The Hong Kong University of Science and Technology

UG Course Syllabus

Course Title: Manufacturing Processes and Systems

Course Code: MECH 3710

Number of Credits: 3

Pre-requisites: MECH 2410

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Course Description

This course introduces the fundamental principles of manufacturing processes, from traditional metal cutting to advanced additive and micro-fabrication technologies. Building on prior knowledge of materials and mechanics, students will learn how engineering materials (metals, polymers, ceramics, composites) are shaped, joined, and surface-treated to produce functional components. The course covers: mechanical and physical properties of materials; theory of metal machining (orthogonal cutting, chip formation, forces, power, temperature, Merchant equation); non-traditional machining (EDM, ECM, laser, water jet, etc.); polymer shaping (extrusion, injection moulding, thermoforming, blow moulding); rapid prototyping and additive manufacturing (SL, SLS, FDM, 3DP, LOM); surface processing (cleaning, plating, conversion coatings, PVD, CVD); and integrated circuit processing (silicon growth, lithography, doping, metallisation, packaging). Economic considerations (machinability, tolerancing, cost optimisation) and design for manufacturing are integrated throughout.

A key feature of this course is the emphasis on developing analytical skills that go beyond routine problem-solving. Through structured assignments, students create multiple-choice questions that require judgment, analysis, and synthesis – not simple recall. This approach helps students cultivate the ability to critically evaluate outputs from automated reasoning systems and to maintain professional value in a changing technological landscape.

Intended Learning Outcomes (ILOs)

- 1. Apply the fundamental theories of metal machining (orthogonal cutting, Merchant equation, power and energy relationships) to estimate cutting forces, power, temperature, and optimal cutting conditions.
- 2. Select appropriate manufacturing processes (traditional machining, non-traditional machining, polymer shaping, additive manufacturing, surface processing, IC fabrication) for a given part geometry, material, production quantity, and quality requirements.

- 3. Explain the physical mechanisms underlying key manufacturing processes, including chip formation, material removal in EDM/ECM, polymer melt flow, layer-based additive manufacturing, and doping in semiconductors.
- 4. Account for the influence of material properties (mechanical, thermal, electrical) on process performance, including machinability, tool life, surface finish, shrinkage, and yield.
- 5. Perform basic economic analyses (cycle time, unit cost, optimisation of cutting speed for maximum production rate or minimum cost) and apply design for manufacturing guidelines to reduce cost and improve producibility.
- 6. Compare and contrast process capabilities, limitations, and trade-offs, including the differences between 2D and 3D shaping, net-shape vs. subtractive processes, and direct vs. indirect rapid tooling.
- 7. Ability to supervise analysis, evaluation, and decision making – demonstrating a level of understanding that exceeds routine factual recall.

Assessment and Grading

Assessment will be criterion-referenced. Grades will not be assigned using a curve. Student performance will be evaluated according to their demonstrated achievement of the intended learning outcomes (ILOs) via:

Assessment Task	Contribution (%)	Due Date	Mapped ILOs
Homework assignments (6)	20%	Throughout the term	ILO 1–7
Midterm examination	30%	Week 7 (2 hours)	ILO 1,3,4,5
Final examination	50%	Final exam period	ILO 1–6

Mapping of Course ILOs to Assessment Tasks

Assessment Task	Mapped ILOs	Explanation
Homework assignments (6)	ILO 1–7	Students complete assignments per topic (mechanical properties, physical properties, machining, shaping, RP, IC/surface processing). Each assignment requires test decision making analysis; students provide a rationale for their design choices.
Midterm examination	ILO 1,3,4,5	Covers mechanical/physical properties, machining theory, non-traditional processes. Includes analytical problems (Merchant equation, forces, power, temperature, process selection).
Final examination	ILO 1–6	Cumulative with emphasis on polymer shaping, RP/AM, surface processing, IC processing, economics, DFM. Includes calculation, short answer, and multiple-choice questions.

