SOLA3507

SOLAR CELLS

Contents

1. Staff contact details

Contact details and consultation times for course convenor

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Moodle: Fiacre Rougieux

Consultation Hours: After lectures

Contact details and consultation times for additional lecturers/demonstrators/lab staff
Please see the course Moodle.

2. Important links

- Moodle
- Health and Safety
- Student Resources
- UNSW Timetable
- UNSW Handbook
- Engineering Student Support Services Centre
- UNSW Photovoltaic and Renewable Energy Engineering

3. Course details

Credit points

This is a 6 unit-of-credit (UoC) course and involves 5 hours per week (h/w) of face-to-face contact.

The normal workload expectations of a student are approximately 25 hours per term for each UOC, including class contact hours, other learning activities, preparation and time spent on all assessable work.

You should aim to spend about 10 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

Contact hours

	Day	Time	Location
Lectures	Monday	1pm - 2pm	Online
	Wednesday	11am – 12pm	Online

Tute H12A	Thursday	12pm – 2pm	Online
Tute H12A	Friday	1pm – 2pm	Online
Tute W15A	Wednesday	3pm – 5pm	TETB LG35
Tute W15A	Friday	3pm – 4pm	Quad G034

Please refer to your class timetable for the learning activities you are enrolled in and attend only those classes.

Summary and Aims of the course

In this course students will gain both a fundamental and practical understanding of the design and operation of solar cells. The course will enable the student to extend their knowledge of semiconductor device and provide a sound basis for a deep understanding of current solar cell technologies. Key practical processes such as solid-state diffusion, gettering and device contacting are introduced. A range of laboratory-based and commercial solar cell technologies are reviewed together with recent technological advances in the field. The course makes use of simulation tools to reinforce an understanding of device physics and the different solar cell technologies. The simulation tools are also used to design and optimize advanced solar cells concepts. The course introduces a suite of relevant characterisation techniques that are used to understand the characteristics of solar cells including spectral response, temperature sensitivity, resistive losses, current generation and open-circuit voltages.

The broad aim of this course is to provide the students with the knowledge that is required to understand the design, operation and characterisation of solar cells.

More specifically the course aims to:

- Develop within students a fundamental theoretical understanding of the operation of solar cells;
- Expose students to a wide range of solar cell technologies, which are practised in laboratory and commercial environments; and
- Teach students to use available tools and techniques to characterise solar cells.

Student learning outcomes

This course is designed to address the learning outcomes below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

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

Learning Outcome		**EA Stage 1 Competencies**
1.	Describe solar cell operations using physical and electrical models	1.1, 1.2, 1.3, 3.2

2.	Simulate solar cell devices using numerical models	1.2, 1.3, 2.1, 2.3
3.	Design solar cells by optimising parameters for maximum efficiency	2.1, 2.3
4.	Analyse measured characteristics of solar cells to determine sources of loss	2.1, 2.3

4. Teaching strategies

The teaching strategy for this course comprises a series of lectures (2 hrs per week) and tutorial sessions (2 + 1 hrs per week). The lecture series will present theory related to the operation, design and characterisation of solar cells. The 2 hours tutorial will be an opportunity to perform the assessable activities. The additional 1-hour tutorial will be used to clarify difficult topics, perform worked exercises, learn software such as PC1D, respond to technical questions asked on the forum.

During the semester students will work through a set of 3 assessable activities with each activity requiring three weeks to complete (i.e., 3 × 2 hrs). Each tutorial activity will be posted on Moodle during the week preceding the activity. It will have a number of learning objectives and students will work through exercises that aim to address these outcomes. Some activities require that students complete calculations, others will involve the use of simulation software and one will involve laboratory measurements. In each activity students will be required to submit prepared pre-work at the start of the tutorial class in the 2nd week dedicated to the activity and submit a report on the activity on the Friday following the last tutorial class dedicated to the activity.

Students can also use their allocated tutorial session to ask tutors any questions they may have about the material taught in lectures. Students are also strongly encouraged to use the discussion group on Moodle to assist their learning. Tutors will monitor the discussions and help answer posted questions.

The course contains a large component of self-learning through the experience gained via using the PC-1D software to simulate various solar cell design aspects. The PC1D software is installed on all the computers in the School's computer lab and can be used for free from my access:
https://www.myaccess.unsw.edu.au/
Students are encouraged to begin familiarising themselves with the operation of the software.

