The Hong Kong University of Science and Technology
UG Course Syllabus

Course Title:	Introduction to Engineering Composite Materials
Course Code:	MECH-3400
Number of Credits:	3
Pre-requisites:	MECH 2040
Instructor:	Prof. Fan Shi
Email:	maefanshi@ust.edu.hk

Course Description

This course introduces the mechanics, design, manufacturing, inspection, and repair of modern composite materials. Emphasis is placed on fiber-reinforced lamina and laminate, with connections between constituent behavior, micromechanics, anisotropic elasticity, strength, material failure, defect inspection and engineering applications.

Students will use rule-of-mixtures concepts and analytical micromechanical models to estimate lamina properties from fiber and matrix mechanical properties. The course then develops the stiffness and compliance descriptions required for macromechanical analysis of anisotropic and specially orthotropic laminae, including stress and strain transformations. Strength prediction and failure modes are examined under representative loading conditions. The course also introduces common composite manufacturing routes and nondestructive evaluation (NDE) methods for detecting and characterizing defects and damage. Homework, a midterm examination, laboratory work, and an integrative final project provide opportunities to apply theory, interpret measurements, communicate technical results, and develop a practical composite design.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Apply mechanics principles to engineering composite materials and structures and calculate relevant mechanical properties.
2. Identify the properties of matrix and reinforcement materials, especially fibers, and explain manufacturing techniques of composite materials.
3. Analyse macromechanical properties of composite structures using anisotropic elastic properties.
4. Identify composite failure mechanisms under representative loading conditions.
5. Explain and select appropriate material testing and property-characterization techniques for composite components.
6. Explain the principles, capabilities, and limitations of nondestructive evaluation methods for composite materials.

Assessment and Grading

This course will be assessed using criterion-referencing. Student performance will be evaluated according to demonstrated achievement of the ILOs through homework, a midterm examination, laboratory work, and a final project. Task-specific instructions and marking schemes may further clarify the criteria below.

Assessment Task	Contribution to Overall Course Grade (%)	Due Date
Homework assignments	30%	Throughout the term
Midterm examination	20%	Midterm period
Laboratory work	10%	As scheduled
Final project: design, presentation, and report	40%	End of term

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
Homework assignments	ILO 1, ILO 2, ILO 3, ILO 4	Structured problems assess mechanics principles, constituent and manufacturing knowledge, micromechanical models, transformed lamina constitutive relations, strength/failure analysis and non-destructive evaluation practice. Solutions must show assumptions, units, and physical interpretation.
Midterm examination	ILO 1, ILO 2, ILO 3, ILO 4	The individual examination assesses foundational concepts and analytical fluency in material mechanics, constituent-to-lamina property prediction, and anisotropic analysis.
Laboratory work	ILO 5, ILO 6	Laboratory activities include manufacturing, mechanical testing and characterization practice, interpretation of inspection evidence, and understanding of the capabilities and limitations of NDE methods.
Final project: design, presentation, and report	ILO 2, ILO 3, ILO 4, ILO 5, ILO 6	The project integrates material selection, manufacturing, mechanics, failure, testing, inspection, and technical communication. Students justify assumptions, compare alternatives, interpret evidence, and present a coherent engineering solution.

Grading Rubrics

The following rubrics describe the general criteria used to assess the major components. More detailed task-specific marking schemes may be provided.

Rubric for Homework Assignments

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Conceptual understanding	Clear, accurate understanding; assumptions and limitations are explained.	Good understanding with minor omissions.	Adequate basics; some gaps or limited depth.	Limited understanding; explanations are incomplete.	Little or no relevant understanding.	ILO 1-3
Application of composite theory	Selects and applies appropriate models correctly and efficiently.	Appropriate methods with minor errors.	Standard methods applied to familiar problems; some procedural errors.	Relevant methods attempted with major errors or weak justification.	Fails to apply appropriate methods.	ILO 1-3
Mathematical accuracy and problem solving	Logical, correct solutions with units, notation, and checks.	Generally correct; minor algebraic or unit errors.	Partial correctness with notable errors.	Incomplete or major mathematical errors.	Largely absent, incorrect, or not submitted.	ILO 1-3
Physical interpretation	Explains trends, limiting cases, and engineering significance.	Reasonable interpretation; some detail missing.	Basic interpretation with weak links to mechanics.	Superficial or unsupported interpretation.	No meaningful interpretation.	ILO 1-3
Clarity of presentation	Clear, well organized, legible, and easy to follow.	Mostly clear and organized.	Understandable but uneven.	Poorly organized or difficult to follow.	Illegible, incoherent, or missing.	ILO 1-3

