

MSE3172: ELECTRONIC PROPERTIES OF SOLIDS

Effective Term

Semester B 2024/25

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 describe a basic knowledge of the key concepts in solid state physics that are relevant to the explanation of electrical, optical, and magnetic properties of materials. Student will engage in 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. Through this course students can explain 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 DEC-A1 app.)		DEC-A2	DEC-A3
1	Explain the knowledge for crystal structures of solids, different physical mechanisms involved in crystal binding and lattice dynamics			x	
2	Discuss the problem of electrons in a periodic potential, describe 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.

Learning and Teaching Activities (LTAs)

LTAs		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 crystal lattices.	1, 2, 3, 4	3 hrs/wk

2	Tutorial	Students will engage in tutorial actives including numerical examples and solutions of advanced problems in solid state physics and materials science, which help the students to explain the basic principles.	1, 2, 3, 4	1 hr/wk
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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	(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)

Additional Readings

Title	
1	C Kittel, “Introduction to Solid State Physics” , John Wiley & Sons Inc. 1996 (QC176 .K57).
2	Omar, “Elementary Solid State Physics” , Addison Wesley Publishing Company.
3	H. P. Myers, “Introductory Solid State Physics” , CRC Press.