Course Outline

School of Photovoltaic and Renewable Energy Engineering

SOLA3507

Solar Cells

Term 1, 2019

Course Coordinator

Dr. Fiacre Rougieux
Room 107 TETB building
Email: fiacre.rougieux@unsw.edu.au
Consultation Hours: Thursday 10 am - 12 pm

Staff Contact Details

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Lecturers

Dr. Fiacre Rougieux

Course Details

Moodle: https://moodle.telt.unsw.edu.au

Credit Points: 6 units

Summary 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.

Aims of the Course

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.

Assumed Knowledge

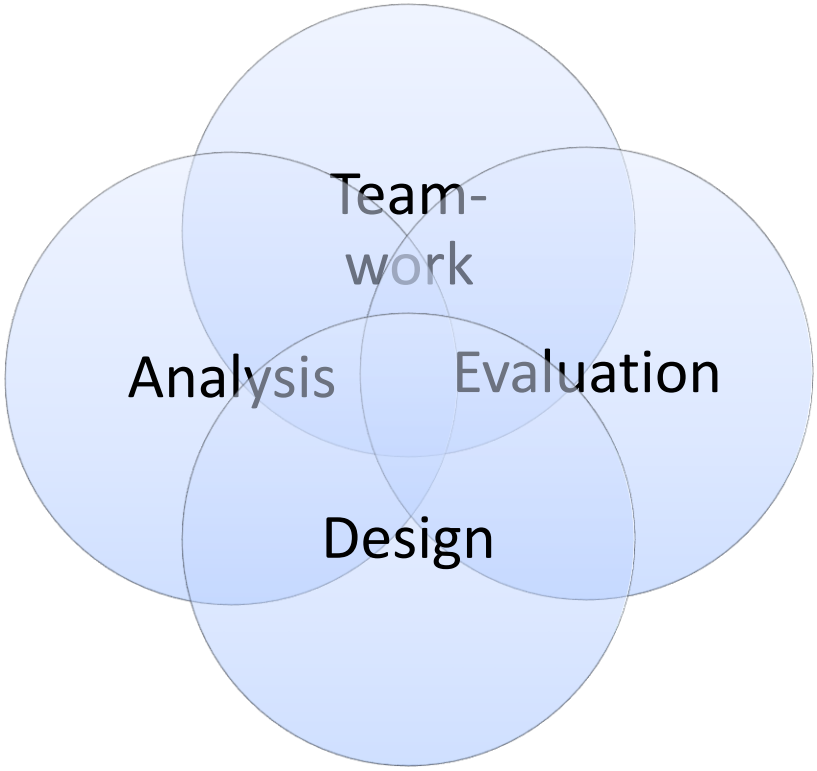
It is assumed that students enrolled in this course are familiar with material covered in SOLA2540 (Applied PV). The textbook "*Applied Photovoltaics"* by S. Wenham *et al*. ("blue book") is strongly recommended for students wishing to revise material taught in SOLA2540.

Student Learning Outcomes (LO)

At the conclusion of this course students should:

LO1. Describe solar cell operations using physical and electrical models;
LO2. Simulate solar cell devices using numerical models;
LO3. Design solar cells by optimising parameters for maximum efficiency;
LO4. Analyse measured characteristics of solar cells to determine sources of loss.

Students are expected to gain the necessary information through lectures, tutorials, textbooks and self-research. Additional information and more detailed explanation will be provided through lectures, and where necessary through access to information in the library.



Graduate Attributes

This course will assist students in their development of the following UNSW Engineering graduate attributes (see: https://teaching.unsw.edu.au/mapping-graduate-capabilities)

- The skills involved in a scholarly enquiry;

- An in-depth engagement with the relevant disciplinary knowledge in its inter-disciplinary context;
- The capacity for analytical and critical thinking and for creative problem solving;
- Information literacy - the skills to appropriately locate, evaluate and use relevant information; and
- The skills of effective communication.

Developed Competencies

The Engineers Australia policy on Accreditation of Professional Engineering programs requires that all programs ensure that their engineering graduates develop Stage 1 elements of competency (see: http://www.engineersaustralia.org.au/membership/assessment/assessment_home.cfm). Listed below are the activities in this course that will help students to achieve at least some of these elements of competency.

Professional Engineering Stage 1 Elements of Competencies	Activities used to Develop Competency
Knowledge and Skill Base	
1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	Lectures on theory of solar cell device operation.
1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	Lectures and tutorials on solar cell engineering processes and underlying physical/chemical theory.
1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline.	Tutorial questions and assignment PC-1D simulation tasks which involve optimisation of aspects of solar cell design
Engineering Application Ability	
2.1 Application of established engineering methods to complex engineering problem solving.	Assignment tasks requiring problem analysis from solar cell characterisation data and PC-1D simulation data.
2.3 Application of systematic engineering synthesis and design processes.	Tutorial and assignment tasks in which aspects of solar cell design are designed and optimised.
Professional and Personal Attributes	
3.2 Effective oral and written communication in professional and lay domains.	Preparing written assignments which effectively communicate how PC-1D simulations were used to optimise aspects of solar cell design or how solar cell characterisation data was used to identify problems in fabricated solar cells.

