ENGG9742
Reactor Physics for Engineers

Course Outline – Semester 1, 2017

Australia's Global University | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Dr. Patrick Burr, Room 643, MSE, p.burr@unsw.edu.au
Course Convener: Dr. Edward Obbard, Room 638, MSE, e.obbard@unsw.ed.au
Laboratory Contact: Mr. Andrew Pastrello, Room 6.2B MSE, a.pastrello@student.unsw.edu.au

Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ENGG972 in the subject line, otherwise they may not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Contact Hours

The course consists of 3 hours of lectures each week, excluding weeks 2, 3, 7 and 11, plus 3 hours of laboratory sessions in weeks 5 – 11.

	Day	Time	Weeks	Location
Lectures	Tuesday	6pm – 9pm	1, 4, 5, 6, 8, 9, 10, 12	Quad G025
Laboratories	Thursday	6pm – 9pm	5 – 11	EET 103

Context and Aims

This course provides students with an introduction to the key elements of nuclear reactor physics, and the key modeling tool used in the nuclear industry. Students completing this course will be able to discuss aspects of reactor physics and the implications that reactor physics has on the engineering of nuclear systems. Students will be able to perform analyses on simple reactor geometries and describe and understand the main reactivity feedback mechanisms, and their significance, on reactor design and control.

Key concepts such as neutron flux and diffusion are first introduced. These are then utilised to demonstrate multiplication and criticality. Various reactor shapes are analysed and the use of reflectors is discussed. The neutron life cycle in thermal reactors is described along with fast and delayed neutron production. Reactor kinetics is discussed including doubling times, reactivity feedback mechanisms, power and temperature coefficients and Xenon poisoning. The course concludes with a discussion on fast reactors and breeding concepts.

The course material is advanced in nature, due to its interdisciplinary content and the depth of material covered. Students taking this course must have the skills of an Honours level graduate engineer such that they are capable of modeling, analysing and critically reviewing complex engineering systems. A prerequisite for this course is ENGG9741 Introduction to Nuclear Engineering as the material builds on the physical processes at work during fission including neutron flux, criticality, moderation, reactor dynamics and transients.

Indicative Lecture Schedule

Period	Summary of Lecture Program
Week 1	Nuclear physics basics
Week 2	*No lecture (ENGG9741 intensive mode)*
Week 3	*No lecture (ENGG9741 intensive mode)*
Week 4	Diffusion theory
Week 5	Multiplication and criticality
Week 6	Reflected reactors, Monte Carlo simulations
Week 7	*No lecture – lab based learning*
Break	
Week 8	Burn-up, activation
Week 9	Xenon, depletion
Week 10	Point kinetics, delayed neutrons
Week 11	*No lecture – lab based learning*
Week 12	Reactor feedback
Week 13	*Revision lecture if required*

Indicative Laboratory Schedule

Period	Summary of Laboratory Program
Week 5	Introduction to python scripting language and OpenMC
Week 6	Realistic geometries and validation of results
Week 7	Flux distribution, tallying, reaction rates
Break	
Week 8	**Assignment due**
Week 9	Compositional changes
Week 10	Time effects
Week 11	Free practice (un-assessed). **Assignment due**

Assessment

Laboratory practical assessments (x5)	15%
Laboratory assignment 1	20%
Laboratory assignment 2	25%
Final Exam (2 hours)	40%

Course Details

Credits

This is a 6 UoC course and the expected workload is 10–12 hours per week throughout the 13-week semester.

Relationship to Other Courses

This is a postgraduate course convened by School of Electrical Engineering and Telecommunications. It is a core class on the MEngSci Nuclear Engineering specialization and can be taken as an elective by 3rd or 4th year students from other schools and faculties on the approval of home school and the ENGG9742 course convener.

Pre-requisites and Assumed Knowledge

A pre-requisite for this course is ENGG9741 Introduction to Nuclear Engineering. It is essential that you are familiar with basic engineering principles and mathematical skills, as well as a basic knowledge of nuclear physics before this course is attempted. A grounding in chemistry and physics is useful, and knowledge of programming (especially Python language) is helpful.

