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DEPARTMENT OF PHYSICS AND ASTROPHYSICS
Semester-IV

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B. SC. (HONOURS) PHYSICS

DISCIPLINE SPECIFIC CORE COURSE – DSC - 10: MODERN PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Modern Physics DSC – 10	4	3	0	1	Class XII Pass with PCM	Studied ‘DSC- Light and Matter’ & Mathematical Physics-I, II & III

LEARNING OBJECTIVES

This course introduces modern development in Physics. Starting from Planck’s law, it develops the idea of probability interpretation and then discusses the formulation of Schrodinger equation and its applications to step potential and rectangular potential problems. This paper aims to provide knowledge about atomic physics, hydrogen atoms and X-rays. This paper covers the in-depth knowledge of lasers, its principle and working. It also introduces concepts of nuclear physics and accelerators.

LEARNING OUTCOMES

After getting exposure to this course, the following topics would be learnt.

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics. Heisenberg’s Uncertainty principle and its applications, photoelectric effect and Compton scattering.
- The Schrodinger equation in 1-dimension, wave function, probability and probability current densities, normalization, conditions for physical acceptability of wave functions, position and momentum operators and their expectation values, Commutator of position and momentum operators.
- Time independent Schrodinger equation, derivation by separation of variables, wave packets, particle in a box problem, energy levels. Reflection and transmission across a step and rectangular potential barrier.
- Modification in Bohr’s quantum model: Sommerfeld theory of elliptical orbits
- Hydrogen atom energy levels and spectra emission and absorption spectra.
- X-rays: their production and spectra: continuous and characteristic X-rays, Moseley Law.
- Lasers and their working principle, spontaneous and stimulated emissions and absorption, Einstein’s A and B coefficients, Metastable states, components of a laser and lasing action in He-Ne lasers and free electron laser.
- Basic properties of nuclei, nuclear binding energy, semi-empirical mass formula, nuclear force and meson theory. Radioactivity.
- Types of Accelerators, Van-de Graaff generator linear accelerator, cyclotron.

SYLLABUS OF DSC – 10

THEORY COMPONENT

Unit – I (9 Hours)

Origin of Quantum Theory: Black body radiation and failure of classical theory, Planck's quantum hypothesis, Planck's radiation law, quantitative treatment of photo-electric effect and Compton scattering, Heisenberg's uncertainty principle, Gamma ray microscope thought experiment, position - momentum uncertainty, consequences of uncertainty principle.

Unit – II (9 Hours)

The Schrodinger Equation: The Schrodinger equation in one dimension, statistical interpretation of wave function, probability and probability current densities. Normalization, conditions for physical acceptability of wave functions with examples, position and momentum operators and their expectation values. Commutator of position and momentum operators

Unit – III (9 Hours)

Time Independent Schrodinger Equation: Demonstration of separation of variable method for time independent Schrodinger equation: Free particle wave function, wave packets, application to energy eigen values and stationary states for particle in a box problem. Reflection and transmission across a step and rectangular potential barrier

Unit - IV (9 Hours)

Atomic Physics: Beyond the Bohr's Quantum Model: Sommerfeld theory of elliptical orbits; Hydrogen atom energy levels and spectra, emission and absorption spectra; Correspondence principle; X-rays: Method of production, Continuous and Characteristic X-rays, Moseley's law.

Lasers: Lifetime of excited states, natural and Doppler width of spectral lines, emission (spontaneous and stimulated) and absorption processes, Einstein's A and B coefficients, principle of detailed balancing, metastable states, components of a laser and lasing action, working principle of a 4 level laser, e.g. He-Ne lasers; qualitative idea of X-ray free electron lasers.

Unit - V (9 Hours)

Basic Properties of Nuclei: Introduction (notation, a basic idea about nuclear size, mass, angular momentum, spin, parity, isospin), N-Z graph, nuclear binding energy, semi-empirical mass formula, and basic idea about the nuclear force and meson theory.

Radioactivity: Law of radioactivity and secular equilibrium.

Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), linear accelerator, cyclotron (principle, construction, working, advantages and disadvantages), discovery of new elements of the periodic table

References:

Essential Readings:

- 1) Concepts of Modern Physics, A. Beiser, 2002, McGraw-Hill.
- 2) Modern Physics, R. A. Serway, C. J. Moses and C. A. Moyer, 2012, Thomson Brooks Cole, Cengage.
- 3) Schaum's Outline of Modern Physics, R. Gautreau and W. Savin, 2020, McGraw Hill LLC

- 4) Modern Physics for Scientists and Engineers, S. T. Thornton Rex, 4th edition, 2013, Cengage Learning.
- 5) Introduction to Modern Physics, F. K. Richtmyer, E. H. Kennard and J. N. Cooper, 2002, Tata McGraw Hill.
- 6) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010.
- 7) Learning Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill.
- 8) Modern Physics, R. Murugesan, S Chand & Co. Ltd.
- 9) Schaum's Outline of Beginning Physics II | Waves, electromagnetism, Optics and Modern Physics, Alvin Halpern, Erich Erlbach, McGraw Hill.
- 10) Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd edition, Tata McGraw-Hill Publishing Co. Ltd.
- 11) Quantum Physics, Berkeley Physics, Vol.4. E. H. Wichman, 1971, Tata McGraw-Hill
- 12) Quantum Mechanics: Theory and Applications, A. Ghatak and S. Lokanathan, 2004, Macmillan Publishers India Limited.
- 13) Introduction to Quantum Mechanics, D. J. Griffith, 2005, Pearson Education.
- 14) Concepts of nuclear physics, B. Cohen, 2003, McGraw-Hill Education.
- 15) Atomic Physics, Ghoshal, 2019, S. Chand Publishing House.
- 16) Atomic Physics, J. B. Rajam & foreword by Louis De Broglie, 2010, (S. Chand & Co.
- 17) Nuclear Physics, S. N. Ghoshal, S. Chand Publishers.
- 18) Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain, 2nd edition, Pearson
- 19) Atomic and Molecular Physics, Rajkumar, RBSA Publishers.
- 20) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer.
- 21) Introducing Nuclear Physics, K. S. Krane, 2008, Wiley India.

Additional Readings:

- 1) Basic Atomic & Molecular Spectroscopy, J. M. Hollas (Royal Society of Chemistry)
- 2) Molecular Spectra and Molecular Structure, G. Herzberg.
- 3) Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach (Series in Fundamental and Applied Nuclear Physics), K. Heyde (Institute of Physics Publishing Third Edition.
- 4) Nuclear Physics: Principles and applications, J. Lilley, 2006, Wiley.
- 5) Schaum's Outline of Modern Physics, 1999, McGraw-Hill Education.
- 6) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
- 7) The Fundamentals of Atomic and Molecular Physics (Undergraduate Lecture Notes in Physics), 2013, Springer.
- 8) Six Ideas that Shaped Physics: Particles Behave like Waves, T. A. Moore, 2003, McGraw Hill.
- 9) Thirty years that shook physics: The story of quantum theory, G. Gamow, Garden City, NY: Doubleday, 1966.

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

Mandatory activity:

- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab
- Familiarization with Schuster's focusing; determination of angle of prism.

At least five experiments to be performed from the following list

- 1) Measurement of Planck's constant using black body radiation and photo-detector
- 2) Photo-electric effect: photo current versus intensity and wavelength of light, maximum energy of photo-electrons versus frequency of light
- 3) To determine the work function of material of filament of directly heated vacuum diode.
- 4) To determine the Planck's constant using LEDs of at least 4 different colours.
- 5) To determine the wavelength of the H-alpha emission line of Hydrogen atoms.
- 6) To determine the ionization potential of mercury.
- 7) To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
- 8) To show the tunneling effect in tunnel diodes using I-V characteristics.
- 9) One innovative experiment designed by the teacher relevant to the syllabus.

References for laboratory work:

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal.
- 3) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th edition, reprinted, 1985, Heinemann Educational Publishers.
- 4) A Laboratory Manual of Physics for Undergraduate Classes, D. P. Khandelwal, 1985, Vani Publisher.
- 5) B.Sc. Practical Physics, H. Singh, S. Chand & Co Ltd.
- 6) B.Sc. Practical Physics, G. Sanon, R. Chand and Co.

DISCIPLINE SPECIFIC CORE COURSE – DSC - 11: SOLID STATE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Solid State Physics DSC – 11	4	3	0	1	Class XII Pass with PCM	Studied 'Thermal Physics, Electricity & Magnetism' and Mathematical Physics-I, II & III

LEARNING OBJECTIVES

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon the arrangement of its atomic and molecular constituents. The gained knowledge helps to solve problems in solid state physics using relevant mathematical tools. It also communicates the importance of solid- state physics in modern society.

