UNSW Course Outline

ZEIT4760 Nuclear Propulsion and Its Assurance - 2024

Published on the 08 Jul 2024

General Course Information

Course Code : ZEIT4760
Year : 2024
Term : Semester 2
Teaching Period : Z2
Is a multi-term course? : No
Faculty : UNSW Canberra
Academic Unit : School of Engineering and Technology
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : UNSW Canberra at ADFA
Campus : UNSW Canberra
Study Level : Undergraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

This course will provide students with an introduction to the key elements of nuclear engineering and nuclear propulsion systems, such as those used as propulsion options for submarines, surface ships, missiles and spacecraft. The aim of this course is to provide students with the basic background knowledge, understanding and vocabulary of nuclear power engineering, its application to nuclear propulsion, and its safety and risk management.

Course Aims

The course will introduce a variety of topics, including:

- Radioactivity and radiation nomenclature and units;
- Nuclear fission and the nuclear fuel cycle;
- Reactor physics and engineering, including different reactor systems, the harnessing of energy, reactor dynamics, neutron life cycle, criticality, reactivity feedback mechanisms and reactor control;
- Nuclear propulsion (nuclear reactors as propulsion option for submarines, surface ships, missiles and spacecraft);
- The impacts of radiation on matter; and
- Civilian and Defence regulation and assurance for nuclear safeguards, radiation safety and platform risk management.

Relationship to Other Courses

The student is expected to have a basic understanding of engineering fundamentals. It is assumed that the student will have a sound understanding of mathematics including, but not limited to algebraic manipulation of equations, exponential functions and differential equations.

Prerequisite - ZPEM 2310 Engineering Mathematics 2B

Course Learning Outcomes

Course Learning Outcomes	Engineers Australia - Professional Engineer (Stage 1)
CLO1 : Explain radioactivity, radiation and nuclear engineering nomenclature, nuclear fission, the nuclear fuel cycle, and the impact of radiation on matter.	• PEE1.1 : Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline • PEE1.5 : Knowledge of engineering design practice and contextual factors impacting the engineering discipline • PEE2.2 : Fluent application of engineering techniques, tools and resources • PEE3.2 : Effective oral and written communication in professional and lay domains
CLO2 : Explain reactor physics and engineering, including different reactor systems, reactor dynamics, feedback mechanisms and reactor control.	• PEE1.1 : Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline • PEE1.5 : Knowledge of engineering design practice and contextual factors impacting the engineering discipline • PEE2.2 : Fluent application of engineering techniques, tools and resources • PEE3.2 : Effective oral and written communication in professional and lay domains
CLO3 : Understand, analyse and apply basic reactor engineering concepts and designs, including nuclear propulsion systems.	• PEE1.1 : Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline • PEE1.3 : In-depth understanding of specialist bodies of knowledge within the engineering discipline • PEE1.5 : Knowledge of engineering design practice and contextual factors impacting the engineering discipline • PEE3.2 : Effective oral and written communication in professional and lay domains
CLO4 : Understand, evaluate and design civilian and Defence regulation and assurance for nuclear safety, radiation safety and platform risk management.	• PEE1.5 : Knowledge of engineering design practice and contextual factors impacting the engineering discipline • PEE3.2 : Effective oral and written communication in professional and lay domains

Course Learning Outcomes	Assessment Item
CLO1 : Explain radioactivity, radiation and nuclear engineering nomenclature, nuclear fission, the nuclear fuel cycle, and the impact of radiation on matter.	• Quizzes • Homework
CLO2 : Explain reactor physics and engineering, including different reactor systems, reactor dynamics, feedback mechanisms and reactor control.	• Group Presentation • Quizzes • Homework
CLO3 : Understand, analyse and apply basic reactor engineering concepts and designs, including nuclear propulsion systems.	• Group Presentation • Quizzes • Homework
CLO4 : Understand, evaluate and design civilian and Defence regulation and assurance for nuclear safety, radiation safety and platform risk management.	• Group Presentation • Quizzes • Homework

Learning and Teaching Technologies

Moodle - Learning Management System

Learning and Teaching in this course

Lectures will be delivered using Power Point (ppt), and these lectures will be recorded so that student may view later. The lecturer will engage students during the lectures.