Following Courses

None

Learning outcomes

After successful completion of this course, you should be able to:

1. Discuss aspects of reactor physics.
2. Explain the concept of criticality, and its estimation in various idealised geometries.
3. Describe basic point kinetics concepts, and prompt and delayed criticality.
4. Describe the main reactivity feedback mechanisms and their significance.
5. Calculate basic parameters of reactor physics, e.g. multiplication factors, critical sizes.
6. Perform point-kinetics reactor transient analyses, and explain the importance of prompt criticality and neutron lifetime.
7. Perform analyses on simple reactor geometries.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Syllabus

1. Nuclear physics
2. Diffusion
3. Multiplication and criticality
4. Thermal reactor and reflected reactor
5. Reactor criticality analysis
6. Monte Carlo simulations
7. Burn-up

8. Xenon poisoning
9. Point kinetics
10. Reactivity feedback

Teaching Strategies

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Laboratory sessions, which support the formal lecture material and also provide you with practical knowledge of a widely used tool in the industry as well as scripting, testing and debugging skills.

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-semester exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Laboratory program

The laboratory schedule is deliberately designed to provide practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend laboratory from Week 5 to Week 10. Laboratory attendance WILL be kept, and you MUST attend at least 80% of labs. You must attempt all set problems in advance of attending the laboratory. The importance of adequate preparation prior to each laboratory cannot be overemphasized, as the effectiveness and usefulness of the session depends to a large extent on this preparation. Group learning is encouraged.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator.

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through lab assignments.

Laboratory Assessment

Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. You are required to maintain a Jupyter lab book (instructions will be provided in the laboratory) for recording your observations.

It is essential that you complete the laboratory preparation before coming to the lab. You are required to write the aim of the laboratory session and your progress in your Jupyter lab book. These will be verified by your demonstrators in the lab. You will be recording your observations/readings in your Jupyter lab book first and then completing and submitting the results as part of the assignments.

At the end of each laboratory session, your work will be assessed by the laboratory demonstrator. Both the results sheet and your Jupyter lab book will be assessed.

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your level of engagement during the lab, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work, and your understanding of the topic covered by the lab.

Assignment

The assignment allows self-directed study leading to the solution of partly structured problems. Marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the code written for the assignment (must be attached to the report), and the understanding of the course material demonstrated by the report.

The assignment reports will be due at 5pm on Wednesday 26th April (week 8) and Friday 19th May (Week 11). Submissions must be made on-line via Moodle. *Late reports will attract a penalty of 10% per day* (including weekends).

Final Exam

The exam in this course is a standard closed-book 2 hour written examination. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course.*

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Laboratory practical assessments	✓	✓	✓		✓	✓	✓
Laboratory assignment 1		✓			✓		✓
Laboratory assignment 2			✓		✓	✓	✓
Final exam	✓	✓	✓	✓	✓	✓	

Course Resources

Textbooks

Prescribed textbook

1. Basic Nuclear Engineering

   Author: Glasstone and Sesonske

   ISBN 978-1-4615-2083-2 (and 81-239-0647-1)

   Publisher Springer US (and CBS Publishers & Distributors India)

Reference books

2. Basic Nuclear Engineering

   Author: Foster and Wright

   ISBN 978-0205078868

   Publisher Allyn and Bacon

3. Nuclear Chemical Engineering

   Author: Benedict, Pigford, Levi

   ISBN 978-0070045316

   Publisher McGraw-Hill

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/guide), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://student.unsw.edu.au/special-consideration.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the myExperience process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods. Specifically, we have increased emphasis on industry-relevant practical skills and increased the portion and assessment weight of laboratory coursework.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
https://student.unsw.edu.au/guide
https://www.engineering.unsw.edu.au/electrical-engineering/resources

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the interactive checkpoint assignments and exams.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	
	PE1.5 Knowledge of engineering design practice	✓
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	✓