NE 255 - Numerical Simulation in Radiation Transport
Tu Th 11:00 AM - 12:30 PM, Room: 285 Cory Hall

Instructor: Rachel Slaybaugh, 4173 Etcheverry Hall,
slaybaugh@berkeley.edu, 570-850-3385
Office Hours: 2:30-3:30 PM Mondays and by appointment

Reader: Kelly Rowland, 4104 Etcheverry Hall
krowland@berkeley.edu
Reader Office Hours: 4:00-5:00 PM Thursdays and by appointment

Course Description: Computational methods used to analyze nuclear reactor systems described by various differential, integral, and integro-differential equations. Numerical methods include finite difference, finite elements, discrete ordinates, and Monte Carlo. Examples from neutron and photon transport, heat transfer, and thermal hydraulics. An overview of optimization techniques for solving the resulting discrete equations on vector and parallel computer systems.

Prerequisites: NE 150; basic programming skills

Grading:

- Take-home tests (6): 60% (lowest grade is dropped)
- Final project: 40%
- Late submissions: -20% for each day it is late with a maximum of -60%*
- Note: If something comes up, let me know *in advance* and I can work it out with you

References and resources:

- Class GitHub: https://github.com/rachelslaybaugh/NE255
- Helpful Resources http://tinyurl.com/ne-technical-resources
- Free Python Ebooks: 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/
- Software Carpentry: http://software-carpentry.org/lessons.html
- The Hacker Within: http://thehackerwithin.github.io/berkeley/
- Library: http://www.lib.berkeley.edu/node

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

- KAERI: http://atom.kaeri.re.kr/
- U.S. Nuclear Data http://www.nndc.bnl.gov/
- E. E. Lewis and W. E. Miller Jr., "Computational Methods of Neutron Transport," J. Wiley & Sons, New York (1993).
- J. J. Duderstadt and L. J. Hamilton, "Nuclear Reactor Analysis," Wiley (1976)
- Y. Y. Azmy and E. Sartori, Eds., "Nuclear Computational Science: A Century in Review," Springer (2010).
- J. Spanier and E. M. Gelbard, "Monte Carlo Principles and Neutron Transport Problems," Dover Publications, Inc., 2008 (Reprinted from 1969 edition).
- A. Hebert, "Applied Reactor Physics," Presses Internationales Polytechnique (2009).
- C. Pozrikidis, "Numerical Computation in Science and Engineering," Oxford University Press, NY (1998).

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
- We may use the Serpent Monte Carlo code (http://montecarlo.vtt.fi/) in this course
- License for MCNP6 is available through RSICC. Log onto the website at http://www-rsicc.ornl.gov. On the left hand portion of the homepage you will see a customer service tab. When you click on that link you will I think need to register and then you can request the software; indicate you are a student and it is for 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: (subject to change)

1. Introduction
   (a) Overview of computational science/engineering
   (b) History of computing and parallelization
   (c) An overview of advanced computer architectures; Vector and parallel processing
2. Types of equations in radiation transport
   (a) General types of differential and integral equations

   (b) Integro-differential form of transport equation
   (c) Integral form of transport equation
   (d) Diffusion approximation to transport equation
   (e) Time-dependent forms of transport equation
   (f) Computational Methods: Probabilistic and Deterministic

3. Numerical Methods for PDEs: Integro-Differential Form of Transport Equation
   (a) Time, energy, angle, and spatial discretization
   (b) Discrete-ordinates (Sn) methods in one spatial dimension (angular approximation, spatial differencing, iterative methods for solving discretized equations)
   (c) Multidimensional discrete ordinates (Sn) methods (angular quadrants, ray effects, streaming effects)
   (d) Discrete-ordinates computer codes; Optimization for vector and parallel processing
   (e) Spherical harmonics (Pn) method
   (f) Transport theory codes

4. Numerical Methods for ODEs
   (a) Numerical solution of the 1st order ODE: Initial value problems
   (b) Numerical solution of the 2nd order ODE: Finite difference method
      i. Formulation of the finite difference equations for the fixed source problem
      ii. Direct solution by Gaussian elimination
      iii. Iterative solutions by Jacobi, Gauss-Seidel, and SOR Methods
      iv. Krylov methods for iterative solution of linear systems
      v. Formulation of the finite difference equation for the eigenvalue (criticality)
      vi. Power and inverse power iterative method
   (c) Numerical solution of the 2nd order ODE: Finite element / Nodal methods
   (d) Diffusion equation in two or more dimensions
   (e) Diffusion theory codes
   (f) Applications of PARCS to the LWR and HTR

5. Integral Form of NTE: Collision Probability Method
   (a) Traditional collision probability method in one and two dimensions
   (b) Collision/transfer probability method in arbitrary 2D/3D geometries
   (c) Ray tracing in arbitrary geometry
   (d) Discrete integral transport
   (e) Interface coupling methods (interface-current, response matrices)
   (f) Optimization of integral transport methods for parallel processing

(g) CP codes: GTRAN2

6. Integral Form of NTE: Method of Characteristics (MOC)
   (a) Method of characteristics in two dimensions
   (b) Choice of Angles
   (c) Choice of boundary conditions
   (d) Ray tracing in arbitrary geometry for MOC
   (e) Linearly anisotropic scattering in MOC
   (f) Approximate methods for solving 3D MOC Problems
   (g) Coupled MOC/CFD
   (h) MOC Codes: MOCHA

7. Probabilistic Numerical Method: Monte Carlo
   (a) Random numbers; Probability density function; Cumulative PDFs
   (b) Analog Monte Carlo
   (c) Nonanalog Monte Carlo; Importance sampling; Variance reduction methods
   (d) Error estimates
   (e) Monte Carlo neutron and photon transport simulation
   (f) All-particle Monte Carlo simulation
   (g) Parallel Monte Carlo
   (h) Monte Carlo codes: MCNP, SERPENT

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