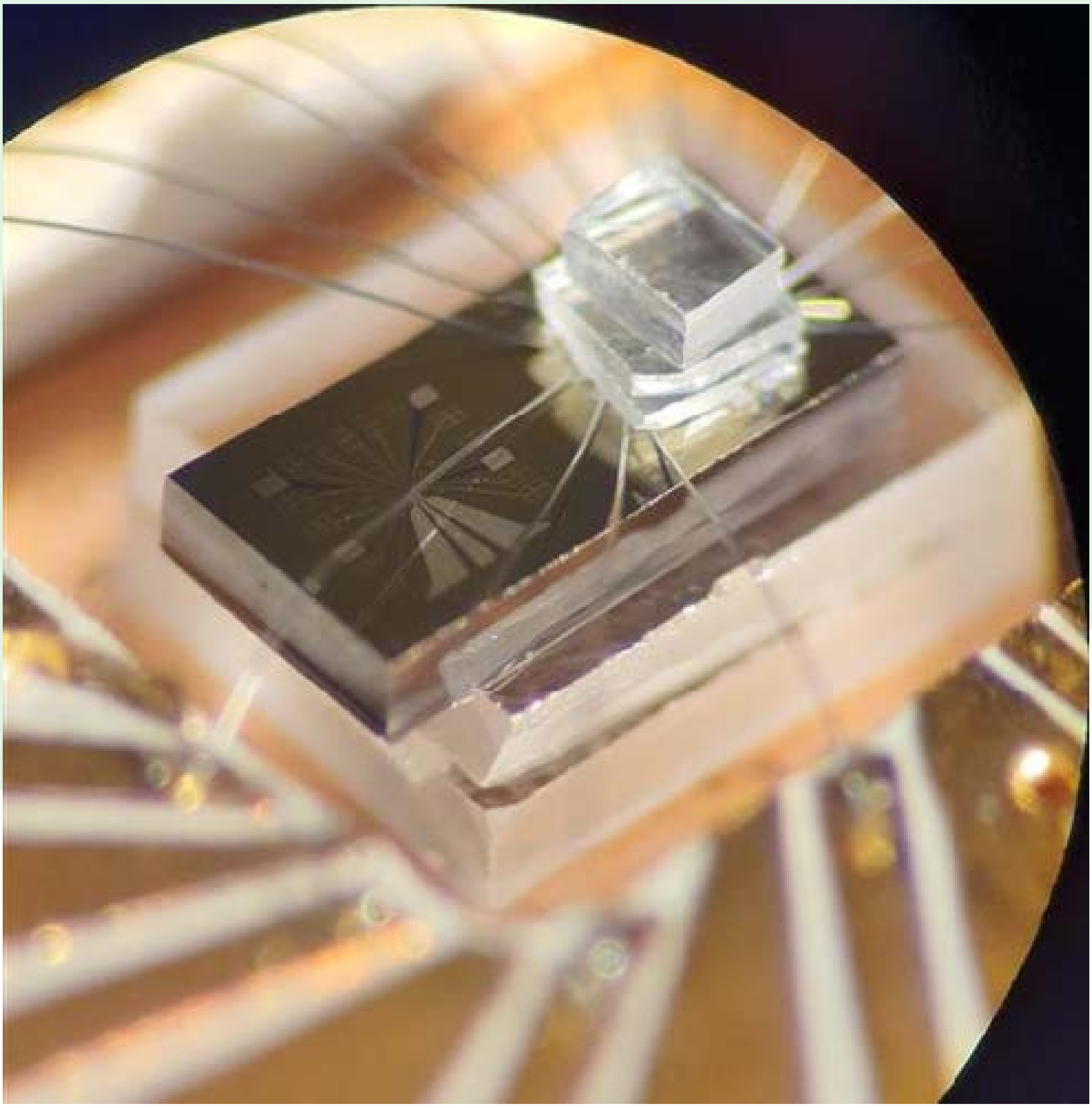
School of Electrical Engineering & Telecommunications

UNSW Engineering

ELEC4603

Solid State Electronics

Term 3, 2022



Course Overview

Staff Contact Details

Convenors

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Demonstrators

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Venkatesh Chenniappan	eet@unsw.edu.au			

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

Solid State Electronics expands significantly on the simple models of electronic devices studied in ELEC2133 (Analogue Electronics) and uses concepts of solid-state physics learned in PHYS1231 (Physics 1B). This is an elective course for computer, telecommunications, and electrical engineering students.

