MMAE 350: Computational Mechanics

Spring 2026

Department of Mechanical, Materials, and Aerospace Engineering
Illinois Institute of Technology

Instructor Information

- **Instructor:** Dr. Michael Gosz
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- **Office Hours:** TBA
- **Class Meetings:** Tue, Thur (11:25am -12:40pm) Stuart Building 113

Prerequisites

MATH 251 (Multivariate and Vector Calculus), MATH 252 (Intro to Differential Equations), MMAE 202 (Mechanics of Solids II). Programming background recommended.

Textbook

M. Gosz, *Computational Mechanics: A Modern Introduction with Machine Learning and AWS Workflows*, 1st edition. Other resources and handouts will be posted on the course Canvas site.

Course Description

This course introduces computational methods used in mechanical and aerospace engineering, with an emphasis on numerical solution of engineering governing equations. Students develop computational fluency using Python and Jupyter notebooks, apply finite-difference, finite-volume, and introductory finite-element methods, and connect numerical algorithms to physical conservation laws in heat transfer, wave propagation, and transport phenomena.

Learning Objectives

Upon successful completion of this course, students will be able to:

1. Develop and execute engineering computations using Python, NumPy, SymPy, and Jupyter notebooks.
2. Formulate and solve systems of linear algebraic equations arising from discretized engineering problems.
3. Apply numerical root-finding techniques, including Newton's method, to nonlinear equations and systems encountered in engineering analysis.
4. Derive finite-difference approximations for spatial and temporal derivatives and implement them for transient and steady-state problems.
5. Analyze the stability and accuracy of explicit and implicit numerical schemes for time-dependent partial differential equations.
6. Solve one- and two-dimensional heat conduction problems using finite-difference methods and matrix-based solution strategies.
7. Model wave propagation in elastic solids using explicit time-marching finite-difference schemes.
8. Apply finite-volume concepts to conservation laws and implement numerical solutions of advection–diffusion equations.
9. Distinguish between strong and weak formulations of governing equations and construct simple finite element approximations for one-dimensional problems.
10. Interpret numerical results in the context of physical behavior, assess solution quality, and communicate computational findings clearly.

Topics Covered

1. Introduction to computational mechanics and engineering workflows using Python and Jupyter notebooks
2. Matrix and vector algebra for engineering applications
3. Numerical solution of nonlinear equations and systems using Newton's method
4. Direct and iterative methods for solving systems of linear algebraic equations
5. Governing equations of heat transfer, wave propagation, and transport phenomena
6. Finite-difference methods for steady and transient partial differential equations
7. Stability and accuracy analysis of time-marching numerical schemes

8. Finite-volume methods for conservation laws and advection–diffusion problems
9. Introduction to weak formulations and one-dimensional finite element methods

Computer Usage

Students will use Python Jupyter Notebooks to complete assignments.

Grading Policy

Student performance in this course will be evaluated using the following components:

- **Homework Assignments (30%)**
  Weekly or biweekly problem sets focused on analytical derivations, numerical methods, and short computational exercises.
- **Computational Notebooks and Labs (25%)**
  Jupyter notebook assignments emphasizing implementation of numerical algorithms, interpretation of results, and clear documentation of computational workflows.
- **Midterm Exams (20% total; 10% each)**
  Two in-class midterm exams, equally spaced throughout the semester, assessing conceptual understanding, mathematical formulation, and problem-solving skills for numerical methods covered up to each exam.
- **Final Exam or Final Project (25%)**
  A comprehensive assessment or project evaluating students' ability to integrate numerical methods, physical modeling, and computational implementation for an engineering problem.

Course Calendar — Spring 2026

Date	Day	Topic
Jan 13	Tue	Course overview; role of computation in engineering; Python, Jupyter, and course workflow
Jan 15	Thu	Arrays, vectors, and matrices in Python; numerical vs. symbolic computation
Jan 20	Tue	Matrix algebra for engineering systems; solving linear systems
Jan 22	Thu	Direct methods for linear systems: Gaussian elimination and LU decomposition
Jan 27	Tue	Matrix structure and sparsity; tridiagonal systems and the Thomas algorithm
Jan 29	Thu	Iterative solvers for linear systems; Gauss–Seidel method
Feb 03	Tue	Nonlinear equations of one variable; Newton's method
Feb 05	Thu	Newton's method for systems of equations; engineering examples
Feb 10	Tue	Applications of nonlinear systems; conditioning and convergence
Feb 12	Thu	Review and problem-solving session (Chapters 1–2)
Feb 17	Tue	Exam 1
Feb 19	Thu	Derivation of the heat equation; boundary and initial conditions
Feb 24	Tue	Finite-difference discretization of the 1D heat equation; FTCS method
Feb 26	Thu	Stability analysis; CFL condition; von Neumann analysis
Mar 03	Tue	Implicit time integration; Crank–Nicolson method
Mar 05	Thu	Matrix formulation of transient heat conduction problems
Mar 10	Tue	Two-dimensional heat conduction; five-point stencil
Mar 12	Thu	Steady vs. transient 2D heat conduction; computational examples
Mar 17	Tue	SPRING BREAK — No Class

