

ELEC3908: Physical Electronics

Introduction

In this course you will learn about fundamental properties of semiconductors materials, semiconductor device fabrication process, physical operation, and physical device modelling for 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

Prerequisite(s): ELEC 2507

Lectures: three hours a week

Laboratory and problem analysis: three hours per week

Instructor

Professor: Ravi Prakash (Office: MC3036)

Email: raviprakash@cunet.carleton.ca

Course Webpage: on Brightspace

Textbook: Please include price of required books

- 1) Lecture notes are provided on Brightspace
- 2) A Course pack is provided as additional reading materials and is available free of charge on Brightspace.
- 3) "Physics of Semiconductor Devices," third edition, S. M. Sze and K. K. Ng, Wiley, ISBN 978-81-265-1702-2 - **\$75.00 CAD**
- 4) "Microelectronic Circuits," sixth edition, Sedra and Smith, Oxford, ISBN 978-0-19-532303-0 - **\$195.00 CAD**

Lecture Outline

In person, on Mondays and Wednesdays from 4:05 PM – 5:25 PM in ME3356

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

Week 1: Introduction to Semiconductor Materials

Week 2: Introduction to Semiconductor Device Fabrication

Week 3: Fabrication of Three Different Types of P-N Diodes

Week 4: Diode Operation

Week 5: Static Diode Models

Week 6: Transient Models of P-N Diodes

Week 7: Introduction to BJT Fabrication

Week 8: BJT Device Operation

Week 9: BJT Device Model and Device Parameter Extraction

Week 10: Introduction to MOSFET Fabrication

Week 11: MOSFET Operation and Device Models

Week 12: MOSFET Transient Model and Device Parasitics

Laboratory and Problem Analysis Sessions

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

Notes for Labs

- There are X labs as follows:
 - Lab0: Demo Lab - introduces students to the hardware and software used and provides general lab safety guidance
 - Lab 1: P-N junction Diodes
 - Lab 2: NPN Bipolar Junction Transistors
 - Lab 3: N-type MOSFETs
- Labs are 3 hours in duration and will be held in Room ME4135. 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 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 is provided on the course Brightspace page. Lab reports are due by midnight a week from the lab exercise. Late lab reports must still be submitted. A late submission penalty of 25% will be applied each day for delayed submissions.

Notes for PA Sessions

- PA sessions will be held as per schedule and location posted on Brightspace. A dedicated set of questions will be posted before each scheduled PA session. Several problems will be assigned each week to help students understand the lecture material, prepare for the midterm exams and final exam. To learn the course material, **IT IS ESSENTIAL THAT YOU ATTEMPT SOLUTIONS FOR THESE PROBLEMS BEFORE THE PA SESSION**. Solutions to these problems will be reviewed in the PA sessions.

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 midterm examination.

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@10% each)	20%
Labs (3@5% each)	15%
Mid-term Exam	15%
Final Exam	50%
Total	100%

Note: Students must receive a passing grade (> 50%) on the final exam in order to pass the course. The students must also attend all lab sessions to pass the course.

Learning Outcomes

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

- 1) Describe the basic concepts of semiconductor device fabrication
- 2) Explain the basic principles of conduction and carrier transport in silicon-based semiconductor materials
- 3) Identify different types of P-N junction diodes, bipolar transistors, and MOSFET devices
- 4) Calculate semiconductor device current based on given DC voltage biasing conditions
- 5) Collect and analyze data from semiconductor devices using a semiconductor parameter analyzer instrument
- 6) Extract physical device parameters using experimentally collected device testing data
- 7) Verify sources of device parasitics arising from device geometries and fabrication processes

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
GA-1 Knowledge base for Engineering	DOE-2 Applied Physics DOE-7 Electronics DOE-11 Semiconductor Devices	Dedicated Exam Questions

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>