

The Hong Kong University of Science and Technology

UG Course Syllabus

Course Title: Mathematical Methods for Civil Engineers

Course Code: CIVL 2035

No. of Credits: [3-1-0:3]

Pre-requisites: MATH 1014 OR MATH 1020 OR MATH 1024 (or a single-variable calculus course that includes integration)

Lectures: Mon & Wed, 10:30am - 11:50am Rm 5403, Lift 17-18 (134 seats)

Tutorials: Mon, noon - 12:50pm Rm 5403, Lift 17-18 (134 seats)

Instructor: Prof. Thomas W. C. Hu **Email:** thomashu@ust.hk

Office Hours: Wed, 3pm – 5pm Room 3585, Lift 27-28

Teaching Assistants:

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Course Description

This course provides a concise introduction to multivariable calculus, linear algebra, and differential equations with an emphasis on civil engineering applications. Main topics include vector operations, partial derivatives and gradients, maximum/minimum problems, line integrals, vector fields and potential functions; systems of linear equations, matrix algebra, determinants, eigenvalues and eigenvectors; first and second order ODEs, Fourier series, Delta functions, Green's functions (Duhamel integrals), and introduction to PDEs. Efficient computational and visualization tools such as graphing calculators and spreadsheets will also be introduced. For CIVL and CIEV students only.

Intended Learning Outcomes (ILOs)

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

1. Perform vector operations such as dot products and cross products, both by hand and using a graphing calculator, and explain the geometrical/physical meaning behind the computations.
2. Visualize functions of two variables, compute partial derivatives both by hand and using a graphing calculator, understand the meaning of directional derivatives, and solve problems involving maxima and minima.
3. Evaluate double and triple integrals, perform integration to obtain centroids, calculate area moments of inertia (/) through integration (for simple shapes) and using AutoCAD's MASSPROP function (for complicated shapes), and appreciate the physical significance of/in bending of beams.
4. Formulate linear equations in terms of matrices and obtain solutions via matrix algebra, both by hand and using Excel's matrix functions such as MMULT and MINVERSE.
5. Understand the eigenvalue problem, obtain eigenvalues and eigenvectors by hand, and by using numerical software when matrix size is large.

6. Perform line integrals and understand the concept of vector fields; construct potential functions in the context of elastic energy, generate stiffness matrices using repeated partial derivatives on the elastic energy, and utilize computer algebra systems to expedite such matrix assembly.
7. Solve first and second ODEs using various methods such as characteristic equations, Delta functions, Fourier series, Green's functions (Duhamel integrals) and computer software such as deSolve; understand the relation between ODEs and Newton's second law of motion.
8. Understand basic terminology of PDEs and recognize basic types of PDEs such as the wave equation, apply series method to solve selected PDEs arising in vibration theory, and visualize time behavior of solutions using a graphing calculator.

Assessment and Grading:

This course will be assessed using criterion-referencing and grades will not be assigned using a curve.

- 4 in-class quizzes (4×12% = 48%) on **Sep. 23, Oct. 14, Nov. 4 & 25 (10:30am - 11:50am lecture time)**
- 1 final exam (52%): time and venue TBC

September 1 ① 2 3 4 5 2 6 7 8 9 10 11 12 3 13 14 15 16 17 18 19 4 20 21 22 23 24 25 26 5 27 28 29 30 October 5 1 2 3 6 4 5 6 7 8 9 10 7 11 12 13 14 15 16 17 8 18 19 20 21 22 23 24 9 25 26 27 28 29 30 31 November 10 1 2 3 4 5 6 7 11 8 9 10 11 12 13 14 12 15 16 17 18 19 20 21 13 22 23 24 25 26 27 28 29 30	1 Commencement of the 2026-27 Academic Year 1 Fall Term commences 1-14 Add/Drop Period 15-29 Extended Drop Period – for PG courses only ○ Sep. 23, Oct. 14, Nov. 4, Nov. 25: Quizzes 1-4 to be held during lecture time. One additional room will be booked and announced. ○ Nov. 20 & 27: make-up lectures (at night, venue to be arranged) 30 Last day of Fall Term classes	26 The day following the Chinese Mid-Autumn Festival 1 National Day 19 The day following the Chung Yeung Festival
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* Assessment marks for individual assessed tasks will be released within two weeks of the assessment date.