It provides a detailed understanding of the physics, design, operation, and limitations of important solid-state electronic and optoelectronic devices used by electrical and telecommunications engineers. It is highly relevant for electrical engineers who intend to pursue further studies of integrated circuit design and/or microfabrication.The topics to be covered include the following:

- Band-structure and doping of semiconductors.
- Drift-Diffusion Equations; Density of states; Fermi function; Law of Mass Action.
- PN Junctions: Derivation of I-V characteristics; Capacitance; Breakdown; Non-idealities.
- Bipolar Junction Transistor (BJT): Operation principles; Derivation of I-V characteristics; Ebers-Moll model; Non-idealities.
- MOSFET: Derivation of I-V characteristics; Structure; Threshold Voltage; Operating-modes. CMOS devices.
- Microfabrication of: BJTs; MOSFETs; CMOS; Integrated circuits.
- Quantum effects: Tunnelling effects in diodes; Tunnel FETs; Quantization of transport; Energy levels in ultra-scaled transistors.
- Optoelectronic & Photonic Devices: Direct vs Indirect Band-gap devices. LEDs; Semiconductor Lasers; Photovoltaic Cells.

Course Aims

Welcome to your survival training for the jungle of new inventions. What will these technologies be? No one knows! But so far, solid state electronics has been the number one tool that engineers choose to create novel technologies, from mobile phones to solar cells.

By taking this course you will learn how to stay on top of the new inventions of the future.

- What are the challenges in making better CPUs? Does it need to be made out of silicon at all?
- How can we produce more colorful monitor screens? What limits photonic communication? When will detectors enable my car to self-drive?
- What if the devices get so small that you only have a few atoms and electrons? And what is the big deal with nanotechnology?

The bleeding-edge of technological development pushes devices beyond their behaviour "as intended". You will need to learn what materials have a special chemistry that can be used to make these devices. How electrons move in these materials and how you can engineer man-made properties to these materials. You will learn how these materials can be put together to form something as simple as a diode or as complex as logical integrated circuits, culminating in the current standard of computers and mobile phones – the CMOS technology. Finally, you will (discover) understand that the aggressive miniaturization of these devices will soon push us over the boundary of quantum mechanics, which will present its challenges but also exciting opportunities!

At the end of the course you should:

1. understand the underlying operating principles of important microelectronic and photonic devices,such as MOSFETs, BJTs and semiconductor lasers;
2. understand the limits of ideal "black box" models of devices, and predict the effect of these nonidealities on real circuits and systems;
3. have an appreciation of the principles of microfabrication relevant to integrated circuit manufacture, and how these affect device performance.
4. have a vision for the future of technology and the independence to self-teach the necessary science to understand it.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Explain the key concepts involved in semiconductor device operation and their characteristics	PE1.1, PE1.2
2. Perform calculation and analysis of semiconductor devices through applying fundamental equations and constants	PE1.2, PE1.3, PE2.1
3. Validate the performance of diodes, transistors and optoelectronics through experiments and simulations	PE1.2, PE1.3, PE1.5, PE2.1, PE2.2
4. Illustrate CMOS fabrication processes, pinpointing future opportunities and challenges of massive integration	PE1.5, PE1.2, PE1.3
5. Recognise the onset of quantum effects and its importance for aggressively miniaturized devices	PE1.1, PE1.2, PE1.5
6. Collaborate in teams to create shared content with diverse pedagogy on solid state electronics and relevant background knowledges	PE1.2, PE1.3, PE1.5, PE1.1, PE2.2, PE3.2, PE3.3, PE3.4, PE3.6

