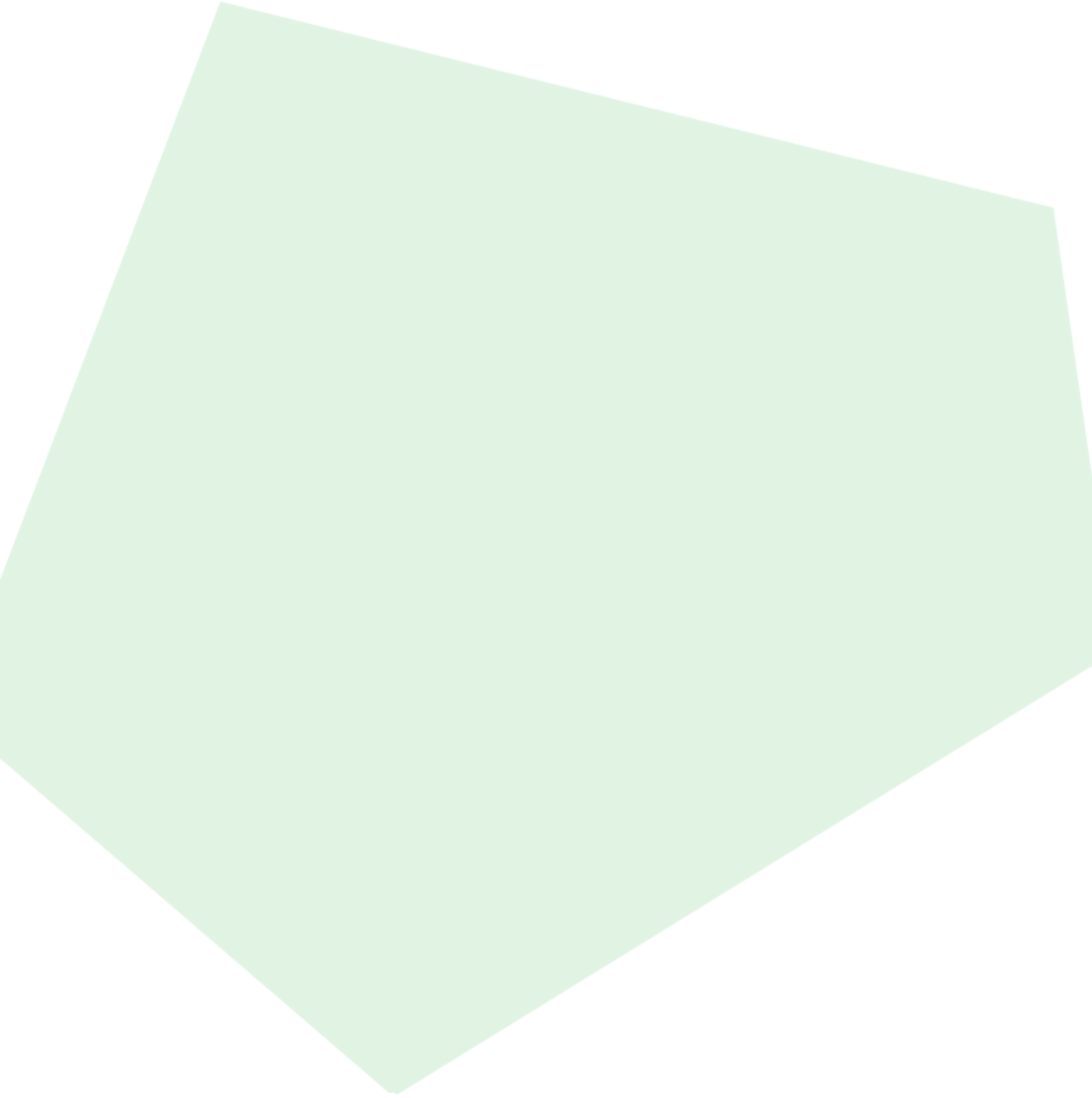




UNSW
SYDNEY



BIOM9621

Biological Signal Analysis

Term 3, 2022



Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Robert Nordon	r.nordon@unsw.edu.au	Email	Room 508, Level 5, Samuels Building	61 2 93850559

Lecturers

Name	Email	Availability	Location	Phone
Reza Argha	a.argha@unsw.edu.au	email		

School Contact Information

Student Services can be contacted via unsw.to/webforms.

