ELEC2146

Electrical Engineering Modelling and Simulation

Course Outline – Semester 2, 2016

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Dr Ray Eaton, Dean's Unit, Level 6 K17, r.eaton@unsw.edu.au
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Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, and using the Moodle forums, rather than via email. Lecturer consultation times will be advised during lectures. 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 ELEC2146 in the subject line, otherwise they risk not be answered.

Keeping Informed: Announcements may be made during classes, via Moodle, https://moodle.telt.unsw.edu.au/login/index.php, or via email (to your student email address). Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Background

This elective course is unique in its scope and emphasis, being the only course offered in Electrical Engineering and Telecommunications devoted specifically to simulation and modelling. It provides a solid grounding in modelling tools that can be applied not only to electrical engineering problems, but also to a variety of other problems addressed by engineering graduates in general. There is an emphasis on linear dynamic systems during the simulation topics, intended as a continuation from ELEC2134 and as a link to other courses in EE&T disciplines, especially in control systems and biomedical engineering. During the modelling topics, the emphasis is on understanding the modelling process, exposure to some possible model structures, parameter estimation methods and measures of the efficacy of a model for a given practical situation/data set.

Contact Hours

The course consists of 2 hours of lectures, a 1-hour tutorial, and a 3-hour laboratory session each week.

	Day	Time	Location
Lectures	Wednesday	3pm - 5pm	Ainsworth 101
(start in week 1)			
Tutorials	Wednesday	5pm – 6pm	Ainsworth 101
(start in week 2)			
Laboratory	Thursday	1pm-4pm	ElecEng 214
(start in week 2)			

Context and Aims

Modelling and simulation are a vital part of many areas of engineering, allowing engineers to reason about the expected behaviour of a system without having to physically implement it. Simulation pervades much of electrical engineering, for example models of individual electronic devices, circuit simulation, network modelling, compression of speech/audio/image/video signals, design of biomedical devices, and modelling of physical systems for control purposes. Modelling allows an abstract representation of a signal or system in a (mathematically) compact and/or simplified form that is extremely useful in many fields, including analysis, design, compression, classification, and control. The main high-level aim of the course is to provide a thorough grounding in aspects of constructing and applying models and their simulation using well-known simulation tools (MATLAB and C). In particular, the course looks at how continuous-time systems can be represented and simulated using (discrete-time) computers. This also provides an interesting insight into the relationship between physical systems and computing algorithms. The course is intentionally designed to have a strong practical focus, with extensive laboratory work serving to develop key skills in computing and applications of mathematics.

Aims: This course aims to:

a) Familiarise you with programming in MATLAB.
b) Convey the analytical and practical details of a range of modelling techniques.
c) Provide an understanding of finite difference approximation and numerical methods for differential equations, in the context of state-space representations of linear systems.
d) Familiarise you with the modelling of dynamical systems and stochastic signals, including the choice of model, choice of model order, parameter estimation and goodness of fit.
e) Provide a thorough grounding in parameter estimation techniques such as least squares (particularly) and maximum likelihood.
f) Give you practical experience with simulating physical systems and modelling typical experimental data, for example second-order circuits, non-linear circuits, electrical machines and power systems, control systems, biomedical systems, and introductory network simulation[1].

Indicative Lecture Schedule

This schedule is approximate; some variation to the timing below can be expected.

Week	Lecture 1st hour	Lecture 2nd hour	Ref	Laboratory
1	Introduction to modelling and simulation	Simulation programming	[1,2,7]	Introductory MATLAB
2	Simulation prog (cont'd) Circuits as dynamic systems	Transfer functions, poles and zeroes	[1,2,3, 4,10,13]	Lab 1: Circuit simulation
3	State space	Linearisation	[1,2,3, 4,10,13]	Lab 2: Linear system simulation
4	Numerical methods for differential equations	Numerical methods for differential equations	[1,2,6 12]	Lab 2: Linear system simulation
5	Runge-Kutta	Runge-Kutta Discretization	[1,2,12]	Lab 3: Numerical DEs

[1] Not all of these applications may be covered (each requires its own understanding of the context); also, in some cases synthetic problems or data may be used in place of more realistic problems or data.

6	Least squares	Least squares	[5,6,9, 12]	Lab 3: Numerical DEs
7	**Mid-session examination, duration 50 min**	Introduction to system identification	[5,11]	Lab 4: Runge-Kutta
8	Introduction to system identification	Stochastic models	[1,8]	Lab 5: Least squares
9	Stochastic models	Parameter estimation	[6,8,9]	Lab 6: System identification
Sep 24	Mid-session break			
10	Parameter estimation	Goodness of fit	[6,8]	Lab 7: Stochastic models
11	Goodness of fit	Model Types	[6]	Lab 8: Parameter Estimation
12	Model Types	Summary and research	[6]	Lab 9: Goodness of fit
13	No lectures			Lab: Catch-up

Course Details

Credits

This is a 6 UoC course and the expected workload is approximately 10 hours per week throughout the 13 week semester.

