DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 10: 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 PHYSICS DSC 10	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Understanding of basic concepts of Physics

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 its atomic and molecular constituents. 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 its planes
- Understand the elementary lattice dynamics and its influence on the properties of materials
- Understanding about 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
- 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 PHYSICS DSC – 10

THEORY COMPONENT

Unit – I - Crystal Structure (10 Hours)

Solids: amorphous and crystalline materials, lattice translation vectors, lattice with a basis, unit cell, types of lattices, Miller indices, reciprocal lattice, Ewald's construction (geometrical approach), Brillouin zones, diffraction of X-rays by crystals. Bragg's law

Unit – II - Elementary Lattice Dynamics (6 Hours)

Lattice vibrations and phonons: linear monoatomic and diatomic chains, acoustical and optical phonons, Dulong and Petit's law, qualitative discussion of Einstein and Debye theories, T^3 law.

Unit – III - Elementary Band Theory **(5 Hours)**

Qualitative understanding of Kronig and Penny model (without derivation) and formation of bands in solids, concept of effective mass, Hall effect in semiconductor, Hall coefficient, application of Hall effect, basic introduction to superconductivity

Unit – IV - Magnetic Properties of Matter **(6 Hours)**

dia-, para-, and ferro- magnetic materials, classical Langevin theory of dia– and para-magnetism (no quantum mechanical treatment), qualitative discussion about Weiss's theory of ferromagnetism and formation of ferromagnetic domains, B-H curve hysteresis and energy loss

Unit – V - Dielectric Properties of Materials **(3 Hours)**

Polarization, local electric field in solids, electric susceptibility, polarizability, Clausius Mossoti equation, qualitative discussion about ferroelectricity and PE hysteresis loop

References:

Essential Readings:

1) Introduction to Solid State Physics, C. 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, L. 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, M. A. Wahab, 2011, Narosa Publications

Additional Readings:

1) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
2) Solid State Physics, R. John, 2014, McGraw Hill
3) Superconductivity: A Very short Introduction – Stephen J Blundell - Audiobook

PRACTICAL COMPONENT

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

At least six 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 determine the coupling coefficient of a piezoelectric crystal
4) To study the dielectric response of materials with frequency
5) To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique
6) To determine the refractive index of a dielectric layer using SPR technique
7) To study the PE Hysteresis loop of a ferroelectric crystal
8) To draw the BH curve of iron (Fe) using a solenoid and determine the energy loss from hysteresis loop
9) To measure the resistivity of a semiconductor (Ge) crystal with temperature (up to 150^{o} C) by four-probe method and determine its band gap
10) To determine the Hall coefficient of a semiconductor sample
11) Analysis of X-ray diffraction data in terms of unit cell parameters and estimation of particle size

12) Measurement of change in resistance of 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) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
3) Elements of Solid-State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India
4) An Advanced Course in Practical Physics, D. Chattopadhyay and P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5) Practical Physics, G. L. Squires, 4th edition, 2015
6) Practical Physics, C. L. Arora, 19th edition, 2015, S. Chand

Annexure-2

B. Sc. Physical Science (Electronics) Semester 6

DISCIPLINE SPECIFIC CORE COURSE – DSC-17 PRINCIPLES AND APPLICATIONS OF SEMICONDUCTOR TECHNOLOGY

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Principles and Applications of Semiconductor Technology DSC – 17	4	3	0	1	Class XII pass with Physics and Mathematics as main subjects	NIL

LEARNING OBJECTIVES

a) Understand the Fundamentals of Transducers including definition of transducers and understanding their role in converting one form of energy to another. Classify different types of transducers based on their operating principles and applications.

b) Learn About Micro-Electro-Mechanical Systems (MEMS): Explain the basic principles and working of MEMS devices. Understand the fabrication processes used in MEMS technology. Explore applications of MEMS in various fields such as sensors, actuators, and biomedical devices.

c) Explore Nano-Electro-Mechanical Systems (NEMS): Understand the principles behind NEMS technology and its evolution from MEMS. Discuss the unique challenges and advantages of NEMS. Investigate the applications of NEMS in advanced technological solutions.

d) Study Sensor Technology: Explain the working principles of various types of sensors (e.g., temperature, pressure, chemical, optical). Understand sensor characteristics such as sensitivity, range, accuracy, and response time. Explore the integration of sensors in modern electronic systems and IoT applications.

e) Analyze Energy Storage Systems: Understand the principles of energy storage technologies, including batteries, supercapacitors and fuel cells. Discuss the materials and design considerations for efficient energy storage. Explore the applications of energy storage systems in portable electronics, electric vehicles, and renewable energy systems.

f) Investigate Organic Electronics: Explain the basic concepts and materials used in organic electronics, including organic semiconductors and conductive polymers. Understand the fabrication techniques for organic electronic devices. Explore applications such as organic light-emitting diodes (OLEDs), organic solar cells, and flexible electronics.