Course Details

Units of Credit 6

Summary of the Course

The aim of biological signal analysis is to extract or reveal *useful* information from biological systems. Biological signals can be electrical, acoustic, mechanical, chemical or visual. The student will acquire mathematical and software skills for deeper analysis of biological signals that will be useful for biomedical research and design of biomedical devices. The course will suit engineering students with mechanical, electrical, chemical, computer science, material science and bioinformatics undergraduate backgrounds. Non-engineering students should check that they have the necessary background in advanced maths including calculus and complex algebra.

Course Aims

1. To gain a practical knowledge of how to record biological signals digitally without artefact
2. To analyse the frequency content of these signals and design digital filters to remove noise
3. To identify a biological system model by analysing system input and output signals
4. To have a working knowledge of the numerical tools required for signal analysis
5. Enhance a biomedical engineering student's design skills

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Summarise the role of signal analysis in several biomedical applications	PE1.1, PE1.2, PE1.4, PE2.1
2. Explain the theory and mathematics concerning the practice of signal analysis	PE1.2
3. Acquire, simulate and display signals using Matlab and Simulink	PE2.1, PE2.2
4. Analyse the acquired data with respect to frequency content using Matlab	PE1.2
5. Avoid and minimise artefacts that can arise during data acquisition	PE1.3
6. Apply data acquisition and simulation software to basic biomedical devices	PE2.2

Teaching Strategies

The course is delivered in blended mode with both face-to-face and online activities. Each week there will be a one hour lecture followed by a tutorial and a laboratory. Online topic tests will allow the student to gauge their level of understanding as the course proceeds to more advanced topics.

The tutorials aim to apply signal analysis to biological signals and medical devices. Laboratories will teach the basics of signal acquisition, sampling and analysis in the time and frequency domains using USB signal generators and oscilloscopes to acquire electronic signals. These laboratories will be conducted face-to-face in active learning spaces. The student will also master Matlab signal acquisition software.

Collaborative learning and project management will be developed through group work including the laboratory activities and a major group project.

Additional Course Information

Presumed knowledge and skills

It is expected that the student has completed one year of university mathematics or the equivalent. Integral calculus and complex numbers will play a particularly important role in the course. Some experience in computing (any language) is desirable but not required. Extensive instruction in using Matlab and Simulink will be provided.

How BIOM9621 relates to other courses

This course is offered in the various biomedical engineering masters programs. It complements BIOM9640 Biomedical Instrumentation and BIOM9650 Biosensors and Transducers.

BIOM9621 focuses on the data acquisition process itself, the conversion of a continuous electrical signal to digital form, and on some of the numerical methods used to analyse digital data.


BIOM9640 is an introduction to the physiological measurement of bioelectric phenomena and neurostimulation and the instrumentation involved. BIOM9650 examines the basic biosensors and transducers used to measure pressure, flow, volume and other physiological variables.

Course content

Introduction to biomedical signal analysis	What are biological signals?
	Some applications of biological signal analysis
	Overview of course
	Simulink and Matlab overview
Linear time invariant systems I	Maths revision
	Definition of a LTI system
	Response of the LTI system to an impulse
Linear time invariant systems II	ODE representation of a LTI system
	Solution by Laplace transform
	Definition of transfer function
	Convolution theorem for Laplace transforms
	Analogue filters
Continuous time Fourier transform	Definition
	Concept of time and frequency domains
	Fourier transform of special functions
	Convolution and Replication theorems
	Representation of a continuous signal as a delta train (shah

	function)
Digital sampling	Application of signal analysis theory to electrical signals
Discrete Fourier transform I	Representation of a continuous signal as a delta train (shah function)
	Definition (DFT versus DTFT)
	Convolution theorem
Discrete Fourier transform II	Introduction to ideal sampling
	Aliasing and Nyquist rate
	zero padding
	z-transform
Digital filtering I	Definition of FIR and IIR filters
	z-transform representation of a digital filter
	Definition of phase and power
	Frequency response of a digital filter
	Filter design methods
Spectrum estimation	Welch's periodogram
	Cross-correlation and autocorrelation
	Effect of sampling and noise on accuracy of spectral estimate
	Short-time Fourier transform
Application of signal analysis theory to biomedical systems	Black box polynomials models, Matlab's System Identification toolbox

