinate system, Celestial hemisphere, Concept of time, Magnitudes: apparent and absolute, constellations. Star dial, Observation of Sun, Eclipses, Moon, planets, meteor showers, transits, occultation's.

   [Abhyankar: chapter2; 2.1-2., Shu: chapter1: 1.1-1.4]

Experiments: (Minimum six)

1. Resolving power of telescope.
2. Study of scattering of light (Diameter of Lycopodium powder).
3. Study of Diffraction using plane grating.
4. To find radius of curvature of a convex lens using optical lever.
5. Measurement of the solar constant.
6. To obtain proper motion of Barnard's star using Aladin.
7. Draw constellation map of a) Orion b) Auriga c) Taurus d) Ursa Major (Big Dipper) marking of pole star.
8. To determine the elements in sun using Fraunhofer spectra.
9. To estimate Astronomical Unit using Venus transit data by parallax method.
10. Data analysis technique using virtual observatory.
11. Determine the period of revolution of sun using virtual laboratory.

References:

1. Abhyankar K.D., 2001, *Astrophysics - Stars and Galaxies*, Tata McGraw Hill, New Delhi
2. Shu F., 1981, *Physical Universe-An Introduction to Astronomy*,University Science Books, U.S.

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1. Roy A.E., Clarke D., 1989, *Astronomy structure of the Universe*, Adam Hilger Pub.
2. Glasstone S., 1965, *Source book on theSpace Sciences*, Van Nostrand Reinhold Inc., U.S
3. Bhatia V. B., 2001, *Textbook of Astronomy and Astrophysics with Elements of Cosmology*, Narosa Publishers, New Delhi.
4. Narlikar J.V., 1976, *Structure of the Universe*, Oxford Paperbacks.
5. Badyanath and Basu., 2010, *An Introduction to Astrophysics*, 2nd Edition, Prentice Hall India Learning Private Limited

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2. http://academics.smcvt.edu/abrizard/astronomy/Astronomy_Notes.pdf
3. https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/
4. http://spiff.rit.edu/classes/phys445/phys445.html
5. https://science.nasa.gov/astrophysics/focus-areas/what-are-galaxies

Course Title **: Instrumentation**

Course Code **: PHY-E8**

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

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

Pre-requisite **: Nil**

Course Objectives **:** The objective of this course is to understand basic concepts related to the various types of measuring instruments and measuring techniques.

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

CLO1 : Understand basic concepts related to the various types of measuring instruments and measuring techniques.
CLO2 : Comprehend basic principles involved in measuring instruments like Ammeter, Voltmeter, Ohmmeter and Multimeters.
CLO3 : Understand working and use of CROs and Signal Generators
CLO4 : Understand working and usage of the various types of transducers.

Theory:

Unit I: Indicators, Display Devices and Signal Generator **[10 h]**

1. **Fundamentals of Measurement** **[4 h]**
   Introduction, Performance Characteristics, Static Characteristics, Errors in Measurements, Types of Static Error, Sources of Error, Dynamic Characteristics, Standard, Electrical Standards.
   [Kalsi: Chapter 1.2 to 1.7, 1.9, 1.10]

2. **Indicators and Display Devices** **[4 h]**
   Types of Instrument, Basic Meter Movement: PMMC Movement and Practical PMMC Movement, Classification of Displays, Use of LED and LCD as Display Devices, Segmental Displays using LEDs.
   [Kalsi: Chapter 2.1, 2.2, 2.8, 2.10, 2.11, 2.12.3]

3. **Signal Generator:** **[2 h]**
   Standard Signal Generator, AF Sine and Square Wave Generator, Function Generator.
   [Kalsi: Chapter 8.4, 8.5, 8.7, 8.8]

Unit- II: Measuring Devices **[20 h]**

1. **Measuring Instruments** **[14 h]**
   DC Ammeter, Multirange Ammeter, Universal Shunt, Requirements of a Shunt, Extending of Ammeter Ranges. Basic Meter as a DC Voltmeter, DC Voltmeter, Multirange Voltmeter, Extending Voltmeter Ranges, Loading, Transistor Voltmeter(TVM), FET DC Voltmeter. AC Voltmeter using Rectifiers, Multirange AC

Voltmeter, AC current measurements using AC Voltmeter and a series Resistor. Ohmmeter: Series type and Shunt type, Multimeter.
Digital voltmeter: Ramp Technique, Digital Multimeters and Frequency meter (with help of Block Diagrams), Q meter.
[Kalsi: Chapter 3.1 to 3.5, 4.2 to 4.7,4.12to 4.15, 4.21, 4.22, 4.25, 5.2, 6.2,6.3,10.7 and Mottershead: Chapter 22: 22-9]

