CONTACT INFORMATION:

- Names & contact information
  - Instructor: Adrian Lupascu
    Office: RAC1 2112 (main office) and QNC 2202
    Email: alupascu@uwaterloo.ca
    Phone: x35468
  - Teaching assistant: Chunqing Deng
    Office: RAC1 1117
    Email: cdeng@uwaterloo.ca
    Phone: x38932

- Office hour: Wed, 3-4 pm, QNC 2202

  Online office hour: Tue, 7-8 pm. During this time I will answer your emails immediately. You can also use the chat utility in LEARN to discuss your questions.

- Contact preferences
  - Adrian Lupascu

    I will usually answer email within two days, typically in the morning. Emails received on holidays or weekends may not be addressed on those days. Please include “PHYS461” at the beginning of your email subject line.

    My main office is in RAC1, but I will also use, to a lesser extent, the QNC office. To avoid wasting time, please call or email first before coming to my office. The RAC1 building is located on the North campus; a shuttle is available (please see schedule at http://community.iqc.uwaterloo.ca/admin/schedule.html).

    Please use the office hour to discuss your questions whenever possible.

COURSE DESCRIPTION:

- Calendar course description


Prereq: PHYS 335 or ECE 231; Level at least 4A.
Antireq: NE 471
Course overview

This course addresses the new physical phenomena arising when the dimensions of physical systems are reduced to micrometers or nanometers. These systems are called *mesoscopic*, a word meant to indicate behavior which is distinct from that of both macroscopic and microscopic systems. The focus will be on electronic structure and electronic transport. The course will start with a review of electronic states and classical transport in regular, macroscopic solids. These principles will be applied to a discussion of the field effect transistor, a widely spread device. We will then discuss the qualitatively different features in electronic transport occurring at small length scales. The following topics in mesoscopic transport will be considered: the Landauer formula of quantized transport, the Landauer-Büttiker formalism for multiterminal conductors, the quantum Hall effect, phase coherent transport, Coulomb blockade, quantum dots, coherent transport in superconducting systems, carbon-based devices (graphene and carbon nanotubes), resonant tunneling. A few applications of nanodevices and nanoanalysis tools in biology and medicine will be discussed, including quantum dots in imaging, visualization using atomic force microscopy, and manipulation using optical tweezers. A brief overview of ethical and regulatory aspects of nanomedicine will be given as well.

LEARNING OBJECTIVES:

The students will learn the principles that govern electronic transport at the nanoscale. The field of mesoscopic electronic transport is a rich playground where concepts learned in courses including thermodynamics, electricity and magnetism, quantum mechanics, and solid-state physics can be applied and further understood. The discussion of applications in biology and medicine is meant to serve as an illustration of the potential of nanosystems in these areas.

RESOURCES:

A courseware package is created for this course. This is required material. The package contains sections from the following sources:


Additional required material is available electronically through the University of Waterloo library website, from the following sources:

Notes and other materials will be made available using LEARN.

Relevant reading material is available in a course reserve at the UW library.

**TOPICS:**

The plan of the course is as follows:

- Introduction to nanotechnology
- Review of solid-state physics
- The field effect transistor – a building block of classical electronics
- Regimes of mesoscopic transport
- Conduction in mesoscopic conductors: Landauer formula, Landauer - Büttiker formalism
- The quantum Hall effect
- Phase coherent transport
- Coulomb blockade
- Quantum dots
- Coherent transport in superconductors, application to quantum bits
- Graphene and carbon nanotubes
- Resonant tunneling devices
- Applications of nanoscience in biology and medicine
- Ethical aspects of nanoscience
- Fabrication methods in nanoscience

**ASSESSMENT:**

Your mark will contain the following components:

- 5 assignments, counting in total 30% of the final mark
- a presentation of a research paper on one of the topics presented in the course, counting 20% of the final mark
- a midterm examination - 20% of the final mark. To be scheduled.
- a final examination - 30%. The date is to be determined.

The assignment tentative dates are:

<table>
<thead>
<tr>
<th>Assignment no</th>
<th>Posted date</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>September 19th</td>
<td>October 3rd</td>
</tr>
<tr>
<td>2</td>
<td>October 3rd</td>
<td>October 17th</td>
</tr>
<tr>
<td>3</td>
<td>October 17th</td>
<td>October 31st</td>
</tr>
<tr>
<td>4</td>
<td>October 31st</td>
<td>November 14th</td>
</tr>
<tr>
<td>5</td>
<td>November 14th</td>
<td>November 28th</td>
</tr>
</tbody>
</table>
Assignments will be posted on LEARN. Completed assignments are to be brought in classroom if the due date is a lecture day. Problems with retrieving material due to interruptions in LEARN are to be handled according to the guidelines at https://uwaterloo.ca/secretariat/service-interruptions-online-learning-environment-guidelines. Assignments handed in late will be penalized; the penalty is 10%/day of the obtained mark. Weekends and holidays do not count towards the penalty. Assignments which are more than 4 days late will not be accepted.

The paper to be presented has to be an important paper in the area of nanophysics connected with the topics discussed in the course. A list of suitable papers will be posted on LEARN. Papers will be assigned on a first come first served basis. Students are welcome to propose the paper they would like to discuss. Paper presentations should last 10-15 minutes with an additional time of 5 minutes for questions. Paper presentations can be done using the blackboard/whiteboard and/or a projector.

The final exam concentrates on the second half of the course. However, the material in the second half relies (partially) on material taught in the first half of the course.

For each of the two exams, you are allowed a nonprogrammable calculator and a double-sided (or equivalently two single-sided) letter-size handwritten(!) sheet(s) of notes.

If students are unable to complete course requirements, then they must inform the instructor (ideally beforehand, but within 48 hours of the assignment or exam time) and present the appropriate documentation (i.e. a completed VIF or other compelling documentation) within five business days.

**ACADEMIC INTEGRITY:**

- **Office of Academic Integrity** provides relevant information for students, faculty and staff.
  - **Academic Integrity**: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility.
  - **Grievance**: Students, who believe that a decision affecting some aspect of their university life has been unfair or unreasonable, may have grounds for initiating a grievance. Students should read Policy #70, Student Petitions and Grievances, Section 4. When in doubt, students must contact the department’s/school’s administrative assistant who will provide further assistance.
  - **Discipline**: Students are expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for their actions. Students who are unsure whether an action constitutes an offense, or who need help in learning how to avoid offenses (e.g., plagiarism, cheating) or about ‘rules’ for group work/collaboration should seek guidance from the course instructor, academic advisor, or the Associate Dean of Science for Undergraduate Studies. For information on categories of offenses and types of penalties, students should refer to Policy #71, Student Discipline. For information on typical penalties, students should check Guidelines for the Assessment of Penalties.
  - **Appeals**: A decision or penalty imposed under Policy 33 (Ethical Behavior), Policy #70 (Student Petitions and Grievances) or Policy #71 (Student Discipline) may be appealed, if
there is a ground. Students, who believe they have a ground for an appeal, should refer to Policy #72 (Student Appeals).

COURSE RULES/CONSIDERATIONS:

- Exam Period Travel:
  - Exam period dates are given in the academic calendar
  - Student travel plans are not considered acceptable grounds for granting an alternative examination time.
- Students with Disabilities:
  - AccessAbility Services, located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If students require academic accommodations to lessen the impact of their disability, they should register with AccessAbility Services at the beginning of each academic term.
- Changes to Course Outlines
  - Revised course outlines will be posted/provided, if course details change (e.g., topics covered, emphasis on certain topics, etc.)
  - Course elements that will not change are the:
    - Grading scheme
    - Course elements related to evaluation