



ELEC 4704: Nanoscale Technology and Devices

Introduction

This course deals with the physics of nanotechnology, applications of nanotechnology, modeling approaches to nanotechnology and use of LLM/AI for modeling.

Course Description and Requirements

Course Description:

Engineering at the nanoscale. Quantum confinement and the effect of scale. Analysis tools: microscopy, spectroscopy. Fabrication: thin films, nanoparticles, nanotubes, graphene, organics. Structures and properties: quantum wells, nanocrystals, nano structuring. Applications and devices: electronics, optoelectronics, photonics.

Prerequisite: ELEC 3908, ELEC 3909.

Lectures: three hours a week,

Includes: Experiential Learning Activity

Problem analysis: two hours a week.

Instructor

Professor: Tom Smy

Email: tomsmy@cunet.carleton.ca

Course Webpage: on Brightspace

Textbook: Please include price of books

1) N/A

Course and Lecture Outline with Problem Analysis

This course will have four primary themes:

- The physics of nanotechnology
- Applications of nanotechnology
- Modeling approaches to nanotechnology
- The use of LLM/AI for modeling

Course Structure

- Lectures Tuesday 1-2:30 in ME 4236. Theoretical material.
- PA/Project: Friday 8:30-10 and 1-2:30 MC 6030
- Physics based material first 6 weeks.
- Technology based material last 6 weeks.

Physics based material: Weeks 1-6

Update your device physics

- Python, MATLAB and AI programming
- Thermal physics
- Modeling Diff. Eq.
- Quantum Mechanics
- Crystals and Quantum
- Light

Nanotechnology: Weeks 6-12

- Introduction
- Tools
- 2D Well Structures
- Nano dots
- Single Electron Devices
- Fabrication
- Esoteric stuff

Modeling and AI

This course will have modeling assignments and a project.

- Coding with LLMs in Python or MATLAB
- The assignments are structured so that you use LLMs/AI to help you code and understand.

PA's

The first six Fridays (Sept 11-October 16) are used for PAs.

- Sept 9: Introduction to programming using AI
- Sept 16: Modeling Differential equations
- Sept 25: Modeling Drift and Diffusion using Monte-Carlo
- Oct 2: Modeling Quantum Wells
- Oct 9: Modeling the SCE - Tunneling and Crystals
- Oct 14: Resonant Tunneling Diode

PA structure

- Each PA will lead you through an assignment that will explore the theoretical material done in the lecture for that week.
- You are expected to use the AI agents to help you understand the material, assist with derivations and coding.

- The PA has deliverables that are due on the following Sunday.

Project

- The project is to use LLMs/AI to help you code a 2D Monte Carlo electron transport program that can be used to model a quantum well based resonant tunnelling diode.
- It will build on two of the PAs done previously and the format will be similar except extended over 3 weeks.
- You will work on it in the Friday labs Nov 6 -Nov 20. I will be in the Lab and checking progress!
- Report will be due Nov 22.

Final

- 180 minutes long, closed book.
- Material to be covered will be the PA tutorials, project and the lecture material from Weeks 1-12.

AI use in this course:

For portions of this course AI tools are designed into the course modules. Students are also encouraged to use AI tools in this course for support in completing several process-based activities. Some acceptable uses include:

- Data analysis (e.g., AI-driven statistical analysis in SPSS or Python; using Excel's AI-powered data analysis tools like Ideas to generate insights and visualizations).
- Coding assistance (e.g., GitHub Copilot for programming assignments, using Visual Studio Code with AI-assisted extensions for programming assignments).
- Generating creative content (e.g., DALL-E for visual projects; using PowerPoint's Designer feature to create visually appealing presentations).
- Summarizing large volumes of text (e.g., using AI to condense research articles; using Word's Smart Lookup and Researcher to condense research articles).

Documenting use of AI:

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

Provide a detailed description of AI usage and proper citation (e.g., 'AI-assisted data analysis performed using Excel's Ideas tool/Python with AI-driven libraries). Please consult resources on the library website.

Ensure critical thinking and personal insight are evident in all submitted work.

AI-generated content should not replace core analysis or primary arguments.

Why have I adopted this policy? This policy allows students to leverage AI for more complex tasks, promoting collaboration between human intelligence and AI. It ensures students learn to effectively integrate AI into their work while maintaining intellectual contributions and critical thinking. By using AI to handle routine or supplementary tasks, students can focus more on deeper learning and analysis of their assignments.

Laboratory and Problem Analysis 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 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:

Mark breakdown

The marks will be assigned as follows:

- 50% Final exam
- 30% Modelling problem assignments
- 20% Modeling Project

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 [50%]

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 be able to apply the appropriate physics to nano-technology devices and systems.
- 2) Apply modeling techniques to the physics and devices of nanotechnology
- 3) Use AI/LLM's to build models and simulations of nanotechnology
- 4) Have a wide understanding of nanotechnologies.

Graduate Attributes

N/A

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>