Carleton University

Department of Electronics

Winter 2026

ELEC4703: Solar Cells

Introduction

In this course you will learn the principles of photovoltaic device operation, and be introduced to aspects of design and fabrication. The focus will be on silicon photovoltaics as they currently dominate the consumer market, however there will be an introduction to specialized and emerging technologies.

Course Description and Requirements

Course Description: Semiconductor band structure, photogeneration, the solar spectrum. Detailed analysis of monocrystalline silicon solar cells. Solar cells based on thin film materials: amorphous silicon, III-V materials, organics, titania-dye cells. Cells for concentrator systems. Photovoltaic power systems. Solar cells for building envelopes.
Includes: Experiential learning activity
Prerequisite(s): ELEC 2501 and ELEC 2507 and fourth-year status in Sustainable and Renewable Energy Engineering, or ELEC 2501 and ELEC 2507 and fourth-year status in Engineering with permission of the instructor.
Lectures: three hours per week
Laboratory and problem analysis: three hours alternate weeks

Instructor

Professor: Niall Tait, ME4158
Email: NiallTait@cunet
Course Webpage: on Brightspace

Textbook

There is no required textbook for this course but there are plenty of references available. Most can be found online through the Carleton University library.
Suggested reading:

1. PVEducation
2. S.M. Sze, **Physics of Semiconductor Devices**, Wiley, 2006.
3. P. A. Lynn, **Electricity from Sunlight: an introduction to photovoltaics**, Wiley, 2010.

Other suggested references:

S. R. Wenham, M. A. Green, M. E. Watt, and R. Corkish, **Applied Photovoltaics**, Earthscan, 2007.
S. Pizzini (Editor), **Advanced Silicon Materials for Photovoltaic Applications**, Wiley, 2012.
S. Fonash, **Solar Cell Device Physics,** Elsevier, 2nd Ed., 2010.

Lecture Outline

In person, Monday/Wednesday 1:05pm - 2:25pm, TC 214
The following topics will be covered during the course lectures with an approximate schedule:
Week 1-2: Solar radiation
Week 3-4: Solar cell operation and properties
Week 5-6: Silicon solar cell design
Midterm Exam: February 11 in-class
Winter Break: February 16-20
Week 7-8: Silicon solar cell fabrication
Week 9-10: Cell characterization
Week 11-12: PV modules and systems

Laboratory and Problem Analysis Sessions

3 hours (alternate weeks) as per schedule and location posted on Brightspace.

Notes for Labs

- We will be designing and testing crystalline silicon solar cells that were previously fabricated in Carleton's Microfabrication facility. There are 5 labs/experiments which are briefly outlined below.
    - Lab 0: Orientation to the lab
    - 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
- Labs are 3 hours in duration and will be held in Room ME 4135. Labs are alternate weeks and will be held according to the schedule shown on the course module in Brightspace. You must complete all labs to pass the course. A TA will take attendance at each lab session.
- Attend each lab punctually. Be prepared for the lab experiment by reading the lab instruction sheets before entering the lab. Some labs have a pre-lab exercise that must be completed before the start of your lab period. You are not permitted to complete the lab unless the prelab is completed. The TA will check that the the pre-lab has been completed.
- A lab report will be submitted online for each lab and by each student. Guidelines for lab report format will be provided. Lab reports are due by midnight two days following the lab session. Late lab reports must still be submitted. One day late it will be worth 50%. Two days late, it is worth 0.

Self-Declaration form and Deferred Term work

Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for submitting a self-declaration form no later than three (3) days after the date/deadline of term work including test/midterm, labs, assignments. Any alternate arrangements made with the instructor for submission of term work should be made as soon as possible but within 3 days of the missed due date. If this is not possible after discussion with the instructor, alternate arrangements must be made before the last day of classes in the term as published in the academic schedule.

Contact the instructor with the completed self-declaration form no later than 3 days after a missed date/deadline of term work including test/midterm, labs, assignments.

