ELEC4603
Solid State Electronics

COURSE STAFF

Course Convenor: Dr. Henry Yang, J12 Newton Building, Room 315, henry.yang@unsw.edu.au
Dr. Andre Saraiva, J12 Newton Building, Room 316, a.saraiva@unsw.edu.au

Laboratory Contact: Mr. Will Gilbert (Head), w.gilbert@unsw.edu.au
Mr. Ensar Vahapoglu
Ms. Ingvild Hansen
Mr. Jonathan Huang
Mr. Kevin Guo

Consultations: You are encouraged to ask questions on the course material before, during and after the lecture class times. Alternatively, queries or concerns about this course can be raised (all other matters) via Microsoft Teams, email contact or during prearranged consultation times. ALL email enquiries should be made from your student email address with **ELEC4603** 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 primarily use Microsoft Teams. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

COURSE SUMMARY

Contact Hours

The course consists of 2 hours of lectures each week (with 1 additional hour from week 1 to week 4), 1 hour of tutorial, and 3 hours of laboratory every two weeks. Laboratories and tutorials begin in weeks 2 and 5, respectively. Refer to the class schedule for details. Students should check their myUNSW timetable to see which group they have been allocated to and the corresponding time schedule/location for the Tutorial/ Laboratory session.

	Day	Time	Location
Lectures	Tuesday	9am – 11am	Microsoft Teams Meeting
	Friday	1pm - 2pm (w1-4)	Microsoft Teams Meeting
Tutorials	Friday	12pm – 1pm	Microsoft Teams Meeting
	Friday	1pm – 2pm	Microsoft Teams Meeting
	Friday	2pm – 3pm	Microsoft Teams Meeting
Labs	Friday	2pm – 5pm	EE 201/Teams Meeting
	Thursday	12pm – 3pm	EE 201/Teams Meeting
	Thursday	3pm – 6pm	EE 201/Teams Meeting
	Tuesday	12pm – 3pm	EE 201/Teams Meeting
	Wednesday	1pm – 4pm	EE 201/Teams Meeting

Context and Aims

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). 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.

This subject endeavours to teach students not only just how these electronic devices operate, but also develop some insight into the underlying solid-state physics. 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; Threshold Voltage; Operating-mode.
- 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.

At the end of the course students should:

a) Understand the underlying operating principles of important microelectronic and photonic devices, such as MOSFETs, BJTs and semiconductor lasers.
b) Understand the limits of ideal "black-box" models of devices and predict the effect of these non-idealities on real circuits and systems.
c) Have an appreciation of the principles of microfabrication relevant to integrated circuit manufacture, and how these affect device performances.

Indicative Lecture Schedule

Period	Summary of Lecture Program	Tutorial	Laboratories
Week 1	Energy Bands and Charge Carriers in Semiconductors		
Week 2	Excess Carriers in Semiconductors		Lab 1: Fibre-Optic Communication (1st session)
Week 3	p-n Junction		
Week 4	Bipolar Junction Transistors		Lab 1: Fibre-Optic Communication (2nd session)
Week 5	Field-effect Transistors **Assignment due**	Tutorial 1: Derivation of diode IV characteristic	
Week 6	**Flexible Week**		
Week 7	CMOS devices **Mid-term Exam**	Tutorial 2: Diode design and Thermal effects	Lab 2: Transistor Characterisation (1st session)
Week 8	Microfabrication	Tutorial 3: Frequency dependent Parameters of BJTs	Lab 2: Transistor Characterisation (2nd session)
Week 9	Quantum Effects and Scaling	Tutorial 4: TBC	
Week 10	Opto-electronic Devices	Tutorial 5: TBC	Lab 2: Transistor Characterisation (marking session) – **Report due**

Assessment

Laboratory Assessments	**20%**
Assignment and Quiz	**15%**
Mid-term Exam (1 hour)	**15%**
Final Exam (2 hours)	**50%**

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. students for more information on safe practices.

COURSE DETAILS

Credits

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 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 Solid State Electronics 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.

Learning outcomes

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

1. Demonstrate an understanding of the key concepts involved in semiconductor device operation and their characteristics.
2. Perform simple analysis of semiconductor devices to derive basic I-V characteristics.
3. Predict the effect of device design variations on device performance.
4. Assess the relative advantages/disadvantages of different classes of electronic and optoelectronic devices for applications.
5. Design simple optoelectronic communication system.
6. Demonstrate an understanding of the technologies used in integrated circuit manufacture and the impact of these technologies on device design and performance.

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

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.

TEACHING STRATEGIES

Delivery Mode

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

- Online lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding.
- Quizzes, which encourage student to get familiar with the topics in upcoming lectures.
- Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material.
- Laboratory sessions, which support the formal lecture material and also provide you with practical construction, measurement and debugging skills.
- Assignment, in which student can apply what they learnt in class to solve real-world engineering design problems.

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-term 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 formal classes throughout the course.

Quizzes

A short video (or other format) will be released on Microsoft Teams prior to each lecture. You should watch the video before the lecture starts, which serves as a preview of the upcoming lecture content. After you have completed watching the video, you must answer simple questions before each lecture starts, which will be marked and counted towards you course assessment.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes and **actively involve in discussion** to gain maximum benefit from this course.

Laboratory program

The laboratory schedule is deliberately designed to provide practical exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend laboratory. Laboratory attendance WILL be kept, and you MUST attend **at least 80% of labs**.

