Engy-4340: Nuclear Reactor Theory

Instructor: Prof. Valmor F. de Almeida

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Lectures: + Mon/Wed 3:30 – 4:45 pm, Olsen Hall 404 North Campus.

Days meetings total : 27.

Week meetings total: 15/16.

Website: On-line course repository and UMass Lowell Blackboard System.

Office hours and location: Thursdays and Fridays 12 to 1 pm or by appointment.

Additional office hours: email prof. de Almeida for appointment.

Additional help: UML Linux Club meetings, Fridays 5 to 6 pm, email prof. de Almeida

Teaching assistant: None.

Catalog description: Emphasis is placed on neutron interactions in various nuclear core and shield configurations along with the development, solution, and analysis of the neutron balance equation for various situations. Several aspects of nuclear reactor core physics including neutron diffusion, criticality, power production, reactor kinetics, reactivity feedback and control, fuel depletion, fission product poisoning, and some energy removal considerations are treated. General reactor core design and safety considerations are also discussed.

Pre-requisites: Engy-3310 Fund. of Nuclear Science & Engineering, and Math-2360 Eng. Differential Equations.
Course designation: Core undergraduate.

Helful: ChEn-3170 Computational Methods in Chemical Engineering.

Textbooks and Notes: Course notes are provided; in addition two textbooks are required (one texbook is used in the pre-req Engy-3310).

1. *Classroom course notes and repository (updated during the semester)*
2. [LB] *Introduction to Nuclear Engineering*, John R. Lamarsh and Anthony J. Baratta, Pearson, 2018 Fourth Edition (or Third Edition), 802 pp.
3. [SF] *Fundamentals of Nuclear Science and Engineering*, J. Kenneth Shultis and Richard E. Faw, CRC Press, 2017 Third Edition (or a recent previous edition), 638 pp.

Other books not required for this course (for information only):

1. *Introduction to Nuclear Reactor Theory*, John R. Lamarsh, ANS, 2002 (1966), 585 pp.
2. *Nuclear Reactor Theory*, George I. Bell and Samuel Glasstone, Van Nonstrand Rheinhold, 1970, 619 pp.
3. *Computational Methods of Neutron Transport*, Elmer E. Lewis and Warren F. Miller Jr., ANS, 1993, 401 pp.
4. *Introductory Nuclear Reactor Theory*, Herbert S. Isbin, Reinhold Chemical Engineering Series, 1963, 624 pp.
5. *The Physical Theory of Neutron Chain Reactors*, Alvin M. Weinberg and Eugene P. Wigner, University of Chicago Press, 1958, 801 pp.
6. *Nuclear Reactor Analysis*, James J. Duderstadt and Louis J. Hamilton, John Wiley Sons, Inc., 1976, 650 pp.
7. *Applied Reactor Physics*, Alain Hebert, Presses internationales Polytechnique, Third Edition 2020, 410 pp.

Software used in this course and homework: Jupyter notebook access options for this course

1. Preferred way: Anaconda free download (use the Python 3 version) for Mac OS X or Windows (Linux too in case you are a rare die-hard programmer; if this is your case come talk to me). After install, use Anaconda-Navigator to start a Jupyter Notebook server.
2. Use the UMass Lowell vLabs Learning Commons machine. Download the VMWare Horizon Client and install on your computer. Login with your academic credentials. Anaconda is pre-installed, use the Anaconda-Navigator to start the Jupyter Notebook application.

3. Use Binder at the course repository

Instructive background **on programming environment, review of undergraduate computational methods:** ChEn-3170

Suplement materials: On-line course repository: https://github.com/dpploy/engy-4340.

Course topics (Fission Reactors):

- Nuclear reactions and neutron interactions
- Power reactor core (multiplication factor formulae)
- Reactor kinetics
- Spatial diffusion of neutrons
- Neutron distributions in reactors
- Thermal energy coupling
- Reactivity feedback
- Long-term reactor core behavior

Grading: for grading purposes the requirements for this course include

- Two midterm exams and a final exam (all closed book, closed notes).
  - Additional, optional oral exam (per appointment) corresponding to any of the written exams taken (grade improvement).
- Homework every other week (total of 7).

Course Grading	**Value**
Midterm 1	20/100
Midterm 2	20/100
Final	15/100
Homework (7)	45/100

Letter Grade Scale	**Value**
A	92+
A-	87–91.9
B+	82–86.9
B	77–81.9
B-	72–76.9
C+	67–71.9
C	62–66.9
C-	58–61.9
D+	54–57.9
D	50–53.9
F	<50

Learning outcomes: Upon completion of this course, a student should be able to

1. Understand nuclear reactions and their energetics.
2. Calculate radioactive decay of nuclides.
3. Know how neutrons interact with matter through scattering and absorption.
4. Quantitatively assess neutron slow down.
5. Apply basic neutron balance law.
6. Understand the kinetics of neutron in single point reactors.

