湖北工業大學
HUBEI UNIVERSITY OF TECHNOLOGY

Course Title	Computational Methods for Partial Differential Equations
Course Code	MATH 4641
Semester	Summer 2026
Course Length	4 Weeks, 60 Contact Hours
Credits	4
Instructor	TBA
Office	TBA
Email	TBA
Prerequisite	CMPT 1011 Introduction to Computer Science MATH 2151 Linear Algebra I MATH 2231 Multivariable Calculus MATH 2311 Differential Equations

Course Description:

This course provides an integrated introduction to the mathematical theory and numerical approximation of Partial Differential Equations (PDEs). PDEs serve as the fundamental language for describing phenomena in physics, engineering, and finance where change occurs across multiple variables. Since analytical solutions are often unavailable for complex models, this course emphasizes the development, analysis, and implementation of computational algorithms. Students will explore the derivation of classical models (elliptic, parabolic, and hyperbolic), the stability and convergence of finite difference methods, and Fourier-based analysis. Practical sessions involve using high-level programming to simulate and visualize phenomena such as heat diffusion, wave propagation, and fluid flow.

Course Goals:

Students who successfully complete this course will demonstrate competency in the following general education core goals:

- **Critical Thinking Skills** – Students will engage in analytical thinking, demonstrating the ability to critically evaluate, synthesize, and apply knowledge to complex problems, and construct well-reasoned solutions and arguments.
- **Independent Research and Inquiry** – Students will conduct independent research, utilizing academic resources to explore relevant topics, formulating research questions, analyzing data, and presenting findings in a coherent, scholarly manner.
- **Problem-Solving and Application** – Students will apply theoretical concepts and methodologies learned in the course to real-world problems, demonstrating the ability to develop practical solutions informed by academic inquiry.

- **Global and Cultural Awareness** – Students will gain awareness of the global and cultural contexts relevant to the course, appreciating diverse perspectives and considering the implications of their studies in a broader, international context.

Student Learning Outcomes:

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

- Derive fundamental PDEs from physical conservation laws and principles;
- Classify PDEs into elliptic, parabolic, and hyperbolic types and understand their distinct behaviors;
- Apply analytical tools such as separation of variables and Fourier analysis to understand solution properties;
- Implement finite difference schemes to approximate solutions to the Heat, Wave, and Poisson equations;
- Connect mathematical models to observable behaviors in applications like heat flow, electrostatics, and traffic dynamics.

Textbooks/Supplies/Materials/Equipment/ Technology or Technical Requirements:

Primary Textbook:
Randall J. LeVeque, *Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems* (SIAM, 2007).
Supplementary Textbooks:
Richard Haberman, *Applied Partial Differential Equations with Fourier Series and Boundary Value Problems* (Pearson, 2013).
Software Requirements:
MATLAB (preferred) or Python

Course Requirements:

Homework Assignments
Regular problem sets combine theoretical exercises (e.g., deriving schemes or proving stability) with short computational tasks (e.g., coding a simple solver and generating visualizations). These reinforce lecture concepts through hands-on practice.

Midterm Examination
An in-person closed-book written exam (180 minutes) covering foundational derivations, classification, finite-difference basics, and early applications. It evaluates conceptual understanding and the ability to apply analytical and numerical tools to straightforward problems.

Final Examination
A comprehensive in-person, closed-book written exam at semester's end that integrates all topics, with emphasis on hyperbolic models, stability analysis, and synthesis of analytical/numerical approaches. It assesses overall mastery and problem-solving across the full range of PDE types studied.

Computational Projects

Two extended projects (one mid-semester on elliptic/parabolic models, one later on hyperbolic/transport applications) require designing a solver, running simulations, analyzing results (including error and stability), and producing a report with visualizations.

Assessments: Activity	**Percent Contribution**
Homework Assignments	20%
Midterm Examination	20%
Final Examination	30%
Computational Projects (2)	30%, 15% of each

Grading:

Final grades will be based on the sum of all possible course points as noted above.

Grade	**Percentage of available points**
A	94-100
A-	90-93
B+	87-89
B	84-86
B-	80-83
C+	77-79
C	74-76
C-	70-73
D	64-69
D-	60-63
F	0-59

Course Schedule:

The schedule of activities is subject to change at the reasonable discretion of the instructor. Minor changes will be announced in class, major ones provided in writing.