Rubric for Midterm Examination

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Composite basic knowledge and concepts	Thorough understanding of composite constituent phases, concepts, design principles and manufacturing technique	General understanding	Basic learning	Limited understanding	No understanding	ILO 1
Micromechanics	Correctly predicts lamina properties and justifies model assumptions.	Mostly correct with minor errors.	Applies basic models with some errors.	Limited ability; major errors.	Cannot apply basic models.	ILO 1
Anisotropic lamina analysis	Accurate constitutive and transformation analysis with sound reasoning.	Generally correct; minor omissions.	Basic analysis with partial correctness.	Incomplete or weak analysis.	No meaningful analysis.	ILO 2
Mathematical accuracy and communication	Work is accurate, logical, clearly structured, and uses proper notation and units.	Mostly clear and accurate.	Understandable but contains errors or omissions.	Poorly organized or substantially incorrect.	Absent, illegible, or unusable.	ILO 1-3

Rubric for Laboratory Work

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Observation and understanding of the demonstration	Demonstrates thorough understanding of the demonstrated procedure, observed phenomena, and their connection to composite-material concepts.	Demonstrates good understanding with only minor omissions.	Demonstrates basic understanding but misses some important connections.	Shows limited understanding of the demonstration or observed phenomena.	Shows little or no understanding of the demonstration.	ILO 5, ILO 6
Post-demonstration quiz: conceptual accuracy	Answers the quiz questions accurately and explains the relevant testing or NDE principles clearly.	Answers most questions correctly with minor conceptual errors.	Answers basic questions correctly but shows some conceptual gaps.	Answers few questions correctly and shows major misconceptions.	Provides mostly incorrect, missing, or irrelevant answers.	ILO 5, ILO 6
Interpretation and application	Correctly interprets the demonstrated results and applies the underlying principles to a related composite-material situation.	Provides a sound interpretation and reasonable application with minor omissions.	Provides a basic interpretation but application is limited or partly incorrect.	Provides a superficial interpretation with weak application.	Provides no meaningful interpretation or application.	ILO 5, ILO 6

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Clarity of quiz responses	Responses are concise, logical, technically precise, and use appropriate terminology.	Responses are clear and mostly precise.	Responses are understandable but uneven or incomplete.	Responses are unclear, poorly organized, or difficult to follow.	Responses are missing or unusable.	ILO 5, ILO 6

Rubric for Final Project

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Topic selection and scope	Selects a meaningful composite-material design or application topic and defines a clear, focused, and feasible scope with relevant objectives.	Selects a relevant topic with a clear scope and only minor omissions.	Selects an acceptable topic, but the scope or objectives need refinement.	Topic is weakly related, overly broad, or poorly defined.	No coherent or relevant project topic is established.	ILO 2-6
Independent exploration and technical depth	Demonstrates substantial self-directed exploration beyond class material and develops a deep, accurate understanding of the selected topic.	Demonstrates good independent exploration and technical understanding.	Demonstrates adequate exploration but relies heavily on basic course material or has limited depth.	Shows little independent exploration or major gaps in technical understanding.	Provides no meaningful exploration or technical understanding.	ILO 2-6
Application of composite-material knowledge	Integrates appropriate concepts in materials, manufacturing, mechanics, failure, testing, or NDE to address the selected design or application problem.	Applies relevant concepts appropriately with minor errors or omissions.	Applies basic concepts, but integration or justification is limited.	Application is superficial, substantially flawed, or weakly justified.	Fails to apply relevant composite-material knowledge.	ILO 2-6
Analysis, evidence, and engineering judgment	Uses reliable sources, data, calculations, or case evidence; compares alternatives and develops well-supported conclusions or recommendations.	Uses appropriate evidence and sound judgment with minor limitations.	Uses adequate evidence, but analysis, comparison, or conclusions are limited.	Evidence is weak or poorly connected to the conclusions.	Claims are unsupported or the analysis is unusable.	ILO 3-6
Group report and teamwork	The report is coherent, technically rigorous, well referenced, and professionally presented; team contributions are well coordinated and integrated.	The report is clear and technically sound; teamwork is generally effective.	The report is understandable but uneven; coordination or integration is limited.	The report is incomplete or poorly organized; teamwork is ineffective or contributions are fragmented.	The report is missing or unusable, or the group does not demonstrate meaningful collaboration.	ILO 2-6
Final presentation and response to questions	Delivers a clear, engaging, well-structured presentation; all members contribute appropriately and respond to questions accurately and thoughtfully.	Delivers a clear presentation with good team participation and mostly sound responses.	Presentation communicates the main work but is uneven; responses show basic understanding.	Presentation is unclear, poorly coordinated, or responses reveal major gaps.	Presentation is missing, incoherent, or the group cannot address basic questions.	ILO 2-6