Schedule (updated weekly):

Week	Day	**Date**	**Notebook**	**Assessment**	**Note**
-	-	September	-	-	-

Week	Day	Date	Notebook	Assessment	Note
1	**W**	**06Sep23**	00/class notes	-	Syllabus/Thermal Neutron Fundam. LB 2/SF 2,3
2	**M**	**11Sep23**	class notes	Homework 01 (due 25Sep23)	Thermal Neutron Fundam. LB 3/SF 4, 6
2	W	13Sep22	class notes	-	Thermal Neutron Fundam. LB 3/SF 4, 6
3	**M**	**18Sep23**	class notes	-	Fission Reaction / HW 01 LB 3/SF 5, 6
3	W	20Sep22	class notes	-	Fission Reaction LB 3/SF 6, 7
4	**M**	**25Sep23**	class notes	Homework 02 (due 11Oct23)	Fission Reaction LB 3/SF 6, 7
4	W	27Sep23	class notes	-	Fission Reaction/Fission Products LB 3/SF 6, 7

Week	Day	Date	Notebook	Assessment	Note
-	-	October	-	-	-
5	**M**	**02Oct23**	class notes	-	Fission Reaction/Fission Products LB 3/SF 6, 7
5	W	04Oct23	class notes	-	Reactivity/Scattering LB 3/SF 6, 7
6	**M**	**09Oct23**	No class	No class	Columbus day holiday
6	W	11Oct23	class notes	Homework 03 (due 25Oct23)	Microscopic Cross Section LB 3/SF 6, 7
7	**M**	**16Oct23**	No class	No class	DOE Workshop Cermet Waste Forms @ ANL
7	W	18Oct23	No class	No class	DOE Workshop Cermet Waste Forms @ ANL
8	**M**	**23Oct23**	-	Midterm 1	-
8	W	25Oct23	class notes	Homework 04 (due 06Nov23)	Cross Section Energy Dependency LB 3/SF 6, 7

Week	Day	Date	Notebook	Assessment	Note
9	**M**	**30Oct23**	class notes	-	Cross Section Energy Dependency LB 3/SF 6, 7

Week	Day	Date	Notebook	Assessment	Note
-	-	November	-	-	-
9	W	01Nov23	class notes	-	Classroom problem solving HW3/Midterm 1 P.4
10	**M**	**06Nov23**	no class	Homework 05 (due 20Nov22)	AIChE meetings
10	W	08Nov23	no class	HW05	AIChE meetings
11	**M**	**13Nov22**	class notes	-	Neutron Excitation Energy / Head-on Elastic Scattering Collision / Collision Probability
11	W	15Nov22	no class	-	Collision Probability / Neutron Slowdown Decrement
12	**M**	**20Nov22**	-	Homework 06 (due 04Dec22)	Neutron Distribution in Energy / Fuel and Moderators / Generation Factor η
12	W	22Nov22	no class	-	Thanksgiving holiday
13	**M**	**27Nov22**	class notes	Midterm 2	-
13	W	29Nov22	class notes	-	Neutron Energy Spectra / Neutron Flux

Week	Day	Date	Notebook	Assessment	Note
-	-	December	-	-	-
14	**M**	**04Dec22**	class notes	Homework 07 (due 18Dec22)	Homework 04 classroom solution
14	W	06Dec22	class notes	-	Homework 05 classroom solution

Week	Day	**Date**	**Notebook**	**Assessment**	**Note**
15	**M**	**11Dec22**	class notes	-	Neutron Flux/Nuclear Heat Source/
15	W	13Dec22	class notes	-	Neutron Flux/Nuclear Heat Source
16	?	16-22Dec22	-	Final Exam ?pm to ?pm ? Hall ?	Comprehensive

General Information

Attendance: Students are expected to attend all classes.

Credit hour policy: A credit hour requires a minimum of 2 hours of out-of-class student **deep work** per 1 hour of instructor-led course activity.

Student conduct code: UMass Lowell

Classroom/Online Conduct: Students are expected to exhibit professional and respectful behavior that is conducive to a mutually beneficial learning environment in the classroom. Examples of inappropriate behavior include: text messaging, listening to music, cell phone use (other than the campus alert system), late arrivals, early departures, use of laptops for other than class purposes, disrespectful comments or behavior, intentional disruptions, failure to follow faculty directives, etc. Students in violation of these standards may be asked to leave class and/or be referred to the Dean of Students for disciplinary action.

Academic Integrity: Cheating and plagiarism will not be tolerated. A first offense will result in a failing grade for the assignment/exam in question and a formal filing with the Office of Provost according to the Academic Integrity Policy. A second offense could lead to a failing grade in the course, suspension or expulsion, as detailed in the policy, defined here.

Instructional Resources: The Centers for Learning and Academic Support Services provide many tutoring resources; more details are available here Technology Resources: For a listing of available computing and software resources available to students, visit here.

Accommodations: In accordance with University policy and the ADA, accommodations are provided for students with documented disabilities. If you have a disability, please contact the Office of Disability Services as soon as possible. Their office is in UC 220 (978-934-4574, Disability@uml.edu). Documentation of disability is confidential. Requests for accommodation for religious reasons should be directed to Equal Opportunity and Outreach at 978-934-3565, Wannalancit Mills, Suite 301.

Counseling Services: As part of the Wellness Center, Counseling Services at UMass Lowell provide mental health counseling, consultation and referrals to help students achieve personal and academic success. They also assist students in better understanding and coping with their feelings, relationships, and choices surrounding their academic success. Visit Veterans' Services: UMass Lowell is committed to helping our military students take full advantage of all the educational benefits available through the federal and state governments. For complete information on the services and resources available please visit our website. University Cancellation Information: If campus is closed (most likely for weather), visit the website for announcements relevant to the class.