



Mechanical and Manufacturing Engineering

Course Outline

Term 2 2019

ENGG9743

Fuel Cycle, Waste and Life Cycle Management

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1. Staff contact details

Contact details and consultation times for course convenor

Name: Dr. Patrick Burr

Office location: Room 402A, Ainsworth building (J17)

Email: p.burr@unsw.edu.au

You are encouraged to ask questions on the course material, through the learning platform (Moodle) and the arranged forum discussions in the first instance, rather than via email. ALL email enquiries should be made from your student email address with ENGG9743 in the subject line; otherwise they may not be answered. Email queries may be answered in the learning platform to benefit all students.

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.

Contact details and consultation times for additional lecturers/demonstrators/lab staff

Lecturers: Dr. Patrick Burr
Dr. Dan Gregg
Dr. Kapila Fernando
Dr. Rohan Holmes

Please see the course [Moodle](#).

2. Important links

- [Moodle](#)
- [Lab Access](#)
- [Computing Facilities](#)
- [Student Resources](#)
- [Course Outlines](#)
- [Engineering Student Support Services Centre](#)
- [Makerspace](#)
- [UNSW Timetable](#)
- [UNSW Handbook](#)
- [UNSW Mechanical and Manufacturing Engineering](#)

3. Course details

Credit points

This is a 6 unit-of-credit (UoC) course.

The normal workload expectations of a student are approximately 25 hours per term for each

UOC, including class contact hours, other learning activities, preparation and time spent on all assessable work.

You should aim to spend about 10-12 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

Contact hours

The course will be delivered online, with weekly installments and corresponding exercises posted to the learning platform. The subject will be supported online with synchronous tutorial classes.

Summary and Aims of the course

This is a postgraduate course in the faculty of Engineering, convened by School of Mechanical and Manufacturing Engineering. It is a core class on the MEngSci Nuclear Engineering specialization and can be taken by students from Arizona State University via the PLS Alliance scheme, and as an elective by 3rd or 4th year students from other schools and Faculties on the approval of home school and the ENGG9743 course convener.

The nuclear fuel cycle is a vital aspect of all nuclear technologies, from power reactors, to nuclear medicine, and this class covers the cycle from extraction to storage and disposal. Fuel cycles vary with reactor technology and the course will review each of the existing processes in use. The course will also review improvements made in recycling processes, and how conventional processes need to be adapted for the requirements of the nuclear industry.

The waste management aspects of this course focus on the growing need in the nuclear industry to understand the physics and engineering aspects of dealing with radiologically contaminated waste, including classification, processing, storage and disposal options.

This course is designed to give in-depth, practical knowledge of the nuclear fuel cycle from the metallurgy of uranium to the disposition of used reactor fuel. It will provide details of current and future nuclear reactor designs for the generation of electricity and radioisotopes, their life cycle and decommissioning. This course will not only provide a comprehensive study of the traditional fuel cycle (the uranium/plutonium once-through cycle), but it will also discuss the closure of the nuclear fuel cycle as well as fuel cycles that may be the future of nuclear power and nuclear technologies. The course also provides an insight into the principles and practices of waste management and disposal.

There is no mandatory pre-requisite for this course; however, it is essential that students are familiar with basic engineering principles and mathematical skills before this course is attempted. It is recommended that students take an introductory course to nuclear engineering (such as ENGG9741 or YENG9741) prior to taking this course to provide an understanding of nuclear fission. A grounding in chemistry and physics is also useful.

Student learning outcomes

This course is designed to address the learning outcomes below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

This course also addresses the IAEA International Nuclear Management Academy (INMA) learning outcomes for masters' level course in Nuclear Technology Management Appendix B.

After successfully completing this course, you should be able to:

Learning Outcome		EA Stage 1 Competencies
1.	Describe the fundamentals of uranium mining, milling and conversions	PE1.3
2.	Discuss fuel fabrication techniques and reprocessing routes	PE1.2, PE1.3
3.	Calculate key parameters for enrichment, fabrication and reprocessing	PE1.3, PE2.1
4.	Illustrate systems and processes required in nuclear engineering facilities beyond conventional engineering practice.	PE1.5, PE2.4
5.	Compare and contrast different reactor systems and different medical isotope production methods.	PE1.4
6.	Describe technological challenges and regulatory aspects associated with decommissioning, environmental protection, monitoring and remediation.	PE1.5
7.	Identify options for processing high level waste for storage and disposal.	PE1.3, PE1.5
8.	Examine the key principles associated site selection, site characterization, waste acceptance criteria for near-surface and deep disposal of radioactive waste.	PE1.5, PE2.3

4. Teaching strategies

Delivery Mode

Fully online. The teaching in this course aims at establishing a good fundamental understanding of the areas covered using video recordings, reading materials, self-moderated (tutor guided) forum discussions, and online (synchronous) tutorials.