Final Grade Descriptors

Grade	Short Description	Elaboration on Subject Grading Description
A	Excellent Performance	Comprehensive and accurate achievement of the course ILOs. Work demonstrates strong mechanics, sound engineering judgment, clear communication, and the ability to integrate design, strength, and inspection considerations.
B	Good Performance	Good achievement of the ILOs with mostly correct analysis and sound understanding. Minor errors or omissions do not undermine the overall solution.
C	Satisfactory Performance	Adequate achievement of core ILOs. Work can apply standard methods to familiar problems but may show gaps, errors, or limited integration and interpretation.
D	Marginal Pass	Minimum acceptable achievement. Understanding and analysis are uneven, with major gaps, but some essential course outcomes are demonstrated.
F	Fail	Insufficient achievement of the ILOs. Work lacks reliable application of core concepts, contains major conceptual or analytical errors, or does not demonstrate the required competencies.

Course AI Policy

Artificial intelligence (AI) tools may be used in this course for learning support, brainstorming, checking understanding, and improving writing clarity, unless an assessment instruction states otherwise. Students remain fully responsible for the accuracy, originality, reasoning, and integrity of all submitted work.

For homework, students should use their own knowledge to finish the homework. AI is not allowed.

During the midterm examination, the use of AI tools is not permitted unless explicitly authorized in the examination instructions.

Communication and Feedback

Course announcements, materials, assessment instructions, and marks will normally be communicated through Canvas. Feedback may include written comments, annotated solutions, rubrics, sample solutions, in-class or tutorial discussion, and verbal feedback during laboratory or project activities.

Students should direct questions about course content, assessment feedback, or marks to the instructor or teaching team within two weeks after the relevant feedback is released. The class and tutorial schedules will be announced through the official timetable and Canvas.

Late Submission Policy

To ensure fairness to students who submit work on time, late homework, laboratory reports, and project components will be subject to a penalty unless prior approval has been granted or valid supporting documentation is provided. Assessment-specific instructions take precedence where stated.

Required Texts and Materials

The main textbook for this course is:

- Engineering Mechanics of Composite Materials, I. M. Daniel and O. Ishai, 2nd edition, Oxford University Press, 2006.

Additional lecture notes, tutorial materials, laboratory instructions, datasets, software guidance, and project requirements will be provided through Canvas. Students should have access to a scientific calculator and suitable software for matrix calculations and technical reporting.

Academic Integrity

Students are expected to uphold HKUST's Academic Honor Code and maintain the highest standards of academic integrity. The University has zero tolerance for plagiarism, cheating, fabrication or falsification of data, unauthorized collaboration, and misrepresentation of work.

Discussion of course concepts and problem-solving strategies is encouraged when permitted, but submitted work must be the student's own unless an assessment is explicitly designated as group work. All sources, external assistance, and substantive AI use must be acknowledged appropriately.

Course Outline

1. Introduction to Composite Materials [Week 1]

- Definitions and classification of composite materials
- Engineering applications and performance analysis

2. Constituents, Types and Manufacturing [Week 2]

- Constituents: fibers, matrices, interfaces, and common material systems
- Overview of hand lay-up, molding, filament winding, pultrusion, and automated processes
- Material selection, sustainability, and design-for-manufacture considerations

3. Lamina Micromechanics [Weeks 3-4]

- Volume and mass fractions; density and constituent relations
- Rule of mixtures and parallel/series idealizations
- Halpin-Tsai and related semi-empirical models
- Prediction of effective longitudinal, transverse, and shear properties

4. Lamina Macromechanics [Weeks 5-7]

- Generalized stress-strain relations and material symmetry
- Stiffness and compliance matrices
- Orthotropic and transversely isotropic behavior
- Coordinate transformations for stress, strain, stiffness, and compliance
- Off-axis response of a unidirectional lamina

5. Lamina Strength and Failure [Weeks 8-9]

- Strength under longitudinal, transverse, and shear loading
- Failure modes and interaction effects
- Introductory maximum-stress, maximum-strain, and interactive failure criteria
- Interpretation and limitations of strength predictions

6. Composite Testing, Nondestructive Evaluation, and Structural Health Monitoring [Weeks 10-12]

- Mechanical testing and property characterization of composite materials
- Common manufacturing defects and in-service damage in composite structures
- Ultrasonic inspection principles, demonstration, and signal interpretation
- Overview of thermography, radiography, acoustic emission, and other NDE methods
- Damage characterization, method limitations, and implications for inspection and repair decisions

7. Final Project Presentations [Week 13]

- Group presentations on self-selected composite-material design or application topics
- Discussion, questions and answers, and peer learning across project topics