The following will be available for students prior to each weekly lecture: the lecture ppt, upcoming homework, and learning objectives

The Learning Management System

Moodle is the Learning Management System used at UNSW Canberra. All courses have a Moodle site which will become available to students at least one week before the start of semester. Please find all help and documentation (including Blackboard Collaborate) at the Moodle Support page.

UNSW Moodle supports the following web browsers:

» Google Chrome 50+

» Safari 10+

** Internet Explorer is not recommended

** Addons and Toolbars can affect any browser's performance.

Operating systems recommended are:

Windows 7, 10, Mac OSX Sierra, iPad IOS10

For further details about system requirements click here.

Log in to Moodle here.

If you need further assistance with Moodle:

For enrolment and login issues please contact:
IT Service Centre
Email: itservicecentre@unsw.edu.au
Phone: (02) 9385-1333
International: +61 2 9385 1333

For all other Moodle issues please contact:
External TELT Support
Email: externalteltsupport@unsw.edu.au
Phone: (02) 9385-3331
International: +61 2 938 53331

Opening hours:
Monday – Friday 7:30am – 9:30 pm
Saturday & Sunday 8:30 am – 4:30pm

Other Professional Outcomes

This course will provide the student with an introduction to key practical elements of engineering. Lectures will be entertaining, homework will be frequent, and students will be surprised at what they learn.

The focus is on nuclear propulsion options for submarines, surface ships, and spacecraft. The course will provide background knowledge, understanding and vocabulary of nuclear power engineering, its application to nuclear propulsion, and its safety and risk management.

Students will gain an understanding of nuclear engineering and its applications.. Students will be introduced to radiation and its interaction with matter, nuclear fission, the nuclear fuel cycle and *principles of reactor physics and engineering. Students will gain an understanding of basic reactor engineering designs and concepts, as they pertain to nuclear propulsion systems, particularly advanced small modular reactors. They will also gain an appreciation of the frameworks for nuclear regulation and assurance for the management of radiation safety, risk, and nuclear safeguards*

Additional Course Information

The course relies upon practical problem solving via weekly homework assignments. Key concepts are presented in a variety of ways.

This course is an elective for the Bachelor of Engineering (Naval Architecture, Mechanical, Electrical, Civil & Aeronautical). Students will be able to:

- relate a quantitative, theory-based understanding of the sciences and fundamentals of engineering.

- select and apply the mathematical, statistical, programming and computational tools and techniques which underpin engineering.

- demonstrate a comprehensive understanding of platform integration for engineering and articulate directions of future knowledge development therein.

- synthesise design practice, contextual factors, norms and accountabilities.

- demonstrate proficiency in applying systematic engineering synthesis and design processes, and critically evaluating and effectively communicating the results and implications to all audiences.

- demonstrate independence, creativity and ethical conduct, and explain the importance of user-focused and sustainable solutions.

Academic Integrity and Plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and students have a responsibility to adhere to this principle of academic integrity. All students are expected to adhere to UNSW's Student Code of Conduct https://www.gs.unsw.edu.au/policy/documents/studentcodepolicy.pdf

Plagiarism undermines academic integrity and is not tolerated at UNSW. *It is defined as using the words or ideas of others and passing them off as your own, and* can take many forms, from deliberate cheating to accidental copying from a source without acknowledgement.

For more information, please refer to the following:

https://student.unsw.edu.au/plagiarism

Referencing

In this course, students are required to reference following the APA 7 / Chicago NB referencing style. Information about referencing styles is available at: https://guides.lib.unsw.adfa.edu.au/c.php?g=472948&p=3246720

Study at UNSW Canberra

https://www.unsw.adfa.edu.au/study

Study at UNSW Canberra has lots of useful information regarding:

- Where to get help
- Administrative matters
- Getting your passwords set up
- How to log on to Moodle
- Accessing the Library and other areas.