Teaching Strategies

The learning will be led by you. To accomplish that, most of the resources and assessment is designed to fit your schedule and your pace.
In order to avoid stressful high-stakes summative exams, we will assess you continuously with multiple weekly deliverables. Your total grade is composed of 4 components: quizzes, Wiki notes, labs and a final exam.
Here is how we planned your course:

1. The bulk of the content is delivered by **Pre-Recorded Videos** of 7 to 16 min duration, which can be watched on your time. There is a total of 20 to 25 videos. You are supposed to watch a average of 3 videos per week. (Estimated time: 45min/week)
2. To help you set the rhythm, you will answer simple questions about the videos for that week. These questions are simple enough that you can answer them by simply watching the videos with attention. Correctly answering this **Quiz** will account for **10%** of your marks. (Estimated time: 15min/week)

3. Then, we will meet online for our weekly **Lecture**. In 2022 we will have 8 lectures. This lecture will not be focused on exposing the main content. Instead, we will use this time to answer questions, analyse the topics of that week in more depth, look at examples and case studies and discuss more modern and advanced issues related to the content. (Estimated time: 120 min/week)
4. In the **Tutorial**, you will discuss problems that follows the lecture, as well as further applications of the content in real-life engineering problems. We will have 8 tutorials in 2022. (Estimated time: 60 min/week)
5. You will then get a more challenging, math-based question to answer. This part of the **Quiz** will account for another **10%** of your total marks, which adds up to **20%** with the **Pre-Recorded videos** questions. You will have until the follwing week's **Lecture** to answer that question. (Estimated time: 30 min/week)
6. Then, you and your team will work together in writing some **Wiki**-Style lecture notes. The topics for these notes are assigned to each team, and typically a team will have one topic to write about every two weeks. The whole class can see your notes and use them for their own learning. They can also help you by providing constructive criticism. You will get marks for these notes, so the more input you get from your colleagues before we mark them, the better for you. These notes have a well-defined structure and marking rubrics, and will amount to **30%** of your final marks. (Estimated time: 240 min every 2 weeks = 120min/week)
7. You will have 6 **Laboratory** sessions, which will support your learning of the content and also provide you with practical construction, measurement and debugging skills. You need to attend **ALL** them, including "Lab 0", which will walk you through the software that needs to be installed and how to use it. Your performance on labs will amount to **20%** of your final marks. (Estimated time: (180 min x 5 main sessions)= 90min/week)
8. Finally, you will have a **Final Exam**, worth **30%** of your final marks. This is a more traditional, summative assessment, but we will base it strongly on the quizzes and content generated by the students in the Wiki-Style Lecture Notes. (Estimated time: 120 min)

And that is it! You are not supposed to do any extra homework, etc. You will be investing a **total of 75 hours** with the activities listed above.

This is a 6 credit course, which means you are expected to invest 150 hours in total (15 hours per week). With this plan, you have a total of 75 hours (7.5hs/week) that you can use to learn the content however you like. We suggest you take this time to read your peers' Wiki notes, rewatch videos, scan through the textbook, study topics that are pre-requisites for the course but you might not remember, try some exercises, peruse through online resources, etc.

Additional Course Information

Relationship to Other Courses

This is a **4th** year course in the School of Electrical Engineering and Telecommunications. It is an **elective course** for computer, telecommunications, and electrical engineering students (including combined degrees).

Pre-requisites and Assumed Knowledge

The prerequisite for this course is **ELEC2133 Analogue Electronics**. It will be assumed that students have mastered this subject. Students are strongly advised to revise any unfamiliar topics in their own time.

Following Courses

There are no following courses for this course, but it suits for students aiming for postgraduate level course **ELEC9704 VLSI Technology**.

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Quizzes	20%	Week 2, Week 3, Week 5, Week 7, Week 8, Week 9, Week 10	1, 2, 5
2. Wiki project	30%	Week 5, Week 10	1, 4, 5, 6
3. Laboratory	20%	Week 3, Week 4, Week 5, Week 7, Week 8, Week 9	1, 2, 3
4. Final Examination	30%	Study Week	1, 2, 4, 5

Assessment 1: Quizzes

Due date: Week 2, Week 3, Week 5, Week 7, Week 8, Week 9, Week 10

After the previous week's tutorial and watching the weekly pre-lecture recordings, you are required to answer simple questions on Moodle. Due before the next lecture.
The quizzes contribute 20% to the total course marks.

