Solid State Physics

PHYS 4508

Course Instructor: Dr. Caroline (Katie) Mitchell

How to address me: Katie or Dr. Mitchell

Gender Pronouns: (she/her/hers) (learn more)

Email: caroline.mitchell3@carleton.ca

Note: If you have a question or would like to talk with me, you can send an email, visit me during student hours (see below), or approach me after lecture.

Student Hours: TBA

What are 'Student Hours'?
Student hours are dedicated times through the week for the course instructor and TAs to meet with YOU. Pop in to introduce yourself, ask questions about the course, or discuss content from the course.

Note: If these If these times don't work for you, email me and we can arrange an alternate time to meet.

Office Location: Online TBA

Class Location: Online via Zoom https://carleton-ca.zoom.us/j/2256336822

Meeting ID: 225 633 6822, Passcode: 456456

Class Times: Monday & Wednesday, 1:05-2:25 pm

Prerequisites: Phys 3606 (Modern Physics II) or Phys 3608 (Modern Applied Physics), and Phys 3701 (Elements of Quantum Mechanics), or permission of the Department.

Welcome to Phys 4508!

Solid state physics emerged as a discipline in the 1940s with developments such as the semiconductor transistor, and now forms a subdiscipline of the biggest field in physics, condensed matter. Research ranges from the very applied (electronics, new materials) to the fundamental (quantum many-body problem, critical phenomena). Solid state physics is a very diverse field which spans quantum physics, electromagnetism, and statistical and thermal physics. There is also overlap and application to many fields, including chemistry, medicine, biology, computing, materials science, and electrical engineering. Experiments in solid state physics are done in settings ranging from small labs to big facilities (synchrotron radiation sources, neutron sources), and theoretical solid state physics is heavily based in computation. Because 3D solids are composed of $\sim 10^{23}$ atoms, and real solids incorporate many local defects, much of solid state physics consists of learning to construct appropriate models and approximations.

Course level learning objectives:

1. – Become familiar with and be able to solve problems using basic concepts of solid state physics, including crystal structure and reciprocal lattice, lattice vibrations and phonons, Bloch theorem and electron energy bands
2. – Develop a foundation for graduate level studies in solid state physics and an appreciation of the field for those pursuing other paths
3. – Develop the ability to work with 3D structures and in Fourier/reciprocal space
4. – Develop the ability to apply appropriate approximations and models
5. – Develop a feel for orders of magnitude in solid state physics (for example, energy and length scales)

Topics and Schedule

Weeks	Topics	Chapters in Kittel
1-3	Crystal structure, bonding, diffraction, and the reciprocal lattice	1,2,3
4-6	Lattice waves (phonons) and thermal properties; dispersion and density of states	4,5
6	Midterm	
7	Winter break	
8-11	Electrons in solids; free and nearly free electron models, electron energy bands	6,7
11-14	Selections from semiconductors, magnetism, surface/nanostructures, review	8, 11-12, 17-18

Learning Materials

Textbook:

Kittel, Charles. *Introduction to Solid State Physics, 8th Edition.* Wiley, 2004.

This text is expensive, so a used copy is a good option if available. The 6th or 7th edition should be fine too, although I don't know if the page numbering is the same, which could make the Reading Assignments trickier. The text can also be found as a pdf online. This book is the classic undergraduate solid state physics text. It covers all the topics at the appropriate level, and has a wealth of reference material, but is quite condensed. The following supplementary texts can be useful to provide different or more in-depth explanations and derivations.

Supplementary Texts:

Ashcroft, N.W. and Mermin. N.D. *Solid State Physics*

The classic graduate solid state physics textbook; well written, with much more conceptual and mathematical detail than Kittel.

Ibach, H. and Luth. H. *Solid-State Physics: An introduction to the Principles of Materials Science* (available free as an E-book on ARES)

Covers similar material to Kittel (although fewer topics), sometimes with a different mathematical approach; very good discussion of experimental techniques related to each topic.