Relationship to Other Courses

ELEC2146 Electrical Engineering Simulation and Modelling builds directly on students' skills and knowledge in circuits, linear systems, differential equations and Laplace transforms gained during ELEC2134 Circuits and Signals. Knowledge gained in ELEC2134 will be extended using simulations, and the relationship between continuous and discrete systems will be explored through numerical integration. This course also builds on COMP1191, extending programming skills (including C programming) and providing an extensive introduction to MATLAB programming. Although ELEC2146 is an elective, it is closely related to other courses offered, in particular signal processing and control systems courses such as ELEC3114 Control Systems and ELEC3104 Digital Signal Processing, and also serves as very helpful background material to a range of final year thesis topics, many of which employ modelling, MATLAB simulation or C coding.

Pre-requisites and Assumed Knowledge

The minimum pre-requisite for the course is ELEC2134 Circuits and Signals (or equivalent) and COMP1911 Computing 1A (or equivalent). Knowledge from 1st and to some extent 2nd year Maths courses is essential.

It is essential that you are familiar with basic principles of programming, circuit theory, transient analysis of 2nd order circuits, AC circuit analysis, and solution of differential equations[2]. Familiarity with matrix operations is also assumed. Previous experience in deriving expressions for the expected value and 2nd order moments of probability density/mass functions would be helpful.

[2] i.e. essentially the content of ELEC2134. If you don't feel confidence with this material, you are strongly advised to spend some time with a text like Alexander and Sadiku (details shown below), which is clearly written, has many worked examples and has many problems (with solutions) to attempt.

Learning outcomes

After successful completion of this course, you should be able to:

1. Express a linear system in terms of its differential equation, transfer function, magnitude response, impulse response and step response, be able to convert between the different forms and explain the advantages of each;
2. Derive expressions that can be used to estimate parameters from different types of data, for different types of model structures;
3. Explain analytically how to simulate a continuous-time system by means of numerical integration;
4. Synthesise MATLAB code to simulate a given system or model;
5. Implement a suitable model for a given problem, making informed choices about the model type and model order, and calculate the model error.
6. Deduce the behaviour of previously unseen models or parameterisations and hypothesise about their merits.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in *Appendix A*. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in *Appendix B*). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in *Appendix C*.

Syllabus

Electrical Engineering Modelling and Simulation surveys the basic techniques required for computer modelling of a range of electrical engineering systems. The course covers the modelling of differential equations and difference equations, finite difference approximation, transfer functions and state-space realisations, presented from a practical perspective. The course will emphasise both analytical and implementation skills, covering an introduction to simulation programming techniques, mainly in MATLAB but also including some basic C programming. Example application areas will include modelling of linear second-order circuits, non-linear circuits, electrical machines and power systems, control systems, biomedical systems, and introductory network simulation. A simulation project will allow development of individual interests within this area.

Teaching Strategies

The course consists of the following elements: lectures, tutorials, laboratory work, project work, and homework comprising self-guided study and a problem sheet. These strategies are largely traditional, however efforts will be made to keep lectures and particularly tutorials interactive (your suggestions on the teaching strategies for this course are welcome). Further, the project is driven by self-directed study, and will require you to seek out and apply knowledge from both within and outside the syllabus. The course has a strong practical focus, with 50% or more of the assessment based on laboratory work, acknowledging both the importance of practical modelling, simulation and programming skills and the importance of the laboratory context in learning theoretical and analytical concepts.

In addition, video lectures are available online for download and it is intended that additional quizzes and tutorial questions (non-assessable) will be made available for further self-study.

Learning in this course

You are expected to attend <u>all</u> lectures, tutorials, labs, and mid-semester exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. 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.

Video Recordings of Lectures

Recordings of all lectures in 2010 are available via http://eemedia.ee.unsw.edu.au/ELEC2146/index.htm (high speed network connectivity will be needed), so you can easily revise concepts from lectures at your own pace or look ahead to future material where needed to support the project or assignment tasks.

Tutorial classes

A number of suggested tutorial problems will be distributed ahead of each class, and brief answers to these will be given at a later date. In general, however, once specific questions have been addressed during the tutorial, different problems (to the tutorial problem sheet) will be discussed and worked through, so that you have a wider range of study materials. The tutor may give example solutions to selected problems, or request you to attempt one or more problems in the class, or a combination of the two. If you would like assistance on a particular aspect of the lectures or tutorials (e.g. going over a particular concept, example or tutorial exercise), please indicate this to the lecturer ahead of the tutorial (preferably a couple of days beforehand). This way, the benefit of the tutorial time can be maximized.

