Syllabus for Geology 326: Numerical Modeling of Earth Systems

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45 Cramer Hall
Office Hours: Wed 1-2 PM
Fri 3-5 PM

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Office Hours Thurs 1-2 PM

Class times and locations:

Lectures:	8:30-9:50 AM	T/Th	Cramer S17
Labs:	10-11:50 AM	T/Th	Neuberger 437
	2-3:50 PM	T/Th	Neuberger 439

Overview: In this course we will cover theoretical and practical aspects of developing numerical models of geologic processes. Throughout the course we will motivate the discussion of numerical modeling with geologic observations, discuss relevant physical and chemical laws, translate conceptual models into well-posed mathematical problems, and use both analytic and numerical techniques to solve equations in order to gain insight into geologic processes. The laboratory portion of the course will involve programming in the MATLAB programming environment. Your grade will be based on weekly laboratory exercises, midterm and final exams, and a final project. The syllabus below provides a rough guide of what we will cover each week. **An up-to-date syllabus and copies of assignments will always be posted on this course's d2l page.**

Labs: The meeting times and locations are listed above. You are expected to attend lab unless you have already completed the week's assignment and turned in your writeup. Each week you will be assigned a lab partner at random. You will work together, taking turns as the "driver" and "navigator", switching roles at intervals determined by the instructor and TA. You will turn in a lab report collaboratively (i.e. one report per team).

Textbook: No textbook purchase is required. Selected readings will be posted on d2l. The Slingerland and Kump text is available as an electronic resource through the PSU library.

Additional Reading Selected from:

Slingerland and Kump. Numerical Modeling of Earth's Dynamical Systems.
Blanchard, Devaney, and Hall. Differential Equations. Brooks/Cole.
Gerya, T.V. Introduction to Numerical Geodynamic Modelling. Cambridge, 2010.
Fowler, Andrew. Mathematical Geoscience. Springer, 2011.
Leveque, Randall. Finite difference methods for ordinary and partial differential equations. SIAM, 2007.
Middleton, G.V. and Wilcock, P.R. Mechanics in the Earth and Environmental Sciences. Cambridge, 1994.

Academic Honesty: You are expected to collaborate during laboratory. However, whatever you hand in (either computer code or written work) must be your own intellectual product. Copying and pasting from internet sources without proper attribution in either code or writing will not be tolerated, and will result in a score of '0' and a mandatory meeting with the instructor and/or department chair. Any submitted work may be run through a plagiarism detector at the discretion of the instructor and TAs. Exams are individual opportunities to demonstrate your understanding. Giving and receiving aid are both forbidden in an exam setting and both activities have a minimum consequence of a grade of '0'.

Final Grade:

- 40% Lab assignments and problem sets
- 20% Midterm Exam
- 30% Final Exam and Project
- 10% Quizzes, attendance, and participation
- 5% Bonus (see note below)

Schedule:

Week	Dates	Topic	Lab	Reading
1	3/29, 3/31	Introduction, what is a model? How to make a good figure in MATLAB	Intro to MATLAB and Algorithms	SK: Ch. 1 MATLAB Style Guide and Intro (d2l)
2	4/5, 4/7	Zero dimensional/box models Solving Initial Value Problems (IVPs)	Radioactive decay, U-series dating	BDH 1.1-1.2 (d2l)
3	4/12, 4/14	Box Models and Conservation Laws Finite Differences for IVPs Linear Algebra refresher	Numerical solution of decay equation	SK: Ch. 2
4	4/19, 4/21	**Final Project Proposal Due 4/19** Predator-prey problem Systems of ODEs	Carbon cycle box model	SK: Ch. 3 Rothman PNAS paper
5	4/26, 4/28	**MIDTERM EXAM 4/26** Div, Grad, Laplace operators Heat Equation	Slopes, gradients, thinking about vector fields	F Lessons 1-5
6	5/3, 5/5	Steady Diffusion Equation Cylindrical/Spherical symmetry		SK: Ch. 4
7	5/10, 5/12	Evolution of planets Dealing with boundary conditions	Hillslope/Scarp Diffusion	
8	5/17, 5/19	Advection-diffusion equation Numerics for advection	Tracers in hydrology	SK Ch. 6-7
9	5/24, 5/26	Inverse problems	Inverse problem – Surface loading	TBA
10	5/31, 6/2	Wave equation, seismic waves **Final Project Due Monday, June 8, 5 PM**	**NO LAB TUESDAY – WORK ON PROJECTS** **LAB FINAL ON THURSDAY**	F Lessons 16-20
F		**FINAL PROJECT PRESENTATIONS DURING NORMAL EXAM TIME**		

