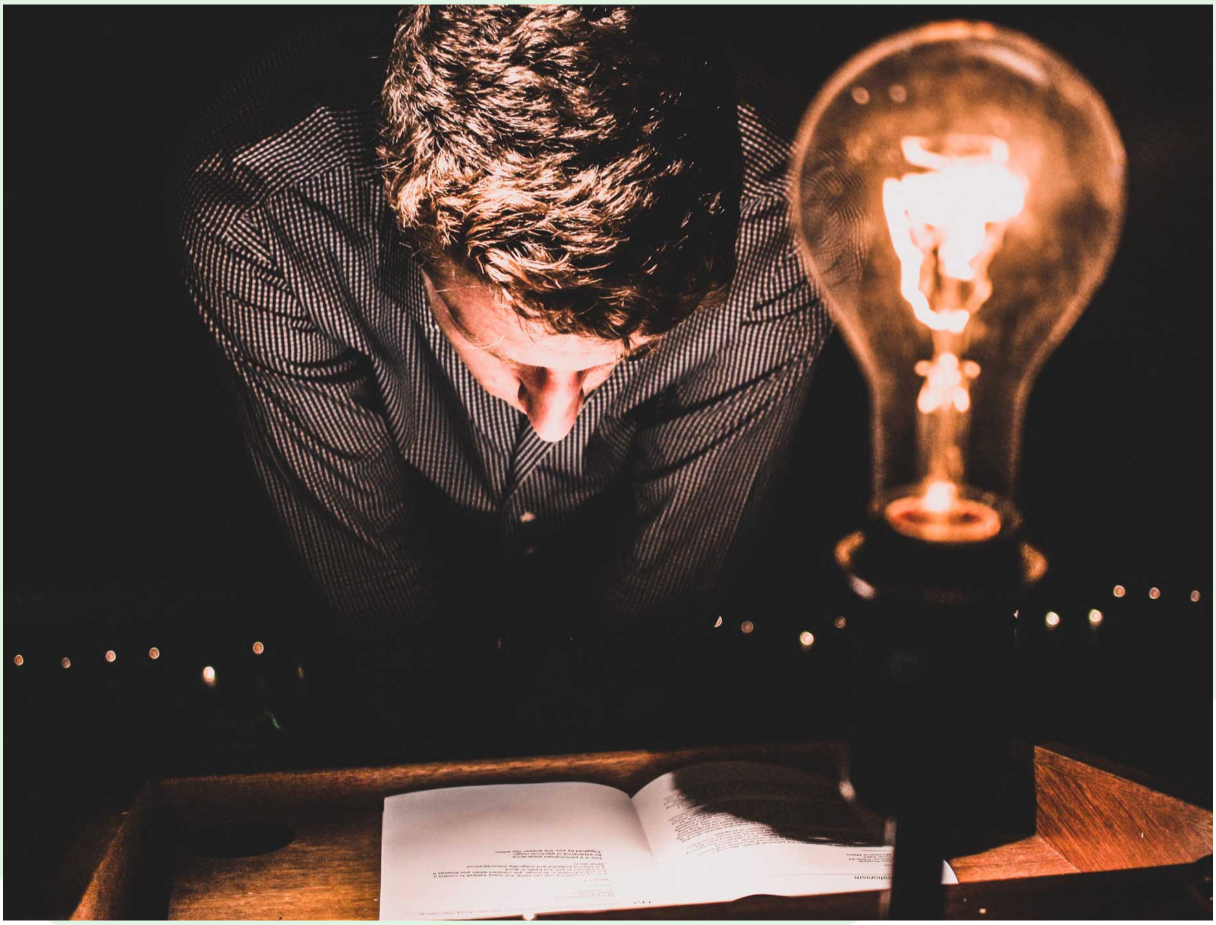
ELEC4631

Continuous - Time Control System Design

Term 2, 2022



Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Dr Hendra Nurdin	h.nurdin@unsw.edu.au	To be announced	G17 Level 3 Room 315	57556

School Contact Information

Consultations: Lecturer consultation times will be advised during the first lecture. 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 ELEC/TELExxxx in the subject line; otherwise, they will 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.**

Student Support Enquiries

For enrolment and progression enquiries please contact Student Services

Web

Electrical Engineering Homepage

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)

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

Course Details

Units of Credit 6

Summary of the Course

Overview of systems and control engineering with emphasis on modern and post-modern developments. Mathematical tools: matrices, quadratic forms, and eigenvalue decompositions. Modeling of linear time-invariant systems by using state space equations. Controllability and observability of linear time-invariant systems. Linear quadratic regulator. Servo-regulator control. Lyapunov stability. Observers. State and output feedback control design. Optimisation based techniques.