Laboratory program

The laboratory schedule is deliberately designed to gain practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. This course should be a great opportunity to developing your programming and debugging skills in relevant languages (MATLAB and C are listed in quite a few job advertisements) with a strong electrical engineering flavour throughout. Generally there will be around one week between the introduction of a topic in lectures and a laboratory exercise on the same topic, sufficient time in which to revise the lecture, attempt related problems and prepare for the laboratory. The laboratory work provides you with hands-on experience with simulation tools and algorithms used widely in electrical engineering. You must be pre-prepared for the laboratory sessions: the laboratory sessions often require comparison with analytical results from the preparation, so this is only possible way to complete the given tasks in the allocated time.

Laboratory classes will start in week 1 of session, with the strongly recommended Introductory MATLAB laboratory. Regular laboratory classes will start in week 2. You will need to bring to the laboratories:

- A USB key for storing MATLAB script files
- A laboratory notebook for recording your work
- Your lecture notes, laboratory preparation and/or any other relevant course materials

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course for Semester 2, 2016 must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator.

Homework and Problem sheets

The lectures can only cover the course material to a certain depth; you must read the textbook(s) and reflect on their content as preparation for or follow-up after the lectures to fully appreciate the course material. Home preparation for laboratory work provides you with the background knowledge you will need. The problem sheets aim to provide in-depth quantitative and qualitative understanding of theory and methods. Together with your attendance at classes, your self-directed reading, completion of problems from the problem sheet and reflection on course materials will form the basis of your understanding of this course.

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through the lab checkpoints (see lab manual), lab exams and the mid-semester exam.

Laboratory Work	20%
Assignment	10%
Project	20%
Mid-Semester Exam	10%
Final Exam (3 hours)	40%

Laboratory Assessment: From week 2, the laboratory work will be assessed in order to ensure that you are studying and that you understand the course material. The laboratory assessment is conducted live at the end of each lab exercise – specifically, the labs will be marked at the next lab after the time allocated for each exercise is complete (in which labs all students must be moving on with the next lab exercise). Late marking of labs will attract a penalty of 20% per week[3]. It is essential that you arrive at each lab having revised lecture materials (and attempted problems from the problem sheet) in advance of each laboratory, and having completed any requested preparation for the labs. Without preparation, marks above 50% may be difficult to obtain. No lab reports are required in this course. During the laboratory, you may consult with others in the class, but you must keep your own notes of the laboratory. In particular, note that laboratory assessment will be conducted individually, not on a per-group basis. ***Please also note that you must pass the laboratory component in order to pass the course.***

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work (according to the guidelines given in lectures), and your understanding of the topic covered by the lab. There are no lab reports; all lab assessment is live.

Assignment: The assignment allows self-directed study leading to the solution of partly structured problems in MATLAB. Marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the code written for the assignment (must be attached to the report), and the understanding of the course material demonstrated by the report.

The assignment report will be due at the Wednesday lecture in Week 12. Late reports will attract a penalty of 10% per day (including weekends).

Project: The project also encourages self-directed learning by setting a challenging modelling problem whose solution draws on content from several parts of the course. Marks will be assigned for the quality and correctness of the report, the detail and extent to which

[3] Unless suitable justification (preferably in advance) is given. Note however that it is always better to submit your work late than not at all.

different modelling and simulation possibilities have been explored, and the clarity with which the aims, experimental methods and results are communicated. This will be written up as a formal report, and all code developed for the project will be included in appendices. Feedback on the general approach taken by individual students will be available informally during the session.

The project report will be due at the Thursday lab in Week 13. Late reports will attract a penalty of 10% per day (including weekends).

Mid-Semester Exam: The mid-session examination tests 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 6. Note that although some revision material is covered in the first three weeks, the mid-session may not contain many questions drawing from this revision material, relative to the new material covered. It may contain questions requiring some (not extensive) knowledge of MATLAB programming, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

Final Exam: The exam in this course is a standard closed-book 3 hour written examination, comprising five compulsory questions. University approved calculators are allowed. 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 (including MATLAB programming), 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 in order to pass the course.**

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes (Percentage contribution)					
Assessment	**1**	**2**	**3**	**4**	**5**	**6**
Laboratory work (20%)	3	3	3	3	3	3
Assignment (10%)	3	3	3	1	1	1
Project (20%)	3	3	-	5	5	5
Mid-session exam (10%)	2	2	2	-	1	2
Final examination (40%)	8	8	8	5	2	8

Note: Percentages are approximate and have been rounded-up.

Course Resources

Textbooks

Prescribed Textbook

The following textbooks are suggested, rather than prescribed, for the course:

[1] Klee, H. (2007). Simulation of Dynamic Systems with MATLAB and Simulink, CRC Press, Boca Raton, FL. – This is a very detailed and comprehensive text, aimed slightly above the level of this course. For anyone with longer-term interests in dynamic systems, this text is highly recommended.