Grading Rubrics

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

Rubric for Homework Assignments (Question-Design Task)

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	ILOs
Mechanical/Physical properties questions	Correctly test stress-strain, hardness, thermal expansion, melting, electrical/electrochemical principles. Distractors capture common misconceptions.	Good coverage with minor errors.	Basic coverage, some inaccuracies.	Weak or incomplete.	No meaningful questions.	ILO 4,7
Machining theory questions	Correctly applies orthogonal cutting, Merchant equation, power/temperature. Requires analysis of chip formation, forces, or conditions.	Mostly correct, minor omissions.	Adequate but some errors.	Significant errors.	No valid questions.	ILO 1,3,7
Non-traditional/shaping/AM/surface/IC questions	Demonstrates deep understanding of process selection, mechanisms, material limitations, economic trade-offs. Distractors plausible but incorrect.	Good understanding, minor gaps.	Basic understanding, some errors.	Weak or incomplete.	No valid questions.	ILO 2,3,5, 6,7
Design sophistication	Incorporates elements that challenge automated problem-solving (e.g., absolute	Good use of such elements, likely to challenge typical	Some use of challenging elements, but may	Minimal use of challenging design.	No attempt to go beyond simple	ILO 7

	language, compound correct answers, hidden constraints, “none of the above” options).	systems.	not be consistently effective.		recall.	
Cognitive demand	All questions at Bloom level 4-5 (Analyze/Evaluate).	Most at level 4-5; one at level 3.	Mix of level 3-4; some level 2.	Predominantly level 2-3.	Recall only (level 1).	ILO 7
Clarity and rationale	Clear, correctly formatted; rationale explains design choices and the analytical skills tested.	Mostly clear, minor issues.	Adequate but lacking depth.	Poorly written or unclear.	Unclear or missing.	All ILOs

Rubric for Midterm Examination

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	ILOs
Mechanical properties analysis	Correctly interprets stress-strain curves, computes E, Y, TS, ductility, hardness.	Mostly correct, minor errors.	Adequate but some gaps.	Limited ability, significant errors.	Unable to analyse.	ILO 4
Physical properties applications	Correctly applies thermal expansion, specific heat, conductivity, diffusion, electrochemistry.	Good application, minor errors.	Adequate but lacks depth or some errors.	Weak or incomplete.	Fails to apply.	ILO 4
Machining theory	Accurately solves chip ratio, shear angle, forces, power, temperature.	Mostly correct, minor errors.	Basic competence, some errors.	Significant errors, incomplete.	No solution.	ILO 1,3
Non-traditional process selection & mechanisms	Selects appropriate process, explains mechanism, accounts for	Good selection, minor omissions.	Adequate but may miss key limitations.	Weak or incorrect.	Cannot select/explain.	ILO 2,3, 6

	limitations.					
Mathematical accuracy and clarity	Work logically structured, correct units, easy to follow.	Generally clear, minor errors.	Understandable but disorganised.	Poorly organised or hard to follow.	Illegible.	All ILOs

Rubric for Final Examination

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	ILOs
Machining economics and optimisation	Correctly computes cycle time, unit cost, optimal speed using Taylor equation.	Mostly correct, minor errors.	Adequate but with some errors.	Significant errors or incomplete.	Not attempted.	ILO 5
Shaping processes for plastics	Explains extrusion (Qd, Qb, die swell), injection moulding (shrinkage, ribs, draft, sink marks), thermoforming, blow moulding, distinguishes TP/TS.	Good explanation, minor omissions.	Basic understanding, some inaccuracies.	Limited or fragmented.	No understanding.	ILO 2,3,4
Rapid prototyping and additive manufacturing	Differentiates SL, SLS, FDM, 3DP, LOM; explains staircase effect, anisotropy, support structures, direct vs. indirect RTM.	Good differentiation, minor gaps.	Adequate but lacks depth or errors.	Weak distinction.	No meaningful comparison.	ILO 2,3,6
Surface processing operations	Selects appropriate cleaning, plating, conversion coating, PVD/CVD; explains mechanisms and limitations.	Good selection, minor omissions.	Adequate but may miss key constraints.	Weak or incorrect.	Unable to select/explain.	ILO 2,3,4
Integrated	Describes	Mostly	Adequate	Limited,	No	ILO

circuit processing	wafer prep, lithography, doping, metallisation, yields; applies yield model.	correct, minor errors.	but some gaps.	significant errors.	understanding.	2,3,4, 6
Design for manufacturing and material-process interactions	Applies DFM guidelines; accounts for property effects on manufacturability.	Good application, minor omissions.	Basic awareness, some errors.	Weak or incomplete.	No application.	ILO 4,5,6
Mathematical accuracy and physical interpretation	Solutions correct, well-organised, clear interpretation.	Generally correct, minor issues.	Adequate but some errors in interpretation.	Major errors or weak interpretation.	Incoherent or missing.	All ILOs

