



## **ELEC 3908: Physical Electronics**

### **Introduction**

This course examines the structure, fabrication, physical operation and modeling of semiconductor diodes, bipolar transistors and MOSFETs.

### **Course Description and Requirements**

#### **Course Description:**

Fundamentals of device physics and operation of the pn junction, bipolar transistor and MOSFET. Basic integrated circuit processing and application to diodes, BJTs and MOSFETs. Correlation between processing, structure, operation and modeling. Consideration of parasitic and small-geometry effects, reliability and process variation.

**Includes:** Experiential Learning Activity

**Precludes:**

**Prerequisite(s):** ELEC 2507.

**Lectures** three hours a week, 4 laboratory sessions of three hours.

### **Instructor**

**Professor:** Tom Smy

**Email:** [tomsmy@cunet.carleton.ca](mailto:tomsmy@cunet.carleton.ca)

**Course Webpage:** on Brightspace

### **Textbook: Please include price of books**

1) N/A

### **Lecture Outline**

In person, Tues. & Thurs 4-5:30 NN 180

The following topics will be covered during the course lectures with an approximate schedule:

Week 1: Introduction

Week 2: Diodes and Semiconductors

Week 3: IC Fabrication and Diode Structure

Week 4: Doping profiles and Carrier Transport

Week 5: Diode Operation and Electrostatics

Week 6: Small Signal Modeling and Extraction

Week 7: Diodes and Light, BJT Structure

Week 8: BJT Operation and Theory

Week 9: Early Effect and SS Operation

Week 10: MOSFET Operation and Structure

Week 11: Square Law Model and Short Channel Effects

Week 12: MOSFET Small Signal Model

## Laboratory and Problem Analysis Sessions

3 hours as per schedule and location posted on Brightspace.

### Notes for Labs

- There are 4 labs as follows:
  - Lab 1: Basic Experimental Procedure
  - Lab 2: Diodes
  - Lab 3: BJT
  - Lab 4: MOSFET
- Labs are 3 hours in duration and will be held in Room ME-4135. Labs and PA sessions usually “alternate” from week to week and will be held according to the schedule shown on the course module in Brightspace. You must attend your lab in the session you are registered. Changing sessions is not allowed without the instructor’s permission. A TA will take attendance at each lab session.
- If for some reason a Lab needs to be rescheduled OR a Lab falls on one of the University holidays, students in those sections must try to rearrange their schedule to make up the lab in another of the regularly scheduled lab sessions, as arranged by the instructor.
- 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 do the lab unless the prelab is completed. The TA will check that the pre-lab has been completed.
- A lab report will be submitted online for each lab and by each student. A template for each lab report will be provided. Lab reports are due by midnight 1 week after the lab. Late lab reports must still be submitted. Each Day Late results in a 10% penalty.

### Notes for PA Sessions

- Please refer to the course schedule available on BrightSpace to learn more about the timing of tutorial sessions.
- Two quizzes, designed to be 45-minutes long, will be held during the term.

### 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.

Instructors can require (or not) the student to submit the self-declaration form. Include the following statement if you require the student to submit a completed self-declaration form:

**Consult with the instructor no later than 3 days after any missed course work or quiz.**

or

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

## Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

- Quizzes (2@15% each) 30%
- Labs (3@5% each). 15%
- Final Exam 55%

a) Final Exam: **Final exams are for evaluation purpose and will not be returned to students.**

ii) The final exam is closed book, 3 hours long and a calculator is allowed.

iii) Final exam weight [55%]

iv) Deferred Final Examinations

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 contact the Registrar's office. Consult the Section 4.3 of the University Calendar (<https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/>)

b) Additional requirement(s):

It is mandatory to complete the Labs.

c) Exam format and e-proctoring statement

The final exam is in person.

## Learning Outcomes

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

- 1) Understand and explain basic Semiconductor physics.
- 2) Use material band-structures to describe basic electronic behavior of materials.
- 3) Use drift, diffusion and recombination/generation to explain carrier dynamics.
- 4) Understand the basic injection model of the Diode and extract parameters.
- 5) Describe the use of capacitance to model the small-signal behaviour of the Diode.
- 6) Explain the use of Integrated Circuit fabrication technology to build integrated devices.
- 7) Explain the structure and operation of Bipolar Transistors.
- 8) Explain the carrier flow in the Bipolar Transistor and development of the basic injection model.
- 9) Extract Bipolar Transistor parameters.
- 10) Explain the small-signal model of the Bipolar Transistor.
- 11) Explain the structure and operation of integrated MOSFETs.
- 12) Explain MOSFET operation and square-law model.

13) Extract MOSFET Transistor parameters.

## AI use in this course:

Students may use AI tools for sharing ideas, clarifying challenging concepts, or getting started on projects. Some acceptable uses include:

Brainstorming ideas (e.g., generating essay topics with ChatGPT, using Microsoft Word's Smart Lookup to find inspiration and related topics).

Creating outlines (e.g., using AI to structure an essay or presentation flow, using Microsoft Word's Outline View with AI suggestions).

Providing definitions or explanations of complex concepts (e.g., using AI to explain a difficult theory, e.g., using Microsoft Word's Researcher tool to find relevant information).

Documenting use of AI: It is necessary to document your use of AI in this course, using the following guidelines:

Clearly identify and cite AI-generated text (e.g., 'The following paragraph was generated by ChatGPT/Microsoft Word's Researcher tool'). Please consult resources on the Library website.

Review, edit, and ensure the accuracy and originality of final submissions.

AI-generated content should not exceed 30% of the total assignment length.

Why have I adopted this policy? This policy supports the use of AI as a supplementary tool, helping students develop ideas and structure their work while emphasizing the importance of transparency and personal engagement with the content.

AI can be used for inspiration and foundational support, and can encourage students to critically assess and refine AI-generated material.

## 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                         | Indicator or Area of Specialization | Indicators                                                                             |
|--------------------------------------------|-------------------------------------|----------------------------------------------------------------------------------------|
| 1. <i>A knowledge base for engineering</i> | DOE-2, DOE-10, DOE-11               | The final exam result is used as indication of the success in obtaining the attribute. |
|                                            |                                     |                                                                                        |

## 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](mailto: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>