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
Quiz 1	ILO1, ILO7	Quiz 1 assesses students' ability to perform vector algebra (dot/cross products) and interpret their geometrical/physical meaning (ILO 1). It also assesses students' ability to solve simple first and second order ODEs using various methods (ILO 7). These foundational skills are essential prerequisites for subsequent topics in structural mechanics.
Quiz 2	ILO7, ILO8	Quiz 2 assesses students' ability to apply more advanced ODE solution techniques (ILO 7), including Fourier series and

		Green's functions. It also assesses students' understanding of basic PDE terminology, recognition of the wave equation, and application of series methods to solve PDEs arising in vibration theory (ILO 8). This quiz bridges the gap between ordinary and partial differential equations.
Quiz 3	ILO2, ILO4	Quiz 3 assesses students' ability to formulate and solve linear systems using matrix algebra (ILO 4) for truss analysis problems. It also assesses students' ability to use partial derivatives (ILO 2) to extract matrix coefficients from statics equations. This integration of multivariable calculus and linear algebra reflects the mathematical foundations of finite element and matrix structural analysis methods.
Quiz 4	ILO4, ILO5, ILO6, ILO7	Quiz 4 assesses students' ability to apply potential energy principles and partial differentiation (ILO 6) to generate stiffness matrices (ILO 4), and perform eigenvalue analysis (ILO 5) to obtain natural frequencies of vibration (ILO 7). This quiz integrates multiple ILOs to reflect the complete process of dynamic structural analysis—from energy formulation to stiffness matrix assembly to modal analysis.
Final exam	All ILO's	The final examination is comprehensive and assesses all 8 ILOs. It tests students' ability to integrate and apply the full range of mathematical tools covered in the course—vectors, multivariable calculus, linear algebra, ODEs, and PDEs—to civil engineering problems. Topics include beam analysis and moment of inertia (ILO 3) and generalized functions for beam analysis (ILO 7), which will be taught as the last topics in CIVL 2035 because the relevant statics concepts are typically covered in the final weeks of CIVL 2110 students take concurrently. The comprehensive nature of the final ensures that students have synthesized all the mathematical methods necessary for subsequent engineering courses and professional practice.

Grading Rubrics

Detailed rubrics are provided below for each assessment task. These rubrics outline the criteria used for evaluation and are designed to be flexible enough to accommodate various question formats (multiple-choice, short-answer, computational exercises) while maintaining consistent standards across all assessments.

General Rubric for Quizzes and Final Examination

All assessments in this course are evaluated based on the following general criteria. Depending on the specific question format, these criteria may be applied to individual questions or to the assessment as a whole.

Criterion	Exemplary	Proficient	Developing	Beginning
Conceptual Understanding	Demonstrates a comprehensive and insightful grasp of the underlying	Demonstrates a solid understanding of core concepts. Can apply methods	Demonstrates adequate understanding of core concepts. Can apply methods to	Demonstrates limited understanding of core concepts. Struggles to

	mathematical concepts. Can explain not only the "how" but also the "why" of the methods used.	correctly and explain the rationale behind them.	familiar problems but may struggle with explanation or unfamiliar contexts.	identify appropriate methods or explain basic principles.
Problem-Solving & Method Selection	Consistently selects the most efficient and appropriate method for each problem. Demonstrates fluency in both hand computation and use of computational tools.	Selects appropriate methods for most problems. Computations are generally accurate with minor, non-critical errors.	Selects appropriate methods for routine problems. May make occasional errors in computation or method application but ultimately reaches reasonable solutions.	Frequently selects inappropriate methods or makes significant computational errors. Struggles to complete problems independently.
Computational Accuracy & Execution	Performs all computations with a high degree of precision. Demonstrates mastery of both hand calculations and software tools (graphing calculator, Excel, etc.) as applicable.	Performs computations accurately, with only minor errors that do not substantially affect the final result.	Performs computations with reasonable accuracy for routine problems. May make errors that occasionally affect the final answer but demonstrates understanding of the underlying process.	Computations are frequently inaccurate or incomplete. Demonstrates limited proficiency with required computational tools.
Engineering Application & Interpretation	Consistently and accurately translates engineering problems into appropriate mathematical formulations. Provides meaningful interpretation of results in the engineering context.	Translates most engineering problems correctly into mathematical form. Can interpret results with reasonable accuracy.	Can translate straightforward engineering problems into mathematical form. May need guidance for more complex applications. Interprets results at a basic level.	Struggles to connect mathematical methods to engineering applications. Unable to interpret results meaningfully.