Learning in this course

You are expected to complete all online tasks, including watching videos, answering quizzes, attending tutorials, and engaging in forum discussions to maximise learning. 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. Learning materials and graded assessments will be paced throughout the duration of the course. As some of the assignments required group interaction, it is essential that you keep up with the pace of the course, and effectively manage your time in this course to view the material and complete the assignments on time.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the synchronous tutorial sessions. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class. In addition, during the tutorial class, 1-2 new questions that are not in your notes may be provided by the tutor, for you to try in class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes to gain maximum benefit from this course.

Lecturers

Dr Patrick Burr has a background in material science and a PhD from Imperial College London, where he also did his undergraduate degree. His research focus is in energy materials, specifically nuclear, photovoltaic and batteries. The aim of his research is to understand the degradation processes of energy materials, with the goal of informing the design and optimisation of novel materials for a greener energy future. Nuclear materials in particular pose the greatest challenge and opportunity, as they are subject to the most extreme environments (as you will learn in this course). Patrick's approach is to use a combination of atomic scale simulation techniques and experimental methods to provide a mechanistic understanding of the processes that occur in materials under demanding environments. He has taught in *Introduction to Nuclear Engineering*, *Nuclear reactor physics*, *Materials Modelling*, *The Nuclear Fuel Cycle*, *Crystallography*, *Ethics and Leadership*, and *Fuel and Energy Engineering*.

Dr Daniel Gregg is a research scientist with over 15 years of experience in Chemistry and Materials Science. Daniel completed his Bachelor of Chemistry with first class honours at Victoria University in Wellington, New Zealand, following which he worked for a year as a research chemist in industry. Daniel completed his PhD in Materials Chemistry within the Inorganic and Synthetic Materials Chemistry group at Trinity College Dublin. He then completed two postdoctoral positions in Ireland, conducting ground-breaking research in Materials Science including the development of a novel family of 'soft' materials with application as nano-wires. During this time Daniel was appointed a teaching fellow in the School of Chemistry where he enjoyed two years as course coordinator and lecturer for a second year Chemistry course. In 2009, Daniel relocated to Melbourne, Australia, where he worked for a year in industry, applying his experience to the development of new pharmaceutical drug candidates. Daniel then moved to Sydney in 2010 where he was appointed Research Scientist in the Institute of Materials Engineering at ANSTO. He currently leads the Nuclear Wasteforms Research Activity group where he focuses on the development of materials with utility in the nuclear fuel cycle and next generation nuclear

energy systems. Daniel is a member of the International Scientific Advisory Committee, for the Materials Research Society Symposium on the Scientific Basis for Nuclear Waste Management. Aside from his research, Daniel is an enthusiastic science communicator and a keen promoter of science to high school and university students.

Dr Rohan Holmes currently leads the Process Engineering Team for ANSTO Synroc. Rohan completed a Bachelor of Chemical Engineering and a Masters of Biomedical Engineering prior to completing a PhD in Polymer Science and Engineering at the University of New South Wales. Rohan completed two postdoctoral positions at ANSTO where research focused on the fabrication of ceramics and the behaviour of materials in molten salt environments. During his time with ANSTO Synroc, Rohan has overseen the design, development, and construction of the ANSTO Synroc Demonstration Plant. He now leads the team responsible for the delivery of the powder production process for the SyMo Facility where intermediate level liquid waste from the production of 99-Mo is immobilised.

5. Course schedule

Week	Mode	Topic
Week 1 (3 rd June)	Asynchronous + Zoom	Overview of nuclear fuel cycle, mining and milling Forum topics 1 – Presentation assigned
Week 2 (10 th Jun)	Asynchronous	Conversion to UF ₆ and enrichment
Week 3 (17 th Jun)	Asynchronous	Conversion to UO ₂ and nuclear fuel fabrication Forum topic 2
Week 4 (24 th Jun)	Asynchronous + Zoom	In reactor behaviour and future fuels
Week 5 (1 st Jul)	Asynchronous	Used fuel characterization, reprocessing and interim storage Presentations due
Week 6 (8 th Jul)	Asynchronous + Zoom	Nuclear waste forms Forum topic 3
Week 7 (15 th Jul)	Asynchronous	Nuclearization of processes Essay Assigned
Week 8 (22 nd Jul)	Asynchronous + Zoom	Waste management Forum topic 4
Week 9 (29 th Jul)	Asynchronous	Waste disposal options
Week 10 (5 th Aug)	Asynchronous + Zoom	Decommissioning, monitoring and remediation Essay Due

6. Assessment

Assessment overview

Assessment		Group Project? (# Students per group)	Length	Weight	Learning outcomes assessed	Assessment criteria	Due date and submission requirements	Deadline for absolute fail	Marks returned
Assignments	Online presentation	No	10 minutes	15%	5	Quality of content, delivery, level of interaction through Q&A and feedback	Week 5	Week 6	Week 6
	Self-moderated forum participation	Whole class	300+ words 2+ interactions	15%	4, 5, 6	Ability to maintain a vibrant and respectful debate environment	Weeks 2, 4, 7 and 9	N/A	Weeks 3, 5, 8 and 10
	Essay	No	< 2000 words	15%	6	Completion and correctness of response to problems, quality of report, understanding of course material	Week 10	Week 11	Week 11
Exam	Final exam	No	2 hours	55%	1-10	All course content from weeks 1-10 inclusive, correctness of responses	Exam period, date TBC	N/A	Upon release of final results

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

Assignments

The assignments allow self-directed study leading to the solution of partly structured problems, open essays and presentations. The due dates of the assignments are provided in the content schedule above and will be confirmed in the lectures.

