Basic Information

Instructor: Dr. M. M. Dignam
Office: Stirling Hall 371
Telephone: 533-6804
Email: dignam@physics.queensu.ca
Web Page: http://www.physics.queensu.ca/~dignam/

Recommended Text: *Introduction to Solid State Physics (8th Edition)*, Charles Kittel (John Wiley and Sons, 2005). This is available in the bookstore. Earlier editions are fine.

Useful References:

- *Solid State Physics*, N. W. Ashcroft and N. D. Mermin, Harcourt College Publishers (1976). This is an excellent text that covers most of the key material in the course. However, much of it is at a higher (graduate) level. Despite this, I think that all students would benefit from many of the excellent presentations in it. I have put this on 3-hour reserve in the Douglas Library.

- *Solid State Physics: An Introduction to Principles of Materials Science (4th Edition)*, Springer-Verlag (2009). This is an interesting text that has many useful and relevant sections. Also it is available free in pdf form on from the library website. However, I did not adopt it as the course text because it is somewhat uneven, is missing some important topics and present some material a much too high and detailed a level.
Class Times: Lectures: Monday 8:30, Tuesday 10:30, Thursday 9:30
all in Stirling Hall, Room 412A
Tutorial: Tuesday 2:30, Stirling Hall, 412C

Office Hours: Mondays and Thursdays: 1:00-3:00

Marking Scheme for PHYS 880:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midterm Test</td>
<td>20%</td>
</tr>
<tr>
<td>Problem Sets</td>
<td>20%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>40%</td>
</tr>
<tr>
<td>Project/Presentation</td>
<td>20%</td>
</tr>
</tbody>
</table>

To be held on Wednesday October 22, 7 PM to 9:00 PM in Stirling Hall 401

Course Goals and Objectives

The aim of this course is to provide students with a background and understanding of the fundamentals of the solid state physics and to expose them to some exciting current research in this field. At the end of this course, students should have the conceptual and mathematical tools to read, analyse and explain current research papers in solid state physics and to understand the physical process underlying many solid state devices.

List of Topics to be Covered:

1. Structure of Solids and Crystal Theory (Kittel, Chs. 1 and 3)
   - Lattice, Basis and Unit Cells
   - Important Structures
   - Interatomic Forces and Crystal Binding

2. X-Ray and Neutron Crystallography and the Reciprocal Lattice (Kittel Ch. 2)

3. Lattice Vibrations: Phonons (Kittel, Chs. 4 and 5)
   - 1D Crystals
   - Lattice with a Basis
   - 3D Crystals
   - Quantization of Lattice Waves: Phonons
Thermal Properties of Phonons

4. Free Electrons in Metals (Kittel, Ch. 6)
   · Drude Model of Electric Conductivity
   · Thermal Conductivity
   · Free Electron Fermi Gas Model

5. Electronic States in Crystals: Band Theory (Kittel, Ch. 7)
   · Bloch's Theorem
   · Tight-Binding Approach
   · Nearly-Free Electron Approach
   · Insulators, Semiconductors and Metals

6. Electron Dynamics in Crystals (Kittel, Chs. 8 and 9)
   · Semiclassical Model
   · Effective Mass
   · Electrons and Holes
   · The Fermi Surface
   · Scattering Due to Impurities and Phonons

7. Semiconductors (Kittel, Ch. 8)
   · Intrinsic Properties
   · Optical Properties
   · Doping
   · p-n Junctions

Research Essay and Presentation

1. All PHYS 880 students must write a research essay and give a 15 minute presentation to the other PHYS 880 students on the topic of their essay.
2. The research essay is due Tuesday December 3 at 4:00 PM. Essays handed in after that deadline will face a 20% penalty. Essays will not be accepted after December 23. The essay should be 15 to 20 double-spaced pages long (12 pt with 1 inch margins), preferably using LaTeX but Word is fine if you can deal properly with equations (which should be centered and numbered at the right). It is not generally intended to be original research, but rather should be an essay on a chosen topic that discusses the state of knowledge in a particular area. It may include some independent derivations and/or computations, but these should be illustrative of the state of the theory and are not expected to be original. It does not need to be on an area of current research if it is on an
advanced topic not covered in the course. It may also include a discussion of state-of-the-art experimental techniques and/or results. The essay will be marked on the following criteria:

- Depth of Research.
- Demonstrated overall understanding of topic.
- Understanding of underlying theory and analysis.
- Understanding of experimental results and techniques (if appropriate).
- Ability to communicate and illustrate important and complex concepts.
- Thoroughness of research (have you referenced all of the main findings in the given area).
- Organizational clarity of the essay.
- Bibliography and references. (5%)
- Grammar and spelling (15%).