Assessment criteria

Marks are assigned according to correct or closest answers.

Assessment 2: Wiki project (Group)

Due date: Week 5, Week 10

The Wiki project is a group project, you will be forming a group size of **4** members. Once you have settled, please nominate a group leader to send us your member list.

You will be given topics that are covered in the course, and build wiki notes around them. You will be creating summerised lecture notes, questions and their worked out example, review of relavent backgrounds, and any supporting multimedia materials.

To facilitate a better teamwork environment, each member of the team will have their own special role.

You are strongly encouraged to build up each Wiki topic before its corresponding lecture in order toreceive feedbacks during the lecture.

Details of the Wiki project will be handed out in a separated project description document.

The Wiki will be marked at two check points: end of **Week 5 (10%)** and end of **Week 10 (20%)**.

Assessment criteria

The total course mark will be given as group marks, unless under special circumstances where the marks will be modified for each individual.

Details of the marking rubrics will be given in the projection descrption.

Assessment 3: Laboratory

Due date: Week 3, Week 4, Week 5, Week 7, Week 8, Week 9

There are 6 laboratory sessions with one preparation Lab-0 to install softwares and registering online accounts for simulation.

Lab-0 contributres 1% and Lab-1 3% to the course total marks. From Lab-2 to Lab-5 each contributes 4% to the total marks.

Demonstrators will strictly follow the guideline below during the assessment:

1. All preliminary preparation, results of experimental measurements and discussion of results must be **neatly recorded** in a laboratory book or electronic document.
2. Marking will only be done during the laboratory period by the demonstrator's present through **oral assessment**. It is the responsibility of the students to make sure that his/her mark is recorded by the demonstrator.
3. Experiments will **only** be marked during a student's assigned lab time. Do not attend another lab group to get marked unless permission has been given by a demonstrator

Assessment criteria

Marks are given based on the report you have prepared during the laboratory. The report will contain short paragraphs of the findings of the simulation, and include screenshots or any other output formats from the softwares.

You will be asked random questions from the demonstrators, sataisfactory answers are expected in order to receive the marks.

Hurdle requirement

A pass grade in laboratory component is required to **pass this course overall**.

Assessment 4: Final Examination

Due date: Study Week

The exam in this course is a two-hour written examination. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory and Wiki project), unless specifically indicated otherwise by the lecturer.

Assessment criteria

Marks will be assigned according to the correctness **AND** the working out of the responses, answers with no working out shown may receive **NO** marks.

Attendance Requirements

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

Course Schedule

Lectures run weekly on **Monday 11am to 1pm**, in **Electrical Engineering G22**, Hybrid mode.

Tutorials run weekly on **Friday 2pm to 3pm**, in **Electrical Engineering G22**, Hybrid mode.

You are required to take **quizzes weekly**. Quiz due at beginning of **each lecture**, where you are required to watch pre-recorded videos in order to answer.

You are required to attend **ALL** laboratories. Laboratory sessions are scheduled in **Week 3,4,5,7,8,9**.

There will be **two check points** of the Collaborative Wiki project, where marks will be awarded based on the content at the check points.

View class timetable

Timetable

Date	Type	Content
Week 1: 12 September - 16 September	Lecture	Introduction to course Band-structure and doping profile of semiconductors
	Tutorial	Tute 1
Week 2: 19 September - 23 September	Homework	Pre-lecture recording and Quiz
	Lecture	Carrier motion and continuity
	Tutorial	Tute 2
	Project	Finalising Wiki project groups and topics
	Assessment	Quizzes
Week 3: 26 September - 30 September	Homework	Pre-lecture recording and Quiz
	Lecture	p-n junction
	Laboratory	Lab 0
	Tutorial	Tute 3
	Assessment	Quizzes
	Assessment	Laboratory
Week 4: 3 October - 7	Laboratory	Lab 1