Additional Information as required

CRICOS Provider no. 00098G

The University of New South Wales Canberra.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Group Presentation Assessment Format: Group	25%	Start Date: 21/10/2024 12:00 AM Due Date: 31/10/2024 12:00 AM
Quizzes Assessment Format: Individual	45%	Start Date: 07/08/2024 03:00 PM Due Date: Not Applicable
Homework Assessment Format: Individual	30%	Start Date: Not Applicable Due Date: Not Applicable Post Date: 01/11/2024 12:00 AM

Assessment Details

Group Presentation

Assessment Overview

Each group will select a nuclear application for propulsion. This group presentation covers the breadth of the course and is scheduled for the final week of class.

Course Learning Outcomes

- CLO2 : Explain reactor physics and engineering, including different reactor systems, reactor dynamics, feedback mechanisms and reactor control.
- CLO3 : Understand, analyse and apply basic reactor engineering concepts and designs, including nuclear propulsion systems.
- CLO4 : Understand, evaluate and design civilian and Defence regulation and assurance for nuclear safety, radiation safety and platform risk management.

Detailed Assessment Description

Students will select a nuclear application for propulsion. A small group (3-6 students) is to present (20-30 minutes). This group presentation covers the breadth of the course and is scheduled for the final week of class (week 13).

Each student in a group will earn the same grade, which will comprise 25% of the course grade.

Grading criteria for the presentation will be provided; aspects of organisation and design are emphasised.

Assessment Length

30 minutes

Submission notes

NA

Assessment information

Each group is to make an oral presentation.

Assignment submission Turnitin type

Not Applicable

Quizzes

Assessment Overview

Quizzes will be taken in class and will be timed.

Course Learning Outcomes

- CLO1 : Explain radioactivity, radiation and nuclear engineering nomenclature, nuclear fission, the nuclear fuel cycle, and the impact of radiation on matter.
- CLO2 : Explain reactor physics and engineering, including different reactor systems, reactor dynamics, feedback mechanisms and reactor control.
- CLO3 : Understand, analyse and apply basic reactor engineering concepts and designs, including nuclear propulsion systems.
- CLO4 : Understand, evaluate and design civilian and Defence regulation and assurance for nuclear safety, radiation safety and platform risk management.

Detailed Assessment Description

Each of three quizzes will cover material from three weeks. Each quiz is worth 15%. Quizzes will be taken in class and will be timed.

Scheduled date of Quiz #1 is Wednesday, 7 August 2024.

Scheduled date of Quiz #2 is Thursday, 19 September 2024

Scheduled date of Quiz #3 is Wednesday, 2 October 2024.

Assessment Length

Quiz will be timed (approximately 30 minutes)

Submission notes

NA

Assessment information

Each of three quizzes will be administered in class.

Assignment submission Turnitin type

Not Applicable

Homework

Assessment Overview

Homework assignments

Course Learning Outcomes

- CLO1 : Explain radioactivity, radiation and nuclear engineering nomenclature, nuclear fission, the nuclear fuel cycle, and the impact of radiation on matter.
- CLO2 : Explain reactor physics and engineering, including different reactor systems, reactor dynamics, feedback mechanisms and reactor control.
- CLO3 : Understand, analyse and apply basic reactor engineering concepts and designs,

including nuclear propulsion systems.
- CLO4 : Understand, evaluate and design civilian and Defence regulation and assurance for nuclear safety, radiation safety and platform risk management.

Detailed Assessment Description

Homework is an important aspect of learning. Each of eight (8) homework assignments is due the week after the material is covered in lecture. The first HW assignment in Week 1 is worth 3%. The second HW assignment in Week 2 is also worth 3%. The subsequent HW assignments are worth 4% each.

Assessment Length

Approximately 2 hours per week.

Assessment information

Homework is due at the first class meeting of the following week.

