UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
Science B 605
403 220-5385
phasoffice@phas.ucalgary.ca

COURSE OUTLINE

1. **Course:** PHYS 507, Solid State Physics - Fall 2021

   Lecture 01: MWF 11:00 - 11:50 in TI STUDIOB

Instructor	Email	Phone	Office	Hours
Dr Paul Barclay	pbarclay@ucalgary.ca	403 220-8517	SB 319	Wednesday 1:00 - 2:30 or by appointment

In Person Delivery Details:

Lectures will be delivered in person. Midterm exam will be take home. Final project will be take home.

Re-Entry Protocol for Labs and Classrooms:

To limit the spread of COVID-19 on campus, the University of Calgary has implemented safety measures to ensure the campus is a safe and welcoming space for students, faculty and staff. The most current safety information for campus can be found here.

Course Site:

D2L: PHYS 507 L01-(Fall 2021)-Solid State Physics

Note: Students must use their U of C account for all course correspondence.

2. **Requisites:**

   See section 3.5.C in the Faculty of Science section of the online Calendar.

   Prerequisite(s):
   Physics 443 or Chemistry 373; and Physics 449 and 455.

3. **Grading:**

   The University policy on grading and related matters is described in F.1 and F.2 of the online University Calendar.

   In determining the overall grade in the course the following weights will be used:

Component(s)	Weighting %	Date
Weekly reading assignment	15	
Midterm assignment	15	Week of October 18
Homework	40	
Presentation	15	Last week of class
Final project	20	Due during week of Dec. 13

   Each piece of work (reports, assignments, quizzes, midterm exam(s) or final examination) submitted by the student will be assigned a grade. The student's grade for each component listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

   The conversion between a percentage grade and letter grade is as follows.

	A+	A	A-	B+	B	B-	C+	C	C-	D+	D
Minimum % Required	95 %	90 %	85 %	80%	75%	70 %	65 %	60%	55%	50 %	45 %

   The University of Calgary offers a flexible grade option, Credit Granted (CG) to support student's breadth of learning and student wellness. Faculty units may have additional requirements or restrictions for the use of the CG grade at the faculty, degree or program level. To see the full list of Faculty of Science courses where CG is not eligible, please visit the following website: https://science.ucalgary.ca/current-students/undergraduate/program-advising/flexible-grading-option-cg-grade

4. **Missed Components Of Term Work:**

The university has suspended the requirement for students to provide evidence for absences. Please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations.

In the event that a student legitimately fails to submit any online assessment on time (e.g. due to illness etc...), please contact the course coordinator, or the course instructor if this course does not have a coordinator to arrange for a re-adjustment of a submission date. Absences not reported within 48 hours will not be accommodated. If an excused absence is approved, one possible arrangement is that the percentage weight of the legitimately missed assignment could also be pro-rated among the components of the course. This option is at the discretion of the coordinator and may not be a viable option based on the design of this course.

5. **Scheduled Out-of-Class Activities:**

   There are no scheduled out of class activities for this course.

6. **Course Materials:**

   Required Textbook(s):

   Steven H. Simon, *The Oxford Solid State Basics, 1st Edition*: Oxford.

   In order to successfully engage in their learning experiences at the University of Calgary, students taking online, remote and blended courses are required to have reliable access to the following technology:

   - A computer with a supported operating system, as well as the latest security, and malware updates;
   - A current and updated web browser;
   - Webcam/Camera (built-in or external);
   - Microphone and speaker (built-in or external), or headset with microphone;
   - Current antivirus and/or firewall software enabled;
   - Stable internet connection.

   For more information please refer to the UofC ELearning online website.

7. **Examination Policy:**

   Calculator and one page (double sided) formula sheet allowed.

   Students should also read the Calendar, Section G, on Examinations.

8. **Approved Mandatory And Optional Course Supplemental Fees:**

   There are no mandatory or optional course supplemental fees for this course.

9. **Writing Across The Curriculum Statement:**

   For all components of the course, in any written work, the quality of the student's writing (language, spelling, grammar, presentation etc.) can be a factor in the evaluation of the work. See also Section E.2 of the University Calendar.

10. **Human Studies Statement:**

    Students will not participate as subjects or researchers in human studies.

    See also Section E.5 of the University Calendar.