Date	Day	Topic
Mar 19	Thu	SPRING BREAK — No Class
Mar 24	Tue	Wave propagation in elastic solids; 1D wave equation
Mar 26	Thu	Explicit time-marching schemes; stability and the CFL condition
Mar 31	Tue	Conservation laws and transport phenomena; integral vs. differential forms
Apr 02	Thu	Finite-volume discretization of the advection–diffusion equation
Apr 07	Tue	Upwind vs. central difference schemes; numerical diffusion
Apr 09	Thu	Weak formulations; introduction to finite element concepts
Apr 14	Tue	One-dimensional finite element method; shape functions and weak form
Apr 16	Thu	Assembly of the global system; solution and interpretation
Apr 21	Tue	Review for Exam 2
Apr 23	Thu	Exam 2
Apr 28	Tue	Computational project workshop; verification and validation
Apr 30	Thu	Course synthesis; comparison of FD, FV, and FEM methods
May 05	Tue	Final Exam or Project Presentations (Registrar-scheduled slot)
May 07	Thu	Final Exam or Project Presentations (Registrar-scheduled slot)

Course Policies

Attendance

Regular attendance is expected. Students are responsible for all material covered in class and all announcements made, regardless of attendance. Excessive unexcused absences may negatively impact your performance and grade.

Late Work

Assignments are due on the date and time specified. Late work will generally not be accepted unless prior arrangements are made with the instructor, or unless extraordinary circumstances can be documented. In such cases, partial credit may be given at the discretion of the instructor.

Academic Integrity

Illinois Tech expects all students to uphold the highest standards of academic honesty. Cheating, plagiarism, or any other form of academic dishonesty will not be tolerated. Violations will be reported and may result in failure of the assignment, failure of the course, and/or additional disciplinary action as outlined in the Illinois Tech Code of Conduct. For more information, see: `https://www.iit.edu/student-affairs/student-handbook`

Collaboration

Collaboration on homework assignments is permitted at the level of discussing concepts and approaches. However, all work turned in must be your own. Copying code, solutions, or written responses from another student or from online sources constitutes academic dishonesty.

Use of Technology

Students are encouraged to use Python, and other computational tools as required by the course. Any use of technology during quizzes or exams must be explicitly permitted by the instructor. Unauthorized use of technology during exams will be considered a violation of academic integrity.

Communication

Course announcements will be made in class and via email or the course LMS (Canvas). It is your responsibility to check email and the course site regularly. Email is the preferred method of communication outside of class hours.

Professional Conduct

Respectful behavior is expected in class, in labs, and in all course-related activities. Disruptive conduct will not be tolerated. Students should contribute to a learning environment that supports diversity of thought and experience.

Accessibility Statement

Illinois Tech is committed to providing an inclusive educational environment and making every effort to ensure equal access for all students. If you are a student with a documented disability and require reasonable academic accommodations, please contact the Center for Disability Resources (CDR) as soon as possible. Accommodations are determined on a case-by-case basis, considering the student's documented needs and the technical requirements of the course.

To request accommodations or learn more, contact:

- **Center for Disability Resources (CDR)**
  Phone: 312-567-5744
  Email: `disabilities@illinoistech.edu`

Students must submit documentation and meet with CDR to establish eligibility and receive an accommodation letter. Provide your letter to the instructor early in the semester to discuss appropriate implementation of accommodations.

For more information, visit: `https://www.iit.edu/cdr`

University Academic Calendar — Spring 2026

Date	**Event**
January 12	Spring Courses Begin
January 19	Martin Luther King, Jr. Day — No Classes
January 20	Last Day to Add/Drop for Full Semester Courses with No Tuition Charges
January 27	Last Day to Request Late Registration
March 13	Midterm Grades Due
March 16–21	Spring Break Week — No Classes
March 30	Last Day to Withdraw for Full Semester Courses
April 6	Fall Registration Begins
May 2	Last Day of Spring Courses
May 3	Last Day to Request an Incomplete Grade
May 4–9	Final Exam Week (Final Grading Begins May 4)
May 13	Final Grades Due at Noon (CST)