MSE3172: ELECTRONIC PROPERTIES OF SOLIDS

Effective Term
Semester B 2023/24

Part I Course Overview

Course Title
Electronic Properties of Solids

Subject Code
MSE - Materials Science and Engineering

Course Number
3172

Academic Unit
Materials Science and Engineering (MSE)

College/School
College of Engineering (EG)

Course Duration
One Semester

Credit Units
3

Level
B1, B2, B3, B4 - Bachelor's Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
(1) AP1201/PHY1201 General Physics I or equivalent *
(2) AP1202/PHY1202 General Physics II or equivalent and
(3) AP2102/MSE2102 Introduction to Materials Engineering

Precursors
MA1201 Calculus and Basic Linear Algebra II

Equivalent Courses
AP3172 Electronic Properties of Solids

Exclusive Courses
PHY3272 Introduction to Solid State Physics

Additional Information
* This pre-requisite requirement is waived for Advanced Standing I students (admitted in 2014/15 and thereafter) and Advanced Standing II students (admitted in 2013/14 and thereafter).

Part II Course Details

Abstract

This course is designed to provide students with a basic knowledge of the key concepts in solid state physics that are relevant to the understanding of electrical, optical, and magnetic properties of materials. This is a self-contained course which includes theoretical descriptions of crystal and electronic structure, lattice dynamics, electrical and optical properties of different materials (metals, semiconductors, dielectrics, magnetic materials and superconductors) based on classical and quantum physics principles. It also emphasizes on the relationship between basic physical principles and macroscopic properties of materials students will encounter in real life.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Demonstrate knowledge for crystal structures of solids, different physical mechanisms involved in crystal binding and lattice dynamics			x	
2	Formulate the problem of electrons in a periodic potential, examine its consequence on the band-structure of solids and explain the physical properties of solids in terms of their band-structure			x	
3	Describe the behavior of solid matters and explain the underlying physical concepts based on solid state theory and principles.			x	
4	Apply physics principles and mathematical methods in solid state physics to explain various physical, electrical and optical properties of materials.			x	

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Teaching and Learning Activities (TLAs)

	TLAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lecture	Explain key concepts, such as crystal structure, electron theory and band structure. Distinguish various types of materials based on electron behaviors in crytal lattices.	1, 2, 3, 4	3 hrs/wk

2	Tutorial	Provide numerical examples and solutions of advanced problems in solid state physics and materials science, and help the students to understand them.	1, 2, 3, 4	1 hr/wk

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Three assignments	1, 2, 3, 4	15	
2	Mid-term test	1, 2, 3, 4	25	

Continuous Assessment (%)

40

Examination (%)

60

Examination Duration (Hours)

2

Additional Information for ATs

For a student to pass the course, at least 30% of the maximum mark for the examination must be obtained.

Assessment Rubrics (AR)

Assessment Task

1. Assignment

Criterion

showing a good understanding of the course materials by being able to solve numerical problems or deriving relevant equations

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not even reaching the marginal leave

Assessment Task

2. Midterm test

Criterion
able to solve common problems and demonstrate an understanding of the key concepts in electron theory

Excellent (A+, A, A-)
High

Good (B+, B, B-)
Significant

Fair (C+, C, C-)
Moderate

Marginal (D)
Basic

Failure (F)
Not even reaching the marginal leave

Assessment Task
3. Examination

Criterion
ability to grasp the concept of the taught materials and to solve common problems concerning the electronic, optical and magnetic properties of solids using electron theory, and explaining the basic structures and working principles of devices.

Excellent (A+, A, A-)
High

Good (B+, B, B-)
Significant

Fair (C+, C, C-)
Moderate

Marginal (D)
Basic

Failure (F)
Not even reaching the marginal leave

Part III Other Information

Keyword Syllabus

- Crystal structure and diffraction
  Primitive and conventional unit cells, Bravais lattice, basis, Miller Indices
  Diffraction, Bragg's law, structure factor, Reciprocal lattice and Brillouin zone.
- Lattice dynamics
  Elastic wave, lattice vibration, vibrational modes and phonons, 1D monatomic and diatomic chains, phonon dispersion curves, acoustic and optical branches, phase and group velocities
  Specific heat, Dulong-Petit model, Einstein model, Debye model, thermal conductivity.
- Fundamentals of electron theory:

Atomic model. The wave-particle duality, The Schrödinger equation and its solution, Energy bands in crystals, Electrons in a crystal, metal, insulator and semiconductors, Fermi surfaces

- Free electron gas
  Drude model, Density of states, Fermi-Dirac distribution and Fermi level, electrical conductivity from free electron gas. Electronic specific heat, thermal conductivity due to free electron in metal.
- Semiconductors Electrons and holes. intrinsic and extrinsic, doping n and p-types semiconductors, donors and acceptors, the Hall effect, optical processes
  p-n junction, drift and diffusion currents, depletion region, built-in potential
- Dielectric properties of solid
  Dielectric constant and polarization, dielectric constant, polarizability, Piezoelectricity, Ferroelectricity and their applications
- Magnetic properties of materials
  Magnetic phenomena and their interpretation. Quantum mechanical consideration. Superconductivity.

Reading List

Compulsory Readings

	Title
1	Nil

Additional Readings

	Title
1	(E-Book) Rolf E Hummel, “Electronic Properties of Materials”, 4rd Edition, Springer, New York, c2011 (QC176 .H86 2001).
2	S O Kasap, “Principles of Electronic Materials and Devices”, McGraw-Hill (TK453 .K26 2006)
3	C Kittel, “Introduction to Solid State Physics”, John Wiley & Sons Inc. 1996 (QC176 .K57).
4	Omar, “Elementary Solid State Physics”, Addison Wesley Publishing Company.
5	H. P. Myers, “Introductory Solid State Physics”, CRC Press.