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

Midterm 20%; February 11 in-class
Labs 30% (4x5% + 10% final report);
Final Exam 50%

a) Final Exam:
   i. Final exams are for evaluation purpose and will not be returned to students
   ii. Final exam will be closed-book, a non-communicating scientific calculator is permitted.
   iii. Final exam grade > 50% is required to pass the course.
   iv. Students who are unable to write the final examination because of a serious illness/emergency or other circumstances beyond their control may apply for accommodation by contacting the Registrar's office. Consult the Section 4.3 of the University Calendar.
b) Additional requirements:
   i. Completion of **all lab experiments** and submission of reports with a combined average grade of >40% on lab reports and the midterm exam is required to pass the course.

Engineering Courses shall have on-campus and proctored final examinations.

AI Use in this course:

Use of generative AI tools (such as ChatGPT) can serve you as a valuable learning tool. However like any reference, AI generated material should be properly cited. *Claiming AI generated material as your own is a violation of academic integrity.*
You are accountable for your work, and if you simply copy and paste AI output it does not benefit anyone. You must be able and may be asked to criticize or defend output you generate with AI. Exams are intended to assess your individual understanding and competency in the subject, AI tools will not be available to you in your exams.

Learning Outcomes

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

1. Explain the fabrication process of a simple homojunction solar cell.
2. Use the relationship between photon energy and material absorption.
3. Analyze the temperature effects on solar cell performance (eg, bandgap energy, IV characteristics)
4. Analyze the effect of material bandgap on the I-V characteristic of solar cells.
5. Analyze series and shunt parasitic resistances.
6. Analyze design trade-offs for efficient and economic solar cells.
7. Analyze shading losses and recombination losses.
8. Analyze total losses due to the solar module design.
9. Analyze carrier lifetime based on the doping level and temperature.
10. Analyze limiting factors for overall efficiency of the solar PV module.
11. Design an optimal anti-reflection coating/coating stack to reduce reflection and increase efficiency.
12. Design an optimal finger/busbar metal grid system for efficient current collection.
13. Design an optimal solar PV module by utilizing blocking and bypass diodes.
14. Design optimal tandem PV cells.
15. Develop an optimal design on a single junction silicon based solar cell.
16. Formulate design improvements to enhance the solar cell efficiency.

17. Measure and evaluate characteristics of a solar cell.

Graduate Attributes

The Canadian Engineering Accreditation Board requires graduates of undergraduate engineering programs to possess 12 attributes: Graduate-Attributes.pdf (engineerscanada.ca) or GA's. Courses in all four years of our programs evaluate students' progress towards acquiring these attributes. Aggregate data (typically, the data collected in all sections of a course during an academic year) is used for accreditation purposes and to guide improvements to programs. Some of the assessments used to measure GAs may also contribute to final grades; however, the GA measurements for individual students are not used to determine the student's year-to-year progression through the program or eligibility to graduate. Accreditation metrics are based on courses common to all students in a program.

This following list provides the GAs that will be measured in this course, along with the indicators that are intended to develop and assess these attributes.

Graduate Attribute and Level	Indicators or Area for Specialization	Methods used for Evaluation
1. GA 2 Problem Analysis, Advanced	2.1 Problem definition 2.2 Approach to the problem 2.3 Use of assumptions 2.4 Interpreting the solution	Exam question
2. GA 4 Engineering Design, Advanced	4.1 Clear design goals 4.2 Detailed design specifications and requirements 4.4 Design solution(s) 4.5 Design implementation, task(s) definition 4.6 Alternate solution(s) definition 4.7 Evaluation based on engineering principles	Exam question

Academic Integrity and Plagiarism

a) Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity. Violations of the Academic Integrity Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

b) One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as "presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own." This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source.

Examples of **violations of the policy include**, but are not limited to:

- Any submission prepared in whole or in part, by someone else;
- Using another's data or research findings without appropriate acknowledgment;
- Submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own;
- Failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotations marks; and
- **Unless explicitly permitted by the instructor in a specific course, the use of generative AI and similar tools to produce assessed content (such as text, code, equations, images, summaries, videos, etc.).**

Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: Contact us 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 accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).

Religious obligation: Contact us 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 click here.

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send us your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, contact us, if needed, to ensure that accommodation arrangements are made.

You should request your academic accommodations in the Ventus Student Portal, for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm.

Please consult the PMC website for the deadline to request accommodations for formally-scheduled exams (if applicable).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the

classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Contact us 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: https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf