CBE 30235: Introduction to Nuclear Engineering

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Course Description

Electrical energy generation is a huge and growing market as the world attempts to reduce reliance on fossil fuels. Nuclear power is a carbon-free way of producing the heat required to generate electricity. In this course, we shall examine the key facets of this generation method: how a sustained fission chain reaction can be safely achieved, how the heat generated can be safely removed, and how the radioactive waste products can be safely disposed of.

The course introduces fundamentals of fission, including neutron capture cross-sections, reactor poisoning, cladding, and shielding. While focus is maintained on conventional Pressurized Water Reactors (PWRs), we will explore alternative approaches such as liquid metal and high-temperature gas reactors, Small Modular Reactors (SMRs), and the historical Light Water Breeder Reactor (LWBR) program.

Course Goals

- Review the fundamentals of nuclear physics with application to radioactive decay.
- Understand the physical principles underlying nuclear fission and reactor operation.
- Explore various reactor types, with an emphasis on PWRs and breeding cycles.
- Analyze thermal-hydraulic and safety considerations in reactor design.
- Review the future landscape of nuclear energy, including SMRs and waste disposal.

Required Text

Lamarsh, J.R. & Baratta, A.J. *Introduction to Nuclear Engineering*, 4th Ed., 2017.

Grading and Assessment

- **Daily Quizzes:** Conceptual/technical checks following each lecture.
- **Weekly Homework:** Quantitative problem sets illustrating key concepts.
- **Final Project (Design Review):** Group presentation and written report.
  - Class size $\approx$ 18 students (6 groups of 3).
  - Each group will present a design review of a specific reactor technology or fuel cycle strategy during the final week.
  - **Note:** There is no final exam in this course.

Generative AI Policy

In this course, Generative AI tools (e.g., ChatGPT, Claude, Gemini, Copilot) are treated as **productivity tools**, similar to a calculator or a spell-checker. While AI is unquestionably an aid to **productivity**, emerging research has shown that it actually can be a detriment to **learning**. Since this class is all about the latter, AI use must be (somewhat) restricted. You are permitted to use these tools, provided you adhere to the following guidelines:

1. **The "Co-Pilot" Rule:** You may use AI to debug code, brainstorm presentation topics, summarize long technical documents, or explain difficult concepts (e.g., "Explain the six-factor formula like I'm a freshman").

2. **The "Author" Rule:** You may **not** use AI to generate the bulk text of your reports or the final logic of your derivations. The final submission must represent your own synthesis and understanding. Cutting and pasting AI output without modification is what impedes the learning process and is considered academic dishonesty.

3. **Verification is Mandatory:** AI models frequently "hallucinate" (invent) facts, citations, and physical constants. In Nuclear Engineering, precision is a safety requirement. **You are 100% responsible for the accuracy of your work.** "The AI told me so" is not a valid defense for incorrect physics or non-existent references.

4. **Transparency:** If you use AI significantly for a project (e.g., to write a script that solves the Point Kinetics equations), you must append a brief note citing the tool and how it was used.

5. **Quizzes:** The use of AI tools during quizzes is strictly prohibited.

Course Schedule

Week	Dates	Topic / Reading
1	1/12, 1/14, 1/16	**Context & Foundations** L1: The Engineering Context (Grid Physics & Demand). L2: Atomic Structure & Mass-Energy Equivalence. L3: The Nuclear Landscape & Excited States.
2	(Skip), 1/21, 1/23	**Natural Nuclear Engineering I** *(Monday 1/19: MLK Day - No Class)* L4: Neutron Decay & The Physics of Beta Radiation. L5: Space Weather & The Atmospheric Source.
3	1/26, 1/28, 1/30	**Natural Nuclear Engineering II** L6: The Carbon-14 Clock & Anthropogenic Effects. L7: Alpha Decay & The Radon Hazard. L8: Geological Clocks (U-Pb, Rb-Sr) & Earth's Heat.
4	2/2, 2/4, 2/6	**Neutron Physics** L9: Neutron Interactions & Cross Sections. L10: The Physics of Neutron Moderation. L11: The Physics of Fission (Liquid Drop Model).
5	2/9, 2/11, 2/13	**Reactor Theory I: Criticality** L12: The Reactor Lattice & Unit Cell Concept. L13: The Six-Factor Formula (k_{eff}). L14: Neutron Diffusion Theory & Fick's Law.
6	2/16, 2/18, 2/20	**Reactor Theory II: Kinetics** L15: Prompt vs. Delayed Neutrons. L16: The Inhour Equation & Reactor Periods. L17: Reactivity Coefficients (α_T, α_V).
7	2/23, 2/25, 2/27	**Reactor Theory III: Control** L18: Fission Product Poisons (Xe-135 & Sm-149). L19: Control Rod Physics & The S-Curve. L20: Flux Shaping & Peaking Factors (F_q).
8	3/2, 3/4, 3/6	**Navy Week: Reflectors & Operations** L21: Two-Group Theory & Reflector Savings. L22: **Guest Lecture:** *Capt. M. B. Ryan (USN).* L23: **Historic Lecture:** *Leighton 1961 ASM Address.*
		Spring Break (3/9 – 3/13)
9	3/16, 3/18, 3/20	**The Road to the PWR** L24: Shippingport & The Seed-Blanket Concept. L25: Breeding Physics (Th-232/U-233) & The LWBR. L26: The Commercial PWR (Thermal Constraints & Chem Shim).
10	3/23, 3/25, 3/27	**Alternative Reactor Systems & Materials Science** L27: The "Other" Water Reactors: BWRs and CANDU.

Week	Dates	Topic / Reading
		L28: Gas & Fast Reactors (HTGR & LMFBR). L29: Radiation Effects on Materials (Embrittlement, Swelling).
11	3/30, 4/1, (Skip)	**The Fuel Cycle** L30: The Front End (Mining, Enrichment, SWU Calcs). L31: The Back End (Reprocessing PUREX & Waste/Yucca). *(Friday 4/3: Good Friday - No Class)*
12	(Skip), 4/8, 4/10	**Reactor Safety (Accident Analysis)** *(Monday 4/6: Easter Monday - No Class)* L32: Design Basis Accidents: LOCA & ECCS. L33: Case Studies (TMI, Chernobyl, Fukushima).
13	4/13, 4/15, 4/17	**Radiation Protection & Regulations** L34: Interaction of Radiation with Matter (Shielding). L35: Biological Dose, Health Physics, and Regulatory Limits. L36: Reactor Safety & Licensing
14	4/20, 4/22, 4/24	**The Future & Student Presentations I** L37: Advanced Designs (SMRs, Molten Salt, Gen IV). Wed 4/22: Wrap-up / Open Design Studio (In-Class Project Work). Fri 4/24: Student Design Reviews (Groups 1 & 2).
15	4/27, 4/29	**Student Presentations II** Mon 4/27: Student Design Reviews (Groups 3 & 4). Wed 4/29: Student Design Reviews (Groups 5 & 6).