# SYLLABUS

**Meeting Times**

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| *Lectures:* | MWF, 11:00-11:50 am |
| *Room:* | Hugel Science Center 225 |
| *Office Hours:* | M 1:00 pm - 3:00 pm |
| | T 10:00 am - 12:00 pm |
| | R 1:00 pm - 2:00 pm |

**Contact Information**


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| *Professor:* | Annemarie Exarhos |
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**Course Overview** The goal of this course is to introduce you to the basic principles of solid state physics, the largest branch of condensed matter physics. Our studies will focus on the the properties of crystalline solids, including their structure, electrical, thermal, and magnetic properties. Underpinning these properties is the way in which macroscopic behavior emerges from the underlying microscopic physics, which is governed by quantum mechanics. Solid state physics is a highly interdisciplinary field, forming the basis of materials science and nanoscience and with far reaching applications in chemistry, biology, and engineering.

**Learning Outcomes** By the end of this course, you will be able to understand and apply the principles of quantum mechanical theory to describe a variety of complex situations involving atomic structures. You will be able to describe the geometry of common crystals in terms of their periodic and reciprocal lattices, calculate materials properties based on the scattering of X-rays, characterize the different types of interactions that bond matter together, understand the role of vibrations in a crystal lattice, explain the importance and origin of band structure in solids, describe the common magnetic properties of solids, and identify and understand the array of experimental tools that can be used to characterize solid state materials, particularly nanostructures.

**Prerequisites** PHYS 335, PHYS 351 or permission of instructor

**Course Policies** Attendance is mandatory and I encourage you to read the relevant sections of the text *before* class so that the material is not completely unfamiliar to you when we start discussing it together. Additionally, there may be several departmental colloquia held at various points throughout the semester that you will be required to attend as part of this course. These talks will be about current research in various fields of physics and will serve to give you some insight as to what is going on in the wide, wide world of research as well as what makes a good (or bad, as the case may be) scientific presentation.

**Course Text**

*Introduction to Solid State Physics*, 8th ed. by Charles Kittel (John Wiley & Sons, Inc., 2005)

Supplementary texts you may find useful:

*The Oxford Solid State Basics* by Steven H. Simon (Oxford University Press, 2014)

*Solid State Physics* by Neil Ashcroft and N. David Mermin (Thomson Learning, Inc., 1976)

**Grading** Grades are determined on the following basis:

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| Participation: | 5% | Problem Sets: | 30% |
| Presentation: | 7.5% | Midterm Exam: | 20% |
| Paper: | 7.5% | Final Exam: | 30% |

**Participation** Your participation grade in this class will be based on your attendance at class meetings and departmental colloquia, your in-class contributions including discussions and asking questions, as well as office hour attendance.

**Projects** Towards the middle of the semester, you will select a topic in solid state physics from a list I will provide to focus on for your final project. If there is a particular topic of interest outside of the list, please speak with me about using it. The topic you choose will give you a chance to independently investigate a subject in depth and then convey your findings to the rest of the class and in a formal paper. Presentations will be **20 minutes** long and will occur during the final week of the semester. The paper should be **7-10 pages** in length and should be formatted using a LaTeX template I will provide. Further details and project topics will be distributed later in the semester.

**Assignments**

Departmental Colloquia: At the class following each departmental colloquium, we will discuss it for a few minutes to see what you (and I) found interesting and what we did/did not like. It is your responsibility to inform me if you will be unable to attend a colloquium prior to the event.

Problem Sets: Homework will be assigned on a roughly weekly basis and will generally be due on **Fridays** at the start of class (**11 am**). Late assignments will be docked an additional 25% for each 24 hour period after the due date, unless you have received an exemption from me ahead of time. Please plan to manage your time accordingly.

Over the course of the semester, I will allow **one** late assignment with no consequences or questions asked. You do not need to notify me ahead of time. If you use this option, you will have an additional 48 hours after the assignment is due to turn it in before the late penalty is applied.