LEARNING OUTCOMES

On successful completion of the module students should be able to,

- Elucidate the concept of lattice, crystals and symmetry operations
- Understand elementary lattice dynamics and its influence on the properties of materials
- Describe the origin of energy bands, and their influence on electronic behaviour
- Explain the origin of dia-, para-, and ferro-magnetic properties of solids
- Explain the origin of the dielectric properties exhibited by solids and the concept of polarizability
- Understand the basics of superconductivity
- In the laboratory students will carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity and the hall set up to determine the hall coefficient of a semiconductor

SYLLABUS OF DSC - 11

THEORY COMPONENT

Unit – I - Crystal Structure

(10 Hours)

Classification of solids as amorphous and crystalline materials, basic understanding of bonding in crystals, closed packed structure and packing fractions, lattice translation vectors, lattice with a basis, types of lattices, unit cell, symmetry elements, crystal planes and Miller indices, reciprocal lattice and Ewald's construction (geometrical), Brillouin Zones, Diffraction of X-rays: single crystal and powder method. Bragg's Law

Unit – II - Elementary band theory

(6 Hours)

Brief discussion on free electron model, success and failure of free electron model, Kronig-Penney model, band gap, direct and indirect band gap, effective mass, concept of mobility, Hall effect (Semiconductor).

Unit – III - Elementary Lattice Dynamics (10 Hours)

Lattice Vibrations and Phonons: Linear monoatomic and diatomic chains, acoustic and optical phonons, Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law

Unit – IV - Magnetic Properties of Matter (9 Hours)

Dia-, Para-, Ferri- and Ferromagnetic Materials, Classical Langevin Theory of dia- and paramagnetism, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, Curie's law, B-H Curve, hysteresis and energy loss, soft and hard material

Unit – V - Dielectric Properties of Materials (7 Hours)

Polarization, local electric field in solids, depolarization field, electric susceptibility, polarizability, Clausius Mossotti equation, classical theory of electronic polarizability, AC electronic polarizability, normal and anomalous dispersion, complex dielectric constant, basic idea of ferroelectricity and PE Hysteresis loop.

Unit – VI – Superconductivity (3 Hours)

Experimental results, critical temperature, critical magnetic field, Meissner effect, Type I and type II superconductors

References:

Essential Readings:

- 1) Introduction to Solid State Physics, Charles Kittel, 8th edition, 2004, Wiley India Pvt. Ltd.
- 2) Elements of Solid State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India.
- 3) Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
- 4) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning.
- 5) Solid-state Physics, H. Ibach and H. Luth, 2009, Springer

Additional Readings:

- 1) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
- 2) Solid State Physics, R. John, 2014, McGraw Hill
- 3) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

- Sessions on the construction and use of specific measurement instruments and experimental apparatus used in the solid state physics laboratory, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the laboratory.

At least four experiments to be performed from the following list

- 1) Measurement of susceptibility of paramagnetic solution (Quinck's tube method).
- 2) To measure the magnetic susceptibility of solids.
- 3) To study the dielectric constant of a material/s (solid/liquid) as a function of temperature and frequency.
- 4) To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique.
- 5) To determine the refractive index of a dielectric material using SPR technique.
- 6) To study the PE Hysteresis loop of a ferroelectric crystal.
- 7) To draw the BH curve of iron (Fe) using solenoid and determine the energy loss from hysteresis loop.
- 8) To measure the resistivity of a semiconductor (Ge) with temperature (up to 150°C) by four-probe method and determine its band gap.
- 9) To determine the Hall coefficient of a semiconductor sample.
- 10) Analysis of X-ray diffraction data in terms of unit cell parameters and estimation of particle size.
- 11) To study magnetoresistance in a semiconductor with magnetic field

References for laboratory work:

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal
- 3) Elements of Solid State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India
- 4) Practical Physics, G. L. Squires, 4th edition, 2015, Cambridge University Press.
- 5) Practical Physics, C. L. Arora, 19th edition, 2015, S. Chand

DISCIPLINE SPECIFIC CORE COURSE – DSC - 12: ANALOG ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Analog Electronics DSC – 12	4	2	0	2	Class XII Pass with PCM	Studied ‘Electrical Circuit Analysis’

LEARNING OBJECTIVES

This course introduces the concept of semiconductor devices and their analog applications. It also emphasizes on understanding of amplifiers, oscillators, operational amplifier and their applications.

LEARNING OUTCOMES

At the end of this course, the following concepts will be learnt.