2. **Oscilloscope** **[6 h]**
   Basic Principle, Block Diagram of Oscilloscope, Simple CRO, Vertical Amplifier, Horizontal Deflecting System, sweep generator, Delay line.
   [Kalsi: Chapter 7.2.1, 7.4, 7.5, 7.5.1, 7.6, 7.7.1, 7.10]

Unit-III: Introduction to Transducers and its applications **[15 h]**

1. **Transducers** **[15 h]**
   Introduction, Electrical Transducer, Selecting a Transducer, Strain Gauges, Resistance Wire Gauge, Types of Strain Gauges(Wire), Foil Strain Gauge, Semiconductor Strain Gauge, Inductive Transducer, Differential Output Transducers, Linear Variable Differential Transducers (LVDT), Capacitive Transducer, Piezo-Electric Transducer, Semiconductor Diode Temperature Sensor, Temperature Transducers: Resistance Temperature Detectors, Thermistors, Thermocouples.
   [Theraja: Chapter 36.1 to 36.3, 36.12 to 36.15] [Kalsi: Chapter 13.1 to 13.3, 13.6, 13.6.1 to 13.6.4, 13.9,13.9.1, 13.9.2, 13.10, 13.11,13.13, 13.15, 13.20.7]

Experiments: **(Minimum six)**

1. Use of CRO and Function Generator (AC/DC voltage measurement, frequency measurement).
2. To measure displacement (linear and angular) using potentiometer/variable inductor/variable capacitor.
3. Construction and design of analog two ranges Voltmeter.
4. Construction and design of analog two ranges Ohmmeter.
5. Crystal Oscillator: Determination of velocity of ultrasonic waves in a liquid medium.
6. Study of strain Gauges
7. Study of LVDT (including calibration) and its use in any one application.
8. Calibration of Thermocouple
9. Thermistor as a temperature sensor.
10. Application of Pt 100 as a temperature sensor.

References:

1. Kalsi H S, 2010, *Electronics Instrumentation*, 3rd Edition, Tata McGraw Hill Education Pvt. Ltd. New Delhi
2. Mottershead Allen, 2000, *Electronics Devices and Circuits: An Introduction*, Prentice-Hall of India Pvt. Ltd., New Delhi
3. Theraja B. L., 2005, *Basic Electronics (Solid State)*, 1stMulticolour Edition, S. Chand and Company Ltd., New Delhi

Additional References:

1. Boylestad R., and Nashelsky L., 2000, *Electronic Devices and Circuit Theory*, 6th Edition Prentice-Hall of India Pvt. Ltd., New Delhi

Web References:

1. https://www.jameco.com/Jameco/workshop/TechTip/working-with-seven-segment-displays.html
2. https://electronics-diy.com/Function_Generator_XR2206.php
3. https://www.electronics-tutorials.ws/io/io_1.html
4. https://www.elprocus.com/cro-cathode-ray-oscilloscope-working-and-application/
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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 central concepts and principles in quantum mechanics, such as the Schrödinger equation, the wave function and its statistical interpretation, the uncertainty principle, stationary and non-stationary states, time evolution of solutions.
CLO2: solve the Schrödinger equation to obtain wave functions for some important types of potential in one and three dimension and give concise physical interpretations and reasoning underlying the mathematical results.
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 and have acquired experience in using both types of methods on quantum mechanical problems
CLO6: use numerical tools and software to solve the Schrodinger equation for more complicated cases.

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 **[20 h]**

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.

References:

1. Eisberg, R. And Resnick, R. 2010, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and particles,* 2nd Edition, Wiley India Pvt Ltd.
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.

Additional References:

1. Beiser, A. 1969, *Perspectives of Modern Physics,* McGraw-Hill Book Company, Singapore.
2. Flugge, S. 2008, *Practical Quantum Mechanics*, Springer (SIE).
3. Rajasekar, S. and Veluswamy, R. 2014, *Quantum Mechanics I: The Fundamentals,* CRC Press, New York.
4. Richtmyer, F., Kennard, E., Cooper, J. 2001, *Introduction to Modern Physics*, 6th ed. Tata McGraw-Hill Book Company, New Delhi.
5. Verma, H. 2012, *Quantum Physics*, TBS, Calicut.
6. Wichmann, E. 2010, *Quantum Physics: Berkeley Physics Course Vol 4*, Tata McGraw-Hill Book Company, New Delhi.

