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:	**Structural Properties of Materials**
Course Code:	**MSE8020**
Course Duration:	**One semester**
Credit Units:	**3**
Level:	**R8**
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)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**Nil**

Part II Course Details

1. Abstract

This course aims to provide graduate students a solid foundation about the structural properties of materials. The structure of crystalline materials and imperfections (point defects, dislocations and grain boundaries) will first be introduced. Then, the idea will be emphasized that the structural characters determine the structural properties. Three types of structural properties will be discussed in details – elasticity, plasticity and fracture. Each of these structural properties will be derived based on the knowledge about material structure, physical assumptions and mathematical tools. To this end, necessary theories of continuum mechanics and micromechanics will be introduced. Upon completion of the course, students are expected to have an in-depth understanding of structure and structural properties of materials and be able to perform quantitative analysis in their research.

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 and use vector and tensor notations	10%		√	
2.	Understand and analyze deformation using linear elasticity	25%		√	√
3	Understand and analyze material plastic deformation and fracture processes	25%	√	√	√
4.	Understand the types of defects in crystalline materials (point defects, dislocations and grain boundaries) and analyze defect properties and their interactions	25%	√	√	
5.	Understand and analyze strengthening mechanisms in materials	15%		√	√
	** 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	
Lecture	Presentation on key concepts, theories and principles. Derivations and applications of theories	√	√	√	√	√	2 hrs/week
Tutorial and Group discussion	Discuss homework and additional problems	√	√	√	√	√	1 hrs/week

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%							
Homework	√	√	√	√	√	30%	
Midterm	√	√		√		20%	
Examination: 50% (duration: 2 hrs)	√	√	√	√	√	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. Homework	Ability to explain the basic concepts, carry out derivation of theory, perform quantitative analysis and apply theory/models in applications	High	Moderate	Basic	Not even reaching the marginal levels
2. Midterm	Ability to explain the basic concepts, carry out derivation of theory, perform quantitative analysis and apply theory/models in applications	High	Moderate	Basic	Not even reaching the marginal levels
3. Examination	Capability to perform quantitative analysis on stress-strain behaviours, defect properties and their interactions, strengthening and fracture behaviours of materials	High	Moderate	Basic	Not even reaching the marginal levels

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. Homework	Ability to explain the basic concepts, carry out derivation of theory, perform quantitative analysis and apply theory/models in applications	High	Significant	Moderate	Basic	Not even reaching the marginal levels
2. Midterm	Ability to explain the basic concepts, carry out derivation of theory, perform quantitative analysis and apply theory/models in applications	High	Significant	Moderate	Basic	Not even reaching the marginal levels
3. Examination	Capability to perform quantitative analysis on stress-strain behaviours, defect properties and their interactions, strengthening and fracture behaviours of materials	High	Significant	Moderate	Basic	Not even reaching the marginal levels

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.)

Part I Crystalline solids and imperfections
- Structure of crystalline materials
- Structure of point defects
- Structure of dislocations
- Structure of grain boundaries
- From structure to structural properties

Part II (Theoretical tools I) Basic continuum mechanics
- Vector and tensor (notation, algebra, analysis)
- Kinematics (deformation gradient, strain, velocity gradient)
- Mechanical and thermodynamical principles (mass balance, force and moment balance, stress, power balance, energy balance, entropy imbalance, free-energy imbalance)

Part III (Structural properties I) Elasticity
- Small deformation assumption
- Linear elasticity (Hooke's law, elastic constant for crystals, Navier's equation)
- Plane stress and plane strain problems

Part IV (Theoretical tools II) Basic micromechanics
- Elastic fields for an Eshelby's inclusion
- Inclusion energy, Eshelby's inhomogeneity

Part V (Structural properties II) Plasticity
- A single dislocation (elastic fields of a dislocation, Peach-Koehler force)
- Strengthening mechanism (strain hardening, general point defect-dislocation interaction, solute strengthening, precipitate strengthening, grain boundary strengthening)
- Crystal plasticity (slip systems, Schmid factor, continuum models for yielding)

Part VI (Structural properties III) Fracture
- Linear elastic fracture mechanics (crack energy, crack elastic fields, stress intensity factor, fracture toughness, energy release rate)
- Nonlinear fracture mechanics (J-integral, HRR field)

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	Lecture notes
2	Tutorial questions
3	Selected articles

2.2 Additional Readings

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

1	Crystals, Defects and Microstructures, R. Phillips, Cambridge University Press, 2004
2	An Introduction to Continuum Mechanics, J. N. Reddy, Cambridge University Press, 2007
3	The Mechanics and Thermodynamics of Continua, M. E. Gurtin, E. Fried and L. Anand, Cambridge University Press, 2010
4	Micromechanics of Defects in Solids, T. Mura, Martinus Nijhoff Publishers, 1987
5	Theory of Dislocations, P.M. Anderson, J.P. Hirth and J. Lothe, Cambridge University Press, 2017
6	Strengthening Mechanisms in Crystal Plasticity, A. Argon, Oxford University Press, 2007
7	Advanced Fracture Mechanics, M. F. Kanninen and C. H. Popelar, Oxford University Press, 1985