ELEC 4703 SOLAR CELLS
COURSE OUTLINE
Winter 2023

Instructor: Professor Robert Gauthier
E-mail: robertgauthier@cunet.carleton.ca
Office: 4146 Mackenzie Building
Ph: 613-520-2600 ext. 5808
Office hours: by appointment

The best way to contact me is by e-mail. I monitor my Carleton e-mail pretty well 24 / 7. Some course related items can be addressed through e-mail. I should promptly answer these. Other issues may need a one-on-one discussion. For the one-on-one meetings, we will use BBB which will be restricted to only you and me AND not recorded (unless you want it recorded). We can also meet, before or after the Wednesday class time.

Teaching Assistants:

1. Minu Sunny ➔ MinuSunny@cmail.carleton.ca

Marking Scheme:

The final grade for the source is calculated based on the following marking scheme:

- Midterm: 15% (in-person → Wednesday March 1, during lecture time)
- Labs 35% (3 Labs 20% and Final report 15%)
- Final Exam: 50% (in-person, to be scheduled)

A final grade of **"F**" will be entered if:

- Your final exam grade is less than 50%. **You must pass the final exam**
- You do not submit all lab reports
- Your computed course grade is less than 50%

The final exam is exclusively for the purpose of evaluating student performance and will not be returned. You may request to review your exam up to two weeks after the final grade is posted by the university.

You have until the day before the regular final exam to submit late material or request a change of grade on previously graded work. After this deadline, no further submissions are accepted, or grade change request considered.

Mid-term:

The mid-term is held after reading week and during the regular class time on March 1, 2023. The midterm is closed book and 75 minutes in duration. The mid-term will be in-person. If you miss the mid-term, with a valid reason, you will be provided with a make up mid-term.

A medical reason for missing the quiz or mid-term must be accompanied with an ORIGINAL of a medical note. Original ➔ not a photocopy, original signatures. Some clinics photocopy or print out the medial report and contain electronic signatures. These are not acceptable.

Website:

Course information will be posted on Brightspace (https://brightspace.carleton.ca/). Check it regularly for course related information (schedule changes for instance), lab instructions, and additional material.

Lectures:

Time: Weekly review: Wednesdays: 1:05 pm – 2:25 pm (If needed Friday 1:05 pm – 2:25 pm)
Recorded lectures are available for viewing prior to Wednesday class.
Note: No classes or labs will be held during the winter break. The lab is closed!

Lab Sessions:

LAB Location: ME 4135

All labs are in-person.

Labs 0, 4 and 5 require measurements in ME 4135.

Labs 1, 2 and 3 take place in ME 4135 and require a computer internet access. Bring your own internet connectable device. TA will be present in ME 4135 to assist you.

Time: Friday: 8:35 am – 11:25 am.

Description: As part of the laboratory activities, you will be designing, simulating, and testing silicon solar cells that will be fabricated in-house at the Carleton Microfabrication facility. There are 5 labs sessions for this course, and an introductory lab to familiarize you with our in-house solar cell testing setup. Details of report requirements will be posted on Brightspace. Brief outline of lab activity is provided below.

Lab 0: Introduction to Solar Cell testing setup
Lab 1: Simulation and analysis of the effect of doping concentrations on cell performance
Lab 2: Design of the front metal contact grid
Lab 3: Analysis and design of the anti-reflection coating
Lab 4: Solar cell testing part 1
Lab 5: Solar cell testing part 2

The labs are setup such that each group can design and test their solar cell. A final report must be submitted by each group summarizing **ALL** lab related activities. All lab reports must include all the required material compiled into a single PDF. Reports are due on midnight of the seventh day following the lab (For a Friday lab → Report due following Thursday by 12 PM.) There is a 10% per day penalty for a late lab. Even though you work in groups, each student must submit a lab report through Brightspace. Your lab report must be a report based on the data you collected (this term).

Additional reading material:

From time to time, I will provide additional course content in the form of web links.

Reference texts:

The textbooks consulted for this course are on-line. The book code [4703-XX] is utilized in my notes to indicate where additional information on the topic may be obtained. Several of the text books are very good references for those considering a carrier in solar cell…..

Course Topics:

- Solar Radiation
- Review of semiconductor materials and P-N junction
- Solar cell operation and properties
- Design of silicon solar cells
- Fabrication of silicon solar cells
- Solar cell characterization
- PV modules and systems

Learning Objectives:

Upon successful completion of this course, students will be able to:

1. Determine the solar spectrum or light source spectrum.
2. Determine photon energy and understand the relationship between photon energy and material absorption.
3. Calculate the bandgap energy and understand the bandgap effects on the IV characteristic of solar cells.
4. Understand the temperature effects on solar cell performance (e.g., bandgap energy, IV characteristics)
5. Understand the fabrication process of a simple homojunction solar cell.
6. Design optimal anti-reflection coating/coating stack to reduce reflection and increase efficiency.
7. Design optimal finger/busbar metal grid system for efficient current collection.
8. Understand the difference between series and shunt parasitic resistances.
9. Understand the design trade-off for efficient and economic solar cells.
10. Determine the shading losses and the recombination losses.
11. Complete an optimal design on a single junction silicon based solar cell.
12. Determine the total losses due to the solar module design.
13. Design an optimal solar PV module by utilizing blocking and bypass diodes.
14. Calculate carrier lifetime based on the doping level and temperature.
15. Understand the limiting factors for overall efficiency of the solar PV module.
16. Test and characterize the solar cells fabricated using a solar simulator.
17. Provide design improvements to enhance the solar cell efficiency.
18. Have a knowledge of non-silicon based solar cells.
19. Be aware of the historical events that led to modern day solar cells.
20. Appreciate the advantages and disadvantages of solar cell.

Graduate Attributes (GA):

An institution must demonstrate that graduates of its programs possess the attributes described below. In addition, the institution must implement and employ processes to demonstrate that program outcomes are being assessed in the context of these attributes, and that the results of such assessments will be applied to the further development of programs.

The graduate attributes are:

1. **A knowledge base for engineering:** Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2. **Problem analysis:** An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3. **Investigation:** An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
4. **Design:** An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.
5. **Use of engineering tools:** An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. **Individual and teamwork:** An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7. **Communication skills:** An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. **Professionalism:** An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9. **Impact of engineering on society and the environment:** An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10. **Ethics and equity:** An ability to apply professional ethics, accountability, and equity.
11. **Economics and project management:** An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.
12. **Life-long learning:** An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

In ELEC 4703, student work is assessed to score GA 2 (Problem Analysis) and GA 4 (Design) for engineering. The graduate attribute scores may be derived through one or more quiz, exams and Lab activity marks. Graduate attribute scores are not used in the determination of the final grade for the course.

Plagiarism and Cheating

The Carleton University Academic Integrity Policy defines principles and consequences of student academic integrity (http://carleton.ca/senate/wp-content/uploads/Academic-Integrity-Policy1.pdf). Instructors, advisors and / or supervisors must report all suspected cases of violation of this Policy to the Faculty Dean who will review the case and recommend the appropriate sanction.

Academic Accommodation

You may need special arrangements to meet your academic obligations during the term.

To arrange accommodation for pregnancy or religious obligation, write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see the Student Guide (https://carleton.ca/equity/accommodation/academic/students/)

To arrange accommodation for a disability, please contact The Paul Menton Centre for Students with Disabilities (PMC)): http://carleton.ca/pmc/students/accommodations/

For support regarding human rights and related issues, please contact Equity Services (https://carleton.ca/equity).

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