Web References:

1. Verma, P. H. (2016). Retrieved from https://hcverma.in/QuantumMechanics
2. Zwiebach, P. B. (2016). *Quantum Physics I*. Retrieved from MIT OpenCourseWare: https://ocw.mit.edu/courses/physics/8-04-quantum-physics-i-spring-2016/video-lectures/part-1/
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 behavior and the operation of basic semiconductor devices.
CLO2: Understand basic circuit laws; semiconductor based analog circuits from a fundamental point of view.
CLO3: Use this knowledge to describe bipolar transistors and its applications.
CLO4: Understand and apply the concept of feedback to study 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, Constant 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*, 1st edition Cambridge University Press.
2. Mehta V. K., Rohit Mehta, *Principles of Electronics*, S. Chand and Co. Ltd. New Delhi

Additional References:

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
3. Mottershead Allen 2000, *Electronics Devices and Circuits: An Introduction*, Prentice-Hall of India Pvt. Ltd., New Delhi.
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

Web References:

1. http://alan.ece.gatech.edu/ECE3040/Lectures/CircuitReview.pdf
2. https://www.electricaltechnology.org/2019/01/what-is-rectifier-types-of-rectifiers-their-operation.html
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 analyzing 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]

Unit III: **[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.

Web References:

1. https://www.youtube.com/watch?v=yQsDxOdn1hk&list=PLYdroRCLMg5NTT00m-7ituVGdtY1X680M
2. https://www.youtube.com/watch?v=SFJ0HXRz-o4
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: Comprehend the phenomenon of elasticity, surface tension, viscosity and their application.

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,* 5th edition, 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: Solve problems in Physics by numerical methods using FORTRAN as a programming language.

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.

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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: Establish the link between electrostatics and magnetostatics using Maxwell's equations.
CLO5: Develop 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: Apply Kronig-Penney Model and Bloch theory to interpret energy band structures in solids, in particular knowing effective mass and E v/s k relationship.
CLO8: Differentiate 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** **[5 h]**

   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** **[11 h]**

   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, 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.

Web References:

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 and thermodynamic potentials.
CLO2: Understand Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics and its application to the classical gas, electrons in a metal and blackbody radiation
CLO3: Understand the specific heat of solids by invoking statistical mechanics.

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.

Web References:

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: Develop the ideas of monolithic linear regulators and understand different types of voltage regulators in LM series
CLO5: Apply binary operations to different digital circuits
CLO6: 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: **[15 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]

3. **Monolithic Linear Regulators** **[5 h]**
   Basic type of IC regulator, Load and line regulation,LM7800 series, Current Boosters, LM -317 or LM7812 as a voltage regulator.
   [Malvino and Bates: 24.4, 24.5]

Unit III [15 h]

1. **Digital Circuits** **[7 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** **[8 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, Fourier transforms of different functions in solving various Physics problems.
CLO4: 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 [15 h]**

   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 study the performance of circuits based on breakdown devices.
CLO5: Corelate the theory to understand the working of these devices.

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)*, 1st Multicolour 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

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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 Schroedinger 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: Separate two body problem into two equivalent single body problems
CLO2: Establish equation of orbit for the motion under inverse square law force and study different types of orbits.
CLO3: Establish the relation between time derivative of a vector in a fixed frame of reference with respect to moving frame of reference.
CLO4: Comprehend the occurrence of some pseudo forces due to relative motion between frames of references such as Coriolis's force, centrifugal force
CLO5: Understand the motion of rigid bodies by solving Euler's equations of motion.
CLO6: Understand the advantages of Lagrangian formulation over Newtonian formulation.
CLO7: Solve various mechanical problems using Lagrangian equation of motion.

Theory

Unit I: **[20 h]**

1. **Two-Body Central-Force Problems** **[10 h]**
   CM and Relative Coordinates; Reduced Mass, The Equations of Motion, The Equivalent One-Dimensional Problem, The Equation of Orbits, The Unbounded Kepler Orbits, Changes of Orbits
   [Taylor: pp. 293 – 315]

2. **Mechanics in Non-inertial Frames** **[10 h]**
   Acceleration without Rotation, The Tides, The Angular Velocity Vector, Time Derivatives in a Rotating Frame, Newton's Second Law in Rotating Frame, The Centrifugal Force, The Coriolis Force, Free Fall, Projectile motion and the Foucault Pendulum.

