NE 155 - Introduction to Numerical Simulations in Radiation Transport
MWF 11:00 AM - 12:00 PM, Room: 285 Cory Hall

Instructor: Rachel Slaybaugh, 4173 Etcheverry Hall,
slaybaugh@berkeley.edu, 570-850-3385

Office Hours: 2:30-3:30 PM Fridays and by appointment.

Course Description: Computational methods used to analyze radiation transport described by various differential, integral, and integrodifferential equations. Numerical methods include finite difference, finite volume, discrete ordinates, and Monte Carlo. Examples from neutron and photon transport; numerical solutions of neutron/photon diffusion and transport equations.

Prerequisites: Math 53 and 54 (Eng 7 or basic programming skills strongly recommended)

References:

- Course notes + handouts: https://github.com/rachelslaybaugh/NE155
- Helpful Resources http://tinyurl.com/ne-technical-resources
- Free Python Ebooks that might fits your needs: http://www.leettips.org/2013/02/top-10-free-python-pdf-ebooks-download.html
- Jupyter (the awesome thing formerly known as iPython): http://jupyter.org/

Grading:

- Homework 40%
- Midterms (2) 15% + 15% = 30%
- Final Project 30%
- Late submissions: -20% for each day it is late with a maximum of -60%*

the Hacker Within:

- Wednesdays, 4-6 pm, 190 Doe Library (BIDS Space)
- Will teach skills useful for this course
- Website: http://thehackerwithin.github.io/berkeley/
- GitHub: https://github.com/thehackerwithin/berkeley

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*The point of this is to try to get you to always do the homework

Computer Information:

- All students will get class computer lab accounts at Davis Etcheverry Computing Facility (DECF) (1171 and 1111 Etcheverry): http://www.decf.berkeley.edu/
- A package with Python and many useful support libraries (called Anaconda) can be downloaded from http://continuum.io/downloads
- Software Carpentry has useful lessons: http://software-carpentry.org/lessons.html
- We may use the Serpent Monte Carlo code (http://montecarlo.vtt.fi/) in this course

Useful Campus Information:

- Mental health resources: http://www.uhs.berkeley.edu/students/counseling/cps.shtml
- Sexual assault support on campus: http://survivorsupport.berkeley.edu/

Course Outline:

1. Introduction
   (a) Overview of computational science/engineering
   (b) History of computing and parallelization
   (c) Types of differential and integral equations in radiation transport
   (d) Overview of numerical simulations: deterministic and probabilistic methods
2. Numerical analysis fundamentals
   (a) Vector and matrix properties
   (b) Eigenvalues and eigenvectors of a matrix; spectral radius of a matrix; convergence of vectors and matrices
   (c) Interpolation and polynomial approximation
   (d) Numerical differentiation and integration
   (e) Direct methods for solving linear systems; Gaussian elimination; pivoting strategies; techniques for special matrices
   (f) Iterative methods for solving linear systems: Jacobi, Gauss Seidel and SOR
3. Neutron diffusion equation in 1-D: numerical solution of 2nd order ODEs
   (a) Derivation of the transport and diffusion equations
   (b) Formulation of the finite difference and volume equations for the "fixed-source" problem
   (c) Direct solution by Gaussian elimination
   (d) Iterative solutions by Jacobi, Gauss Seidel, and SOR
   (e) Formulation of the finite difference and volume equations for the eigenvalue (criticality) problem
   (f) Power and inverse power iterative methods
   (g) Extension to 2-D

4. Point kinetics equation: numerical solution of initial value problem
   (a) Taylor method
   (b) RungeKutta method
   (c) Predictor-corrector methods
5. Probabilistic numerical simulations: Monte Carlo method
6. Neutron transport equation in 1-D: numerical solution of integro-differential equations

Academic Honesty: Berkeley's honor code is

> As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.

The University provides some basic guidance about academic integrity: http://sa.berkeley.edu/conduct/integrity. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. Questions related to course assignments and the academic honesty policy should be directed to me.

My policy is that you may work together on homework, *but you must specifically cite with whom you worked and what you did together*.

Extra Help: Do not hesitate to come to my office during office hours or by appointment to discuss a homework problem or any aspect of the course.

Attendance: Students are expected to attend classes regularly. A student who incurs an excessive number of absences may be withdrawn from this class at my discretion.

Other Policies: This course abides by the university policies for

- Accommodation of religious creed: http://registrar.berkeley.edu/DisplayMedia.aspx?ID=Religious%20Creed%20Policy.pdf
- Conflicts between extracurricular activities and academic requirements: http://academic-senate.berkeley.edu/sites/default/files/committees/cep/guidelines_acadschedconflicts_final_2014.pdf
- In case of illness please do not come to class if you have a fever or something highly contagious. Please attend if there is any chance you will pay attention and not get others sick: http://academic-senate.berkeley.edu/committees/coci/toolbox#16

Schedule: *Note that all dates are subject to change*

Lecture	Date	Topic	Assigned	Due
1	20-Jan	introduction	hw 1	
2	22-Jan	computing and parallelization		hw 1
3	25-Jan	types of equations		
4	27-Jan	transport equation		
5	29-Jan	transport equation	hw 2	
6	1-Feb	diffusion equation		
7	5-Feb	diffusion equation		
8	5-Feb	diffusion equation	hw 3	hw 2
9	8-Feb	interpolation		
10	10-Feb	interpolation cont'd; approximation		
11	12-Feb	numerical differentiation	hw 4	hw 3
-	15-Feb	*President's Day*		
12	17-Feb	numerical integration		
13	19-Feb	numerical integration		
14	22-Feb	vectors and matrices reviews		
15	24-Feb	1-D finite diff and vol intro	hw 5	hw 4
16	26-Feb	1-D finite vol for DE		
17	29-Feb	norms and convergence		
18	2-Mar	direct solvers		
19	4-Mar	iterative solvers		hw 5
20	7-Mar	catch up + exam review		
21	9-Mar	**Midterm 1 (through TE/DE)**		

Lecture	Date	Topic	Assigned	Due
22	11-Mar	1-D finite vol soln methods	hw 6	
23	14-Mar	eigenvalues review		
24	16-Mar	eigenvalue solvers		
25	18-Mar	FVM for 1-D eigenvalue		
-	21-25 Mar	*spring break*		
26	28-Mar	project planning, return midterm, FVM for 1-D eig	hw 7	hw 6
27	30-Mar	2-D finite vol for DE		
28	1-Apr	2-D finite vol for DE		
29	4-Apr	point kinetics		
30	6-Apr	Taylor and Runge Kutta		abstract
31	8-Apr	predictor-corrector methods	hw 8	hw 7
32	11-Apr	Monte Carlo intro		
33	13-Apr	MC probability and statistics		
34	15-Apr	MC random sampling		
35	18-Apr	MC tracking and collisions		interim report
36	20-Apr	MC tallies		hw 8
37	22-Apr	exam review, MC wrap up		
38	25-Apr	**Midterm 2 (through MC)**		
39	27-Apr	variance reduction		
40	29-Apr	review midterm 2, go over presentation/report expectations		
-	2-6 May	*RRR week*		
final	10-May	Final presentations, 7 to 10 pm		final reports