Presentation (15%)

Each student will be given one topic for which they will have to prepare an online (asynchronous) presentation. The topics will be a Generation IV reactor technology or a nuclear medicine production technology. Marks will be given for quality of content, quality of delivery, and level of interaction through Q&A and feedback.

Self-moderated forum (15% pass/fail)

Each fortnight a new (controversial) forum topic will be issued together with some reading material. A student (or group of students) will be nominated as the topic moderator. They will provide an initial summary of the topic, and ask provocative questions. The entire class will participate with their comments and opinions, maintaining a collegial and encouraging form for debate. The students are expected to provide a minimum of two interactions and 200 words per topic. The topic moderator will also be assessed on their ability to maintain a vibrant and respectful debate environment. All marks are pass/fail.

Problem or Essay (15%)

Students will have to solve a partially structured problem and/or write an essay on a topic related to waste management. Marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the report, and the understanding of the course material demonstrated by the report.

Presentation

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Submission

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 20 percent (20%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

- a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
- b. Online quizzes where answers are released to students on completion, or
- c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
- d. Pass/Fail assessment tasks.

Marking

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

Examinations

The exam in this course is an open-book 2-hour written examination. 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, 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 to pass the course.

You must be available for all tests and examinations. Final examinations for each course are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates.

For further information on exams, please see the [Exams](#) webpage.

Calculators

You will need to provide your own calculator of a make and model approved by UNSW for the examinations. The list of approved calculators is available at student.unsw.edu.au/exam-approved-calculators-and-computers

It is your responsibility to ensure that your calculator is of an approved make and model, and to obtain an "Approved" sticker for it from the [Engineering Student Support Services Centre](#) prior to the examination. Calculators not bearing an "Approved" sticker will not be allowed into the examination room.

Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

Please note that UNSW now has a [Fit to Sit / Submit rule](#), which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's [Special Consideration page](#).

7. Expected resources for students

Reference Textbooks

1. Basic Nuclear Engineering

Author: Foster and Wright

ISBN 978-0205078868

Publisher Allyn and Bacon

2. Nuclear Chemical Engineering

Author: Benedict, Pigford, Levi

ISBN 978-0070045316

Publisher McGraw-Hill

3. Comprehensive Nuclear Materials Book

Author: Rudy Konings

ISBN 978-0080560274

Year Published 2012

4. Nuclear Energy: Principles, practices and prospects

Author: David Bodansky

ISBN 978-0387207780

Year Published 2005

UNSW Library website: <https://www.library.unsw.edu.au/>

Moodle: <https://moodle.telt.unsw.edu.au/login/index.php>

8. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include continuing to evaluate and modify our delivery and assessment methods. The exam length was reduced from 3 hours to 2, comprising 5 questions instead of 7, and the corresponding weight was reduced from 70% to 55%. The assignment weight was increased from 3*10% to 3*15% to reflect the expected work-load commitment.

9. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here:

www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

10. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and policies. In particular, students should be familiar with the following:

- [Attendance](#)
- [UNSW Email Address](#)
- [Computing Facilities](#)
- [Special Consideration](#)
- [Exams](#)
- [Approved Calculators](#)
- [Academic Honesty and Plagiarism](#)
- [Student Equity and Disabilities Unit](#)
- [Health and Safety](#)
- [Lab Access](#)

Appendix A: Engineers Australia (EA) Competencies

Stage 1 Competencies for Professional Engineers

	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

Appendix B: IAEA International Nuclear Management Academy (INMA) learning outcomes for masters' level course in Nuclear Technology Management

INMA Competency Area*	INMA Competency Level
2.1 Nuclear power plant and other facility design principles	1
2.2 Nuclear power plant/facility operational systems	1
2.3 Nuclear power plant/facility life management	1
2.5 Systems engineering within nuclear facilities	1
2.9 Nuclear fuel cycle technologies	2
2.10 Nuclear waste management and disposal	2
2.11 Nuclear power plant/facility decommissioning	1
2.12 Nuclear environmental protection, monitoring and remediation	1
2.13 Nuclear R&D and innovation management	1
2.14 Application of nuclear science	2
3.1 Nuclear engineering project management	1

*Grosbois, J. de, F. Adachi, and H. Hirose. 2017. "International Nuclear Management Academy Master's Programmes in Nuclear Technology Management." IAEA.