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Group project 	16%	20/11/2022 11:59 PM	1, 2, 3, 4, 5, 6
2. Major topics online quizzes	40%	Not Applicable	2, 4, 5
3. Lab reports	20%	Not Applicable	2, 3, 4, 5
4. Online Math Revisions Quiz	4%	27/09/2022 11:59 PM	
5. Major assignment	20%	15/11/2021 11:59 PM	

Assessment 1: Group project (Group)

Due date: 20/11/2022 11:59 PM

This year the project will be to design a ventilator controller to support patients with COVID pneumonia. The patients physiology will be simulated using Pneuma, a Matlab/Simulink physiological model of the cardiovascular system, lungs, and neural control of these systems. Students will form groups of 4 and will be allocated to perform a review of a Pneuma subsystem. The project deliverables are

1. Literature review
2. Signal analysis
3. Design of the controller
4. Evaluation of the controller
5. Group presentation (8%, instead of the week 10 lecture and tutorial)
6. Individual reports (8%).

Assessment criteria

Marking rubrics for the individual report

a) literature review for the allocated system (1 mark)

Criteria	Mark
Incomplete, low-quality presentation	0.5
Complete, high-quality presentation	1

b) application of signal analysis mathematical theory to the allocated system (1 mark)

Criteria	Mark
Partial analysis	0.5
Complete analysis	1
*Criteria for complete analysis: Is the system linear and time-invariant? What is the frequency response of the system? What is the impulse response of the system? How does the mathematical model relate to the physiological model	

c) description of the controller design and any testing (1 mark)

Criteria	Mark
No "closed-loop" controller design provided but has a comprehensive analysis of physiological response to manual control of ventilator	0.5
Closed-loop design provided with testing	1

d) verification of the system controller and the results of your simulation the 10 patient lung function signals (1 mark)

Criteria	Mark
x number of patients that survive for your simulations	$(x-m)/(M-m)$
M highest number of patients saved for all simulations	
m lowest number of patients saved for all simulations	

e) reflection on how well the team worked together including your role (1 mark)

Criteria	Mark
Does not provide roles and responsibilities of group members, and what was achieved as a group. No contribution to group work	0
Provides roles and responsibilities of group members and provides what each member contributed to the group output. Minor contribution to group work	0.5
Comments on potential shortcomings of teamwork and how to form an 'ideal' medical device R&D team in the future. A significant contribution to group work	1

f) additional analysis or refinement or value-add to the group's output (slide show and shared material) conducted by yourself. (2 marks)

Criteria	Mark
Does not report what was shared between group members, and acknowledges the contribution of individual members	0
Resolves additional minor issues not solved by the group e.g., enhances literature review	1
Resolves additional major issues not solved by the group e.g., modified controller design to increase patient survival.	2

Assessment 2: Major topics online quizzes

There will be 5 online quizzes that will assess signal analysis theory covering 1) Linear time-invariant systems 1 2) Linear time-invariant systems 2 3) Fourier Transform 4) Digital Sampling 5) Z-transform and Digital Filtering. They will be based upon online learning activities for each of these major topics. The online quiz will be before the lab tutorial and lecture (10-11am) on 28-Sep, 5-Oct, 12-Oct, 26-Oct, 16-Nov.

Assessment 3: Lab reports

There will be two lab reports (10 % each) based on analogue and digital signal processing labs. It is mandatory to attend all laboratory practical sessions face-to-face if possible. You will be acquiring valuable data that will go in final reports. For online overseas students we will provide online demonstration sessions for you to acquire the data for the lab reports.