SK = Slingerland and Kump, **F**=Farlow, **MW**=Middleton and Wilcock, **BDH**=Blanchard, Devaney and Hall

Logistics and Deadlines: The laboratory assignments will be distributed on Tuesdays at the beginning of lab. Your completed laboratory assignment must be submitted **through d2l** no later than 11:59 PM on the following Sunday. The assignments will be designed to be completed within the ~4 hours of laboratory time each week.

Late work policy: Late work will only be accepted if prior approval is obtained from the instructor. Except under special circumstances, a late work penalty of 20% will be applied.

Exams: Exams are an opportunity to develop individual mastery of concepts covered in the class. A list of learning objectives is provided on the next page. Exams will be closed book and closed notes, and may involve programming (i.e. writing MATLAB code on paper that would run without error and perform specified tasks), conceptual reasoning, quantitative problem solving, or recall of factual information from lectures and assigned readings.

Quizzes: Each week on Thursday there may be a short assessment at the beginning of lab. These cannot be made up, but I will drop your lowest score.

Final Project: You will be given a description of the final project requirements next week.

Extra Credit: Extra credit is for extra work. There will be opportunities to earn bonus points throughout the quarter. These get tallied in a separate bonus category on d2l and will only be applied to your final grade if you turn in all of the assignments.

It is the University's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please register with the Disability Resource Center (DRC) (503-725-4150 or drc@pdx.edu) in order to establish reasonable accommodations. Once you have registered with the DRC, please schedule a time to talk to me so that we can discuss your needs for the term.

Course Learning Objectives

Success in G326 should mean that you can:

1. Define a 'model' in the context of modeling Earth Systems
2. Define and apply a conservation law
3. Write statements of balance (or conservation) in words and mathematical symbols
4. Describe systems using box models
5. Characterize a differential equation
    a. Linear vs. non-linear
    b. ODE vs. PDE
    c. Parabolic, hyperbolic, elliptic
6. Solve simple first-order ordinary differential equations including:
    a. Decay equation
    b. Simple harmonic oscillator
7. Understand and apply basic concepts from linear algebra including matrix-vector multiplication, dot product, and solving linear systems using Gaussian elimination.
8. Understand and use Forward-, Backward-, and Centered-difference approximations to derivatives
9. Know some basic properties of Earth and Earth materials. Radius of Earth, densities of rocks, sediments, and water, thermal diffusivity of rock etc…
10. Write a computer program that uses Forward Euler or Backward Euler methods to solve an ODE
11. Solve the steady-state diffusion equation (aka Poisson equation) analytically
12. Write a computer program to solve the steady-state diffusion equation (Poisson equation)
13. Write a computer program to solve a time-dependent diffusion equation (Heat equation)
14. Define the relationship between diffusion length scales and time scales in time-dependent diffusion problems
15. Understand the concepts of advection and diffusion, and the terms in an advection-diffusion equation
16. Understand the significance of dimensionless numbers and define and use the Peclet number
17. Prepare a well-written laboratory report
18. Prepare figures suitable for publication or presentation in a talk or poster
19. Demonstrate mastery of simple built-in MATLAB commands including (but not limited to):
    a. =, +, -, ^, /,*, ==, <=, <, >=, >, |, ||, .*, .^, ./, \, :
    b. linspace, logspace, meshgrid
    c. size, length, reshape
    d. plot, scatter, quiver, contour/contourf, pcolor, colorbar
    e. if/else, for/end, do/end
20. Identify a few instances where mathematical or numerical models have significantly advanced our understanding of geologic processes.

I have received and read the syllabus for G326: Numerical Modeling of Earth Systems

Printed Name______________________________ **Signature** ________________________________

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