11. **Reappraisal Of Grades:**

    A student wishing a reappraisal, should first attempt to review the graded work with the Course coordinator/instructor or department offering the course. Students with sufficient academic grounds may request a reappraisal. Non-academic grounds are not relevant for grade reappraisals. Students should be aware that the grade being reappraised may be raised, lowered or remain the same. See Section I.3 of the University Calendar.

    a. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **ten business days** of either being notified about the mark, or of the item's return to the class. If the student is not satisfied with the outcome, the student shall submit the Reappraisal of Graded Term work form to the department in which the course is offered within 2 business days of receiving the decision from the instructor. The Department will arrange for a reappraisal of the work within the next ten business days. The reappraisal will only be considered if the student provides a detailed rationale that outlines where and for what reason an error is suspected. See sections I.1 and I.2 of the University Calendar

b. **Final Exam:** The student shall submit the request to Enrolment Services. See Section I.3 of the University Calendar.

12. **Other Important Information For Students:**

a. **Mental Health** The University of Calgary recognizes the pivotal role that student mental health plays in physical health, social connectedness and academic success, and aspires to create a caring and supportive campus community where individuals can freely talk about mental health and receive supports when needed. We encourage you to explore the mental health resources available throughout the university community, such as counselling, self-help resources, peer support or skills-building available through the SU Wellness Centre (Room 370, MacEwan Student Centre, Mental Health Services Website) and the Campus Mental Health Strategy website (Mental Health).

b. **SU Wellness Services:** For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

c. **Sexual Violence:** The Sexual Violence Support Advocate, Carla Bertsch, can provide confidential support and information regarding sexual violence to all members of the university community. Carla can be reached by email (svsa@ucalgary.ca) or phone at 403-220-2208. The complete University of Calgary policy on sexual violence can be viewed at (https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Sexual-and-Gender-Based-Violence-Policy.pdf)

d. **Misconduct:** Academic integrity is the foundation of the development and acquisition of knowledge and is based on values of honesty, trust, responsibility, and respect. We expect members of our community to act with integrity. Research integrity, ethics, and principles of conduct are key to academic integrity. Members of our campus community are required to abide by our institutional Code of Conduct and promote academic integrity in upholding the University of Calgary's reputation of excellence. Some examples of academic misconduct include but are not limited to: posting course material to online platforms or file sharing without the course instructor's consent; submitting or presenting work as if it were the student's own work; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; borrowing experimental values from others without the instructor's approval; falsification/fabrication of experimental values in a report. Please read the following to inform yourself more on academic integrity:

Student Handbook on Academic Integrity
Student Academic Misconduct Policy and Procedure
Research Integrity Policy

Additional information is available on the Student Success Centre Academic Integrity page

e. **Academic Accommodation Policy:**

It is the student's responsibility to request academic accommodations according to the University policies and procedures listed below. The student accommodation policy can be found at: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Student-Accommodation-Policy.pdf

Students needing an accommodation because of a disability or medical condition should communicate this need to Student Accessibility Services in accordance with the Procedure for Accommodations for Students with Disabilities: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Accommodation-for-Students-with-Disabilities-Procedure.pdf.

Students needing an accommodation in relation to their coursework or to fulfil requirements for a graduate degree, based on a Protected Ground other than Disability, should communicate this need, by filling out the Request for Academic Accommodation Form and sending it to Dr. David Feder by email phas.ahugrd@ucalgary.ca preferably 10 business days before the due date of an assessment or scheduled absence.

f. **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). Students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page. For more information, see Legal Services website.

g. **Student Union Information:** VP Academic, Phone: 403-220-3911 Email: suvpaca@ucalgary.ca. SU Faculty Rep., Phone: 403-220-3913 Email: sciencerep@su.ucalgary.ca. Student Ombudsman, Email: ombuds@ucalgary.ca.

h. **Surveys:** At the University of Calgary, feedback through the Universal Student Ratings of Instruction (USRI) survey and the Faculty of Science Teaching Feedback form provides valuable information to help with

evaluating instruction, enhancing learning and teaching, and selecting courses. Your responses make a difference - please participate in these surveys.

i. **Copyright of Course Materials:** All course materials (including those posted on the course D2L site, a course website, or used in any teaching activity such as (but not limited to) examinations, quizzes, assignments, laboratory manuals, lecture slides or lecture materials and other course notes) are protected by law. These materials are for the sole use of students registered in this course and must not be redistributed. Sharing these materials with anyone else would be a breach of the terms and conditions governing student access to D2L, as well as a violation of the copyright in these materials, and may be pursued as a case of student academic or non-academic misconduct, in addition to any other remedies available at law.

Homework policy: Homework is to be handed in**via D2L**.

Your worst homework score will not be counted towards your final grade. Late homework will not be accepted.

Expected knowledge and skills of students entering the course:

Understanding of interference, wavefunctions, plane waves, simple harmonic oscillators, differential equations. Familiarity with the structure of atoms and solids. Understanding of the role of eigenfunctions in quantum mechanics and their relationship to a Hamiltonian. Ability to solve the Schrödinger equation, understanding of electromagnetics.