   [Taylor: pp. 327 – 358]

Unit II: **[10 h]**

1. **Rotational Motion of Rigid Bodies** **[10 h]**
 Properties of the Center of Mass, Rotation about a Fixed Axis, Rotation about Any Axis, the Inertia Tensor, Principal Axis of Inertia, Finding the Principal Axis; the Eigenvalue Equations, Precession of a Top due to a Weak Torque, Euler's Equations, Euler's Equations with Zero Torque, Euler Angles, Motion of Spinning Top

 [Taylor: pp. 367 – 403]

Unit III: **[15 h]**

1. **Collision Theory** **[5 h]**
 The Scattering Angle and Impact Parameter, The Collision Cross Section, Generalizations of the Cross Section, Differential Scattering Cross Section and its Calculations Rutherford Scattering
 [Taylor: pp. 557 – 582]

2. **Lagrange's Equations** **[10 h]**
 Constraints, Generalised coordinates, D'Alembert's Principle. Lagrange's Equations, A general expression for kinetic energy, Symmetries and laws of conservation. Cyclic or ignorable coordinates
 [Taylor: pp. 237 – 275 and Takwale: Section 8.1-8.7]

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. Taylor J. R., 2005, *Classical Mechanics*, University Science Books, USA
2. Takwale R. G., and Puranik P. S., 1992, *Introduction to Classical Mechanics*, Tata Mc-Graw Hill, New Delhi

Additional Reference:

1. Symon K. R., 1971, *Mechanics*, Addison Wesley, New York

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 – the constituents and their properties, mass number and atomic number, relation between the mass number and the radius and the mass number, average density, range of force, saturation property, stability curve, the concepts of packing fraction and binding energy, binding energy per nucleon vs. mass number graph, explanation of fusion and fission from the nature of the binding energy graph.
CLO2: Gain knowledge on basic concept of nuclear force and Meson theory of nuclear force
CLO3: Learn the basic aspects of nuclear reactions, the Q-value of such reaction and its derivation from conservation laws.
CLO4: Know about the liquid drop model, its justification so far as the nuclear properties are concerned, the semi-empirical mass formula.
CLO5: Know about the shell model, evidence of shell structure, magic numbers, predictions of ground state spin and parity, theoretical deduction of the shell structure, consistency of the shell structure with the Pauli exclusion principles.
CLO6: Learn about the process of radioactivity, the radioactive decay law, the emission of alpha, beta and gamma rays, the properties of the constituents of these rays and the mechanisms of the emissions of these rays, outlines of Gamow's theory of alpha decay and Pauli's theory of beta decay with the neutrino hypothesis, the electron capture, the fine structure of alpha particle spectrum, the Geiger-Nuttall law, the radioactive series.
CLO7: Learn about the principles and basic constructions of nuclear reactor and the reactor facilities available in India.
CLO8: Gain knowledge on the basic aspects of particle Physics – the fundamental interactions, elementary and composite particles, the classifications of particles: leptons, hadrons (baryons and mesons), quarks, gauge bosons. The students should know about the quantum numbers of particles: isospin, electric charge, strangeness, lepton numbers, baryon number and the conservation laws associated with them.
CLO9: Solve numerical problems, relating theoretical predictions and experimental measurements, in nuclear and particle physics.

Theory:

Unit I: **[10 h]**

1. **Basic Nuclear Properties** **[4 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. **Nuclear Reactions** **[3 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]

Unit II: **[15 h]**

1. **Radioactivity:** **[5 h]**
   Law of Radioactive Decay, Law of Successive Disintegration, Radioactive equilibrium, Radioactive series, Units of Radioactivity, Radioactive Dating.
   [Jain: 6.1-6.5] [Ilangovan: 2.8]

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]

Unit III: **[20 h]**

1. **Liquid drop model of a nucleus** **[6 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]

2. **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]

3. **Nuclear Energy** **[3 h]**
   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]

4. **Elementary Particle Physics** **[7 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]

Experiments:

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 Q-value of Nuclear Reaction
6. Tutorial on Radioactivity
7. Tutorial on Radioactive Decays
8. Tutorial on Nuclear Models
9. 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.

Web References:

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:

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

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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: Understand the fundamentals of materials science.
CLO2: Understand the properties and applications of materials.
CLO3: Investigate the relationship that exists between the structures and properties of materials.

Theory:

Unit I: **[10 h]**

1. **Structure of Crystalline Solids** **[10 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]

Unit II: **[15 h]**

1. **Imperfections in Solids** **[8h]**
   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]

2. **Diffusion** **[7h]**
   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: **[20 h]**

1. **Applications and Properties of Ceramics** **[13h]**
   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]
   Electrical properties of materials
   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. **Structures of Polymers** **[7h]**

   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]

Experiments: (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

Additional Reference:

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

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1. https://nptel.ac.in/courses/113/102/113102080/
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