Assignment submission Turnitin type

Not Applicable

General Assessment Information

Key concepts will be presented more than once, and they will be emphasised in the homework assignments. Quizzes will be timed and use of thumb rules will be encouraged.

Although all required information will be presented in lectures, students are encouraged to supplement their learning via recommended reading. Applicable chapters and sections of the text will be identified each week.

Murray, R.L., & Holbert, K.E. (2020). Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (8th edition). Butterworth-Heinemann.

Feedback before the census date

Students will get the written feedback and grades of HW 1-3 and Quiz #1 by the census date.

Late Submission of Assessment

Unless prior arrangement is made with the lecturer or a formal application for special consideration is submitted, a penalty of 5% of the total available mark for the assessment will apply for each day that an assessment item is late up to a maximum of 5 days, after which a grade of 0 will be applied.

Use of Generative AI in Assessments

It is prohibited to use any software or service to generate information or answers for quizzes. If its use is detected, it will be regarded as serious academic misconduct.

Grading Basis

Standard

Requirements to pass course

The minimum passing grade is 50%.

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 15 July - 19 July	Activity	Learning Objectives • State the characteristics of protons, neutrons, and electrons • Describe the Bohr model of an atom. • Define the following terms: nuclide, isotope, atomic number, mass number • Given the standard notation of a particular nuclide, determine the number of neutrons, protons, and electrons. • Describe the three forces that act on nucleons in the nucleus. • Define the terms enriched uranium and depleted uranium. • Define mass defect and binding energy. • Calculate mass defect and binding energy given information about atomic masses of constituents. • Describe the following processes: alpha decay, beta-minus decay, internal conversion. • Explain why one or more gammas typically accompany particle emission. • Determine the type of decay that radionuclides in certain regions of the Chart of the Nuclides undergo. • Define radioactivity, Becquerel, decay constant, and half-life. • Demonstrate the relationship among half-life, decay constant, and activity. • Given the initial activity and the decay constant of a nuclide, calculate the activity at any later time. • Define radioactive equilibrium. • Describe elastic and inelastic scattering of a neutron with a nucleus. • Describe radiative capture and particle ejection. • Explain the fission process using the liquid drop model. • Describe excitation energy and critical energy. • Define fissile, fissionable, and fertile materials. • Describe the process of transmutation and breeding. • Describe the curve of binding energy per nucleon versus mass number. • Explain why only heavy nuclei undergo fission. • Explain why U235 fissions with thermal neutrons, whereas U238 fissions only with fast neutrons. • Describe fission products in terms of mass groupings and radioactivity. • Given nuclides involved, calculate energy released from fission. • Describe interactions of the following with matter: alphas, betas, gamma and neutrons.
Week 2 : 22 July - 26 July	Activity	Learning Objectives • Define two types of neutron sources: intrinsic and external. • List an example of each type of neutron source. • Define the following terms: atom density, neutron flux, barn, mean free path. • Define two types of cross section: macro and micro. • Express macroscopic cross section in terms of microscopic cross section. • Describe how the absorption cross section of typical nuclides varies with neutron energy at energies below the resonance absorption region. • Describe resonance absorption in terms of nuclear energy levels. • Express mean free path in terms of macroscopic cross section. • Given the number densities (or total density and component fractions) and microscopic cross sections of components, calculate the macroscopic cross section for a mixture. • Calculate a macroscopic cross section given a material density, atomic mass, and microscopic cross section. • Given the neutron flux and macroscopic cross section, calculate the reaction rate. • Describe the relationship between neutron flux and reactor power. • Define the following terms: thermalization, moderator, moderating ratio. • List three desirable characteristics of a moderator. • State the origin of prompt neutrons and delayed neutrons. • Estimate the fraction of neutrons that are born as delayed neutrons from the fission of U235. • Explain the mechanism for production of delayed neutrons. • Explain prompt and delayed neutron generation times. • Explain the effect of delayed neutrons on reactor control. • State the average energy at which prompt neutrons are produced. • Contrast the neutron energy spectra in a fast and thermal reactor. • Explain the reason for the shape of the fast, intermediate, and slow energy regions of the neutron flux spectrum for a thermal reactor. • Describe three heavy elements that are used as nuclear fuels.
	Activity	
Week 3 : 29 July - 2 August	Activity	Learning Objectives • Define the following terms: infinite multiplication factor, effective multiplication factor, critical, subcritical, supercritical. • Define each term in the six-factor formula.