October	Assessment	Laboratory
Week 5: 10 October - 14 October	Homework	Pre-lecture recording and Quiz
	Lecture	BJT
	Laboratory	Lab 2
	Tutorial	Tute 4
	Project	Wiki project first check point Due by end of Friday
	Assessment	Quizzes
	Assessment	Wiki project
	Assessment	Laboratory
Week 6: 17 October - 21 October	Lecture	Flexible week Revision & Wiki exhibition
	Tutorial	Flexible week Revision
Week 7: 24 October - 28 October	Homework	Pre-lecture recording and Quiz
	Lecture	MOSFET
	Laboratory	Lab 3
	Tutorial	Tute 5
	Assessment	Quizzes
	Assessment	Laboratory
Week 8: 31 October - 4 November	Homework	Pre-lecture recording and Quiz
	Lecture	Microfabrication
	Laboratory	Lab 4
	Tutorial	Tute 6
	Assessment	Quizzes
	Assessment	Laboratory
Week 9: 7 November - 11 November	Homework	Pre-lecture recording and Quiz
	Lecture	Quantum effects
	Laboratory	Lab 5
	Tutorial	Tute 7

	Assessment	Quizzes
	Assessment	Laboratory
Week 10: 14 November - 18 November	Homework	Pre-lecture recording and Quiz
	Lecture	Optoelectronics
	Tutorial	Tute 8
	Project	Wiki project second check point Due by end of Friday
	Assessment	Quizzes
	Assessment	Wiki project
Study Week: 21 November - 24 November	Assessment	Final Examination

Resources

Prescribed Resources

Textbooks

The prescribed textbook (free library access) set for this course is:

- Christo Papadopoulos, Solid-State Electronic Devices: An Introduction (Springer, 2014). https://primoa.library.unsw.edu.au/permalink/f/238ui7/UNSW_ALMA51227971010001731

An alternative textbook, which covers much of the same material, but with greater emphasis on semiconductor fabrication, is:

- S. M. Sze & M. K. Lee, Semiconductor Devices, Physics and Technology (Wiley, 3rd ed., 2012). https://primoa.library.unsw.edu.au/permalink/f/1gq3lal/UNSW_ALMA21173723460001731

Muller & Kamins was formerly the textbook for this course:

- R. S. Muller, T. I. Kamins & M. Chan, Device Electronics for Integrated Circuits (Wiley, 3rd ed., 2003). https://primoa.library.unsw.edu.au/permalink/f/1gq3lal/UNSW_ALMA21171428390001731

On-line resources

Microsoft Teams

- As a part of the teaching component, Microsoft Teams will be used to disseminate teaching materials, host channels and occasionally. Assessment marks will also be made available via Microsoft Teams: https://student.unsw.edu.au/teams-students

Moodle

- Moodle will be used to host quizzes. https://moodle.telt.unsw.edu.au/

Mailing list

- Announcements concerning course information will be given in the lectures and/or on Microsoft Teams and/or via email (which will be sent to your student email address).

Course Evaluation and Development

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 online student survey myExperience. 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.

Starting 2020, this course has been refreshed with content that fits better with modern solid-state technologies, with additional delivery methods such as quizzes. Changes in content included dropping the section on legacy digital circuits, and inclusion of quantum effect of nano-scale transistors.

In 2021, with collective feedbacks from the students, further changes to the course has been made.

- The lecturer/tutorial hours has been readjusted. More turotial sessions have been introduced to ensure students have more problem solving chances.
- The new colloborative Wiki project encourages students to engage with each other online, and perform a literature review style group-learning platform.
- Laboratory transformations are in the progress, dropping what students find as "irrelavant contents" to the course. However, new 2021 laboratory activities will be online simulation only due to lockdown restrictions.

The overall change is to move towards a more formative learning environment, providing more progressive feedback rather than focusing on summative assessments.

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

Photo taken by James Slack-Smith and Wee Han Lim

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	✓