

# PHYS 403/604 Fall 2023

## Solid State Physics

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**Office Hours:** Tuesday & Thursday: 11:30-12:30 pm.

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### **Course description (from the registrar)**

An introductory course in solid state physics. Topics include specific heat, chemical bonding, crystal structures and lattice vibrations, free electron gas, energy bands, insulators, semiconductors and metals.

I will assume that you have a working knowledge of multivariable Calculus, special functions, vector analysis, differential equations, Fourier series and Taylor series.

### **Course Overview**

In this course you will be given the opportunity to work on real world problems using toy models and utilizing some of the mathematical tools you have acquired in your physics and math courses. Solid state physics is an applied field that utilizes a lot of the knowledge you have already acquired in the lower-level physics core courses as well as Statistical Mechanics. We will also use concepts and techniques of Quantum Mechanics. I understand that some of you have not yet completed this course. I will do my best to explain the concepts and provide as much background as needed but at some instances you will have to accept some facts until you are formally taught these techniques in the relevant class.

### **Learning Objectives:**

After successfully completing this class, you should be able to:

Understand how solids are held together and how their structure is reflected in macroscopic observations.

Use toy models of spheres and springs to describe the structure and vibrations in solids.

Understand what makes a material an insulator, metal or semiconductor and appreciate the utilization of these three types of materials in modern technology.

## Textbooks

*The Oxford Solid State Basics* by Steven H. Simon.

## Course grade

Homework: 25%

Midterm: 20%

Final (cumulative): 30%

Final project: 20%

Presentation: 5%

*In principle, everyone can get an A. I will not curve the grades but may change (lower) the limits depending on the difficulty of the exams and homework*

### **PHYS 403**

A: score  $\geq 90$  %

B: 80 - 89 %

C: 70 – 79 %

D: 60 – 69 %

F: score < 60 %

### **PHYS 604**

A:  $\geq 93$  %, A-: 90 - 92%

B+:87-89% B:83-86 %, B-:80 - 82%

C+:77-79% C:73-76 %, C-:70 -72%

D+:67-69% D:63-66 %, D-:60 -62%

score < 60 %

## Course management

I will use **blackboard** to post course announcements, reading assignments and homework assignments, and post grades. Please do not use the digital dropbox. Send me an email instead.

## Course policies

### Reading assignments

Please come prepared to class. There is going to be a reading assignment for each lecture. I will not be able to cover every little part of the textbook. I will try to cover the most difficult and important points of each chapter. You are responsible for all the material in the chapter unless it has specifically been excluded.

### Term Paper and Oral Presentation:

- Term paper suggested length 10 pages APS Physical Review Journal format, with a minimum of 15 references. The paper should include an abstract, a description of the problem, its scientific significance and its current state. You will start with a topic relevant to Condensed Matter Physics and use everything we learned during the semester to build it on an independent module. The paper should have the “look and feel” of a real journal article: title, abstract, text, figures/figure-captions, equations, references, etc. I will run all submissions through SafeAssign.
- Oral Presentation: You will be the ‘Professor’ for that day teaching a regular class on the topic of your choice.

### Topic for term paper and oral (same topic for both):

You should not pick a topic directly related to your research.

- Magnetism and magnetic materials
- Applications of solid-state physics in energy generation
- Applications of solid-state physics in energy storage
- Superconductivity
- Superfluidity
- Semiconductor physics and devices
- Optical properties of materials and their applications
- Spin Dynamics and Transport in Gases and Solids
- 2D atomic crystals: physics and applications
- Topological quantum materials: physics and applications
- Physics at Surfaces
- Defects in materials

### Evaluation criteria for the paper and presentation

1. The selected topic is relevant to the class.
2. Enough background materials were covered.
3. The significance of the topic was clear.
4. The sequence of the material was logical.
5. Adequate references.
6. Good examples were used to illustrate key points.
7. The material was of appropriate depth/level.
8. The speaker spoke clearly, was well-paced and used appropriate volume.
9. The speaker understood the subject material presented.
10. The speaker was able to answer the questions thoroughly.

