

### **Course Syllabus**

PC400A Quantum-Nano Science and Quantum Devices  
Department of Physics and Computer Science, Faculty of Science, Waterloo Campus  
Winter | Year 2020

#### **Instructor Information**

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Weekly Office Hours (M 2:00 -3:00 pm) or by appointment

#### **Course Information**

There is a growing interest and importance of the applications of quantum methods in electronics as well as in computing and optical communication. These developments resulted in the emergence of fields called quantum computers and quantum communication. In order to make the theoretically predicted breakthrough a reality, one needs to design a new class of devices based on optical and/or solid state fundamentals where quantum effects play the dominant role. One possible way to achieve this goal is by shrinking the dimensions of physical devices but this is not always the case, as it is known that quantum effects are important and even directly observed in macroscopic systems. However, as the physical dimensions get smaller, e.g. as is the case of semiconductor integrated circuits, one enters the quantum nano-world.

Credit: 0.50

Prerequisite: PC242, MA205.

Course location: MW 5:30-6:50 pm in N1059

#### **Course Overview and Approach**

After taking this course you will, among other things, be able to:

- understand the basic concepts of nano physics
- learn about basic nano-devices
- learn about basic modeling techniques in nanoelectronics
- learn about current 'hot' topics.

The course is structured in terms of thematic units which will help students study in a fair detail and understand the most important aspects of nano physics. The course is lecture based. During each class students will be able to ask questions if they need more clarification. After the lecture I would expect students to have at least basic understanding of the most important parts of the topics discussed.

## Course Goals and Learning Outcomes

Through your work in this course, you will acquire an introductory but firm understanding of concepts and techniques in relativistic dynamics, quantum mechanics and some applications.

- we will apply this understanding and these techniques to physical problems,
- you will broaden and deepen your physical and mathematical problem solving skills.

## Course Tools and Learning Materials

Principal course textbook is:

**George W. Hanson**, "Fundamentals of Nanoelectronics", Prentice Hall 2008 plus lecture transparencies.

## Student Evaluation for PC400A

Your grade will be computed as follows:

Assignment 1:	10% due date: Jan. 29, in class or by e-mail.
Assignment 2:	10% due date: Feb. 24, in class or by e-mail.
Assignment 3:	10% due date: March 25, in class or by e-mail.
Midterm:	30%, March 4, in class.
Term Project:	30% due date: Apr. 1, in class or by e-mail.
Research Paper Presentation:	10%, week 12, in class.

## Notes

### Project (Individual or a group of two students):

Students will have to present a project and submit the report on a recent topic in Quantum-Nano device area. Students will collect several very recent full length journal papers on a specific quantum nano device. The students will collect those papers that explain the operation and characteristics of the device by preferably physics based theoretical models (e.g., review papers). They need to simulate the results of the papers to prove their understanding.

They have to analyze the research work critically, find its important contributions, drawbacks and limitations, and highlight current problems and research trends on the topic.

**Assignment:** Assignments are compulsory.

**Midterm exam:** This closed book exam will be held on March 4, 2020. Students are permitted to bring one 8.5× 11 sheet of notes. They can use both sides. Notes must be hand written (original).

Midterm will be in class. Midterm will be based on theoretical questions and small problems (all multiple choice).

## Tentative plan

1. Introduction: nano research on a world scale, basic electronic nanostructures.
2. Fabrication
3. Summary of basic quantum mechanics and solid state physics.
4. Mesoscopic physics: basic discoveries, important scales in nano-world, the Landauer formula.
5. Basic semiconductor nanostructures: quantum wells, quantum wires, quantum dots.
6. Electronic devices: resonant tunneling diodes (RTD), single electron transistors (SET), nano-wire transistors.
7. Modeling: the Boltzman equation, non-equilibrium Green's functions (NEGF).
8. Passive plasmonics.
9. Active plasmonics.
10. Photonic nano-devices: nano-lasers, single-photon transistors.
11. Applications of quantum wires - Majorana fermions
12. Linear optics quantum computers
13. Metamaterials including active metamaterials.
14. Quantum computers: basic principles, quantum-dots based, superconducting qubits.

## University and Course Policies (proposed and required text)

Laurier has several senate approved policy statements it requires instructors to include in their syllabus. Those with specific wording approved by senate are indicated specifically below.