A few notes about assigned problem sets:

- It is to your advantage to do the assigned homework. I have chosen the problems to help *you* learn the material. Physics can be a complicated thing, but repeatedly working with it (and at it) is essential in order to gain physical intuition and get comfortable with the mathematical theory.
- Feel free to use computational aids for some of the mathematics if you prefer, but note that there is some advantage to working things out by hand. Not being able to solve problems "by inspection" could end up hurting you on an exam where you may not be permitted to use computational tools and, frequently, there are mathematical tricks you can use to easily simplify a problem that you will not appreciate if you ask a program to do the work.
- I encourage you to work on these problem sets collaboratively, though I do expect you to

take 10-15 minutes to give a problem "the old college try" on your own so you enter into discussion with others having some ideas to contribute. You will make your life easier as well as improve your understanding if you work with others (either by explaining it or having it explained to you). I expect solutions to be written up individually (or, if your handwriting is illegible, typed), and all collaboration should be properly acknowledged.

- I expect your problem sets to be clearly and logically organized. This means that:
  - Each problem should start on a **new** page.
  - Write out the problem (or an abbreviated version containing all relevant information). Draw a picture/diagram if useful.
  - Clearly work out the problem, commenting your work as you go. Problem sets should never contain just the math; use words to describe what you are doing and to reference where in the text an equation came from and why it is relevant.
  - Remember to keep track of units (by writing them out with all your calculations)! Do the units work out as you expect they ought to at the end of a problem? Dimensional analysis is the easiest check to ensure you have tackled the problem correctly.
  - Box your final solutions or major milestones as you do the problem. This makes it easier to grade and also for you to follow your own work when you look it over.
  - Comment on the significance of your answer. (Does it make sense? Is it what you expected? Why or why not?)
  - Attach a cover page to your problem set. This can be the problem sheet or something else, but it should have your name and a clear acknowledgement of all those you have collaborated with on the assignment. This includes fellow students, faculty, SIs, etc. (anyone who you consulted or worked with).
  - Please see me if you have any questions about this! I know it seems a bit ridiculous listed out like this, but I promise that it will serve you well in the long run. Writing in science is different from the traditional humanities paper, but the point is the same: to clearly and effectively communicate something. This will help you to accomplish that.

**Accommodations** In accordance with Lafayette College policy, reasonable academic accommodation and support services are available to students who have a documented disability. It is your responsibility to provide me with the appropriate paperwork from the Accessibility Services Office. More information is available at `https://hub.lafayette.edu/`.

**Gender Inclusion** This is a gender-inclusive classroom. I have been provided with a class roster and your legal names. I will gladly honor any requests to be addressed by a different name or pronoun than appears on the class. Please make me aware of any preferences.

**Academic Honesty** I expect that you will abide by the "Principles of Intellectual Honesty" appearing in the Lafayette College Student Handbook. The Physics department also has an Academic Honesty policy for rules regarding collaboration with others. This document is available on the Moodle page for this class. Please feel free to ask if you have any questions about this policy.

**COVID-19 Policy** If you suspect you have COVID-19 and are seeking a Dean's Excuse, please contact Bailey Health Center for consultation and COVID-19 testing. If a positive test result is received, you must follow the College's protocols for clearance. If symptoms are significant enough to interfere with remote learning/engagement with classes, Bailey Health Center will submit a Dean's Excuse confirmation to the Office of Advising, who will process the Dean's Excuse.

If through Bailey Health Center's protocols you are not cleared to attend in-person classes for a period of time, I will be informed of this status through the Office of Advising. You must not return to class until medically cleared to do so. I will also be notified when you are cleared to return to in-person classes. Please note that Bailey Health Center or the Dean's Office will not disclose to me your specific medical information; they will not specify to me if you have to "isolate" due to a positive COVID-19 test, or "quarantine" due to possible exposure. They will only specify if you are "not cleared" or "cleared" to attend in-person classes. Additionally, please email me so that together we can make a plan to help you keep up with the course until you are cleared to return to in-person instruction.

