MSE6265: QUANTUM THEORY OF SEMICONDUCTORS

Effective Term

Semester A 2025/26

Part I Course Overview

Course Title

Quantum Theory of Semiconductors

Subject Code

MSE - Materials Science and Engineering

Course Number

6265

Academic Unit

Materials Science and Engineering (MSE)

College/School

College of Engineering (EG)

Course Duration

One Semester

Credit Units

3

Level

P5, P6 - Postgraduate Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

Nil

Precursors

Nil

Equivalent Courses

AP6265 Emerging Semiconductor Devices in 21st Century (From the old curriculum)

Exclusive Courses

AP5265 Semiconductor Physics and Devices (From the old curriculum) , AP8265 Emerging Semiconductor Devices in 21st Century (From the old curriculum)

Part II Course Details

Abstract

This course introduces the quantum mechanics (QM) of semiconductors from theory to applications. It aims to facilitate students to develop a stronger fundamental background of semiconducting materials, and to provide guided examples on applying QM theories to understand materials properties.

The course covers the basic principles of QM, including wave-particles duality, energy quantization, uncertainty principle, postulations in QM, the Schrodinger wave equation, and hydrogen atom model. It is then followed by the discussion on particle-in-a-box problem to density-of-state in semiconductors, the crystal structure of semiconductors, the periodic structure to the origin of energy gap in semiconductors. The course also covers the carrier density and the carrier transport theory in semiconductors. Finally, we will discuss the application of QM on semiconductor devices such as p-n junction and Schottky junction and connect the theories with the fabrication of semiconductor materials and devices.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Master the fundamental principles and postulates of quantum mechanics, Schrodinger wave equation, and atomic orbitals of elements.	30		x	
2	Solve the particle-in-a-box problem to understand the quantum mechanical approximation.	10		x	
3	Explain the molecular orbital theory, the periodic crystal structure of semiconductors, and the origin of energy gap in semiconductors.	20	x	x	
4	Explain the intrinsic and extrinsic semiconductors and their transport property.	20	x	x	x
5	Develop theoretical connections between electronic device functionalities and fundamental properties of semiconductors as well as their fabrication processes.	20	x	x	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	Students will gain a conceptual overview of the basic principles of quantum mechanics and comprehensive understanding of their utilization in understanding semiconductor materials and devices.	1, 2, 3, 4, 5	26 hrs / 13 wks
2	Tutorials	Students will gain a deeper understanding on how to apply quantum mechanics to describe semiconducting behaviour and device properties.	1, 2, 3, 4, 5	13 hrs / 13 wks

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Midterm	1, 2, 3	40	-	No

Continuous Assessment (%)

40

Examination (%)

60

Examination Duration (Hours)

2

Assessment Rubrics (AR)

Assessment Task

Midterm (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Individual ability of problem solving; able to apply knowledge on differentiating different requirements and judging various technical issues of semiconductor devices.

Excellent

(A+, A, A-) High

Good

(B+, B, B-) Significant

Fair

(C+, C, C-) Moderate

Marginal

(D) Fair

Failure
(F) Not reaching marginal level

Assessment Task
Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Having an in-depth understanding on the selected semiconductor property, device working principle, limitations, and future development.

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not reaching marginal level

Assessment Task
Midterm (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Individual ability of problem solving; able to apply knowledge on differentiating different requirements and judging various technical issues of semiconductor devices.

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not reaching marginal level

Assessment Task
Examination (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Having an in-depth understanding on the selected semiconductor property, device working principle, limitations, and future development.

Excellent

(A+, A, A-) High

Good

(B+, B) Moderate

Marginal

(B-, C+, C) Basic

Failure

(F) Not reaching marginal level

Part III Other Information

Keyword Syllabus

- The fundamentals of quantum mechanics.
- Particle-in-a-box problem
- Schrodinger equation and atomic orbitals.
- Molecular orbital theory and band theory of solid.
- Intrinsic and extrinsic semiconductors.
- Carrier transport in semiconductors.
- Fabrication of semiconductors and devices.

Reading List

Compulsory Readings

	Title
1	S. M. Sze and Kwok K. Ng, "Physics of Semiconductor Physics (3rd)", Wiley, 2007
2	Donald A. Neamen, “Semiconductor physics and devices, 4/e”, McGraw-Hill

Additional Readings

	Title
1	Charles Kittel, "Introduction to Solid State Physics", Wiley