	MATH 4641 Schedule	
Lecture	Topic	Readings
L1	Introduction to PDEs; derivation from physical principles (conservation laws)	LeVeque Ch. 1 & 2 (introductory sections)
L2	Classification of PDEs (elliptic, parabolic, hyperbolic)	LeVeque Ch. 2
L3	Finite-difference approximations: truncation error, basic operators	LeVeque Ch. 1
L4	Steady-state problems and boundary conditions	LeVeque Ch. 2
L5	Poisson equation discretization (Dirichlet/Neumann)	LeVeque Ch. 2
L6	Error analysis: local/global truncation, consistency, convergence	LeVeque Ch. 2
L7	Extension to general elliptic equations	LeVeque Ch. 3
L8	Iterative solvers for sparse linear systems	LeVeque Ch. 4
L9	Fourier analysis fundamentals and series expansion	Haberman Ch. 3
L10	Separation of variables and eigenvalue problems	Haberman Ch. 2
L11	Von Neumann stability analysis via Fourier modes	LeVeque Ch. 9
L12	Parabolic equations: heat/diffusion model	Haberman Ch. 1 & Ch. 2; LeVeque Ch. 9 intro
/	**Midterm Exam**	Covers L1-12

L13	Explicit finite-difference schemes for parabolic PDEs	LeVeque Ch. 9
L14	Implicit schemes and stability criteria	LeVeque Ch. 9
L15	Convergence and error estimates for diffusion problems	LeVeque Ch. 9
L16	Hyperbolic equations: transport/advection model	LeVeque Ch. 10
L17	Upwind schemes and CFL condition	LeVeque Ch. 10
L18	Numerical handling of advection-dominated flows	LeVeque Ch. 10
L19	Wave equation discretization and energy conservation	LeVeque Ch. 10-11
L20	Numerical dispersion and stability for waves	LeVeque Ch. 10-11
L21	Nonlinear extensions and shock formation **Project 1 due**	LeVeque Ch. 10
L22	Visualization techniques and application examples	LeVeque Ch. 2-11 (selected visualization examples)
L23	Conservation laws and entropy solutions overview	LeVeque Ch. 10
L24	Advanced topics: higher-order methods or multi-dimensional cases	LeVeque Ch. 3, 9-11 (selected extensions)
L25	Review, synthesis, and open applications **Project 2 due**	All chapters
/	**Final Exam (Cumulative)**	/

Accommodation Statement:

Academic accommodations may be made for any student who notifies the instructor of the need for an accommodation. It is imperative that you take the initiative to bring such needs to the instructor's attention, as he/she is not legally permitted to inquire. Students who may require assistance in emergency evacuations should contact the instructor as to the most appropriate procedures to follow.

Academic Integrity Statement

Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in coursework may receive a reduced or failing grade for the work in question and/or for the course.

Academic dishonesty includes, but is not limited to, dishonesty in quizzes, tests, or assignments; claiming credit for work not done or done by others; hindering the academic work of other students; misrepresenting academic or professional qualifications within or outside the University; and nondisclosure or misrepresentation in filling out applications or other University records.

Other Items:

Attendance and Expectations

All students are required to attend every class, except in cases of illness, serious family concerns, or other major problems. We expect that students will arrive on time, be prepared to listen and participate as appropriate, and stay for the duration of a meeting rather than drift in or out casually. In short, we anticipate that students will show professors and fellow students maximum consideration by minimizing the disturbances that cause interruptions in the learning process. This means that punctuality is a must, that cellular phones be turned off, and that courtesy is the guiding principle in all exchanges among students and faculty. You will be responsible for the materials and ideas presented in the lecture.

Assignment Due Dates
All written assignments must be turned in at the time specified. Late assignments will not be accepted unless prior information has been obtained from the instructor. If you believe you have extenuating circumstances, please contact the instructor as soon as possible.

Make-Up Work
The instructor will not provide students with class information or make-up assignments/quizzes/exams missed due to an unexcused absence. Absences will be excused and assignments/quizzes/exams may be made up only with written documentation of an authorized absence. Every effort should be made to avoid scheduling appointments during class. An excused student is responsible for requesting any missed information from the instructor and setting up any necessary appointments outside of class.

Access, Special Needs, and Disabilities
Please notify the instructor at the start of the semester if you have any documented disabilities, a medical issue, or any special circumstances that require attention, and the school will be happy to assist.