Quiz 1 Rubric (ILOs 1 & 7 – Vector Algebra & Simple ODEs)

Criterion	Exemplary	Proficient	Developing	Beginning
Vector Algebra (ILO 1)	Accurately performs dot/cross products by hand and using calculators; provides clear and insightful	Accurately performs vector operations with minor errors; explains the meaning of	Performs basic vector operations correctly in most cases; explains	Makes significant errors in vector computations; unable to explain

	explanations of geometrical/physical meanings	computations correctly.	meaning at a basic level.	geometrical/physical meaning.
Simple ODEs (ILO 7)	Consistently selects appropriate methods; solves first and second order ODEs accurately; clearly understands the connection to Newton's 2nd law.	Solves ODEs accurately in most cases; selects appropriate methods for standard problems.	Solves ODEs for routine problems with occasional errors; demonstrates basic understanding of methods.	Struggles to solve basic ODEs; unable to select or apply appropriate methods.

Quiz 2 Rubric (ILOs 7 & 8 – Advanced ODEs & Basic PDEs)

Criterion	Exemplary	Proficient	Developing	Beginning
Advanced ODEs (ILO 7)	Applies Fourier series and Green's functions with fluency and accuracy to solve complex ODE problems.	Applies advanced ODE techniques correctly in most standard cases.	Applies techniques to routine problems with occasional errors; shows basic familiarity with the methods.	Struggles to apply advanced ODE techniques; unable to select the appropriate method.
Basic PDEs (ILO 8)	Correctly identifies PDE types; applies series methods accurately; visualizes and interprets solution behavior confidently.	Identifies basic PDE types correctly; applies series methods with reasonable accuracy.	Recognizes basic PDE terminology; applies series methods to routine problems with occasional errors.	Struggles to identify PDE types or apply series methods; unable to visualize solution behavior.

Quiz 3 Rubric (ILOs 2 & 4 – Matrix Methods & Partial Derivatives for Truss Analysis)

Criterion	Exemplary	Proficient	Developing	Beginning
Matrix Algebra for Truss Analysis (ILO 4)	Formulates and solves linear systems fluently; correctly assembles truss stiffness matrices	Solves linear systems accurately & can assemble truss stiffness in most cases	Solves basic linear systems correctly; follows matrix assembly procedures with guidance	Struggles with matrix formulation or solution; cannot assemble stiffness matrices
Partial Derivatives for Coefficient Extraction (ILO 2)	Accurately computes partial derivatives to build matrix from statics equations; shows deep understanding of the calculus–linear algebra connection.	Computes partial derivatives correctly in most cases to extract coefficients; understands the underlying relationship.	Computes basic partial derivatives for coefficient extraction with occasional errors; has a basic grasp of the calculus–linear algebra connection.	Struggles with partial derivative computations; unable to extract coefficients from statics equations.

Quiz 4 Rubric (ILOs 4, 5, 6 & 7 – Potential Energy, Stiffness Matrices & Eigenvalue Analysis)

Criterion	Exemplary	Proficient	Developing	Beginning
Potential Energy & Stiffness	Constructs potential functions and uses partial differentiation to	Constructs potential functions and stiffness matrices correctly in	Can follow stiffness matrix	Unable to construct potential

Matrices (ILOs 4, 6)	generate stiffness matrices with fluency; correctly assembles global stiffness matrices for structural systems.	most cases; understands the energy method conceptually.	generation procedures for standard problems; understands basic energy concepts.	functions or generate stiffness matrices; lacks understanding of energy methods.
Eigenvalue Analysis for Vibration Frequencies (ILOs 5, 7)	Obtains eigenvalues/eigenvectors accurately by hand and using numerical software; correctly interprets natural frequencies and mode shapes in structural vibration contexts.	Obtains eigenvalues/eigenvectors accurately in most cases; can use numerical software with guidance; understands basic vibration interpretation.	Solves basic eigenvalue problems; can use software for routine cases with some assistance; has basic awareness of vibration concepts.	Struggles with eigenvalue computations; unable to use numerical software effectively; cannot interpret vibration results.