		• Given values for each factor in the six-factor formula, calculate the number of neutrons that will be present at any point in the life cycle. • List physical changes in the reactor core that will influence the thermal utilization factor, reproduction factor, or resonance escape probability. • Explain the effect that temperature changes will have on the following: thermal utilization factor, resonance escape probability, fast non-leakage probability, and thermal non-leakage probability. • Define the term reactivity. • Conveert between reactivity and keff. • Convert measures of reactivity between Δk/k, 10-4 Δk/k, %Δk/k, and percent millirho (pcm). • Explain the relationship between reactivity coefficients and reactivity defects. • Explain the conditions of over moderation and under moderation. • Describe why many reactors are designed to be operated in an under moderated condition. • State the effect that a change in moderator temperature has on the moderator to fuel ratio. • Define the temperature coefficient of reactivity. • Explain why a negative temperature coefficient of reactivity is desirable. • Describe why the fuel temperature coefficient is more effective than the moderator temperature coefficient in terminating a rapid power rise. • Explain the concept of Doppler broadening of resonance absorption peaks. • List one nuclide that is present in many types of reactor fuel assemblies that has significant resonance absorption peaks. • Explain why the pressure coefficient of reactivity is usually negligible in a reactor cooled and moderated by a subcooled liquid. • Define the void coefficient of reactivity. • Identify the moderator conditions under which the void coefficient of reactivity becomes significant. • Define the following terms: burnable poison, non-burnable poison, chemical shim. • Explain the use of burnable neutron poisons in a reactor core. • State two reasons why fixed non-burnable neutron poisons are used in reactor cores. • Provide an example of a material used as a fixed non-burnable neutron poison. • List two methods of production and two methods of removal for xenon-135 during reactor operation. • State the equation for equilibrium xenon-135 concentration. • Describe how equilibrium xenon-135 concentration varies with reactor power level. • Describe how xenon-135 concentration changes following a reactor shutdown from steady-state conditions. • Explain the effect that pre-shutdown power levels have on the xenon-135 concentration after shutdown. • Describe the approximate time following a reactor shutdown at which the reactor can be considered "xenon free." • Explain what is meant by a xenon precluded startup. • Describe how xenon-135 concentration changes following an increase or a decrease in the power level of a reactor. • Define integral control rod worth and differential control rod worth. • Describe the shape of a typical differential control rod worth curve and explain the reason for the shape. • Describe the shape of a typical integral control rod worth curve and explain the reason for the shape. • Given an integral or differential control rod worth curve, calculate the reactivity change due to a control rod movement between two positions.
Week 4 : 5 August - 9 August	Activity	Learning Objectives • List three uses or purposes of the OPAL reactor. • Describe the OPAL reactor core, including the geometry and materials of the following: fuel assemblies, control elements, reflector. • Explain the use of burnable poison at OPAL. • Contrast the function and use of the four safety plates with those of the central, cruciform regulating rod. • List advantages of the following materials at OPAL: zircaloy, hafnium, aluminium 6061. • Describe the axial and radial neutron flux profile for OPAL, assuming a homogeneous core. • Explain which reactivity coefficients are most significant at OPAL. • Given an integral or differential control rod worth curve for OPAL, calculate the reactivity change due to a control rod movement between two positions. • Convert between reactivity and the associated value of keff for typical values at OPAL. • Explain the effect of Xe after an OPAL reactor trip or shutdown. • Describe how negative reactivity is added to the OPAL reactor upon initiation of the second shutdown system. • Calculate a macroscopic cross section given a material density, atomic mass, and microscopic cross section that is specific to OPAL. • Given the neutron flux and macroscopic cross section, calculate the reaction rate.

