NE 419/519 Special Topics

Advanced Reactor Theory and Concepts

Fall 2025

Course Description

This course is intended to provide you with an understanding of the technology associated with advanced reactors (ARs) using coolants other than light water viz., molten salt, gas, or liquid metal. Moving nuclear fission from a water coolant to the coolants of salt, gas, and metal will revolutionize fission, just as jet engines and fracking revolutionized commercial air transportation and oil/gas production, respectively. The AR technology is expected to bring several benefits over light water reactors (LWRs), such as enhanced safety features, flexible operations, lower costs, increased efficiency, reduced waste production, higher resource utilization, and lower proliferation risk, etc. To achieve these benefits, the neutron energy (or spectrum) and thermal dynamics in various AR designs differ significantly from LWRs, so will their system designs. This course will focus on the fundamentals of AR concepts, including their neutronics, systems, and safety performance, as well as technology roadmap and policy issues.

Learning Outcomes

Upon satisfactory completion of this course, students should be able to:

- Explain the fundamentals of advanced reactor designs and their characteristics.
- Articulate design features of three types of advanced reactors: metal-cooled reactors, molten salt reactors, and high-temperature gas-cooled reactors.
- Evaluate advanced reactor concepts from the perspective of reactor physics, thermal-hydraulics, and fuel performance.
- Perform reactor core design for advanced reactors using advanced modeling and simulation tools.
- Describe the regulation framework and policies for advanced reactors.
- Estimate the cost of advanced reactor designs and their associated fuel cycle options.

Meeting Time and Location

Tuesday & Thursday 11:45 am – 1:00 pm, 331 Lampe

Instructors

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Course structure

The class is divided up into four sections: gas cooled reactor, molten salt reactor, and metal cooled reactor, and policy and licensing issues related to those reactors. Within each coolant there are four cross cutting subsections: I. Historical Overview; II. Neutronics/Thermal-Hydraulics/Fuel; III. Systems, and IV. Technology Roadmap. The 17 different learning modules are listed below:

Modules	Lesson Title
	Reactor Design and Analysis
1	Fundamentals of Reactor Physics
2	Fundamentals of Fuel Performance
3	Fundamentals of Thermal-Hydraulics
4	Fundamentals of Core Design
	Metal Cooled Reactors
5	Historic Overview and Current Concepts
6	Neutronics/Thermal-Hydraulics/Fuel
7	Reactor Plant Systems and Basic Operation
8	Technology Roadmap and Policy Issues
	Gas Cooled Reactors
9	Historic Overview and Current Concepts
10	Neutronics/Thermal-Hydraulics/Fuel
11	Reactor Plant Systems and Basic Operation
12	Technology Roadmap and Policy Issues
	Salt Cooled Reactors
13	Historic Overview and Current Concepts
14	Neutronics/Thermal-Hydraulics/Fuel
15	Reactor Plant Systems and Basic Operation
16	Technology Roadmap and Policy Issues
	General
17	Advanced Reactor Policy & Licensing

Course materials

The course materials consist primarily of archival papers from the literature, the materials from Generation-IV Internal Forum, lecture slides, and the time we spend together during lectures, since there are no operating advanced reactors in the U.S.

Requisites and restrictions

C- or better in NE 301 Co-requisite: NE 401

Office hour

Person	Time	Location
Jason Hou	Thursday 3 - 3:30 pm	1139 BEL or Zoom

Cole Howard	Friday 11 am - 12 pm	Zoom

Assignments

- Homework (2-3): 25%
- Projects (7): 50%
- Term Paper: 25% (NE 591 students only)

The assignments above must be submitted to the drop box on Moodle. Late submission will result in 20% off per day late. No exceptions.
There will be no exams and therefore no need for EOL students to find proctors to administrate the exams.

Grading policy

97-100 A+	93-96 A	90-92 A-	87-89 B+	83-86 B	80-82 B-	77-79 C+
73-76 C	70-72 C-	67-69 D+	63-66 D	60-62 D-	0-59 F	

Attendance (On-campus Students)

Per university policy, full participation in classes and examinations is expected of all students. Instructors may use reasonable academic penalties commensurate with the importance of the work missed because of unexcused absences. Please refer to the University Policy on Attendance Regulations REG 02.20.3 for details on university policy regarding attendance and excused absences.

Academic integrity

Academic integrity encompasses the core values and basic principles of honesty and responsibility that govern our practices as scholars, researchers, and creative artists in the university. Academic dishonesty includes cheating, fabricating or falsifying data or sources, improper collaboration, and plagiarism.
Falsification is the practice of omitting or altering research materials, equipment, data, or processes in such a way that the results of the research are no longer accurately reflected in the research record. Fabrication is the practice of inventing data or results and recording and/or reporting them in the research record.

Plagiarism is presenting someone else's work and/or ideas as your own work or ideas either deliberately or unintentionally. This includes but is not limited to turning in all or part of a lab report composed by someone other than yourself and claiming it as your own, and including information or ideas from external sources without proper citations. Plagiarism can be avoided by carefully and correctly citing sources whenever you use someone else's words, equations, graphics, or ideas. Plagiarism in this course results in one or more of the following

consequences: failure of the assignment, failure of the course, and/or disciplinary action by the University.

Mental Health

As a student you may experience a range of personal issues that can impede learning, such as strained relationships, increased anxiety, alcohol/drug concerns, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may impact your ability to participate in daily activities. It is very important that you have a support system and that you ask for help when you are struggling. The Counseling Center at NC State offers confidential mental health services for full time NC State students, including same-day emergency services. Please visit https://counseling.dasa.ncsu.edu/ to get connected.

Use of AI tools

This course permits you to use artificial intelligence (AI) tools, such as chatbots, text generators, paraphrasers, summarizers, or solvers, to get guidance on assignments, as long as you do so in an ethical and responsible manner. Essentially, you can think of these tools as ways to help you learn but not to entirely create work for assignments like discussion board posts, essays, presentation slides, and so on. AI is more like your tutor or TA, not a replacement for your independent thinking.

This means that you must:

- Not use AI tools to replace your own thinking or analysis or to avoid engaging with the course content.
- Cite or explain any AI tools you use. Provide the name of the AI tool, the date of access, the URL of the interface, and the specific prompt or query you used to generate the output.
- Be transparent and honest about how you used the AI tool and how it contributed to your assignment. Explain what you learned from the AI tool, how you verified its accuracy and reliability, how you integrated its output with your own work, and how you acknowledged its limitations and biases.

You are accountable for any mistakes or errors made by the AI tool. Always check and edit the output before submitting your work. If you discover any inaccuracies or inconsistencies in the output after submission, notify the instructor immediately and correct them as soon as possible.

Using AI tools in an unethical or irresponsible manner, such as copying or paraphrasing the output without citation or transparency, using the output as your own work without verification or integration, or using the output to misrepresent your knowledge or skills, is considered a form of academic dishonesty and will result in a zero grade for the assignment and possible disciplinary action. If you have any questions about what constitutes ethical and responsible use of AI tools, please consult with the instructor before submitting your work.