3. Students will give a 15 minute presentation of their research topic to the PHYS 880 class. The presentation will be followed by five minutes of questions from the class and professor. The presentation will be graded on the following criteria:

- Use of visuals and quality of visuals
- Continuity, cohesion and flow of presentation
- Poise and professionalism
- Choice, presentation and explanation of key ideas
- Use of allotted time
- Understanding of the questions
- Clear and concise answers
- Poise and professionalism (including admitting errors or ignorance)

4. You may suggest a topic of your own or you can choose from the list of topics below. With each of these topics you may decide to narrow your focus, which is fine as long as you clear it with me. If you choose your own topic, it must be approved by me ahead of time.

**Suggested Topics:**

1. Band structures and/or defects in photonic crystals
2. Band structures and/or defects in phononic crystals
3. Modern advances in calculating semiconductor bandstructures
4. Using the Boltzmann equation to calculate carrier transport in crystals
5. Electrical and/or optical properties of graphene
6. Electrical and/or optical properties of bi-layer graphene
7. Electrical and/or structural properties of carbon nanotubes
8. Electrical and/or optical properties of quantum dots
9. Electrical and/or optical properties of quantum wires
10. Advanced X-Ray scattering techniques and results
11. Advanced Neutron scattering techniques and results
12. Scanning tunnelling microscopes and surface density of states
13. The integer and fractional quantum Hall effects
14. Anderson localization
15. Density functional theory

Additional Information

1. There will be 6 assignments, essentially one every other week.
2. The midterm will be written at a time TBA.
3. Class notes, assignments, assignment solutions, and general course information will be posted on the course website: http://www.physics.queensu.ca/~phys480. This can also be reached from the physics homepage by clicking on “Undergraduate Studies” and then clicking on “Course Information”. The notes and problem sets are password protected; I will give you the password on the first day of classes.
4. The tutorials will be run every week. At the tutorials I will go over some new problems, answer questions on lecture material and upcoming problem sets, review previous problem sets. Solutions presented at the tutorials will NOT be posted online, but I will sometimes post the problems.
5. Calculators acceptable for use during tests and examinations are those that support the basic calculating functions required by most Arts and Science and Applied Science courses but are not programmable.
6. All components of this course will receive numerical percentage marks. The final grade you receive for the course will be derived by converting your numerical course average to a letter grade according to Queen’s Official Grade Conversion Scale
7. Late Policy: 10% will be deducted from problem sets that are handed in late. However, if a problem set is handed in after the solutions are posted, at mark of 0% will be assigned to that problem set. Solutions will generally be posted 3 to 5 days after the problem set due date.
Academic Integrity

Academic integrity is constituted by the five core fundamental values of honesty, trust, fairness, respect and responsibility (see www.academicintegrity.org). These values are central to the building, nurturing and sustaining of an academic community in which all members of the community will thrive. Adherence to the values expressed through academic integrity forms a foundation for the "freedom of inquiry and exchange of ideas" essential to the intellectual life of the University (see the Senate Report on Principles and Priorities).

Students are responsible for familiarizing themselves with the regulations concerning academic integrity and for ensuring that their assignments conform to the principles of academic integrity. Information on academic integrity is available in the Arts and Science Calendar (see Academic Regulation 1), on the Arts and Science website (see http://www.queensu.ca/artsci/academics/undergraduate/academic-integrity), and from the instructor of this course. Departures from academic integrity include plagiarism, use of unauthorized materials, facilitation, forgery and falsification, and are antithetical to the development of an academic community at Queen's. Given the seriousness of these matters, actions which contravene the regulation on academic integrity carry sanctions that can range from a warning or the loss of grades on an assignment to the failure of a course to a requirement to withdraw from the university.

Disability Accommodations

Queen's University is committed to achieving full accessibility for persons with disabilities. Part of this commitment includes arranging academic accommodations for students with disabilities to ensure they have an equitable opportunity to participate in all of their academic activities. If you are a student with a disability and think you may need accommodations, you are strongly encouraged to contact the Disability Services Office (DSO) and register as early as possible. For more information, including important deadlines, please visit the DSO website at: http://www.queensu.ca/hcds/ds/.

Copyright of Course Materials

The material on this website and in all course notes, assignments, tests and exams is copyrighted and is for the sole use of students registered in PHYS/ENPH 480 or PHYS 880. This material is for a registered student’s personal use, but shall not be distributed or disseminated to anyone other than students registered in PHYS/ENPH 480 or PHYS 880. Failure to abide by these conditions is a breach of copyright, and may also constitute a breach of academic integrity under the University Senate’s Academic Integrity Policy Statement.