Final Examination Rubric (All ILOs 1–8)

The final examination covers all ILOs (1–8). The following general rubric applies to the examination as a whole:

Criterion	Exemplary	Proficient	Developing	Beginning
Comprehensive Mathematical Proficiency	Demonstrates exceptional proficiency across all ILOs. Consistently selects appropriate methods, performs computations accurately, and provides meaningful interpretations in engineering contexts. Shows fluency with both hand calculations and computational tools.	Demonstrates solid proficiency across most ILOs. Handles standard problems confidently with only minor errors. Shows competence with computational tools.	Demonstrates adequate proficiency in core ILOs. Can solve routine problems but may struggle with more challenging or unfamiliar questions.	Demonstrates limited proficiency across multiple ILOs. Struggles with method selection, computation, or interpretation.
Integration of Methods	Seamlessly integrates knowledge from different areas (calculus, linear algebra, ODEs/PDEs) to solve comprehensive problems.	Integrates knowledge from different areas with reasonable success. Shows understanding of connections between topics.	Shows some ability to integrate knowledge from different areas but may need prompting to see connections.	Struggles to integrate knowledge across topics; addresses problems in isolation without recognizing broader connections.

Engineering Context Application	Consistently and accurately applies mathematical methods to civil engineering contexts; provides clear interpretations of results.	Applies methods to engineering contexts with general accuracy; provides reasonable interpretations.	Applies methods to straightforward engineering contexts; interpretations are basic but acceptable.	Struggles to apply mathematical methods to engineering contexts; interpretations are unclear or incorrect.
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Final Grade Descriptors:

Grades	Short Description	Elaboration on subject grading description
A	Excellent Performance	Demonstrates a comprehensive grasp of engineering math problems, fluent in problem-solving, and significant confidence in problem formulation. Exhibits a high capacity for scholarship, going beyond core requirements to achieve learning goals.
B	Good Performance	Shows good knowledge and understanding of engineering math, competence in problem-solving, and has the ability to analyze and evaluate issues.
C	Satisfactory Performance	Possesses adequate knowledge of engineering math, some competence in dealing with familiar problems, and some capacity for analysis and critical thinking.
D	Marginal Pass	Has threshold knowledge of engineering math, potential to achieve key professional skills, and the ability to make basic judgments. Benefits from the course and has the potential to develop in the discipline.
F	Fail	Demonstrates insufficient understanding of engineering math and lacks the necessary problem-solving skills. Shows limited ability to formulate engineering math problems and exhibits minimal effort towards achieving learning goals. Does not meet the threshold requirements for professional practice or development in the discipline.

Course AI Policy

No AI is allowed during assessment

Communication and Feedback

Assessment marks for individual assessed tasks will be communicated via Canvas within two weeks of submission. Students who have further questions about the grading should consult the instructor within five working days after the grading is released.

Recommended Texts and Materials

Main reference: Lecture notes by Prof. Hu

Other references:

W. E. Boyce, R. C. DiPrima and D. B. Meade, *Elementary Differential Equations and Boundary Value Problems*, Wiley.

D. C. Lay, S. R. Lay and J. J. McDonald, *Linear Algebra and its Applications*, Pearson.

E. Butkov, *Mathematical Physics*, Addison-Wesley.

Academic Integrity

Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST's Academic Honor Code and to maintain the highest standards of academic integrity. The University has zero tolerance of academic misconduct. Please refer to [Academic Integrity | HKUST – Academic Registry](#) for the University's definition of plagiarism and ways to avoid cheating and plagiarism.

Additional Resources

CAS (Computer Algebra System) calculators are used extensively for efficient ODE solving, vector and matrix algebra, numerical work and graphing. The first tutorial will be used to loan you the calculators (you must return the calculator to TAs at the end of final exam).