Ziman, J.M. *Principles of the Theory of Solids* (available free as an E-book on ARES)

A concise and readable book, with very nice discussions of concepts; another classic text.

Simon, Steven H. *The Oxford Solid State Basics* (available free as an E-book on ARES)

A very good modern text with a different organization of topics and conceptual framework. Nice to read, with fun footnotes and trivia. There is an accompanying set of lectures on YouTube.

Technology Checklist:

- ☐ An internet-enabled computer (laptop/desktop)
- ☐ Zoom software installed on computer (can also install on phone as backup!)
- ☐ Access to reliable internet
- ☐ Webcam
- ☐ Headset with microphone

Assessment in this Course

Research about learning strongly suggests that the most important factor in learning is doing the work of reading, writing, recalling, practicing, synthesizing, and analyzing. Learning happens best when students actively engage material on a consistent basis.

Grade Breakdown

COMPONENT	GRADE VALUE	DESCRIPTION
ASSIGNMENTS	50%	6 or 7 assignments
READING ASSIGNMENTS	8%	A single question or problem to be completed before each class; completing 80% of these earns the full 8%
PARTICIPATION	2%	Attending 80% of the lectures earns the full 2%
MIDTERM	15%	Online exam (no e-proctoring) with ~15 min follow-up oral exam
FINAL EXAM	25%	Online exam (no e-proctoring) with ~15 min follow-up oral exam

Assignments

There will be six or seven assignments, covering one to two weeks of material.

For the assignments, solutions must be neatly presented and complete, including appropriate diagrams. Students are encouraged to discuss assignments, however, the work that each student submits must be their own. In the assignments, I am looking for understanding and explanation, not just an answer. Please feel free to contact me for help with the assignments.

Reading Assignments

There will also be short reading assignments (a single question or problem to work on) due before each class. Completing 80% of these assignments will earn you the full 8% reading assignment mark. These assignments are designed to help you prepare for class, and to reinforce important concepts.

Midterm and Final Exam

The midterm and final exam will be online. I will not be using e-proctoring. Both the midterm and the final exam will include a follow-up oral component, approximately 15 min in length. The midterm is tentatively scheduled for the week before the winter break, and the final exam will take place during the exam period.

Inclusive Teaching Statement

I am committed to fostering an environment for learning that is inclusive for everyone regardless of gender identity, gender expression, sex, sexual orientation, race, ethnicity, neurodivergence, ability, age, class, etc., and I hope that our class will support diversity of experience, thought and perspective. I welcome emails or in-person communications to let me know your preferred name or pronoun. I also welcome emails or in-person communications to discuss any concerns, worries or suggestions that you may have in relation to this course, including concerns related to remote learning and the COVID-19 pandemic.

Land Acknowledgement

Here at Carleton University, it is important that we acknowledge that the land on which we gather is the traditional and unceded territory of the Algonquin nation.

Community Guidelines

The following values are fundamental to academic integrity and are adapted from the International Center for Academic Integrity*. In our course, we will seek to behave with these values in mind

	As students, we will…	As a teaching team, we will…
Honesty	• Honestly demonstrate our knowledge and abilities on assignments and exams • Communicate openly without using deception, including citing appropriate sources	• Give you honest feedback on your demonstration of knowledge and abilities on assignments and exams • Communicate openly and honestly about the expectations and standards of the course through the syllabus, and with respect to assignments and exams
Responsibility	• Complete assignments on time and in full preparation for class • Show up to class on time, and be mentally/physically present • Participate fully and contribute to team learning and activities	• Give you timely feedback on your assignments and exams • Show up to class on time, and be mentally & physically present • Create relevant assessments and class activities
Respect	• Speak openly with one another, while respecting diverse viewpoints and perspectives • Provide sufficient space for others to voice their ideas	• Respect your perspectives even while we challenge you to think more deeply and critically • Help facilitate respectful exchange of ideas
Fairness	• Contribute fully and equally to collaborative work, so that we are not freeloading off of others • Not seek unfair advantage over fellow students in the course	• Create fair assignments and exams, and grade them in a fair, and timely manner • Treat all students equitably
Trust	• Not engage in personal affairs while on class time • Be open and transparent about what we are doing in class • Not distribute course materials to others without authorization	• Be available to all students when we say we will be • Follow through on our promises • Not modify the expectations or standards without communicating with everyone in the course
Courage	• Say or do something when we see actions that undermine any of the above values • Accept a lower or failing grade or other consequences of upholding and protecting the above values	• Say or do something when we see actions that undermine any of the above values • Accept the consequences (e.g., lower teaching evaluations) of upholding and protecting the above values