Course Aims

In recent years, modern systems and control have found numerous interesting applications in broad areas of automatic control, signal processing, communication, economics, finance, circuit analysis, mechanical and civil engineering, aeronautics, navigation and guidance etc. The purpose of this course is to provide students very basic concepts and problem solutions of modern systems and control that are useful for the mentioned applications.

The course will:

1. Further enhance students' understanding of simple as well as more complex continuous-time control systems.
2. Give a deeper introduction to state-space representation of continuous-time control systems, particularly for single input single output (SISO) linear systems.
3. Help students to understand the importance of the system state.
4. Familiarise students with the stability concept for linear and nonlinear systems, and controllability and observability concepts for linear systems.
5. Give students an understanding of basic analysis and synthesis tools for state space control systems, including basic design techniques for nonlinear systems.
6. Provide opportunities for students to gain practical experience in the use of computer-based state space design and analysis tools in Matlab and Simulink.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Demonstrated understanding of the notion of stability and know how to analyse stability using the direct and indirect methods of Lyapunov.	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2, PE3.3, PE3.4
2. Demonstrate the ability to analyse simple to moderately complex control systems (linear and nonlinear) using Lyapunov theory.	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2, PE3.3, PE3.4
3. Demonstrate a satisfactory understanding of linear systems and the fundamental notions of controllability and observability.	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2, PE3.3, PE3.4

Learning Outcome	EA Stage 1 Competencies
4. Demonstrate the ability to apply concepts and methods from modern control theory to design state feedback controllers, observers, and output feedback controllers for linear systems.	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2, PE3.3, PE3.4
5. Demonstrate the ability to synthesise control systems by convex optimization methodologies.	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2, PE3.3, PE3.4
6. Demonstrate the ability to design tracking controllers for linear state space systems.	PE1.1, PE1.2, PE1.3, PE2.1, PE2.2, PE3.3, PE3.4
7. Demonstrate the ability to synthesise modern state space controllers using Matlab and Simulink.	PE1.5, PE2.1, PE2.2, PE3.2, PE3.3, PE3.4, PE3.6

Teaching Strategies

Delivery Mode

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

- Lectures (hybrid - in-person and online), which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Tutorials (hybrid - in-person and online), which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Laboratory sessions (hybrid - in-person and online), which support the formal lecture material and also provide you with practical construction, measurement and debugging skills;
- Online consultations with the lecturer outside of class hours, according to the scheduled times.

Lectures

The lectures provide the students with explanation of the core material in the course. Numerous examples of analysis and design of simple to moderately continuous time dynamical systems using are discussed in order to convey their qualitative understanding.

Students are expected to attend the lectures and prepare themselves for them.

Tutorials

The tutorials enable students to analyze and design control systems. Students are expected to attend the tutorials and are expected to attempt to solve given tutorial questions before attending the tutorial.

Laboratories

The laboratories provide the students with hands-on experience to design, analyze and stimulate control systems. Students will also learn how to use of Matlab for system analysis and synthesis. Students must come prepared for the laboratory sessions.

Learning in this course

You are expected to attend all online lectures, tutorials, labs, and attempt quizzes and the mid-session exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. Reading additional texts beyond the lecture notes 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 formal classes throughout the course.
Especially important are learning strategies that you have to adopt.

- Learning is effortful - you have to make the effort.
- You have to develop your own mental models for how things work. I can give you insights, but you have to develop your own “schema”.
- You learn from errors and from discovering misconceptions.
- You cannot do this just by listening or reading. You have to try things out.
- Firstly, close your books and explain and write down concepts for yourself or for friends. Check. If your concept is not complete and accurate, do it again. You learn through the tip of your pen.
- Do all the tutorial problems to test your new-found understanding.
- You learn by doing. Make sure you become competent in the laboratory. Always come prepared before attending the labs, and pace yourself to complete in-lab tasks and experiments within the assigned lab time.
- The ultimate test of whether you have learned something is whether you can use it next year, or when you begin working. Only your schema are enduring. You will forget details, and setting out to simply memorise things is worthless - of minor assistance for exams only

Additional Course Information

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10-week term.

Relationship to Other Courses
This is a 4th year elective undergraduate course and a 1st year/postgraduate course in the School of Electrical Engineering and Telecommunications.

