



MECH9720

Solar Thermal Energy Design

Term Two // 2021

Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Robert Taylor	robert.taylor@unsw.edu.au	By Appointment	402C Ainsworth Building	02 9385 5400

Demonstrators

Name	Email	Availability	Location	Phone
Amr Omar	amr.omar@unsw.edu.au	By Appointment	Room 402, Ainsworth Building	
David Saldivia Salazar	d.saldiviasalazar@unsw.edu.au	By Appointment	Tyree Building	

School Contact Information

Location

UNSW Mechanical and Manufacturing Engineering

Ainsworth building J17, Level 1

Above Coffee on Campus

Hours

9:00–5:00pm, Monday–Friday*

*Closed on public holidays, School scheduled events and University Shutdown

Web

[School of Mechanical and Manufacturing Engineering](#)

[Engineering Student Support Services](#)

[Engineering Industrial Training](#)

[UNSW Study Abroad and Exchange](#) (for inbound students)

[UNSW Future Students](#)

Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

(+61 2) 9385 4097 – School Office**

**Please note that the School Office will not know when/if your course convenor is on campus or available

Email

[Engineering Student Support Services](#) – current student enquiries

- e.g. enrolment, progression, clash requests, course issues or program-related queries

[Engineering Industrial Training](#) – Industrial training questions

[UNSW Study Abroad](#) – study abroad student enquiries (for inbound students)

[UNSW Exchange](#) – student exchange enquiries (for inbound students)

[UNSW Future Students](#) – potential student enquiries

- e.g. admissions, fees, programs, credit transfer

[School Office](#) – School general office administration enquiries

- NB: the relevant teams listed above must be contacted for all student enquiries. The School will only be able to refer students on to the relevant team if contacted

Course Details

Credit Points 6

Summary of the Course

The following assumed knowledge is expected for postgraduate students undertaking this course: MMAN2600 and MMAN2700.

Characteristics of solar radiation and solar collectors. Collector efficiency evaluation and prediction of long term performance. System modelling, energy storage; computer simulation and modelling of performance and economic worth.

Course Aims

Solar thermal energy is created when radiation from the sun is converted to heat energy (directly) or into electrical energy (indirectly via heat) for applications in the residential, industrial, and commercial sectors. This course will give you an engineering perspective of how solar thermal technology is designed, constructed, and operated. The first section of the course deals with the characteristics of sunlight, along with some methods of analysis and measurement of solar radiation. The second section of the course covers the working principles of solar thermal technology (low and high tech) and gives you the general tools necessary to analyze heat and mass transfer within these devices. Lastly, we will cover how these technologies can be integrated into systems including control, circulation, and storage. The content reflects the experience of the lecturer/guests in the research, development, and installation of these systems, experience which is drawn upon throughout the lectures and demonstrations. This course focuses on the terminology, principles and methods used in solar thermal engineering. Engineering heat transfer analysis will be used to solve much of the quantitative components of the course (MECH3610).

This course should aid students who intend to take more classes, or pursue a career, in renewable energy and/or the thermal sciences. The course deliberately stays away from photovoltaics and focuses on the conversion of solar energy into heat. This heat can then be used for a wide variety of applications ranging from pool heating at ~30 oC to processing minerals (e.g. Aluminum) at >700 oC.

In summary, this course will provide an engineering basis for a technical analysis of the characteristics of solar radiation and solar collectors. It will provide students with tools for conducting solar thermal collector efficiency evaluations and for the prediction of long-term performance of solar thermal systems. Thus, the course will include energy storage and system modeling via computer simulation of the performance and economic worth of solar thermal systems.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Obtain a basic understanding of how to measure and calculate salient radiation properties and data that will allow you to solve solar thermal energy design problems	PE1.1

Learning Outcome	EA Stage 1 Competencies
2. Be able to use engineering terminology associated with solar thermal energy systems	PE1.2, PE1.3
3. Understand and be able to use the terminology associated with solar thermal energy to create a professional report.	PE3.1, PE3.5
4. Apply the above to solar thermal systems from an engineering perspective	PE2.1, PE2.2, PE2.3, PE2.4

Teaching Strategies

The teaching strategies that will be used include:

- Weekly LIVE Teams Discussions and Demonstration sessions (from Week 2), both in Teams.
- Asynchronous presentation of the material as video recordings of past lectures, in Moodle.
- 25 Interactive Lessons, in Moodle
- Course Notes, in Moodle
- A mix of qualitative and quantitative materials
 - Quantitative engineering calculations of heat and mass transfer and design trade-offs for these technologies
 - Qualitative considerations of engineering design choices and the market for these technologies, along with career opportunities
- A virtual 360 Laborator and/or face-to-face labs, to conduct testing in accordance with Australian standards for solar thermal collectors
- The use of software tools to solve solar engineering problems

Additional Course Information

In this course we will use the **Teams** channel for most communications (Discussion/Demonstration sessions and continuous Q&A) and **Moodle** as the main file transfer medium (hosting the Lessons, recorded Lectures/Demos, assessment instructions, and also ALL assessment submission will be in **Moodle**).

