

Computational Problem Solving in Civil Engineering

CIVE 481/881 Spring 2026

Schedule and Location

Lecture: 3:00-4:15 p.m. Monday PKI 161 / Wednesday Kiewit Hall A549
January 12, 2026 – April 29, 2026
Final project due: 11:59 p.m. online, May 5, 2026
Office hour: MW 4:15 p.m. – 5:30 p.m. or by appointment

Instructor

Dr. Yumeng Zhao
Department of Civil and Environmental Engineering, UNL
Email: yzhao52@unl.edu; Office: PKI 204D

Course Prerequisite

MATH221 and CSCE155A or 155E or 155H or 155N

Textbook

Not required. Suggested reference books:

- [1] D'Ambrosio, Raffaele. Numerical approximation of Ordinary Differential Problems: From Deterministic to Stochastic Numerical Methods. Springer Nature, 2023.
- [2] Daniel J. Duffy. Numerical Methods in Computational Finance: A Partial Differential Equation (PDE/FDM) Approach. John Wiley & Sons, 2021.
- [3] Park, Kyung W et al., Applied Numerical Methods Using MATLAB. John Wiley & Sons, 2020.
- [4] Schafer, Michael. Computational Engineering – Introduction to Numerical Methods. Springer Nature, 2022.

Course Required Materials

Homework paper sheets and computers for coding and testing

Course Expectations and Rules Specific to Course

Attendance is required

Continuity of Instruction Policy

In the event an instructional continuity day is called by the University, students will be contacted via Canvas announcement and emails

Artificial Intelligence

The use of AI tools (e.g., ChatGPT) is **strictly prohibited** for writing the core logic of homework assignments. Submissions are subject to code-verification; if it is confirmed that the core code was AI-generated, the entire assignment will receive a grade of **zero**. However, students are **permitted and encouraged** to use AI tools for non-core tasks, such as generating code for visualization, and to generally enhance their learning experience.

Homework

Students are encouraged to discuss course topics in groups; however, all assignments must be completed independently and submitted on time. Unless otherwise noted, assignments are due at 11:59 p.m., 7 days after assigned. Each assignment must be submitted as a PDF file on Canvas. Late submissions will receive **zero credit** unless a prior arrangement is made at least 24 hours before the deadline. Plagiarism will not be tolerated. Refer to Student Code of Conduct at <https://studentconduct.unl.edu/university-nebraska-student-code-conduct-0/>.

Students should make their best efforts to solve all assigned problems. grades will be given based on your efforts, procedures (see above listed items), and understanding of concepts. Sketches and diagrams should be included in homework if it helps answer the questions.

For the coding part of the homework, any computer language (e.g. Python, MATLAB, C++) are allowed. Post figures and the entire code onto the homework answer sheets.

Exam

One mid-term exam is scheduled. Final exam is not planned. All students must take the mid-term exam in person. If any arrangement is needed due to medical reasons, please contact the instructor in advance. The exam will be in closed book/note format. Formulas and other necessary information will be provided on the question sheets.

Course Grading Policy

Homework 50%
Mid-term exam: 20%
Final project: 30%

Grading scale:

100 >= A+ > 97 > A >= 93 > A- > =90
90 > B+ > =87 > B = > 83 > B- => 80
80 > C+ > =77 > C > =73 > C- > =70
70 > D+ > =67 > D > =63 > D-> =60
60 > F >= 0

UNL Course Policies and Resources

Students are responsible for knowing the university policies and resources found on this page (<https://go.unl.edu/coursepolicies>):

- University-wide Attendance Policy
- Academic Honesty Policy
- Services for Students with Disabilities
- Mental Health and Well-Being Resources
- Final Exam Schedule
- Fifteenth Week Policy
- Emergency Procedures
- Diversity & Inclusiveness
- Title IX Policy
- Other Relevant University-Wide Policies

Lecture Schedule

Week	Day	Date	Topic
1	M	01/12	Introduction: discretization error/truncation/round-off
1	W	01/14	1 st order ODE #1: Euler-Forward/Backward/Centered
2	M	01/19	Martin Luther King Day, No Class
2	W	01/21	1 st order ODE #2: stability, consistency, convergence, Lax-Richtmeyer-Theorem
3	M	01/26	Systems of 1 st order ODEs #1
3	W	01/28	Systems of 1 st order ODEs #2 tridiagonal matrix inversion, Thomas algorithm
4	M	02/02	Systems of 1 st order ODEs #3 sparse matrix inversion, LU factorization
4	W	02/04	Systems of 1 st order ODEs #3 iterative solver, the Jacobi Method
5	M	02/09	Higher-order ODEs #1: Boundary conditions
5	W	02/11	Higher-order ODEs #2: Ruge-Kutta Method
6	M	02/16	Higher-order ODEs #3: Predictor-Corrector, Euler-Richardson method
6	W	02/18	1 st order PDE: advection equation
7	M	02/23	1 st order PDE: numerical diffusion in advection equation
7	W	02/25	Higher order PDE: diffusion equation
8	M	03/02	Advection-diffusion equation in commercial software
8	W	03/04	Systems of PDE #1: mass/momentum conservations
9	M	03/09	Systems of PDE #2: cavity flow
9	W	03/11	Midterm Exam
10	M	03/16	Spring Break, No Class
10	W	03/18	Spring Break, No Class
11	M	03/23	Introduction to FVM
11	W	03/25	Introduction to FEM
12	M	03/30	Introduction to SPH
12	W	04/01	Introduction to DEM
13	M	04/06	Statistical methods and Machine Learning overall
13	W	04/08	Monte Carlo Method, Decision Tree and Random Forest
14	M	04/13	Gaussian Processes
14	W	04/15	Neural Networks # 1: Theory
15	M	04/20	Neural Networks # 2: data-only tasks
15	W	04/22	Neural Networks # 3: NN for differential equations
16	M	04/27	Final Project Presentation #1
16	W	04/29	Final Project Presentation #2
			No Final Exam. Final Project Due Date 05/05