Pre-requisites and Assumed Knowledge
The pre-requisite for this course is ELEC3114 Control Systems. It is also essential that you are familiar with MATH2069, Mathematics 2A, and MATH2099, Mathematics 2B, before this course is attempted. Students are expected to be familiar and comfortable with:

- Vector calculus: functions of several variables, multivariable calculus, scalar fields, vector fields, gradients (MATH2069)
- Linear algebra: matrices, matrix inversion, matrix determinant, vectors, vector spaces, basis vectors, linearly independence, linear span of vectors, null/kernel spaces, characteristic equations, eigenvalues, eigenvectors, diagonalisation of a matrix, exponentiation of a matrix, Jordan canonical form (MATH2099)
- Control systems: Laplace transform, inverse Laplace transform, transfer functions, poles and zeros, feedback loop, steady-state error (ELEC3114)

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Quizzes	12%	Week 4 (Quiz 1) and Week 8 (Quiz 2)	1, 2, 3, 4
2. Lab Work	12%	Not Applicable	1, 4, 5, 7
3. Midterm Exam	20%	01/07/2022 03:45 PM	1, 2, 3
4. Final Examination	56%	Centrally timetabled	1, 2, 3, 4, 5, 6

Assessment 1: Quizzes

Start date: Week 3 (Quiz 1) and Week 7 (Quiz 2)
Assessment length: 1 week
Submission notes: Submissions after the specified deadline (to be announced on Moodle) are automatically deemed as late. Late quiz submissions will attract a deduction of 25% of the full marks per day that they are late.
Due date: Week 4 (Quiz 1) and Week 8 (Quiz 2)
Marks returned: 100

The two short take home quizzes are given to provide you with some feedback on some sections of the course. These should be done independently and honestly. Marks will be assigned according to correctness of the responses. Plagiarism is a serious academic misconduct that will entail a heavy penalty.

- Quiz 1 (6%) covers materials up to Week 2
- Quiz 2 (6%) covers materials from Week 4 to Week 7

Assessment criteria

Marks will be assigned according to the correctness of the responses.

Assessment 2: Lab Work

Assessment length: 10 weeks (Week 2 to Week 10)

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 lab book for recording your observations. A lab book is an A4 size notebook containing a mix of plain pages and graph sheets. You have to purchase your own lab book from any store.

It is essential that you prepare well before coming to the lab. This means reading through the lab manual and reviewing any relevant materials from lectures as required for the lab. You will be recording your observations/readings and your solutions to the lab exercises in your lab book. After completing each experiment, your work will be assessed by the laboratory demonstrator. The demonstrators will keep a recording of the marks that you achieved in any particular lab.

Students must not be late to the labs by more than 10 minutes. Demonstrators may turn away late students. No extra time will be provided to complete the labs for students who are late.

Assessment criteria

Assessment marks will be awarded according to how much of the lab you were able to complete, your demonstrated understanding of the experiments conducted during the lab, and your demonstrated understanding of the topics covered by the lab.

Assessment 3: Midterm Exam

Start date: 01/07/2022 02:15 PM
Assessment length: 1 hour
Submission notes: A penalty for late submissions applies at 25% of the full mark for submissions late by up to at most 5 minutes, 50% for submissions that are more than 5 minutes and up to 10 minutes late, and 75% for submissions that are more than 10 minutes and up to 15 minutes late. No marks will be awarded for submissions more than 15 minutes late.
Due date: 01/07/2022 03:45 PM
Marks returned: 100

The mid-term examination will test your general understanding of the course material and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course material up to the end of Week 4. It will definitely contain numerical and analytical questions.

The midterm exam will be held during the Week 5 Friday lecture hours.

Assessment criteria

Marks will be assigned according to the correctness of the responses.

Assessment 4: Final Examination

Start date: Centrally timetabled
Assessment length: 2 hours
Submission notes: A penalty for late submissions applies at 25% of the full mark for submissions late by up to at most 5 minutes, 50% for submissions that are more than 5 minutes and up to 10 minutes late, and 75% for submissions that are more than 10 minutes and up to 15 minutes late. No marks will be awarded for submissions more than 15 minutes late.
Due date: Centrally timetabled
Marks returned: 100

The final exam for this course will be centrally scheduled during the UNSW T2 examination period. It will be online and details of the final exam will be advised in Week 10. The examination tests analytical and critical thinking and general understanding of the course material. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer.

Assessment criteria

Marks will be assigned according to the correctness of the responses.