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, performe 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 downloaded for free from:
http://www.engineering.unsw.edu.au/energy-engineering/pc1d-software-for-modelling-a-solar-cell

Students are encouraged to begin familiarising themselves with the operation of the software.

Assessment

Assessable Tasks

Assessment Task	% Final Mark	Learning Outcomes Assessed	Due Date
Exercise 1	15%	L01, LO2	Wks 1 - 3
Exercise 2	15%	L01, LO2, L03	Wks 4 – 6
Exercise 3	15%	LO1, L04	Wks 7 - 9
Online Quizzes	10%	L01, LO2, L03	Wk 1 - 10
Final exam	45%	LO1, LO4	TBA

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 the course in Week 12, student average marks on the quizzes will be scaled to a final mark of 5.

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.

Submission of Assessment Tasks

All assessment reports are to be submitted electronically via Moodle.
Penalties (see Section 10) will apply to the late submission of minor and major assignments.

Academic Honesty and Plagiarism

Plagiarism

Plagiarism is the presentation of the thoughts or work of another as one's own. Examples include:[1]

- Direct duplication of the thoughts or work of another, including by copying work, or knowingly permitting it to be copied. This includes copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person's assignment without appropriate acknowledgement;
- Paraphrasing another person's work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- Piecing together sections of the work of others into a new whole;
- Presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a tutor; and,
- Claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed. [2]

Submitting an assessment item that has already been submitted for academic credit elsewhere may also be considered plagiarism. The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does *not* amount to plagiarism. Students are reminded of their

[1] Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle.
[2] Adapted with kind permission from the University of Melbourne.

rights and responsibilities in respect of plagiarism, as set out in the University Undergraduate and Postgraduate Handbooks, and are encouraged to seek advice from academic staff whenever necessary to ensure they avoid plagiarism in all its forms.

The Learning Centre website is the central University online resource for staff and student information on plagiarism and academic honesty. It can be located at:
www.lc.unsw.edu.au/plagiarism
The Learning Centre also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- Correct referencing practices;
- Paraphrasing, summarising, essay writing, and time management;
- Appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is available on request from The Learning Centre.
Students 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 items.

Course Schedule

Week No	Week Starting	Lecture	Tutorials 1	Tutorials 2
1	18 Feb	Generation and recombination	Exercise #1	Simulation
Si	25 Feb	Carrier collection and electrochemical potential	Exercise #1	Simulation
3	4 Mar	The ideal Solar Cell	Exercise #1	Design
4	11 Mar	Diffusion and Gettering	Exercise #2	Design
5	18 Mar	Contact Formation and Metallisation	Exercise #2	Design
6	25 Mar	Solar Cell characterisation	Exercise #2	Analysis
7	1 April	Solar Cell Optics	Exercise #3	Analysis
8	8 April	Loss analysis	Exercise #3	Analysis
9	15 April	Efficiency limits	Exercise #3	Analysis
10	22 April	High efficiency cell concepts	Revision Exercises	Revision Exercises

Due to Good Friday, Easter Monday and Anzac Day some lectures and tutorials will take place in week 11.

Notes:
Assume lectures and tutorial sessions are as indicated in your timetables unless told otherwise.
Tutorial activities marked in bold are assessable activities.

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.

Course Evaluation and Development

At the end of the course, you will be asked to complete two evaluation forms – one for the course and one for the course coordinator using the UNSW's Course and Teaching Evaluation and At the end of the course, you will be asked to complete two evaluation forms – one for the course and one for the course coordinator using the UNSW's Course and Teaching Evaluation and Improvement (MyExperience) Process. Your feedback is much appreciated and taken very seriously. Continual improvements are made to the course based in part on such feedback and this helps us to improve the course for future students.

Other Information

Special Consideration for Illness or Misadventure

If you are unable to submit a piece of assessment on time, or to participate fully in laboratory sessions, due to illness or some other event which was beyond your control, you must follow the central UNSW procedures for seeking special consideration. Details of these can be found at https://my.unsw.edu.au/student/atoz/SpecialConsideration.html.

Please be aware that requests for special consideration need to be submitted to UNSW Student Central as soon as is practicable after the problem occurs and within three working days of the due date of the relevant assessment task.

Penalties for Late Submission of Work

Where a student submits a piece of assessment late, and a request for special consideration has not been approved, the student will be penalised by a deduction of marks.

Late written work will be penalized 5% of the value of the assessment task per day. Once solutions are provided for the assessment task the maximum penalty will apply. Requests for special consideration should be submitted, as for all other subjects, through the Registrar. An extension of time may only be granted under exceptional circumstances beyond the student's control.

Disability Support

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course coordinator prior to, or at the commencement of, their course, with the Equity and Disability Officer in the school office (9385 7993) or with the Equity Officer (Disability) in the Equity and Disability Unit (EADU) 9385 4734. Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

Further information for students with disabilities is available at:
http://www.studentequity.unsw.edu.au/disabil.html.