AME 480/580
Spring 2018

INTRODUCTION TO NUCLEAR ENGINEERING
FOR
MECHANICAL AND AEROSPACE ENGINEERS

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Course Text: *Fundamentals of Nuclear Reactor Physics* by E.E. Lewis

In case of emergency:

Leave Rm 336 in an orderly fashion
If safe reconvene on the NE corner of Helen and Mountain
If not safe seek shelter further North
Wait until role is taken

COURSE MOTIVATION

By any measure, nuclear energy will play a prominent role in the US energy policy as well as in the future prosperity of the nations around the world. The basic truth of this statement comes from the observation that energy use in the US and elsewhere is on the rise and closely ties to overall economic health. More importantly, however, is that the nuclear option is the only near-term option that does not directly pollute the atmosphere with CO_2 greenhouse gas (GhG). The lack of GhG emission is most significant with regard to reducing overall global atmospheric heating which is fast becoming increasingly detrimental to our biosphere. However, as with any energy source, there are still unresolved issues that may significantly affect future deployment of nuclear power. In particular, nuclear reactor safety is an issue because of the high levels of radiation involved contained within a nuclear reactor and, as recently witnessed at Fukusima, its unanticipated potential release to the environment. The primary task of the Department of Energy (DoE), the commercial nuclear power industry, the Nuclear Regulatory Commission (NRC) and, indirectly, universities is to provide safe nuclear energy by protecting the public from radiation release at all costs. This is also true regarding the safe storage of the highly radioactive spent fuel, which the US may or may not reprocess in the near or far future. In addition to the use of nuclear energy for power production, the generation of hydrogen as a secondary energy source from nuclear fission for the transportation sector is a very real possibility. In this way, mobile hydrogen fuel appears where needed. Thus, given all the future uses (including medical) of nuclear energy (and in spite of the Fukusima accident), nuclear power will be a part of the world's energy future.

For these reasons, it is appropriate to offer an introductory course in nuclear engineering presented in the AME Department to mechanical, aerospace and other interested engineering students. The course is given to seniors as a senior elective (AME480) and to graduates (AME580) and covers fundamental nuclear engineering principles through the study of nuclear and reactor physics, with emphasis on reactor design. Students will gain an overview of how a nuclear reactor works from the nuclear physics responsible for nuclear heat generation, to the heat removal of the energy released in nuclear fission.

The main motivation for presenting this course is to provide engineering students with a modest competitive edge when it comes to jobs in the nuclear field; after all, the primary engineer hired to service the ~100 operating nuclear power plants in the US is a mechanical engineer. Thus, there is an advantage if a mechanical engineer, fresh out from UA, has some knowledge concerning nuclear power and nuclear reactors.

COURSE CONTENT

1. Introduction to Nuclear Reactions

We will introduce basic nuclear engineering concepts like radioactive decay, binding energy, fission, fusion and nuclear reaction energetics. We will go over how these basic concepts are key to nuclear reactor design and waste management.

2. Interaction of radiation with matter

We will cover how neutrons interact with ambient media. Primarily, we will look at neutron scattering, absorption and fission. We will introduce the concepts of microscopic and macroscopic cross-sections for neutron-nuclear interactions and their dependence on neutron energy.

3. Neutron energy distributions

Here, we introduce the concept of thermalization of neutrons. Neutron thermalization is of prime importance for nuclear reactors. We will briefly go over the core composition of a couple reactor types – light water reactors and heavy water reactors. We will also introduce the concept of a criticality for nuclear systems.

4. Reactor Kinetics

We introduce the neutron balance equation for infinite and finite media. We go over multiplying systems, prompt criticality, kinetics and delayed neutrons. We will also introduce simple numerical methods for time-stepping.

5. Neutron Diffusion

We derive the neutron diffusion equation and determine its analytical solution in simple geometries. Then we give a brief introduction to the finite volume method and solve the steady state diffusion equation in slab geometry using this method. We also go over simple solution techniques for solving linear systems of equations. We also revisit the concept of criticality here and see how to calculate multiplication factor and criticality criteria for nuclear reactors.

GRADING

1) Homework assignments* (7-8)	(50%)
2) Midterm exam (1)	(25%)
3) Final exam (1)	(25%)

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In addition to the homework and exams, graduate students are expected to do an extra homework. Undergraduates will be allowed to do this homework for extra credit.

COURSE PREPARATION

Willingness to learn is the only pre-requisite for this class, however, some prior experience with solving ODE's and PDE's will be very helpful. Moreover, familiarity with any of MATLAB, Python, C++, or Fortran will also be useful.

WHAT TO EXPECT

- Learn the "nuclear engineering" jargon
- Basic understanding of reactor physics and kinetics
- Learn where the diffusion equation comes from
- Learn how to solve diffusion equation analytically and numerically
- Learn numerical methods
  - Discretization – finite volume method (finite element if time permits)
  - Time-stepping – backward Euler (Runge-Kutta if time permits)
  - Linear Solvers - Gauss-Jacobi and Gauss-Seidel (multigrid if time permits)
  - Eigenvalue calculation – inverse power iteration (Rayleigh quotient if there is interest and we have time)