Photovoltaic and Renewable Energy Engineering

Course Outline

Term 3 2020

SOLA9120

Advanced Photovoltaic Manufacturing

Contents

1. Staff contact details

Course staff:

Course Convener:	Prof Gavin Conibeer, TETB 245 (K-H6-132), g.conibeer@unsw.edu.au
Lecturers:	Prof G Conibeer, Dr Ran Chen – ran.chen@unsw.edu.au Dr Adrian Shi – lei.shi@unsw.edu.au
Course tutor:	Dr Adrian Shi
Guest lecturers:	Dr Rhett Evans – Rhett.evans@unsw.edu.au Dr Nathan Chang – n.chang@unsw.edu.au,

Consultations:
For all enquiries about the course, please contact the course convenor. A regular weekly consultation time will be available immediately after lectures on MS Teams. For all other questions or enquiries, you are encouraged to ask the lecturer during and after the on-line lectures or post your question on the Discussion Board on Moodle.

Keeping Informed:
All course material and announcements will be posted on Moodle. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

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.
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 13 hours per week on this course throughout the 10-week term. 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	Wednesday	10am – 12.30pm weeks 1-5 & 7-10	MS Teams and Moodle
Tutorials	Thursday	10am – 12pm weeks 1-5 & 7-10	MS Teams, Moodle, VMES, Minitab

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

Summary and Aims of the course

Silicon photovoltaic solar cells have reached the modern age of high-volume manufacturing. Solar cell manufacturing capacity has expanded 100-fold in the past 15 years and has reached 100 gigawatts of annual production. Photovoltaic engineers, scientists and managers must have a good working understanding of how solar cells are manufactured, improved and sustained in real solar cell factories, in order to succeed in their fields.
Students enrolled in this class will learn about the manufacture of silicon solar cells, specifically about engineering in the manufacturing environment. The course covers several engineering tools/methods used by engineers to improve solar cell performance and reduce solar cell cost in manufacturing, namely statistical decision making, cost modelling and regression modelling. Students will use these tools in the course's virtual laboratory – the Virtual Cell Factory – where they will work as virtual employees of the "Virtual Cells Inc." company. This company is in dire financial straits, and students will work to "save the company" from imminent bankruptcy.
Students who successfully complete this course will have a practical understanding of the manufacturing engineering skills/tools that engineers use to make improvements in cost and performance in a real solar cell factory environment.

Assumed Knowledge
Students should have a good foundation in basic mathematics, statistics, physics, and chemistry.

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.

Learning Outcomes of This Course
Students who successfully complete this course will:

1. Be able to create good quality graphical models that are appropriate for the data being analysed, including scatter plots, bar charts, histograms, distribution histograms, population distribution histograms, variability diagrams, Pareto charts, and more.
2. Have a good understanding of the normal probability distribution and be able to (1) plot the normal distribution, (2) integrate the normal probability distribution over a range using Excel, Minitab and/or standard tables, (3) compute Z and T values using Excel, Minitab and or standard tables.

3. Be able to analyse samples of normal distributed populations to extract (1) an estimate of the mean, (2) an estimate of the standard deviation and (3) confidence intervals on the mean when the standard deviation is either known or estimated.
4. Be able to compute a statistical comparison of means and draw appropriate conclusions for several cases of the Z (standard deviation known) and T (standard deviation unknown) and for one (test of mean) or two samples (difference of means).
5. Have a good understanding of basic product cost accounting methods and be able to construct cost behaviour models, transactions/conversions, T-accounts, COGM/COGS computations, and financial summary statements.
6. Understand basic manufacturing process-cost modelling and be able to construct a process-cost model from basic cost inputs of throughput, yield, materials, labour etc.
7. Be able to construct a single-factor, polynomial regression model, including experiment design, regression coefficient determination, testing of the model and use of the model to make decisions about engineering improvements/changes.
8. Be able to construct a multiple-factor, polynomial regression model using the Screening-to-RSM Design of Experiments approach, including experiment design, screening of significant factors/interactions and use of the model to optimise a production process.
9. Be able to combine 1-8 above to make statistical-plus-cost based decisions about engineering improvements and changes.
10. Present (written and oral presentation) data, analysis, and discussion in a concise, compelling argument that supports engineering decisions in a manufacturing environment.
11. Have a broad understanding and appreciation of basic principles of photovoltaics manufacturing science and engineering and a good foundation for future learning in this area.
12. Gain improved data handling and analysis skills, especially with MS Excel and Minitab.