[2] This class statement of values is adapted from Tricia Bertram Gallant, Ph.D.

Special Information Regarding COVID-19

All members of the Carleton community are required to follow COVID-19 prevention measures and all mandatory public health requirements (e.g., wearing a mask, physical distancing, hand hygiene, respiratory and cough etiquette) and mandatory self-screening prior to coming to campus daily.

If you feel ill or exhibit COVID-19 symptoms while on campus or in class, please leave campus immediately, self-isolate, and complete the mandatory symptom reporting tool. For purposes of contact tracing, attendance will be taken in all classes and labs. Participants can check in using posted QR codes through the cuScreen platform where provided. Students who do not have a smartphone will be required to complete a paper process as indicated on the COVID-19 website.

All members of the Carleton community are required to follow guidelines regarding safe movement and seating on campus (e.g., directional arrows, designated entrances and exits, designated seats that maintain physical distancing). In order to avoid congestion, allow all previous occupants to fully vacate a classroom before entering. No food or drinks are permitted in any classrooms or labs.

For the most recent information about Carleton's COVID-19 response and required measures, please see the University's COVID-19 webpage and review the Frequently Asked Questions (FAQs). Should you have additional questions after reviewing, please contact covidinfo@carleton.ca.

Please note that failure to comply with University policies and mandatory public health requirements, and endangering the safety of others are considered misconduct under the Student Rights and Responsibilities Policy. Failure to comply with Carleton's COVID-19 procedures may lead to supplementary action involving Campus Safety and/or Student Affairs.

Note About COVID-19 & Mental Health

The global pandemic has led to extra stress and uncertainty for everyone, and while we may all be experiencing the same storm, this does not mean that we are all in the same boat! If you are struggling, please do not hesitate to reach out. I am happy to listen, and/or direct you to resources that might help. In terms of class, if you need extra help or missed a lesson, don't stress! Email me and we will set a time to meet. I'll work with you, I promise. Remember that Carleton also offers an array of mental health and well-being resources, which can be found here.

Children & video sessions

You are welcome to have children with you during video sessions as I fully understand that childcare situations may be complicated for many of us at this time. Do your best to participate and engage, but also please get in touch with me if you have any questions or concerns.

University Policies

In accordance with the Carleton University Undergraduate Calendar Regulations, the letter grades assigned in this course will have the following percentage equivalents:

A+ = 90-100	B+ = 77-79	C+ = 67-69	D+ = 57-59
A = 85-89	B = 73-76	C = 63-66	D = 53-56
A- = 80-84	B- = 70-72	C- = 60-62	D- = 50-52

F = <50
WDN = Withdrawn from the course
ABS = Student absent from final exam
DEF = Deferred
FND = (Failed, no Deferred) = student could not pass even with 100% on final exam

Academic Accommodations, Regulations, Plagiarism, Etc.

Carleton University is committed to providing access to the educational experience in order to promote academic accessibility for all individuals.

Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. The purpose of accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University. More information can be found at: https://students.carleton.ca/course-outline/

University rules regarding registration, withdrawal, appealing marks, and most anything else you might need to know can be found on the university's website, here:

https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/

Academic Accommodations for Students with Disabilities

If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or pmc@carleton.ca for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made. For more details, visit the Paul Menton Centre website.