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: 23 May - 27 May		
Week 1: 30 May - 3 June	Lecture	Brief review of linear algebra and vector calculus (Tue)
	Lecture	Brief review of linear algebra and vector calculus (continued, Fri)
Week 2: 6 June - 10 June	Lecture	Dynamical systems, state stability, and Lyapunov functions (Tue)
	Lecture	Dynamical systems, state stability, and Lyapunov functions (continued, Fri)
	Tutorial	Tutorial 1: Brief review of linear algebra and vector calculus (Wed)
	Laboratory	Laboratory 1
Week 3: 13 June - 17 June	Lecture	State-feedback control using Lyapunov functions (Tue)
	Lecture	Linear time invariant state space systems (Fri)
	Tutorial	Tutorial 2: Brief review of linear algebra and vector calculus (Wed)
	Tutorial	Tutorial 3: Dynamical systems, state stability, and Lyapunov functions (Thu)
	Laboratory	Laboratory 1
	Assessment	**Quiz 1**
Week 4: 20 June - 24 June	Lecture	Controllability, observability, and pole placement (Tue)
	Lecture	Introduction to linear quadratic regulator (LQR) theory (Fri)
	Tutorial	Tutorial 4: State-feedback control using Lyapunov

		functions (Wed)
	Tutorial	Tutorial 5: Linear time invariant state space systems (Thu)
	Laboratory	Laboratory 2
Week 5: 27 June - 1 July	Lecture	Observers, output feedback, and the first method of Lyapunov (Tue)
	Tutorial	Tutorial 6: Controllability, observability, and pole placement (Wed)
	Tutorial	Tutorial 7: Introduction to linear quadratic regulator (LQR) (Thu)
	Laboratory	Laboratory 2
	Assessment	Midterm Exam: A penalty for late submissions applies at 25% of the full mark for submissions late by up to at most 5 minutes, 50% for submissions that are more than 5 minutes and up to 10 minutes late, and 75% for submissions that are more than 10 minutes and up to 15 minutes late. No marks will be awarded for submissions more than 15 minutes late.
Week 6: 4 July - 8 July		**Flexibility Week** No lectures, tutorials or labs. Please use this week for revision.
Week 7: 11 July - 15 July	Lecture	An introduction to linear matrix inequalities (LMIs) (Tue)
	Tutorial	Tutorial 8: Observers, output feedback, and the first method of Lyapunov (Wed)
	Laboratory	Laboratory 3
	Assessment	**Quiz 2**
Week 8: 18 July - 22 July	Lecture	Controller and observer synthesis using LMIs (Tue)
	Tutorial	Tutorial 9: An introduction to linear matrix inequalities (LMIs) (Wed)
	Laboratory	Laboratory 3
Week 9: 25 July - 29 July	Lecture	State and output feedback control for reference tracking (Tue)
	Tutorial	Tutorial 10: Controller and observer synthesis using LMIs (Wed)

	Laboratory	Laboratory 4
Week 10: 1 August - 5 August	Lecture	Review lecture (Tue)
	Tutorial	Tutorial 11: State and output feedback control for reference tracking (Wed)
	Laboratory	Laboratory 4

Resources

Prescribed Resources

Lecture notes
Lecture notes will be posted on Moodle.

Recommended Resources

Further texts and references
Additional resources that will be useful as references besides the lecture notes are

1. Franklin, Powell and Emami-Naeini, Feedback Control of Dynamic Systems, 6th edition, Addison- Wesley.
2. Jean-Jacques E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, 1991.
3. Two courses EE263 “Introduction to Linear Dynamical Systems” and EE363 “Linear Dynamical Systems” at Stanford University (USA). All info available on the websites: http://www.stanford.edu/class/ee263/ and http://www.stanford.edu/class/ee363/

Course Evaluation and Development

Additional explanations and examples will be introduced in the lectures to further aid in understanding the subtle concepts of locally and globally positive and negative semidefinite functions. Online labs will be streamlined and previous best practices will be emphasised for all demonstrators running online labs.

Laboratory Workshop Information

Online laboratories sessions are only for students who are studying remotely from outside of Australia. All students who are in Australia must attend the in-person laboratory sessions.

Academic Honesty and Plagiarism

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.

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.

Academic Information

COVID19 - Important Health Related Notice

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.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

Student Responsibilities and Conduct

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

Workload

It is expected that you will spend at least **15 hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both formal classes and *independent, self-directed study*. In periods where you 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.

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 can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application **prior to the start** of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. Be aware of the "fit to sit/submit" rule which means that if you sit an exam or submit an assignment, you are declaring yourself well enough to do so and cannot later apply for Special Consideration. For more information and how to apply, see https://student.unsw.edu.au/special-consideration.

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

Disclaimer

This Course Outline sets out description of classes at the date the Course Outline is published. The nature of classes may change during the Term after the Course Outline is published. Moodle should be consulted for the up-to-date class descriptions. If there is any inconsistency in the description of activities between the University timetable and the Course Outline (as updated in Moodle), the description in the Course Outline/Moodle applies:

Image Credit

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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	✓