Fourier transform lab due on 18-Oct (11:59 pm) 2. Digital sampling lab due on 25-Oct (11:59 pm).

Assessment 4: Online Math Revisions Quiz

Due date: 27/09/2022 11:59 PM

These quizzes will assess Maths and Matlab prerequisites for this course.

Assessment 5: Major assignment

Due date: 15/11/2021 11:59 PM

Major assignment

Attendance Requirements

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

Course Schedule

Lecture Wednesday 10:00 am – 11:00 am Online and [Quadrangle 1043](#)

Tutorial/Laboratory Wednesday 11:00 am – 1:00 pm [Quadrangle 1043](#)

[View class timetable](#)

Timetable

Date	Type	Content
Week 1: 12 September - 16 September	Tut-Lab	Introduction to biomedical signal analysis (RN)
	Tut-Lab	Introduction to Matlab.
Week 2: 19 September - 23 September	Tut-Lab	Measure the frequency response for a low pass filter.
	Tut-Lab	Linear time-invariant systems I (RN)
	Online Activity	Introduction to Simulink I/O.
	Tut-Lab	Physical examples of LTI systems.
Week 3: 26 September - 30 September	Online Activity	LTI 1 online quiz 10:00-11:00 am (8%)
	Tut-Lab	Linear time-invariant systems II (RN)
	Tut-Lab	Model the frequency response for a low pass filter
	Assessment	Online Math Revisions Quiz
Week 4: 3 October - 7 October	Online Activity	LTI 2 online quiz 10-11 am (8%)
	Tut-Lab	Continuous-time Fourier transform (RN)
	Tut-Lab	Simulation of the arterial pulse
Week 5: 10 October - 14 October	Online Activity	Fourier Transform online quiz 10-11 am (8%)
	Tut-Lab	Digital sampling (RN)
	Tut-Lab	Estimate Fourier series coefficients for the arterial pulse waveform
	Tut-Lab	Digital acquisition of signals and frequency domain analysis

Week 6: 17 October - 21 October	Group Work	Group formation, project selection (supplied) and allocation of roles and responsibilities. Acquisition of signal for the project (supplied).
	Group Work	Medical Device Design (RN/RA)
Week 7: 24 October - 28 October	Tut-Lab	z-transform and introduction to digital filtering. Using Matlab to design digital filters (RA)
	Tut-Lab	Evaluating z-functions on the unit circle. DFT with zero-padding. Explore the effects of windowing. Ad-hoc filter design and difference equation implementation. FIR and IIR filter design. (Tutorial)
Week 8: 31 October - 4 November	Tut-Lab	Ziegler-Nichols tuning of PID controllers (Tutorial)
	Tut-Lab	PID control (RA). Using Matlab/Simulink to design and tune control system
	Tut-Lab	Matlab exercises (Practical)
Week 9: 7 November - 11 November	Online Activity	Digital sampling online quiz 10-11 am (8%)
	Tut-Lab	Sampling and spectral analysis of biological signals (RA)
	Tut-Lab	Periodogram and short time Fourier transform (tutorial)
Week 10: 14 November - 18 November	Online Activity	z-transform and introduction and digital filtering online quiz 10-11 am (8%)
	Group Activity	Medical Device Design and Analysis (group presentations) Groups present their medical device design concept and simulate its performance.

Resources

Prescribed Resources

All material will be provided via Moodle. Teams tutorials will be recorded.

Recommended Resources

DATES TO NOTE

Refer to MyUNSW for [Important Dates](#).

PLAGIARISM

Beware! An assignment that includes plagiarised material will receive a 0% Fail, and students who plagiarise may fail the course. Students who plagiarise will have their names entered on plagiarism register and will be liable to disciplinary action, including exclusion from enrolment.

It is expected that all students must at all times submit their own work for assessment. Submitting the work or ideas of someone else without clearly acknowledging the source of borrowed material or ideas, is plagiarism.

