Chowgule Education Society's

Parvatibai Chowgule College of Arts and Science

Autonomous

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Best Affiliated College-Goa University Silver Jubilee Year Award

DEPARTMENT OF PHYSICS

SYLLABUS

SEMESTER V AND VI

SEMESTER V

Course Title : **Electromagnetic Theory – II**

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

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

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

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

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

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

Theory:

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

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

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

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

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

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

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

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

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

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

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

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

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

Experiments: (Minimum Six)

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

References:

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

Additional Reference:

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

Web References:

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

Course Title : **Solid State Physics**

Course Code : **PHY-E9**

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

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

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

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

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

Theory:

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

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

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

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

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

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

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

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

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

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

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

Experiments: (Minimum Six)

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

References:

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

Additional References:

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

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.
CLO2: Comprehend concepts of thermodynamic potentials and their physical interpretation.
CLO3: Understand Maxwell-Boltzmann distribution law and its application to classical gas.
CLO4: Learn Bose-Einstein statistics and derive classical radiation laws of black body radiation.
CLO5: Comprehend Fermi-Dirac statistics and its application to the electrons in metals
CLO6: Understand the concept of Fermi energy and electronic contribution to specific heat of metals.
Theory

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

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

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

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

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

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

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

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

Experiments: (Minimum Six)

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

References:

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

Additional References:

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

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: Apply binary operations to different digital circuits
CLO5: Understand the clocked digital electronics and its applications in different types of Counters

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

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

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

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

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

Unit III **[20 h]**

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

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

2. Sequential Circuits [10 h]

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

Experiments (Minimum Six):

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

References :

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

Additional References:

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

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

Course Title : **Mathematical Physics**

Course Code : **PHY-E12**

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

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

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

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

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

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

Theory:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Experiments: (Minimum Six)

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

References:

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

Additional References:

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

Web References:

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

Course Title : Solid State Devices

Course Code : PHY-E6

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1(Practical)

Pre-requisite : Nil

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

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

Theory:

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

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

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

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

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

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

   [Theraja: Chapter 15]

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

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

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

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

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

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

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

Unit III: Field Effect Transistors [10 h]

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

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

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

   Bell: Chapter 8: 8-9]

Experiments: **(Minimum six)**

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

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

References:

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

Web References:

1. https://nptel.ac.in/courses/117106091/
2. https://www.elprocus.com/types-of-diodes-and-applications/
3. https://www.electronicshub.org/types-of-diodes/
4. https://www.electronicshub.org/thyristor-basics/
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SEMESTER VI

Course Title **: Atomic and Molecular Physics**

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

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

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

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

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

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

CLO1: solve the case of the hydrogen atom using the three-dimension time-independent Schrödinger equation, identify atomic effect such as space quantization and interpret the wave functions and probability densities.

CLO2: become familiar with the orbital, spin and total angular momentum of many electron atoms.

CLO3: explain the observed dependence of atomic spectral lines on externally applied magnetic fields.

CLO4: grasp the physics of diatomic molecules, their electronic states, vibrations and rotations and their spectra.

CLO5: comprehend classical and quantum theory of Raman effect.

CLO6: develop analytical and computing skills through problem solving, and computer-based exercises, which involve quantum mechanical systems such as the Harmonic oscillator, Hydrogen atom and Morse potential.

Theory:

Unit I: **[15 h]**

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

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

Unit II: [15 h]

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

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

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

Unit III: [15 h]

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

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

Experiments: (Minimum Six)

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

11. Double Refraction

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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.

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

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

Course Title : **Mechanics – II**

Course Code : **PHY-E13**

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

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

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

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

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

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

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

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

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

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

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

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

Theory

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

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

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

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

Moving Coordinate Systems [10 h]

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

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

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

The Rotation of a Rigid Body [10 h]

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

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

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

Unit III: Lagrangian Formulation [10 h]

Lagrangian Formulation [10 h]

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

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

List of Experiments: (Minimum Six)

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

References:

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

Additional Reference:

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

Web References:

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

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

Course Title : Nuclear and Elementary Particle Physics

Course Code : PHY-E14

Marks : 75 (Theory) + 25 (Practical)

Credits : 3 (Theory) + 1 (Practical)

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

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

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

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

CLO1: Learn the ground state properties of a nucleus.

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

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

CLO4: Learn the basic aspects of nuclear reactions

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

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

Theory:

Unit I: [20 h]

1. Basic Nuclear Properties [5 h]

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

[Jain: 1.1, 1.2, 3.1-3.9]

2. Nuclear forces [3 h]

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

[Patel: 8.6] [Ilangovan: 1.9]

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

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

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

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

4. Nuclear Shell Model [4 h]

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

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

Unit II: [15 h]

1. Nuclear Reactions [2 h]

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

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

2. Radioactive decay [10 h]

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

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

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

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

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

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

3. Nuclear Energy [3h]

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

[Patel: 6.1-6.5, 6.7-6.9]

Unit III: **[10 h]**

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

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

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

Practicals: (Minimum Six)

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

2. Determination of Absorption Coefficient using GM counter

3. Verification of Inverse Square Law using GM counter

4. Tutorial on Basic Properties of the Nucleus

5. Tutorial on Liquid Drop Model and Nuclear Shell Model

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

7. Tutorial on Nuclear Energy

8. Tutorial on Elementary Particle Physics

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

References:

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

Additional References:

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

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1. https://www.youtube.com/playlist?list=PLF15670EECA944A13
2. http://inside.mines.edu/~kleach/PHGN422/#
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7. https://www.youtube.com/tTDHS64wJkk
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Course Title : **Introduction to Special Theory of Relativity**

Course Code : **PHY-E15**

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

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

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

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

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

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

Theory

Unit I: **[20 h]**

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

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

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

Unit II: **[10 h]**

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

Unit III: **[15 h]**

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

Experiments: (Minimum Six)

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

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

Reference:

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

Additional References:

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

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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: Describe the different types of crystal structures of solid materials.
CLO2: Identify and describe the defects and imperfections in solids and their effects on the properties of materials.
CLO3: Apply the knowledge of electrical properties of materials to solve problems related to their applications.
CLO4: Understand diffusion mechanism and apply it to solve problems related to materials processing and analysis.
CLO5: Identify and describe the different types of ceramics and their applications.
CLO6: Understand the concept of polymers and their importance in various applications.

Theory:

Unit I: **[15 h]**

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

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

[Callister: 5.1 – 5.13]

Unit II: [15 h]

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

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

Unit III: [15 h]

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

Practicals: (Minimum Six)

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

References:

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

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