Addressing Human Rights Concerns

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca.

Religious Obligations

Please contact me 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, please review the Student Guide to Academic Accommodation (PDF, 2.1 MB).

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/sexual-violence-support/

Accommodations for Missed Work

Carleton recognizes that these are unprecedented times during the COVID-19 pandemic, and that students may be experiencing greater stress and other life factors that are not in their control. As a result, Carleton has put into place a protocol for students to apply for accommodations using a self-declaration form in the event of missed work. The form can be found at: https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf

For Pregnancy

Please contact me 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, please review the Student Guide to Academic Accommodation (PDF, 2.1 MB).

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 must be provided to students who compete or perform at the national or international level. Please contact me 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, see the Senate Policy on Accommodation for Student Activities (PDF, 25KB).

Academic Integrity

Academic misconduct undermines the values of honesty, trust, respect, fairness, and responsibility that we expect in this class. Carleton University provides supports such as academic integrity workshops to ensure, as far as possible, that all students understand the norms and standards of academic integrity that we expect you to uphold. Your teaching team has a responsibility to ensure that their application of the Academic Integrity Policy upholds the university's collective commitments to fairness, equity, and integrity. (adapted from Carleton University's Academic Integrity Policy, 2021).

Examples of actions that do not adhere to Carleton's Academic Integrity Policy include:

- Plagiarism
- Accessing unauthorized sites for assignments or tests

- Unauthorized collaboration on assignment and exams

Sanctions for not abiding by Carleton's Academic Integrity Policy

A student who has not adhered to Carleton's Academic Integrity Policy may be subject to one of several sanctions:

1. If you take full responsibility for your actions, and it is the first time you have violated the policy, you will receive zero on the assessment. If you are found to have violated the policy but do not take responsibility, an additional grade deduction will be applied (e.g. an A- will become a B+)
2. Subsequent violations of the policy may result in more severe sanctions such as failing the course, suspension from all studies and/or expulsion.

Process of an Academic Misconduct Investigation

Step 1: The instructor believes misconduct has occurred and submits documentation to the Dean of the Faculty of Science.

Step 2: The Dean reviews documentation and can proceed with or dismiss the allegation.

Step 3: If sufficient evidence, the student receives an allegation statement by email. Ombuds services is copied on the email.

Step 4: The student provides a written response to the evidence provided.

Step 5: Either party may request a meeting between student, dean, and the ombudsperson.

Step 6: Dean informs the student of the decision.

Appeal: Student has the right to appeal the decision.

Additional details about this process can be found on the Faculty of Science Academic Integrity website. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. The Policy is strictly enforced and is binding on all students.

Plagiarism

Plagiarism is the passing off of someone else's work as your own and is a serious academic offence. For the details of what constitutes plagiarism, refer the Faculty of Science

Academic Integrity website. To further understand Academic Integrity, consider attending the Learning and Support Academic Integrity Workshop.

What are the Penalties for Plagiarism?

A student found to have plagiarized an assignment may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; and/or a reprimand; a refusal of permission to continue or to register in a specific degree program; academic probation; award of an FNS, Fail, or an ABS.

What are the Procedures?

3. All allegations of plagiarism are reported to the Dean of Faculty of Science. Documentation is prepared by instructors and/or departmental chairs.
4. The Dean writes to the student and the University Ombudsperson about the alleged plagiarism.
5. The Dean reviews the allegation. If it is not resolved at this level then it is referred to a tribunal appointed by the Senate.

Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. The Policy is strictly enforced and is binding on all students.

Assistance for Students

Academic and Career Development Services: http://carleton.ca/sacds/

Writing Services: http://www.carleton.ca/csas/writing-services/

Peer Assisted Study Sessions (PASS): https://carleton.ca/csas/group-support/pass/

Math Tutorial Centre: https://carleton.ca/math/math-tutorial-centre/

Science Student Success Centre: https://sssc.carleton.ca/