IMPORTANT NOTE: For **Teams** communications, we will *endeavor to respond to all questions within 1-2 business days*.

Suggested approaches to learning in the course include:

- Careful reading of at least one mode of all course content (Lectures, Lessons, Note, Discussion)
- Carry out all the demonstration problem calculations
- Active participation in the Lab group assessment
- Complete SAM assignment Tasks early
- Additional reading related to the material presented in lectures to broaden the knowledge base
- Conscientiously going through ALL the worked problems
- Perusal of the past examination paper(s), sample Lesson problems, to practice typical Exam questions
- Asking questions and interaction with fellow students in **Teams**

Assessment

Assignments, marking guidelines, assessment submission, and other details (i.e. Rubrics) will be available on **Moodle**, please check in regularly. If deemed necessary, clarifications and/or hints may be provided via **Teams**, so please endeavor to check both **Moodle** and **Teams** regularly during the session.

Assessment Tasks

Assessment task	Weight	Due Date	Student Learning Outcomes Assessed
Weekly Quizzes	10%	Not Applicable	1, 2, 3, 4
Laboratory Report	25%	30/07/2021 05:00 PM	1, 2, 3, 4
System Advisor Model Report(s)	25%	Not Applicable	1, 2, 3, 4
Exam	40%	20/08/2021 05:00 PM	1, 2, 3, 4

Assessment Details

Assessment 1: Weekly Quizzes

Start date: Not Applicable

Length: 10 weekly Quizzes

Details:

Purpose: The weekly Moodle quizzes are designed to incrementally progress students through the course content (roughly in line with the Lessons and Lectures).

Skills: The quizzes require simple calculations based upon unit conversions and the equations presented in Lessons, Lectures, and the course notes.

Knowledge: Qualitative information is also assessed regarding solar thermal materials, components, and systems terminology/knowledge. Some quizzes may require searching the web to find relevant information.

Task: 10X Quizzes are released/due in Moodle weekly. (Typically due before the next scheduled lecture time.) Each Quiz will have 1-5 questions and should take 15-20 minutes to complete.

Deadline for absolute fail: After weekly deadline closes in Moodle (i.e. ~1 week from opening of the Quiz).

Marks Returned: Immediately after submission deadlines.

Additional details:

Exact opening due dates/times to be provided in Moodle.

Submission notes: Due each week before the next scheduled lecture time.

Turnitin setting: This is not a Turnitin assignment

Assessment 2: Laboratory Report

Start date: 14/06/2021 09:00 AM

Details:

Purpose: The purpose of the Laboratory is to measure and calculate the efficiency of 3 types of solar thermal collectors (flat plate, evacuated tube, and parabolic concentrator).

Skills: Students will learn how to measure solar thermal performance data and the analytical procedures (e.g. outlier removal and regression analysis) required create solar collector efficiency correlation equations, following a process similar to Australian (AS 2535) and International Standards (ISO 9806).

Knowledge: Knowledge of industry practice will be gained from doing the analysis. The final Report will contain the information required from an Accredited test lab, a key step that ALL solar thermal collectors sold in Australia must go through to obtain small-scale technology certificates (STCs).

Task: A final Laboratory Report will be written and submitted as a group assessment (4-6 students per group) which is similar to a solar collector standardized test report. Some of the mark for this assessment (10-20%) will come from peer assessment.

Deadline for absolute fail: 5 days after deadline (late penalty of 20% per day).

Marks returned: Within 2 weeks of submission deadline.

Submission notes: Students must also submit a peer review as part of the marking.

Turnitin setting: This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

Assessment 3: System Advisor Model Report(s)

Start date: 14/06/2021 09:00 AM

Length: 2-5 pages per Task

Details:

Purpose: The aim of this assessment is for students to learn how to do a pre-feasibility techno-economic analysis of the 3 main solar thermal technologies (hot water, industrial process heat, and concentrated solar thermal electricity).

Skills: Use of a software package, the System Advisor Model, which can provide high-level transient analysis of renewable energy systems, utilizing global weather data inputs and detailed cost estimations.

Knowledge: Upon submission, students will know how to conduct a desktop parametric study, and present the findings for, solar thermal systems at a level close to what would be required from a preliminary feasibility report for a graduate role at an engineering design, procurement, and construction and/or an engineering consulting firm.