By achieving these objectives, students will gain a comprehensive understanding of the principles and applications of transducers, MEMS & NEMS, sensors, energy storage systems, and organic electronics, equipping them with the skills needed for innovative research and development in these cutting-edge technologies

LEARNING OUTCOMES

Upon successful completion of this course the students will be able to:

a) Explain the Fundamentals of Transducers: Define transducers and describe their role in converting different forms of energy. Classify and distinguish various types of transducers based on their principles and applications.

b) Understand MEMS Technology: Explain the operating principles and fabrication processes of Micro-Electro-Mechanical Systems (MEMS). Identify and analyze applications of MEMS in sensors, actuators, and biomedical devices.

c) Explore NEMS Technology: Understand the principles and challenges associated with Nano-Electro-Mechanical Systems (NEMS). Discuss the advantages and applications of NEMS in advanced technological solutions.

d) Comprehend Sensor Technologies: Explain the working principles of various sensors, including temperature, pressure, chemical, and optical sensors. Analyze sensor characteristics such as sensitivity, range, accuracy, and response time. Integrate sensors into electronic systems and IoT applications.

e) Analyze Energy Storage Systems: Understand the principles behind different energy storage technologies, including batteries, supercapacitors, and fuel cells. Discuss the materials and design considerations for efficient energy storage solutions. Evaluate the applications of energy storage systems in portable electronics, electric vehicles, and renewable energy systems.

f) Understand Organic Electronics: Explain the basic concepts and materials used in organic electronics, including organic semiconductors and conductive polymers. Describe the

fabrication techniques for organic electronic devices. Explore applications such as organic light-emitting diodes (OLEDs), organic solar cells, and flexible electronics.

By achieving these outcomes, students will gain a comprehensive understanding and practical skills in transducers, MEMS & NEMS, sensors, energy storage systems, and organic electronics. They will be equipped to innovate and contribute to advancements in these cutting-edge technologies.

SYLLABUS OF DSC – 17

THEORY COMPONENT

Unit – 1 [14 lectures]

Basics of Transducers: Fundamentals of transducers, classification and general characteristics, displacement transducers, strain gauges, pressure and force transducers, transducers for biomedical applications (pulse / heart rate).

Basics of MEMS and NEMS: Introduction to design of MEMS and NEMS, Overview of Nano and Micro electromechanical Systems, Applications of MEMS (e.g. Micro-Cantilevers) and NEMS (e.g. Switches)

Unit – 2 [10 lectures]

Basics of Sensors: Difference between sensor, transmitter and transducer - Primary measuring elements - selection and characteristics: Range; resolution, Sensitivity, error, repeatability, linearity and accuracy. Classification of sensors: Physical, Chemical and Biological. Types of sensors: resistive, capacitive, inductive, electromagnetic, thermoelectric, piezoelectric, piezoresistive, photosensitive and electrochemical sensors

Unit - 3 **[7 lectures]**

Basics of Energy Storage: Electrochemical energy storage devices - EMF, reversible and irreversible cells, free energy, thermodynamic calculations of the capacity of a battery. Types of batteries - Primary (Non-Rechargeable) Batteries: Alkaline Batteries, Zinc-Carbon Batteries, Lithium Batteries, Silver Oxide Batteries. Secondary (Rechargeable) Batteries: Lead-Acid Batteries, Nickel-Cadmium (NiCd) Batteries, Nickel-Metal Hydride (NiMH) Batteries, Lithium-Ion (Li-ion) Batteries, Lithium Polymer (LiPo) Batteries, Sodium-Sulfur (NaS) Batteries

Unit - 4 **[14 lectures]**

Basics of Organic Electronics: Need for organic materials in the semiconductor industry

Structure of Conducting Polymers, π-Conjugation and doping, conformational changes, Types of Conducting Polymers – Polyacetylene (PA), Polypyrrole (PPy), Polyaniline (PANI)