(The tentative syllabus is subject to change)

Final Project

Timeline

2/18: Each student should book a 1:1 meeting with the instructor no later than this date to discuss the initial idea of the course project;

3/25: submission of the finalized course project title and a brief outline of the tasks to be completed;

4/22: report progress of the course project;

04/27 & 04/29: project presentation (~20 minutes per project). Incomplete project at this point is allowed.

5/5: due date of the submission of the course project materials (presentation slides and report PDF) onto canvas (no later than 5/5 11:59 p.m.).

Graduate student project should be related to the student's research.

Each student should work on the project individually.

Final deliverables include slides, a presentation based on the slides and a project pdf file.

As a general rule, you should choose a modeling project that relies on solving fundamental equations of mathematical physics numerically in space and/or time. Start from formulization your equations. Then you want to discretize your equations and develop a computer program that solves the equations numerically. Any computer language is allowed.

It is desirable that the modeling be motivated by the need to understand a process or system. Thus, it is helpful to develop a model for a system for which you have existing real data. These data can be taken from any literature source, from something you have done in another course, or from a Web site that provides real data. The data do not have to pertain directly to the final model, but may instead be relevant to some intermediate step in your model (e.g., a steady-state solution).

Project Report Outline

1. Introduction

What is the main theme?

Why is it important?

What are the motivations for the study?

How is it currently being studied?

2. Modeling approach

What are the fundamental physical/chemical/etc. processes?

Include all relevant equations.

Describe all terms and parameters.

Describe all assumptions being made.

Describe the numerical methods used.

3. Results

What tests did you run with the model?

Describe the results.

How do the results compare with any analytical solution (if exist) you developed?

How do the results compare with those in literature?

How do the results compare to data that pertain to this process?

How can you explain any differences?

4. Conclusions

What did the model tell you about the process you were studying?

How could the model be improved?

5. References

Follow the format described in the next section

6. Appendix

Printout of model code with commentaries

Examples of Project Topics

- Structural Engineering

- Beam Deflection Analysis: Solving the Euler-Bernoulli beam equation (4th order ODE) using Finite Difference methods to predict deflection under non-uniform loads.
- Dynamic Response of Buildings: Simulating a multi-story building as a "shear frame" (System of ODEs) subjected to earthquake ground motion.
- Heat of Hydration in Concrete Dams: Modeling the 2D heat diffusion (PDE) in a massive concrete pour to predict thermal cracking risks.
- Truss Analysis Solver: Implementing a direct stiffness method solver using the numerical linear algebra techniques (Gaussian elimination/LU factorization).
- PINNs for Plate Bending: Using Physics-Informed Neural Networks to solve the Kirchhoff–Love plate theory equations for a simply supported plate.
- Geotechnical Engineering
 - 2D Soil Consolidation: Simulating the dissipation of excess pore water pressure over time using Terzaghi’s consolidation equation (Parabolic PDE / Diffusion equation).
 - Seepage Under a Dam: Solving Laplace’s equation (Steady-state PDE) to visualize flow nets and calculate uplift pressure using Finite Differences or FEM.
 - Pile Driving Dynamics: Modeling the propagation of stress waves down a pile using the 1D Wave Equation (Hyperbolic PDE).
 - Granular Flow on Slopes: Using the Discrete Element Method (DEM) concepts to simulate rockfall or dry sand avalanches.
 - Slope Stability Prediction: Using Decision Trees or Random Forests to classify slope stability based on input factors like angle, cohesion, and friction angle.
- Materials
 - Asphalt Temperature Modeling: Simulating heat transfer in pavement layers (Diffusion PDE) to predict freeze-thaw cycles and black ice formation.
- Hydraulics & Water Resources
 - Pollutant Transport in Rivers: Modeling a chemical spill using the 2D Advection-Diffusion equation to predict downstream concentration profiles.
 - Reservoir Routing: Using Runge-Kutta methods to solve the storage equation (ODE) for flood routing through a dam spillway.
 - Pipe Network Analysis: Solving the non-linear system of equations for flow distribution in a water supply network (Hardy Cross method equivalent) using iterative solvers (Newton-Raphson or Fixed Point).
 - Lid-Driven Cavity Flow: Implementing the classic CFD benchmark to simulate recirculating flow in a tank.
 - Shallow Water Equations: Simulating a 2D dam break or tidal wave propagation using a finite volume approach
- Environmental Engineering
 - BOD/DO Sag Curve: Modeling the oxygen deficit in a river downstream of a wastewater discharge using the coupled Streeter-Phelps equations (System of 1st order ODEs).
- Transportation Engineering
 - Traffic Flow Shockwaves: Modeling traffic density using the Lighthill-Whitham-Richards (LWR) model, which treats traffic as a fluid (Advection PDE/Conservation Law).
- Machine Learning Applications
 - Concrete Strength Prediction: Using Gaussian Processes or Random Forest to regress compressive strength based on mix design parameters (cement, water, aggregate, admixtures).

- Surrogate Modeling for Stress: Training a Neural Network to predict maximum stress in a bridge component based on variable load inputs, replacing expensive FEM simulations.