Task: 3 separate analysis Tasks are to be conducted in the free to download software package, System Advisor Model (SAM). The Assessment instructions will provide details on the parameters of interest and the questions to be addressed (and reported upon) within this analysis. The Tasks will be due in Weeks 5 (Task 1 = 2 July), 7 (Task 2 = 16 July), and 10 (Task 3 = 6 August).

Deadline for absolute fail: 5 days after submission deadlines for each Task (20% per day late penalty, according to School policy.)

Marks returned: Within 2 weeks of submission deadlines.

Additional details:

This assessment is broken down into 3 'Tasks' – on the design of low, medium, high temperature solar thermal systems. For each Task you will need to do annual, parametric simulations in SAM and then write a single, individual report that covers all the criteria mentioned in the Tasks.

The Task Reports should be organized, easy to read, and any supporting material should be properly labeled and referenced. For full marks on your reports you must justify all choices and assumptions and use concise tables and/or figures to compare and contrast your results. Detailed assessment introductions and the Marks associated with each Task will be provided in Moodle.

Submission notes: Submit 3 Separate Tasks Moodle

Turnitin setting: This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

Assessment 4: Exam

Start date: 16/08/2021 08:00 AM

Length: ~15 Questions

Details:

Purpose: The Exam will comprehensively assess student's knowledge of the course content, using an even mix of quantitative and qualitative questions.

Skills/Knowledge: Since this is a 'take home' Exam, students will have a full week to apply, and enhance, their analysis/reasoning skills and fundamental knowledge on the performance and feasibility of solar thermal resources, materials, components, and systems.

Task: A 'take home' Exam, delivered as a Quiz in Moodle. It will contain ~15 Questions, each of which may have multiple parts. Students will have a full business week (Monday to Friday) to complete it. It is recommended that students answer (and save) a few questions each day, rather than trying to complete it all at once.

Submission notes: Submit at any time within the week (before the deadline).

Turnitin setting: This is not a Turnitin assignment

Attendance Requirements

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

Course Schedule

[View class timetable](#)

Timetable

Date	Type	Content
O Week: 25 May - 28 May	Module	Moodle course visible to students, including orientation video and Course Notes.
Week 1: 31 May - 4 June	Online Activity	Solar Thermal Overview / 3 Moodle Lessons: Introduction to Solar Energy Systems; Non-Concentrating Solar Thermal Collectors; Concentrating Solar Thermal Collectors
	Lecture	Week 1 Lecture Video.
	Online Activity	Weekly Teams Discussion (attendance optional)
Week 2: 7 June - 11 June	Online Activity	2 Moodle Lessons: The Solar Resource; Black Bodies and Radiation
		Week 2 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
Week 3: 14 June - 18 June	Online Activity	2 Moodle Lessons: Solar Instruments and Measurements Part 1 & Part 2
	Online Activity	Week 3 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
	Tut-Lab	Sydney-based students will have the opportunity to attend a 1-hour in person lab (to be scheduled). [Other students can do the 360 virtual lab.]
Week 4: 21 June - 25 June	Online Activity	2 Moodle Lessons: Inclined Surfaces and Diffuse Radiation Models; Applications of Inclined Surfaces
	Online Activity	Week 4 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
	Tut-Lab	Sydney-based students will have the opportunity to attend a 1-hour in person lab (to be scheduled). [Other students can do the 360 virtual lab.]
Week 5: 28 June - 2 July	Online Activity	4 Moodle Lessons: Absorber Plates and Reflection; Collector Efficiency and Operation; Solar Collector

		Heat Losses; Evaluating the Solar Collector Efficiency Factor
	Online Activity	Week 5 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
	Tut-Lab	Sydney-based students will have the opportunity to attend a 1-hour in person lab (to be scheduled). [Other students can do the 360 virtual lab.]
Week 6: 5 July - 9 July	Online Activity	Flexibility week. Revision of previous content.
Week 7: 12 July - 16 July	Online Activity	2 Moodle Lessons: Collector Stagnation Temperature, Part 1 & Part 2
	Online Activity	Week 7 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
Week 8: 19 July - 23 July	Online Activity	3 Moodle Lessons: Flat Plate Solar Collector Optimisation; TRNSYS & Other Solar Modelling Software; Solar Hot Water Systems Part 1
	Online Activity	Week 8 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
Week 9: 26 July - 30 July	Online Activity	2 Moodle Lesson: Evacuated Tubes; Solar Hot Water Systems Part 2
	Online Activity	Week 9 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).
Week 10: 2 August - 6 August	Online Activity	2 Moodle Lessons: Large Scale Solar Thermal Development, Part 1 and Part 2
	Online Activity	Week 10 Lecture Video.
	Online Activity	Weekly Teams Discussion.
	Module	Weekly Demonstration session. Video recordings and/or live sessions with demonstrators (choice of LIVE or asynchronous videos).