		• Demonstrate the ability to calculate the following, given data that is specific to OPAL: average thermal neutron flux, fuel usage, reactivity and keff.

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

General Schedule Information

In general, lectures are on Wednesday and Thursday afternoons. Tutorial and lab are on Friday.

Wednesday lecture 1500-1700 hours in LecSth03

Thursday lecture 1400-1600 hours in LecThSth05

Friday tutorial 1200-1300 hours LecThSth05

Friday lab 1700-1800 hours LecThSth05

Week 1 begins Monday, 15 July 2024. Note the two week mid-term break after week 6. Classes on 10/11 October (week 11) are lost due to military training. Compensation day on Friday 16 August - classes to be delivered on Tuesday 13 August.

Topics by week:

1 - Nuclear Fundamentals (atomic structure, mass defect and binding energy, radioactive decay and radioactivity, neutron interactions, fission)

2 - Reactor Theory (neutron sources, cross sections and neutron flux, reaction rates, neutron moderation, flux spectrum)

3 - Reactor Theory (neutron life cycle, reactivity and coefficients, neutron poisons, xenon and samarium, control rods)

4 - Theory to Practice - OPAL (application of reactor theory to the specific design of the OPAL reactor)

5 - Reactor Operations (subcritical multiplication, reactor kinetics, reactor operations)

6 - Nuclear Power Reactors (basics of commercial reactors and application of reactor theory and operation to a PWRs)

7 - Nuclear Power Reactors (basics of commercial reactors and application of reactor theory and operation to a PWRs)

8 - Radiation Safety (radiation units, biological effects, detection and measurements, the ALARA principle, dose monitoring)

9 - Small Modular Reactors (application of learnings from weeks 1-8 to specific SMR designs)

10 - Nuclear Propulsion (application of learnings from weeks 1-9 to the design and operations of nuclear technology for propulsion)

11 - Radioactive Waste/Military

12 - Nuclear Design Criteria (e.g, general design criteria, brittle fracture prevention, containment)

13 - Presentations and miscellaneous Topics (e.g.,nuclear fuel cycle, nuclear safeguards and non-proliferation)

Course Resources

Prescribed Resources

Weekly lectures, homework assignments, and learning objectives.

Compulsory Text

Murray, R.L., & Holbert, K.E. (2020). Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (8th edition). Butterworth-Heinemann.

Recommended Resources

Recommended Readings

Lamarsh, J.R., & Baratta, A.J. (2018). Introduction to Nuclear Engineering (4th edition). Pearson Education.

Yu, J. (2022). Fundamental Principles of Nuclear Engineering. Tsinghua University Press.

Sforza, P.M. (2012). Theory of Aerospace Propulsion. Elsevier.

Additional Costs

None

Course Evaluation and Development

Student feedback is encouraged. Students are encouraged to use the recommended UNSW methods.

One of the key priorities in the 2025 Strategy for UNSW is a drive for academic excellence in education. One of the ways of determining how well UNSW is progressing towards this goal is by listening to our own students. Students will be asked to complete the myExperience survey towards the end of this course.

Students can also provide feedback during the semester via: direct contact with the lecturer, the "On-going Student Feedback" link in Moodle, Student-Staff Liaison Committee meetings in schools, informal feedback conducted by staff, and focus groups. In addition, student feedback will be welcome at any time and via any method desired. Student opinions really do make a difference. Refer to the Moodle site for this course to see how the feedback from previous students has contributed to the course development.

Important note: Students are reminded that any feedback provided should be constructive and professional and that they are bound by the Student Code of Conduct Policy

https://www.gs.unsw.edu.au/policy/documents/studentcodepolicy.pdf

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Lecturer	Jack Dillich		Building 17, Room 221	TBD	As requested, generally Wednesday - Friday.	No	Yes