City University of Hong Kong
Course Syllabus

offered by Department of Materials Science and Engineering
with effect from Semester A 2023/24

Part I Course Overview

Course Title:	**Quantum Theory of Semiconductors**
Course Code:	**MSE6265**
Course Duration:	**One Semester**
Credit Units:	**3**
Level:	**P6**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Nil**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**AP6265 Emerging Semiconductor Devices in 21st Century (From the old curriculum)**
Exclusive Courses: *(Course Code and Title)*	**AP5265 Semiconductor Physics and Devices (From the old curriculum)** **AP8265 Emerging Semiconductor Devices in 21st Century (From the old curriculum)**

Part II Course Details

1. Abstract

(A 150-word description about the course)

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 new 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, hydrogen atom model, and mathematics of QM. 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, application of QM on several unique opto-electronic properties of emerging semiconducting nanomaterials, such as quantum dots, 2D materials, and organic semiconductors, will be discussed.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Understand the fundamental principles and postulates of quantum mechanics, and Schrodinger wave equation.	20%		√	
2.	Apply the quantum mechanical particle-in-a-box problem to understand the density-of-state in semiconductors	20%		√	
3.	Understand the periodic crystal structure of semiconductors and the origin of energy gap in semiconductors	20%		√	
4	Understand the control of carrier concentration and Carrier transport in semiconductors	20%			√
5	Develop theoretical connections between electronic and optoelectronic device functionalities applications and fundamental properties of semiconductors.	20%	√		
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

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 self-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.

3. Teaching and Learning Activities (TLAs)

(TLAs designed to facilitate students' achievement of the CILOs.)

TLA	Brief Description	CILO No.					Hours/week (if applicable)
		1	2	3	4	5	
1	Lectures	√	√	√	√	√	26 hrs / 13 wks
2	Tutorials	√	√		√		13 hrs / 13 wks

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.					Weighting*	Remarks
	1	2	3	4	5		
Continuous Assessment: 50%							
Assignments	√		√		√	30%	
Midterm	√	√	√			20%	
Examination (duration: 2 hours)	√	√	√	√	√	50%	
** The weightings should add up to 100%.*						100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted in Semester A 2022/23 and thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Assignment	Understand the physics of quantum mechanics in semiconductors.	High	Moderate	Basic	Not reaching marginal level
2. Midterm	Individual ability of problem solving; able to apply knowledge on differentiating different requirements and judging various technical issues of semiconductor devices.	High	Moderate	Basic	Not reaching marginal level
3. Examination	Having an in-depth understanding on the selected semiconductor property, device working principle, limitations, and future development.	High	Moderate	Basic	Not reaching marginal level

Applicable to students admitted before Semester A 2022/23

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignment	Understand the physics of quantum mechanics in semiconductors.	High	Significant	Moderate	Basic	Not reaching marginal level
2. Midterm	Individual ability of problem solving; able to apply knowledge on differentiating different requirements and judging various technical issues of semiconductor devices.	High	Significant	Moderate	Basic	Not reaching marginal level
3. Examination	Having an in-depth understanding on the semiconductor property, device working principle, limitations, and future development.	High	Significant	Moderate	Basic	Not reaching marginal level

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

(An indication of the key topics of the course.)

- The birth of quantum mechanics.
- The key concept and postulates in quantum mechanics.
- Mathematics in quantum mechanics
- Density of states and the origin of energy gap in semiconductors.
- Controlling the carrier concentration in semiconductor.
- Carrier transport in semiconductors.
- Quantum size effect, heterojunction, quantum well, Coulumb blockade effect, ballistic transport in emerging semiconducting nanomaterials.

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

1.	S. M. Sze and Kwok K. Ng, "Physics of Semiconductor Physics (3rd)", Wiley, 2007
2.	Serway, Moses, and Moyer, "Modern Physics", Sounders College Publishing

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

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