Resources

Prescribed Resources

Restating the above, the following represents a list of the most useful resources for this course:

- MECH9720 Course Notes* (in Moodle)
- The course notes are needed to solve the demonstration session problems and roughly follow along with the course content.
- Online Lessons (in Moodle)
- Video recordings of lectures from previous years (in Moodle)
- Video recordings of problem solving demonstrations (in Moodle)
- Live in-person/online problem solving demonstrations (Teams or in-person)
- A Virtual 360 Lab tool
- Assignment details (templates, examples, rubrics) in Moodle
- Lecture notes/slides in Moodle
- Worked and numeric solutions to selected problems in Moodle
- An ongoing discussion in Teams (with Live access during scheduled lecture times)
- Links to solar resources and other supplementary information

Recommended Resources

Aside from the Course Notes, which are provided on Moodle, the following are suggested for further reading:

- Duffie J.A. & Beckman, W.A. Solar Engineering of Thermal Processes, Wiley 2013 [4th edition available from <https://library.unsw.edu.au> in the Wiley eBooks Collection]
- Cengel, Y.A. and Ghajar, A.J., Heat and Mass Transfer, McGraw Hill, 2011
- Academic Journals: Solar Energy, J. Solar Energy Engineering, Applied Energy, Energy Renewable Energy, Renewable and Sustainable Energy Reviews.

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 removal of the PG report (additional work for PG students), the addition online quizzes (in lieu of a test), resources and feedback (including the adaptive lecture lessons), new laboratory facilities (now as a virtual lab as well), and changes to the assessments to manage student workload (the Lab is now a group report), more worked problems have been made available, and additional feedback on progress throughout the course has been implemented.

Laboratory Workshop Information

During the course, we will have an opportunity for in-person students to conduct a physical lab activity on the rooftop (Level 6) of the Ainsworth building. For those that would like to attend in person, we will have an online sign-up sheet in due course.

Submission of Assessment Tasks

Assessment submission and marking criteria

Should the course have any non-electronic assessment submission, these should have a standard School cover sheet.

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.

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.

Late policy

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:

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

Examinations

You must be available for all quizzes, tests and examinations. For courses that have final examinations, these 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.

Special Consideration

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.

UNSW now has a [Fit to Sit / Submit rule](#), which means that if you attempt 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](#).

Please note that students will **not** be required to provide **any** documentary evidence to support absences from any classes missed **because of COVID-19 public health measures such as isolation**. UNSW will **not** be insisting on medical certificates from anyone deemed to be a positive case, or when they have recovered. Such certificates are difficult to obtain and put an unnecessary strain on students and medical staff.

Applications for special consideration **will** be required for assessment and participation absences – but no documentary evidence **for COVID 19 illness or isolation** will be required.

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

Academic Information

Credit points

Course credit is calculated in Units-Of-Credit (UOC). The normal workload expectation for one UOC is approximately 25 hours per term. This includes class contact hours, private study, other learning activities, preparation and time spent on all assessable work.

Most coursework courses at UNSW are 6 UOC and involve an estimated 150 hours to complete, for both regular and intensive terms. Each course includes a prescribed number of hours per week (h/w) of scheduled face-to-face and/or online contact. Any additional time beyond the prescribed contact hours should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

On-campus class attendance

Public distancing conditions must be followed for all face-to-face classes. To ensure this, only students enrolled in those classes will be allowed in the room. No over-enrolment is allowed in face-to-face classes. Students enrolled in online classes can swap their enrolment from online to a **limited** number of on-campus classes by Sunday, Week 1. Please refer to your course's Microsoft Teams and Moodle sites for more information about class attendance for in-person and online class sections/activities.

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by [NSW health](#) or government authorities. Current alerts and a list of hotspots can be found [here](#). **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate.** We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed. Further information is available on any course Moodle or Teams site.

In certain classroom and laboratory situations where physical distancing cannot be maintained or there is a high risk that it cannot be maintained, face masks will be considered **mandatory PPE** for students and staff.

For more information, please refer to the FAQs: <https://www.covid-19.unsw.edu.au/safe-return-campus-faqs>

Guidelines

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](#)
- [Special Consideration](#)
- [Exams](#)
- [Approved Calculators](#)
- [Academic Honesty and Plagiarism](#)

Important Links

- [Moodle](#)
- [Lab Access](#)
- [Computing Facilities](#)
- [Student Resources](#)
- [Course Outlines](#)
- [Faculty Transitional Arrangements for COVID-19](#)
- [Makerspace](#)
- [UNSW Timetable](#)
- [UNSW Handbook](#)
- [Equitable Learning Services](#)

Image Credit

[Solar Thermal Collector Array](#)

CRICOS

CRICOS Provider Code: 00098G

Acknowledgement of Country

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	✓
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	✓
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering 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	✓
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	✓
PE3.2 Effective oral and written communication in 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	