Syllabus
NE 860 Nuclear Reactor Thermalhydraulics

Hitesh Bindra

Spring 2018

1 Introduction

Engineering principles underlying the design and operation of nuclear power plant components and systems. Specifically, focus in this course will be on energy generation, heat conduction, single- and two phase flows, and on energy removal in single- and two-phase flows. Equal emphasis will be placed on the fundamental physics, underlying theory and its applications to practical design and operational problems encountered in the field of nuclear power engineering and thermal-hydraulics.

2 Instructional Details

Instructor: Hitesh Bindra, Office WD-137 E, (785) 532-3039; e-mail `hbindra@ksu.edu`

Student Evaluation:

Table 1: Assignments and weightage for grade evaluation

20 Quizzes	40 %
4 Software projects	60 %

Examination Dates

Midterm (s): NO MIDTERM EXAMINATION

Final: NO FINAL EXAMINATION

3 Curriculum

Course overview:

A key goal of the course will be to teach basic design philosophy for nuclear reactors, which includes reactor power distribution from neutronics, thermal energy density and material constraints, heat flux, pressure and temperature limits, and technical specifications. The reactor coolant or heat transport system is of central importance for the design philosophy since it is the interface between the heat source and the heat sink. Design and analysis are tightly coupled, i.e., nuclear systems design is guided by analysis results and analysis, in turn, is performed on specific designs to determine its performance. Plant heat cycles, component function and design, and component thermodynamics will also be covered. The scope will be limited to the phenomenological and first order continuum based modeling of the reactor systems. Simulation will be emphasized, incorporated and used throughout the course. The system level analysis will be done with the help of approximation, homogenization and spatial averaging for the constituting components. Detailed multi-dimensional modeling of complex critical components such as pressurizer, suppression pools, reactor header and expanders will also be discussed. The students will be trained on basic simulation set-up for transient scenarios such as loss of forced circulation, loss of coolant accidents and loss of regulation accidents, using RELAP, TRACE and other codes.

Course Topics:

1. Reactor Engineering (3 hours)
   - Basic design of nuclear reactor systems
   - Heat generation, Heat flux and Linear Heat Rating
   - System-scale design calculations

2. Heat Conduction and Fuel Safety (6 hours)
   - Review of transient heat conduction (2 hours)
   - Fuel thermal conductivity models (1 hour)
   - Numerical methods for heat conduction (1 hour)
   - Fuel and cladding safety calculations (2 hour)

3. Fluid mechanics (8 hours)
   - Basic Fluids Review of fundamental (1 hour)
   - Navier-Stokes equations (2 hour)
   - Flow inside conduits (2 hours)
   - Flow in plena, Flow Instabilities and External flows (2 hours)
   - Compressible flows- Choking (1 hour)

4. Convective Heat Transport (6 hours)
   - Simplified conjugate heat transfer (2 hours)
   - Numerical solution to convection-diffusion (2 hours)
   - Introduction to modeling with ANSYS package (2 hours)

5. Radiative Heat Transport (4 hours)
   Fundamentals of heat radiation (2 hours)
   Boltzman Transport Equation and Participating Medium (2 hours)

6. Multi-phase flows (8 hours)
   Flow regimes and characterization (2 hour)
   Modeling two-phase flows (2 hours)
   Critical flow (Blowdown) (2 hours)
   Introduction to modeling with RELAP (2 hours)

7. Phase Change processes (4 hours)
   Nucleate Boiling (2 hours)
   Critical Heat Flux and DNBR (1 hour)
   Flashing and Condensation (1 hour)

8. Reactor Safety Codes (4 hours)
   Severe Accidents (2 hours)
   Historical perspective of nuclear accidents (1 hours)
   Coupled multiphysics transients (1 hour)

Expected Outcomes:

- Understand different nuclear systems and differences in various types of NPPs,
- Understand and model fundamental modes of thermal energy transport
- Familiarize and use commercial and government codes for different thermal-hydraulic applications
- Understand thermal characteristics of nuclear fuel and cladding designs
- Solve and analyze thermal hydraulics of coolant systems under steady state reactor operation
- Analyze reactor safety and understand nuclear system accidental situations in history

Required text: No required textbook. Handouts or Important references will be uploaded on canvas.

Additional references:

- M.M. El-Wakil, Nuclear Heat Transport, American Nuclear Society, 1978.
- N.E. Todreas and M.S. Kazimi, Nuclear Systems, Vol. I; Thermalhydraulic Fundamentals, CRC Press, 2012.

4 University Requirements

Honor System:

Kansas State University has an Honor System based on personal integrity, which is presumed to be sufficient assurance that, in academic matters, one's work is performed honestly and without unauthorized assistance. Undergraduate and graduate students, by registration, acknowledge the jurisdiction of the Honor System. The policies and procedures of the Honor System apply to all full and part-time students enrolled in undergraduate and graduate courses on-campus, off-campus, and via distance learning. The honor system website can be reached via the following URL: `www.ksu.edu/honor`. A component vital to the Honor System is the inclusion of the Honor Pledge which applies to all assignments, examinations, or other course work undertaken by students. The Honor Pledge is implied, whether or not it is stated: "On my honor, as a student, I have neither given nor received unauthorized aid on this academic work." A grade of XF can result from a breach of academic honesty. The F indicates failure in the course; the X indicates the reason is an Honor Pledge violation.

Students with Disabilities:

Any student with a disability who needs a classroom accommodation, access to technology or other academic assistance in this course should contact the Student Access Center and/or the instructor. Services are available to students with a wide range of disabilities including, but not limited to, physical disabilities, medical conditions, learning disabilities, attention deficit disorder, depression, and anxiety. If you are a student enrolled in on-campus/online courses through the Manhattan or Olathe campus, contact accesscenter@k-state.edu, 785-532-6441.

Classroom Conduct:

All student activities in the University, including this course, are governed by the Student Judicial Conduct Code as outlined in the Student Governing Association By Laws, Article VI, Section 3, number 2. Students who engage in behavior that disrupts the learning environment may be asked to leave the class.

Relationship of Course to Professional Component:

This course strengthens and extends the analysis and design tools unique to the nuclear engineering profession. It hones both the analytical and conceptual skills of the students as well as introduce them to important technical concepts for thermalhydraulics and reactor safety. Professional presentation of technical material is emphasized in the biweekly homework assignments, which will also train students in making use of a wide variety of data sources.