- To learn about diodes and its uses in rectification
- To gain an insight into working principle of photodiodes, solar cells, LED and zener diode as voltage regulator
- To gain an understanding of construction and working principle of bipolar junction transistors (BJTs), characteristics of different configurations, biasing and analysis of transistor amplifier
- To be able to design and understand use of different types of oscillators
- To learn the fundamentals of operation amplifiers and understand their operations to compare, add, or subtract two or more signals and to differentiate or integrate signals etc.

In the laboratory course, the students will be able to study characteristics of various diodes and BJT. They will be able to design amplifiers, and oscillators. Also different applications using Op-Amp will be designed.

SYLLABUS OF DSC - 12

THEORY COMPONENT

Unit – I - Two-terminal devices and their applications (5 Hours)

IV characteristics of a diode and its application as rectifier (half-wave and full wave rectifier), IV characteristics of a zener diode and its use as voltage regulator, principle, structure and characteristics of (1) LED, (2) Photodiode and (3) Solar Cell

Unit – II - Bipolar junction transistors (4 Hours)

n-p-n and p-n-p transistors, IV characteristics of CB and CE configurations, active, cut-off and saturation regions, current gains α and β , relations between α and β , physical mechanism of current flow

Unit – III – Amplifiers and sinusoidal oscillators (11 Hours)

Load line analysis of transistor, DC load line and Q-point, fixed bias and voltage divider bias,

transistor as 2-port network, h-parameter equivalent circuit of a transistor, analysis of a single-stage CE amplifier using hybrid model (input and output impedance, current and voltage gain)

Sinusoidal Oscillators: General idea of positive and negative feedback, Barkhausen's criterion for self-sustained oscillations, RC phase shift oscillator, determination of frequency, Hartley and Colpitts oscillators

Unit – IV - Operational Amplifiers (Black Box approach) (10 Hours)

Characteristics of an ideal and practical Op-Amp (IC 741), open-loop and closed-loop gain, frequency response, CMRR, slew rate and concept of virtual ground

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Comparator and Zero crossing detector (7) Wein bridge oscillator

References:

Essential Readings:

- 1) Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill
- 2) Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall
- 3) Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- 4) Microelectronic circuits, A. S. Sedra, K. C. Smith and A. N. Chandorkar, 6th edition, 2014, Oxford University Press.
- 5) Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd edition, 2002, Wiley India
- 6) Electronic Principles, A. Malvino, D. J. Bates, 7th edition, 2018, Tata Mc-Graw Hill Education.
- 7) Electronic Devices and circuit Theory, R. L. Boylestad and L. D. Nashelsky, 2009, Pearson

Additional Readings:

- 1) Learning Electronic Devices and circuits, S. Salivahanan and N. S. Kumar, 3rd edition, 2012, Tata Mc-Graw Hill
- 2) Microelectronic Circuits, M. H. Rashid, 2nd edition, Cengage Learning
- 3) Microelectronic Devices and Circuits, D. A. Bell, 5th edition, 2015, Oxford University Press
- 4) Basic Electronics: Principles and Applications, C. Saha, A. Halder and D. Ganguli, 1st edition, 2018, Cambridge University Press
- 5) Solid State Electronic Devices, B. G. Streetman and S. K. Banerjee, 6th edition, 2009, PHI

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

- Session on the construction and use of specific analogue devices and experimental apparatuses used in the lab, including necessary precautions
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

At least six experiments to be performed from the following list

- 1) To study the V-I characteristics of a Zener diode and its use as voltage regulator.
- 2) Study of V-I and power curves of solar cells, and find maximum power point and efficiency.
- 3) To study the characteristics of a Bipolar Junction Transistor in CE configuration.
- 4) To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
- 5) To design a Wien bridge oscillator for given frequency using an op-amp.
- 6) To design an inverting amplifier using Op-amp (741, 351) for dc voltage of given gain
- 7) To design inverting amplifier using Op-amp (741, 351) and study its frequency response
- 8) To design non-inverting amplifier using Op-amp (741, 351) and study frequency response
- 9) To add two dc voltages using Op-amp in inverting and non-inverting mode
- 10) To study the zero-crossing detector and comparator
- 11) To investigate the use of an op-amp as an integrator
- 12) To investigate the use of an op-amp as a differentiator.

References for laboratory work:

- 1) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino and M. A. Miller, 1994, Mc- Graw Hill
- 2) Student Manual for The Art of Electronics, T. C. Hayes and P. Horowitz