Final Grade Descriptors

Grade	Short Description	Elaboration
A	Excellent	Demonstrates excellent command of manufacturing principles. Applies machining theory, process selection, economics, and DFM accurately and insightfully. Designs consistently challenging, high-cognitive-demand questions. Clearly explains physical mechanisms and trade-offs. Work is accurate, well-organised, and shows strong engineering judgement.
B	Good	Demonstrates good understanding of main concepts. Applies most methods correctly, shows good ability to select processes and perform economic analyses. Designs mostly effective questions with good cognitive demand. Minor weaknesses in depth or precision.
C	Satisfactory	Adequate understanding of core concepts. Can apply standard methods to familiar problems. Designs questions with basic challenging elements and adequate cognitive demand. Some errors or gaps in reasoning, but achieves main learning outcomes at acceptable level.
D	Marginal Pass	Threshold understanding. Can attempt basic calculations and process

		selection. Designs questions with weak challenging features or low cognitive demand. Work may contain significant errors or incomplete reasoning.
F	Fail	Insufficient understanding. Unable to apply basic theories, select appropriate processes, or design effective analytical questions. Major conceptual and mathematical errors.

Course AI Policy

The use of artificial intelligence (AI) tools is permitted in this course for learning support, brainstorming, checking understanding, improving writing clarity, and assisting with coding or software-related tasks. However, students remain fully responsible for the accuracy, originality, and integrity of all submitted work.

For homework and project submissions, students may use AI tools to support their learning, but they must ensure that the final submitted work reflects their own understanding and reasoning. Students should not submit AI-generated solutions without verification, explanation, and independent judgement. Any use of AI that contributes substantively to submitted work should be acknowledged where appropriate.

During the final examination, the use of AI tools is not permitted

Communication and Feedback

Assessment marks for individual tasks will normally be communicated via Canvas within two weeks of submission. Feedback may include written comments, annotated solutions, marking rubrics, sample solutions, or verbal discussion during tutorials or office hours.

Homework feedback will focus on correctness, design sophistication, cognitive demand, and clarity of rationale. Midterm and final exam feedback will be provided through solution keys and, where appropriate, individual consultation.

Students who have questions about feedback or marks should contact the instructor or teaching team within two weeks after the feedback is released.

Late Submission Policy

To ensure fairness to students who submit work on time, late submissions for homework assignments will be subject to a penalty of 10% of the attained mark per day, unless prior approval has been granted by the instructor or valid supporting documentation is provided.

Required Texts and Materials

The main textbook for this course is:

Principles of Modern Manufacturing: Materials, Processes, and Systems, SI Version, Global Edition by Mikell P. Groover (ISBN: 978-1-119-24909-2)

Additional recommended (optional) references include:

- Materials Science and Technology: A Comprehensive Treatment / edited by R.W. Cahn, P. Haasen, E.J. Kramer, Weinheim, FDR : VCH, 1991

- Electroceramics : materials, properties, applications / A.J. Moulson and J.M. Herbert, Wiley, 2003

- Principles of polymer processing / Zehev Tadmor, Costas G. Gogos, Hoboken, N.J. : John Wiley . 2006

- Castings / John Campbell. Oxford : Butterworth Heinemann . 2003

- Joining: understanding the basics / edited by F.C. Campbell, Materials Park, Ohio : ASM International . . 2011

Other materials, including lecture slides, tutorial handouts, homework assignments, assignment guidelines, datasets, and software-related guidance, will be provided via Canvas.

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 academic misconduct, including plagiarism, cheating, fabrication of data, and misrepresentation of work.

Students may discuss course concepts, homework strategies, and project ideas with classmates, the instructor, and teaching assistants. However, submitted work must be the student's own unless a task is explicitly designated as group work. For project work, students must ensure that all data processing, analysis, interpretation, and writing are conducted honestly and that any external assistance is acknowledged where appropriate.