All assessments which you hand in **must** have a [Non Plagiarism Declaration Cover Sheet](#). This is for both individual and group work. Attach it to your assignment before submitting it to the Course Coordinator or at the School Office.

Plagiarism is the use of another person's work or ideas as if they were your own. When it is necessary or desirable to use other people's material you should adequately acknowledge whose words or ideas they are and where you found them (giving the complete reference details, including page number(s)). The Learning Centre provides further information on what constitutes Plagiarism at:

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

ACADEMIC ADVICE

Last year we had problems with contract cheating and 'sharing' of assignment answers which are very serious breaches of academic conduct. Please read the [student conduct policy](#) and the [academic misconduct procedure](#). It is expected that students attend all lectures and tutorial sessions.

Assignments submitted after the due date without prior notification and permission will be subject to a deduction in marks.

UNSW has a wide range of student support services. The resources listed below should be used by students needing assistance related to aspects of their overall University experience. Specific help regarding this course can be sought from the course coordinator.

<http://www.student.unsw.edu.au/>

https://my.unsw.edu.au/student/howdoi/HowDoI_MainPage.html

<http://www.counselling.unsw.edu.au/>

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course coordinator prior to, or at the commencement of, their course, or with [Disability Support Services](#). Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

If you believe that your performance in an assessable component of the course has been affected by illness or another unexpected circumstance, you should make an application for special consideration as soon as possible after the event by visiting UNSW Student Central. Please talk to the course coordinator as well and note that considerations are not granted automatically.

UNSW has strict policies and expectations relating to Occupational Health and Safety (OHS) accessed at <http://www.ohs.unsw.edu.au/>

Course Evaluation and Development

Student feedback has helped to shape and develop this course, including feedback obtained from on-line evaluations as part of UNSW's Course and Teaching Evaluation and Improvement ([MyExperience](#)) process. To discourage cheating and encourage independent problem-solving skills, we have increased the percentage of assessment contributed by the final exam.

Laboratory Workshop Information

Lectures, tutorials and laboratories will be held in the active learning space. Group work for acquiring data for labs, but students should work individually to prepare their lab reports.

Submission of Assessment Tasks

Laboratory reports and major assignments will require a [Non Plagiarism Declaration Cover Sheet](#).

Assignments should be submitted on time. A daily penalty of 5% of the marks available for that assignment will apply for work received after the due date. Any assignment more than 5 days late will not be accepted. The only exemption will be when prior permission for late submission has been granted by the Course coordinator. Extensions will be granted only on medical or compassionate grounds under extreme circumstances.

Academic Honesty and Plagiarism

PLAGIARISM

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All assessments which you hand in must have a [Non Plagiarism Declaration Cover Sheet](#). This is for both individual and group work. Attach it to your assignment before submitting it to the Course Coordinator or at the School Office.

Plagiarism is the use of another person's work or ideas as if they were your own. When it is necessary or desirable to use other people's material you should adequately acknowledge whose words or ideas they are and where you found them (giving the complete reference details, including page number(s)). The Learning Centre provides further information on what constitutes Plagiarism at:

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

Academic Information

COURSE EVALUATION AND DEVELOPMENT

Student feedback has helped to shape and develop this course, including feedback obtained from on-line evaluations as part of UNSW's myExperience process. You are highly encouraged to complete such an on-line evaluation toward the end of Term. Feedback and suggestions provided will be important in improving the course for future students.

DATES TO NOTE

Refer to MyUNSW for Important Dates, available at:
<https://my.unsw.edu.au/student/resources/KeyDates.html>

ACADEMIC ADVICE

For information about:

- Notes on assessments and plagiarism,
- Special Considerations,
- School Student Ethics Officer, and
- BESS

refer to the School website available at
<http://www.engineering.unsw.edu.au/biomedical-engineering/>

Supplementary Examinations:

Supplementary Examinations for Term 1 2022 will be held on (TBC) should you be required to sit one.

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

Engraved portrait of French mathematician Jean Baptiste Joseph Fourier (1768 - 1830), early 19th century.

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	