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.

4. Teaching strategies

The teaching strategy for this course comprises a series of lectures on different aspects of statistical analysis of large data sets. Each lecture is linked to a turoial in which students apply the statistical methods to real data sets. In addition students work in teams on a virtual solar cell fabrication facility through a platform known as the the Virtual Manufacturing Execution System (VMES). The teams each aim to increase the profitability of their virtual production line through a combination of increased quality, reduced cost and increased yield. They do so by applying statistical test methods from the lectures and tutorials to the data generated by the VMES to calculate new test paramters to improve productivity.

5. Course schedule

(subject to modification during term)

Week	Date	Lectures	Tutorials	Assessments	
1	Sept 16 Sept 17	1 Introduction; Recap of PV manufacturing & graphing; *G Conibeer*	Tut 0: Setup Tut 1: Graphs (yield)		
2	Sept 23 Sept 24	2 Confidence Intervals *Gavin Conibeer*	Tut 2: Population models		
3	Sept 30 Oct 1	3 Hypothesis 1 *Ran Chen*	Tut 3: Confidence intervals	Assign 1 released	
4	Oct 7 Oct 8	4 Hypothesis 2 *Ran Chen*	Tut 4: HT Z test		
5	Oct 14 Oct 15	5 Finance(calc &table) *Gavin Conibeer*	Tut 5: HT T tests and TutX	Assign 1 submitted	
6	Oct 21 Oct 22			Assign 2 released	
7	Oct 28 Oct 29	Midterm Exam	Tut 6: Cost/performance	Midterm Exam	
8	Nov 4 Nov 5	6 Regression models *Adrian Shi*	Tut 7: Regression models	Assign 2 submitted Assign 3 released	
9	Nov 11 Nov 12	7Design.ofExperiments *Gavin Conibeer*	Tut 8: Ass 3 guide		
10	Nov 18 Nov 19	*Nathan Chang:* Monte Carlo	*Rhett Evans:* Big Data	Assignment 3 to be submitted	Guest lectures
Study	Nov 23 Dec 2				
				Final Exam	

6. Assessment

The assessment of the course consists of tutorials, three assignments, a midterm test, and a final examination paper.

Assessment	**Group Project?** (4 Students per group)	**Length**	**Weight**	**Course material assessed**	**Due date and submission requirements**	**Marks returned**
Assignments 1 2 3	No	10-15pages 10-15pages 10-15pages	35%	Lectures 2-4 Lectures 5 Lecture 6-7	via Moodle 5pm Fri 16th Oct 5pm Fri 6th Nov 5pm Fri 20th Nov	Two weeks after submission
Tutorials (x7)	Yes	Weekly 2 hr tutorials	10%	Weekly topics on the course	During week 4, 7 and 10 demonstration classes	The class after each tutorial
Mid-term test	No	1 hour	15%	Lectures 1-5	28th Oct	Two weeks after submission
Final exam	No	2 hours	40%	All course	Exam period, date TBC	Upon release of final results

Assignments

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 percent (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.

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

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.

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

7.1 Texts and Reference Materials. The main text for this course is:

- Introduction to Photovoltaics Manufacturing Science and Technology by Jeffrey Cotter (2015)

7.2 Hardware and Software Applications. The tutorials of this course use the following hardware/software:

- Windows PC (laptop suggested) or Apple Mac with a Windows shell
- "Virtual Manufacturing Execution System (VMES)" software: Download link will be posted on Moodle.
- Microsoft Excel or equivalent
- Minitab: Download link and instructions will be posted on Moodle.

7.3 In addition, the following reference materials may be helpful:

- PV-Manufacturing.org: A free online resource about photovoltaic manufacturing
- PVEducation.org: A free online resource about solar cell basics.
- Applied Photovoltaics by Stuart R Wenham, Martin A Green, Muriel E Watt and Richard Corkish
- Engineering Statistics Books: There are a number of good engineering statistics books, some suggestions:
  - Design and Analysis of Experiments by Douglas C Montgomery
  - Engineering Statistics by Douglas C Montgomery, George C Runger and Norma F Hubele
- Cost Accounting Books: Accounting is a wide field, if you're looking for a book, check for a chapter on Process Costing or Product Costing, in addition to basic info on cost behaviours, T-accounting and financial statements. For example:
  - Cost Accounting by Cecily A Raiborn, Michael R Kinney and Jenic Prather-Kinsey

7.4 Lecture Notes will be made available on Moodle as they are presented in the on-line class.

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.

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