Structure of an OLED, Hole Injection Layer (HIL), Hole Transport Layer (HTL), Emissive Layer (EML), Electron Transport Layer (ETL), Electron Injection Layer (EIL), Working Principle, Charge Injection, Charge Transport, Recombination, Light Emission

Introduction to Silicon based solar cells, thin film solar cells, Dye sensitized solar cell, Organic solar cell: Structure of an Organic Solar Cell, Substrate, Anode, Hole Transport Layer (HTL), Photoactive Layer, Donor and acceptor Material, Bulk hetero junction devices, Light Absorption, Exciton Diffusion, Charge Separation, Charge Transport, Charge Collection

PRACTICAL COMPONENT – 30 Hours

(Any 6 to be performed)

1. Study of High Precision Resistance Strain Gauge characteristics.
2. Study of Force Sensor characteristics.
3. Study of Piezoresistive Sensor characteristics.
4. Study of Piezoelectric Sensor characteristics.
5. Study of Pulse Sensor / Heart Rate Sensor characteristics.
6. Study of gas sensor characteristics.
7. Study of solar cell characteristics.
8. Study of photodiode characteristics.
9. Study of LIDAR characteristics

Texts/References:

1. Suganuma Katsuaki, Introduction to Printed Electronics, Springer, 2014.
2. Stergios Logothetidis, Handbook of Flexible Organic Electronics - Materials,Manufacturing, and Applications, 1st Ed., Woodhead Publishing, 2014.
3. Eugenio Cantatore, Applications of Organic and Printed Electronics: A Technology Enabled Revolution, Springer, 2012.
4. Wolfgang Brütting and Chihaya Adachi, Physics of Organic Semiconductors, 2ndEd., Wiley-VCH, 2012.
5. Anna Köhler and Heinz Bässler, Electronics Processes in Organic Semiconductors -An Introduction, 1st Ed., Wiley-VCH, 2015.
6. Wenping Hu, Organic Optoelectronics, 1st Ed., Wiley-VCH, 2013.
7. Sam-Shajing Sun and Larry R. Dalton, Introduction to Organic Electronic and Optoelectronic Materials and Devices, 2nd Ed., CRC Press, 2015.
8. Franky So, Organic Electronics: Materials, Processing, Devices, and Applications, CRC Press, 2010.

B.Sc. (Physical Sciences/Mathematical Sciences) Semester-VI with Mathematics as one of the Core Discipline

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 6 (Discipline A-6): PROBABILITY AND STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Probability and Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to:
- Make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- Render the students to several examples and exercises that blend their everyday experiences with their scientific interests to form the basis of data science.

Learning Outcomes: This course will enable the students to:
- Understand some basic concepts and terminology-population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots.
- Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential, and lognormal.
- Understand the remarkable fact that the empirical frequencies of so many natural populations, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem.
- Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

SYLLABUS OF DISCIPLINE A-6

UNIT-I: Descriptive Statistics, Probability, and Discrete Probability Distributions (15 hours)
Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem, and independent events; Discrete random variables & probability distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

UNIT-II: Continuous Probability Distributions (15 hours)

Continuous random variables, Probability density functions, Uniform distribution, Cumulative distribution functions and expected values, The normal, exponential, and lognormal distributions.

UNIT-III: Central Limit Theorem and Regression Analysis (15 hours)

Sampling distribution and standard error of the sample mean, Central Limit Theorem, and applications; Scatterplot of bivariate data, Regression line using principle of least squares, Estimation using the regression lines; Sample correlation coefficient and properties.

Practical (30 hours)

Software labs using Microsoft Excel or any other spreadsheet.

1) Presentation and analysis of data (univariate and bivariate) by frequency tables, descriptive statistics, stem-and-leaf plots, dotplots, histograms, boxplots, comparative boxplots, and probability plots ([1] Section 4.6).
2) Fitting of binomial, Poisson, and normal distributions.
3) Illustrating the Central Limit Theorem through Excel.
4) Fitting of regression line using the principle of least squares.
5) Computation of sample correlation coefficient.

Essential Reading

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2022.

Suggestive Reading

- Mood, A. M., Graybill, F. A., & Boes, D. C. (1974). Introduction to the Theory of Statistics (3rd ed.). Tata McGraw-Hill Pub. Co. Ltd. Reprinted 2017.