5. Course schedule

Week No	Week Starting	Lecture	Tutorials 1	Tutorials 2
1	17 Feb	Generation and recombination	Exercise #1	Simulation
2	24 Feb	Carrier collection and electrochemical potential	Exercise #1	Simulation

3	2 Mar	The ideal Solar Cell, Diffusion and Gettering	Exercise #1	Design
4	9 Mar	Contact Formation and Metallisation	Exercise #2	Design
5	16 Mar	Solar Cell characterisation	Exercise #2	Design
7	30 Mar	Solar Cell Optics	Exercise #3	Analysis
8	6 April	Loss analysis	Exercise #3	Analysis
9	13 April	Efficiency limits	Exercise #3	Analysis
10	20 April	High efficiency cell concepts	Revision Exercises	Revision Exercises

6. Assessment

Assessment overview

Assessment	**Group Project?** (# Students per group)	**Length**	**Weight**	**Learning outcomes assessed**	**Assessment criteria**	**Due date and submission requirements**	**Deadline for absolute fail**	**Marks returned**
Exercises	Yes for Exercise 3 (12)	5000 words	45%	1, 2, 3 and 4	Analysis, Evaluation and Design of solar cells	See Moodle	See Moodle	Two weeks after submission
Online Quizzes (10)	No	Multiple choice	10%	1, 2 and 3	Lecture material from respective week.	During week 4, 7 and 10 demonstration classes	N/A	Upon completion
Final exam	No	2 hours	45%	1 and 4	All course content from weeks 0-11 inclusive.	Exam period, date TBC	N/A	Upon release of final results

Assignments

Students will be required to submit reports for three assessable exercises that will be conducted through the tutorial program during semester. Each exercise will be conducted over a period of 3 weeks. Students will be able to work on the exercise during their tutorial sessions and must submit a report via Moodle by midnight of the Friday of the last week of the activity. Each exercise will be marked out of 100 and scaled to a final mark of 15.

During the course, students should complete the provided online quizzes in their own time. These quizzes are designed to help students revise material presented each week in class and adaptive help will be provided for questions where possible. Multiple attempts will be

permitted for all quizzes and at the completion of course in Week 10, student average marks on the quizzes will be scaled to a final mark of 5.

Presentation

All non-electronic submissions should have a standard School cover sheet, which is available from this course's Moodle page.

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Submission

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 30%-mark reduction on the first day and an additional 10% per day thereafter, consistent with other SPREE courses.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
b. Online quizzes where answers are released to students on completion, or
c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
d. Pass/Fail assessment tasks.

Marking

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

Examinations

The final exam for postgraduate students and undergraduate students will be the same. All material presented in the course is examinable in the final exam.

You must be available for all quizzes, tests and examinations.

Final examinations for each course are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates.

For further information on exams, please see the Exams webpage.

Calculators

You will need to provide your own calculator of a make and model approved by UNSW for the examinations. The list of approved calculators is available at student.unsw.edu.au/exam-approved-calculators-and-computers

It is your responsibility to ensure that your calculator is of an approved make and model, and to obtain an "Approved" sticker for it from the Engineering Student Supper Services Centre prior to the examination. Calculators not bearing an "Approved" sticker will not be allowed into the examination room.

Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

Please note that UNSW now has a Fit to Sit / Submit rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

7. Expected resources for students

Learning resources for this course include:

- The PC1D software package is included on all the computers in 416 and 455
- M. A. Green (1982) "Solar Cells". Red book.
- Jenny Nelson, "The Physics of Solar Cells"
- Photovoltaic Solar Energy: From Fundamentals to Applications
- Peter Wurfel, Physics of Solar Cells

Additional reference material made available to students via Moodle

UNSW Library website: https://www.library.unsw.edu.au/
Moodle: https://moodle.telt.unsw.edu.au/login/index.php

8. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include the implementation of team-based learning as way to promote collaboration and the development of a community of learners. Additional improvements include the development of real-life scenarios exercises to prepare students to problem faced when in the industry.

9. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here:
www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

10. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Equitable Learning Services

Appendix A: Engineers Australia (EA) Competencies

Stage 1 Competencies for Professional Engineers

	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