- 1. Academic Calendars:** Students are encouraged to review the [Academic Calendar](#) for information regarding all important dates, deadlines, and services available on campus.
- 2. Special Needs:** Students with disabilities or special needs are advised to contact Laurier's Accessible Learning Centre for information regarding its services and resources.
- 3. Plagiarism:** The University has approved the following wording for inclusion on all course syllabi about the use of the institutionally supported plagiarism software tool. "Wilfrid Laurier University uses software that can check for plagiarism. If requested to do so by the instructor, students are required to submit their written work in electronic form and have it checked for plagiarism." (Approved by Senate May 14, 2002) .

In addition to the statement above you may wish to add the following text about academic integrity.

- 4. Academic Integrity:** Laurier is committed to a culture of integrity within and beyond the classroom. This culture values trustworthiness (i.e., honesty, integrity, reliability), fairness, caring, respect, responsibility and citizenship. Together, we have a shared responsibility to uphold this culture in our academic and nonacademic behaviour. The University has a defined policy with respect to academic misconduct. As a Laurier student you are responsible for familiarizing yourself with this policy and the accompanying penalty guidelines, some of which may appear on your transcript if there is a finding of misconduct. The relevant policy can be found at Laurier's [academic integrity](#) website along with resources to educate and support you in upholding a culture of integrity. Ignorance is not a defense.
- 5. Classroom Use of Electronic Devices:** State your classroom practice and any consequences for student failure to comply – see [Policy 9.3](#) (Approved by Senate March 8, 2012).
- 6. Late Assignment Policy:** Specify any penalties that will be assessed when deadlines for the completion of course components are not met (Approved by Senate May 23, 2012). Refer to the Handbook on Undergraduate Course Management for more information.
- 7. Final Examinations:** Students are strongly urged not to make any commitments (i.e., vacation) during the examination period. Students are required to be available for examinations during the examination periods of all terms in which they register. Refer to the Handbook on Undergraduate Course Management for more information.
- 8. Foot Patrol, the Wellness Centre, and the Student Food Bank:** The University approved the inclusion of information about select wellness and safety services and supports on campus in the course information provided to students. (Approved by Senate November 28, 2011.) Specific language (by campus) is provided below.

**Multi-campus Resource:**

- Good2Talk is a postsecondary school helpline that provides free, professional and confidential counselling support for students in Ontario. Call 1-866-925-5454 or through 2-1-1. Available 24-7.

**Kitchener/Waterloo Resources:**

- [Waterloo Student Food Bank](#): All students are eligible to use this service to ensure they're eating healthy when overwhelmed, stressed or financially strained. Anonymously request a package online 24-7. All dietary restrictions accommodated.
- [Waterloo Foot Patrol](#): 519.886.FOOT (3668). A volunteer operated safe-walk program, available Fall and Winter daily from 6:30 pm to 3 am. Teams of two are assigned to escort students to and from campus by foot or by van.
- [Waterloo Student Wellness Centre](#): 519-884-0710, x3146. The Centre supports the physical, emotional, and mental health needs of students. Located on the 2<sup>nd</sup> floor of the Student Services Building, booked and same-day appointments are available Mondays and Wednesdays from 8:30 am to 7:30 pm, and Tuesdays, Thursdays and Fridays from 8:30 am to 4:15 pm. Contact the Centre at x3146, [wellness@wlu.ca](mailto:wellness@wlu.ca) or @LaurierWellness. After hours crisis support available 24/7. Call 1-844-437-3247 (HERE247).

**Brantford Resources:**

- [Brantford Student Food Bank](#): All students are eligible to use this service to ensure they're eating healthy when overwhelmed, stressed or financially strained. Anonymously request a package online 24-7. All dietary restrictions accommodated.
- [Brantford Foot Patrol](#): 519-751-PTRL (7875). A volunteer operated safe-walk program, available Fall and Winter, Monday through Thursday from 6:30 pm to 1 am; Friday through Sunday 6:30 pm to 11 pm. Teams of two are assigned to escort students to and from campus by foot or by van.
- [Brantford Wellness Centre](#): 519-756-8228, x5803. Students have access to support for all their physical, emotional, and mental health needs at the Wellness Centre. Location: Student Centre, 2nd floor. Hours: 8:30 am to 4:15 pm Monday through Friday. After hours crisis support available 24/7. Call 1-884-437-3247 (HERE247).