The experimental component of this course is complementary to the lectures. In it, students will have the opportunity to gain experience with the use of optoelectronic devices, as well as to characterise the dc parameters of BJTs and MOSFETs.

A pass grade in all laboratory experiments is required to **pass this course overall**. All of the experiments are compulsory and are worth, in total, **20%.**

The preliminary preparation for each laboratory experiment consists in reading through the laboratory notes and familiarising yourself with the concepts involved. Ensure that you understand what each experiment is about before the relevant laboratory session.
Keeping systematic notes is an important aspect of experimental technique. Your laboratory notebooks should be the primary record of your design and calculations and results of your experiments. The preliminary preparation should be done in the laboratory notebook. Results, measurement, and observations should be recorded directly into the notebook as they are gathered (and not on loose scraps of paper). Except when drawing circuits and waveforms, pen must be used rather than pencil. There is no need to do a 'draft' and then a 'good copy' — this merely wastes time.

The notes for laboratory experiments may be downloaded from the Microsoft Teams. The experiments are:

Lab 1.	**Fibre-Optic Communication**	(2 lab sessions)
Lab 2.	**Characterisation of Transistors**	(3 lab sessions + report)

Laboratory sessions are scheduled on even weeks (week 6 shifted to week 7). **Please ensure that you attend all sessions**. Please take careful note of the **laboratory experiment completion deadlines**.

Special online simulation-based labs will be arranged for students who could not come to campus.

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 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 coordinators.

ASSESSMENT

The assessment scheme in this course reflects the intention to assess your learning progress through the term. Ongoing assessment occurs through the quiz, lab checkpoints (see lab manual), and the mid-term exam. There will be **NO** laboratory exam in this course. All parts of the assessment will be marked according to the amount of work done, the correctness of the work, and the displayed knowledge and understanding of the topic.

Laboratory Assessment (20%)

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. **Work presented in loose sheets will NOT be marked**.
2. **Assessment of Lab 1 will be conducted orally**. It is the student's responsibility to organise the documentation of his/her laboratory work in a fashion that shows understanding and achievements. During the oral examination, **students are expected to demonstrate the operation of their circuit**. Do not dismantle the circuit until you have received a written clearance in your laboratory notebook that the assessment is complete. Marking will only be done during the laboratory period by the demonstrator's present. It is the responsibility of the students to make sure that his/her mark is recorded by the demonstrator. 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 of Lab 2 will be conducted both orally in the lab and through a lab report.
3. Lab 1 will be marked out of 20. Lab 2 will be marked out of 30 (20 marks demonstration, 10 marks report). A pass grade in all laboratory experiments is required to pass this course overall.

Assignment and Quiz (15%)

The assignment allows self-directed study leading to the solution of partly structured problems. Marks will be assigned according to how completely and correctly the problems have been addressed and the understanding of the course material demonstrated by the report. The assignment will weight **10%** of the total mark.

There will be one compulsory written **assignment**. It is expected that the students complete assignments on their own. **Students found guilty of academic misconduct, including excessive collaboration, copying another's assignment, or allowing one's assignment to be copied by another student, will not receive any marks for that assignment.** In addition, a more severe penalty may be imposed.
Late submissions will attract a penalty of 20% per day (including weekends). All assignment report, both handwritten or typed, should be carefully converted into pdf file and upload to Microsoft Teams.

Before submitting your report, make sure of the following:

- Report is complete, any missing page due to scan will NOT be assessed. Late penalty will be applied if the missing page is submitted after the deadline.
- Report is reasonably easy to read, typing report is not compulsory but make sure your answer is as neat as possible.
- Make sure the school individual assignment cover sheet is signed and attached at the first page. The report without cover sheet will NOT be assessed. You may find the cover sheet through the link: http://scoff.ee.unsw.edu.au/forms/Individualassignmentcover.pdf

Additionally, there will be a quiz **before each lecture** class starts. You may need to watch a short video that is related to the lecture and answer simple questions on Microsoft Teams. Please make sure you complete the quiz before the given deadline. Quiz will weight **5%** of the total mark.

Mid-Term Exam (15%)

There will be a one-hour written exam in Week 7. More information about the mid-term will be available in the first few weeks of the course

Final Exam (50%)

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), unless specifically indicated otherwise by the lecturer. 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. **Please note that you must pass the final exam in order to pass the course**.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes					
Assessment	**1**	**2**	**3**	**4**	**5**	**6**
Laboratory Assessments	✓	✓	✓	✓	✓	
Assignment and Quiz	✓	✓	✓	✓		✓
Mid-term exam (1 hour)	✓	✓	✓	✓		
Final exam (2 hours)	✓	✓	✓	✓		✓

COURSE RESOURCES

Textbooks

The prescribed textbook set for this course is:

- D. K. Bhattacharya & Rajnish Sharma, Solid state electronic devices (Oxford University Press, 2013). https://primoa.library.unsw.edu.au/permalink/f/jhud33/UNSW_ALMA51177759560001731

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, quizzes. Assessment marks will also be made available via Microsoft Teams: https://student.unsw.edu.au/teams-students

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).

OTHER MATTERS

Dates to note

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

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/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.

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 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.

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 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.
The prescribed textbook has changed to a more modern one with online open access for students.
The main hub of the course has moved to Microsoft Teams, where students can find resources easily and be more actively involved in discussions.

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

APPENDICES

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:

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through assignment work.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	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	✓