[2] Woods, R. L., and Lawrence, K. L. (1997), Modelling and simulation of dynamic systems, Prentice-Hall, Upper Saddle River, NJ. – This is a more introductory level text that also deals with dynamic systems, across all areas of engineering. The coverage of the course is not very complete, but the style is fairly straightforward and there are many problems (with answers) given.

You may want to **check the availability and coverage of the texts before purchasing**, as some topics in the syllabus are not featured. Unfortunately there is no single text that covers all topics in a satisfactory depth. Additional references, listed below and at the end of some lecture note sets, will in combination provide complete coverage of the course. Please contact the lecturer for further text recommendations where needed. Lecture notes will be provided, however these do not treat each topic exhaustively and additional reading is required.

Reference books

The following books are good additional resources for various topics, and many should be available in the library:

[3] Alexander, C. K., and Sadiku, M. N. O. (2007). Fundamentals of Electric Circuits, McGraw-Hill, New York. – An excellent reference for assumed knowledge (ELEC2134) and many topics covered in the first 2-3 weeks of lectures.

[4] Bobrow, L. S. (1987). Elementary Linear Circuit Analysis, Holt, Rinehart and Winston, New York. – A good reference for assumed knowledge, and a gentle introduction to state-space and simulation of state-space systems (Chapter 7).

[5] van den Bosch, P. P. J., and van der Klauw, A. C., Modelling, Identification and Simulation of Dynamical Systems, CRC Press, Boca Raton, FL, 1994. – Good coverage of many parts of the course, including modeling ideas and system identification, but some parts of the course are covered only briefly. Not available in the UNSW Library.

[6] Gershenfeld, N. (1999). The Nature of Mathematical Modeling, Cambridge University Press, Cambridge, UK – This book gives some good intuition concerning a wide range of mathematical models, including some covered in this course, but with few examples.

[7] Gilat, A. (2008). MATLAB: An Introduction with Applications, John Wiley and Sons, Hoboken, NJ. – An introductory guide to MATLAB. There are many many other similar ‘Introduction to MATLAB’ books, including in the library.

[8] Gubner, J. A. (2006), Probability and Random Processes for Electrical and Computer Engineers, Cambridge University Press – A very helpful reference for many topics relating to stochastic models.

[9] Haigh, J. (2002). Probability Models, Springer, London, UK. – A helpful introductory level text relevant to the stochastic models topic.

[10] Kamen, E. W., and Heck, B. S. (2007). Fundamentals of Signals and Systems, Prentice-Hall, Upper Saddle River, NJ. – A very good introductory text for linear systems theory, differential equations, transfer functions and state-space.

[11] Ljung, L. (1987). System Identification: Theory for the User, Prentice-Hall, Englewood Cliffs, NJ. – A key reference in the area of system identification, but too advanced for this course, so may be of little use here.

[12] Rao, S. S. (2002). Applied numerical methods for engineers and scientists, Prentice-Hall, Upper Saddle River, NJ. – This is a very good text for all aspects of numerical methods covered in the course (numerical solution of differential equations, numerical integration etc).

[13] Ziemer, R. E., Tranter, W. H., and Fannin, D. R., (1998). Signals and Systems: Continuous and Discrete, Prentice-Hall, Upper Saddle River, NJ. – Good coverage of linear systems theory, including state space

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Some additional on-line resources relevant to the course:

- http://www.mathworks.com/academia/student_center/tutorials/launchpad.html
- http://www.mathworks.com/access/helpdesk/help/toolbox/ident/index.html?/access/helpdesk/help/toolbox/ident/ug/ug_intropage.html&http://www.google.com.au/search?sourceid=navclient&ie=UTF-8&rlz=1T4GGLL_en&q=System+Identification+Toolbox%2c+User%27s+Guide
- http://wikis.controltheorypro.com/index.php?title=Introduction_to_System_Identification
- http://sting.deis.unibo.it/virtue/DemoVirtue/Sid.html

Other Matters

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.

Student Responsibilities and Conduct

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

Workload

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

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.

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 should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://student.unsw.edu.au/special-consideration.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods.

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:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- **Scholars** capable of independent and collaborative enquiry, rigorous in their analysis, critique and reflection, and able to innovate by applying their knowledge and skills to the solution of novel as well as routine problems;
- **Professionals** capable of ethical, self- directed practice and independent lifelong learning;

For more detail on UNSW Graduate Capabilities: https://teaching.unsw.edu.au/graduate-capabilities

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard select those that apply

	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	

Note: Larger bold ticks in bold indicate the program learning outcomes most covered by this course.