**Mask Policy** The Pennsylvania Department of Education guidelines for instruction state that "[f]ace coverings should be worn by all students, faculty, and staff in all classrooms," and "[s]tudents, faculty, and staff should maintain a safe social distance of at least 6 feet apart when feasible. This includes offices, classrooms, laboratories, hallways, restrooms, common areas, and outdoor spaces." Therefore, without exception, all Lafayette faculty members and students should be masked and socially-distanced when in classroom spaces. Universal masking for the community is critical to our success in mitigating disease spread and therefore, even faculty or students who have been fully vaccinated should continue to wear masks in all designated areas of campus.

**Moodle Privacy Statement** Please note that Moodle contains student information that is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure to unauthorized parties violates federal privacy laws. Courses using Moodle will make student information visible to other students in this class. Please remember that this information is protected by these federal privacy laws and must not be shared with anyone outside the class. Questions can be referred to the Registrar's Office.

**Federal Credit Hour Compliance Statement** The student work in this course is in full compliance with the federal definition of a four credit hour course. Please see the Registrar's Office web site (https://registrar.lafayette.edu/wp-content/uploads/sites/193/2013/04/Federal-Credit-Hour-Policy-Web-Statement.doc) for the full policy and practice statement.

**Tentative Lecture Schedule and Associated Readings**

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| **Week 1** | Feb. 8 | Introduction | |
| | Feb. 10 | Crystal Structures | Ch. 1 |
| | Feb. 12 | " | |
| **Week 2** | Feb. 15 | " | |
| | Feb. 17 | X-Ray Diffraction & Reciprocal Lattices | Ch. 2 |
| | Feb. 19 | " | |
| **Week 3** | Feb. 22 | " | |
| | Feb. 24 | " | |
| | Feb. 26 | " | |
| **Week 4** | Mar. 1 | Crystal Binding | Ch. 3 |
| | Mar. 3 | " | |
| | Mar. 5 | " | |
| **Week 5** | Mar. 8 | Phonons: Crystal Vibrations | Ch. 4 |
| | Mar. 10 | " | |
| | Mar. 12 | " | |
| **Week 6** | Mar. 15 | Phonons: Thermal Properties | Ch. 5 |
| | Mar. 17 | " | |
| | Mar. 19 | " | |
| **Week 7** | Mar. 22 | Free Electron Gas | Ch. 6 |
| | Mar. 24 | " | |
| | Mar. 26 | " | |
| **Week 8** | Mar. 29 | " | |
| | Mar. 31 | **no class** (Spring Break) | - |
| | Apr. 2 | **Midterm Exam** | Chs. 1-6 |
| **Week 9** | Apr. 5 | Band Theory of Metals and Insulators | Ch. 7 |
| | Apr. 7 | " | |
| | Apr. 9 | " | |
| **Week 10** | Apr. 12 | Semiconductors | Ch. 8 |
| | Apr. 14 | " | |
| | Apr. 16 | " | |
| **Week 11** | Apr. 19 | de Hass-van Alphen Effect & Landau Levels | Ch. 9 |
| | Apr. 21 | " | |
| | Apr. 23 | " | |

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| **Week 12** | Apr. 26 | Diamagnetism & Paramagentism | Ch. 11 |
| | Apr. 28 | " | |
| | Apr. 30 | " | |
| **Week 13** | May 232 | Ferromagnetism & Antiferromagnetism | Ch. 12 |
| | May 5 | " | |
| | May 7 | " | |
| **Week 14** | May 10 | Nanostructures & Characterization Techniques | Ch. 18 |
| | May 12 | " | |
| | May 14 | Final Presentations | - |
| **Week 15** | May 17 | **no class** (Break Day) | - |
| | May 19 | Final Presentations | - |

**FINAL EXAM (comprehensive):** date and time TBD by the Registrar