Students should refer to the HKUST Academic Registry for the University's definitions of academic misconduct and guidance on academic integrity.

Course Outline

Week(s)	Topic	Detailed Content	ILOs	Assignment
1	Introduction and Overview of Manufacturing	Definition, industries, production quantity/variety, manufacturing capability, materials classification, processing vs. assembly, production systems, cycle time and cost models; machinability, tolerances, surface finish, machining economics, product design guidelines	ILO 5,6	–
2	Mechanical Properties of	Stress-strain (tensile, compressive, shear),	ILO 4	Assignment 1 (5 questions)

	Materials	engineering vs. true stress/strain, elastic modulus, yield strength, tensile strength, ductility, strain hardening, flow curve; hardness (Brinell, Rockwell); temperature effects, recrystallisation, hot working; fluid viscosity, viscoelasticity		
3	Physical Properties of Materials	Density, thermal expansion (shrink fit, expansion fit), melting (solidus, liquidus, glass transition); specific heat, thermal conductivity, thermal diffusivity; mass diffusion (carburising, nitriding, doping); electrical properties (resistivity, conductivity, semiconductors); electrochemistry (electrolysis, Faraday's laws)	ILO 4	Assignment 2 (5 questions)
4–5	Theory of Metal Machining	Orthogonal cutting model, chip thickness ratio, shear plane angle, shear strain; chip types; forces (cutting, thrust, friction, shear); Merchant equation; power and energy (cutting power, specific energy); cutting temperature (Cook, Trigger)	ILO 1,3	Assignment 3 (5 questions)
6	Nontraditional Machining and Thermal Cutting	Mechanical (USM, WJC, AWJC, AJM, abrasive flow); electrochemical (ECM, ECD, ECG); thermal (EDM, wire EDM, EBM, LBM, PAC, air carbon arc, OFC); chemical (CHM, maskants, undercut)	ILO 2,3,6	–
7	Midterm Examination	Covers weeks 1-6	ILO 1,3,4,5	–
8	Shaping Processes for Plastics	Polymer melt behaviour (pseudoplastic, viscoelastic, die swell); extrusion; injection moulding (mould types,	ILO 2,3,4,6	Assignment 4 (5 questions)

		shrinkage compensation, ribs, draft, sink marks); thermoforming; blow moulding; compression/transfer moulding for thermosets; rotational moulding; calendering, blown-film, RIM		
9	Rapid Prototyping and Additive Manufacturing	Material addition vs. removal, CAD → STL → slicing; layer-forming modes; specific processes (SL, MPSL, SLS, 3DP, FDM, DDM, LOM); cycle time and cost equations; applications (design, analysis, tooling – direct/indirect RTM, parts production); problems (staircase effect, shrinkage, anisotropy, support structures)	ILO 2,3,5,6	Assignment 5 (5 questions)
10	Surface Processing Operations	Cleaning (alkaline, solvent, acid, pickling, ultrasonic, mechanical blast, shot peening, mass finishing); diffusion and ion implantation; plating (electroplating, electroforming, electroless, hot dipping); conversion coatings (phosphate, chromate, anodising); vapour deposition (PVD, CVD); organic coatings, porcelain enamelling, thermal spraying, hard facing	ILO 2,3,4,5	Assignment 6 (5 questions)
11–12	Integrated Circuit Processing	Silicon processing (EGS, Czochralski/float-zone, wafer slicing, polishing); lithography (photolithography, mask, photoresist, exposure techniques, EUV, e-beam, X-ray); layer processes (thermal oxidation, CVD, diffusion, ion implantation, metallisation, wet/dry	ILO 2,3,4,6	–

		etching); IC packaging (DIP, PGA, SMT, ceramic vs. plastic, hermetic sealing); yields (Yc, Ys, Yw, Ym, Yt, multiplicative model)		
13	Review and assignment debrief	Discussion of question-design strategies; review of common pitfalls; approaches to developing higher-order analytical skills	ILO 7	–
Final	Final Examination	Cumulative, covering all topics. Format includes multiple-choice, short answer, and extended problems.	ILO 1–6	–