Final presentation information

The final presentation will consist of an oral presentation of a scientific research paper that is related to material covered in class. This will be delivered over Zoom or in class.

Length: 10 minutes + 2 minutes for questions

Slides in PDF or PPT form

Evaluation criteria:

Clarity of visual presentation: 30%

Oral presentation: 30%

Communication of scientific content: 30%

Response to questions: 10%

Midterm information

The midterm will differ from the homework in that they will not be from the textbook. It will be take home and will have at least a 24 hour time limit.

Final project information

This non-textbook project will strive to include more computational and/or research aspects, as well as homework-like questions. It will be assigned roughly two weeks in advance of the due date.

Reading assignment information

On a roughly weekly basis you will be asked to read something from the literature, popular press, a science blog, etc. and write a short response addressing an assigned question.

Schedule of topics:

Week 1: Lectures 1 – 2, (Sept. 8/10)

Boltzmann, Einstein and Debye specific heat — Chapter 2

Operational concepts: partition function calculation of energy

Fundamental concepts: thermal energy as excitations of a Harmonic oscillator, Boltzann vs. Einstein statistics, particle in a box and density of states, Debye frequency/temperature.

Week 2: Lectures 3 – 5, (Sept. 13/15/17)

Drude theory of electrons — Chapter 3

Sommerfeld theory of electrons — Chapter 4 (not 4.3)

Fundamental concepts: electron gas, electronic conductivity matrix, Fermi-Dirac statistics, Fermi exclusion principle, Fermi energy/temperature, density of states, difference between Fermi temperature and sample temperature and explanation/interpretation of this difference, impact of high Fermi temperature**.**

Week 3: Lectures 6 – 8, (Sept. 20/22/24)

Periodic table — Chapter 5

Bonding in solids — Chapter 6 (6.2 in detail)

Types of matter (not covered in class) Chapter 7

Fundamental concepts: filling of electron states due to Fermi exclusion principle, interactions between outer shell electrons of nearby atoms, bonding = minimizing energy.

Vibrations of atoms in a lattice Chapter 9

Week 4: Lectures 9 – 11, (Sept. 27/29, Oct. 1)

Vibrations of diatomic atomic lattice Chapter 10

Fundamental concepts: reciprocal lattice, normal modes and phonons, phonon dispersion, optical and acoustic phonons, Brillouin zone

Tight binding of electrons Chapter 11

Fundamental concepts: properties of tight binding potential, electron bands, band filling (influence of Fermi statistics), effective mass, valance and conduction band, conduction and insulation properties of full vs. partially full bands.

Week 5: Lectures 12 – 14, (Oct. 4/6/8)

Crystal structure Chapter 12

Reciprocal lattice Chapter 13

Discussion of scattering by a periodic potential (optical and electronic) Chapter 14

Photonic Crystal book

Lattice properties (primitive lattice vector, other definitions in 12.1), different 3D lattices, lattice notation, reciprocal lattice vectors, Brillouin zones in 3D (warning: very important section!)

Week 6: Lectures 15 – 16 (Oct. 13/15)

Thanksgiving Oct. 11 – no class

Electrons in a periodic potential Chapter 15

Nearly free electron model, perturbation theory, Bloch's theorem

Midterm this week

Week 7: Lectures 17 – 19 (Oct. 18/20/22)

Insulator, semiconductors, and metals Chapter 16

Predicting electronic and optical properties of materials from their bandstructure

Week 8: Lectures 20 – 22 (Oct. 25/27/29)

Semiconductors Chapter 17

Week 9: Lectures 23 – 25 (Nov. 1/3/5)

Semiconductor devices Chapter 18

Week 10: Reading week (Nov. 8 – 12)

No class

Week 11: Lectures 26 – 28 (Nov. 15/17/19)

Semiconductor devices/lasers Chapter 18

Week 12: Lectures 30 – 32 (Nov. 22/24/26)

Topological photonics

Weeks 13 and 14 (Nov. 29, Dec. 1/3/6/8)

Review

Presentations

Course Outcomes:

- Understand the basics of the behaviour of solid state / condensed matter systems.
- Derive quantities such as electrical and thermal conductivity.
- Understand the origin and importance of electronic band structure.
- Explain the impact of periodic potentials on the wavefunction of an electron, and be able to make analogous predictions for other systems including photonic and phononic crystals.

- Predict the behaviour of materials and understand how they are used in technologies including transistors, integrated circuits, and lasers.

Electronically Approved - Sep 08 2021 07:30

Department Approval

Electronically Approved - Sep 08 2021 19:53

Associate Dean's Approval