### Timeline:

**by Sep 18:** Email instructor topics of choice ranked 1-3.

**Sep 19:** Topics discussed in class. Possible revisions discussed.

**Oct 30:** First draft of paper to instructor.

**Nov 2:** Instructor will give feedback on drafts, with suggested modifications.

**Nov 29:** Final draft to instructor.

**Nov 30- Dec 12:** In-class presentations.

### Homework

Homework should be turned in at the beginning of the class period on the due date. Late homework will not be accepted under any circumstances. You should turn in well organized and neat solutions not your scrap paper. **Equations and results that are subsequently used and/or referred to should be numbered. Final result should be placed in a box. I WILL NOT GRADE MESSY HOMEWORK.**

I will assign about 8-10 homework sets in the course of the semester. It is to your advantage to do all the homework problems and though tempting **not to use** the solutions that are available through various sources. This is the only way to develop your problem-solving skills and be successful in the class. You can drop the lowest homework score. This should take care of any illness, job and family related emergencies or hangover issues.

I will grade homework for completeness and accuracy. In general, **each part** of a problem will be worth 3 points and the points will be assigned as follows:

3: complete solution and correct results is reached

2: mostly correct solution: start with the correct assumption but did not reach the correct result;

1: Valiant efforts but there are issues with the logic and understanding

0: had no clue but thought I should write anything related even tangentially

I will not provide complete solutions to the homework as I would like to use the same problems in the future iterations of the course. However, I will provide notes on your homework to get you on the right track and I am available to discuss the solutions during office hours.

**Graduate students taking this as PHYS 604 will be asked to do some additional homework.**

### Use of Mathematica (or any other math software):

I expect you to be able to carry out all the mathematical operations required in your homework manually. You can use Mathematica to confirm your results if you like but the solution should have all the mathematical steps included in detail. If you use Mathematica to skip steps in your derivations you will get a zero for the whole problem.

### Acceptable use of Mathematica:

You can use Mathematica as a reference tool, for example to look up integrals. I don't expect you to evaluate integrals analytically unless it is specifically asked. I use the "Schaum's Easy Outline of Mathematical Handbook of Formulas and Tables" routinely.

You can use Mathematica for plots.

### Cell phone use:

Please turn off your cell phone as soon as you get in class and keep your phone in your pocket. You are welcome not to come to class; I will not hold it against you. But when in class you are not to check email, text or post on Facebook.

### Exams

Exam solutions should be neat and organized, including explanations of what and why you are doing things (think **partial credit!!!**). Equations and results that are subsequently used and/or referred to should be numbered. **I will not grade sloppy solutions.**

All the exams are closed book. You can bring one single-sided page of your own handwritten notes for the midterm exam and a double-sided page for the final. The use of any electronic device is not allowed. Using such a device will be treated as cheating. Do not use any scrap paper of your own. You must turn off your cell phone during class and the exams. If you are caught using a cell phone during an exam you will be asked to turn in your paper.

### Midterm

There is going to be one midterm exam at a date to be announced. Make up exams will be given only if you miss the exam for a documented medical or legal problem or for a death in your immediate family. The instructor must be notified within 24 hours of the missed exam. Make up exams maybe oral or written.

### Final Exam

The final exam will be cumulative but will be primarily based on the material covered after the midterm. No make-up exam will be given for the final (see note on incompletes below).

### Incompletes

Please read carefully the catalog statement on acceptable grounds for incompletes. In this course, incompletes are given only if you miss the final exam due to a documented medical or legal problem or for a death in your immediate family. According to the catalog you must be doing "qualitatively satisfactory" work in order to qualify for an incomplete. For this course it means that your class averages is at least a C.

### General guidelines.

In order to be successful in the course you should be able to handle the mathematical aspect with ease. At the same time you need to have a good grasp of the physics concepts and be able to apply the principles you have been taught to treat systems that you may be unfamiliar with. If you are unsure about a concept or technique, try to review it from your old textbook, notes or see me for help. Ignoring a weakness will come back to haunt you. Come to class

prepared and ready to ask questions. I will not be able to cover every little topic but will focus on the most important points of each chapter.

Do not start on the homework the day before it is due. Giving yourself ample time to think about the problems and digest the material is important. Often you will catch yourself finding the solution to a “difficult” problem after thinking about it for some time, setting it aside and going back at it with a new approach. I do not discourage you from working in groups; however, to benefit the most you should go to your group’s meeting prepared. Discuss with your classmates the merits of the various approaches to solve a problem and make sure that you understand why you are following the approach you have chosen. Remember that during exams you will not be able to bounce ideas off each other. If uncertain on how to get started on a problem go through the reading materials carefully. You will most certainly find hints to get you going. The best way to prepare for an exam is to go over the lecture notes and homework problems then attempt a few extra ones from the compilation at the end of each chapter.

### Academic Integrity

By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal. To read the full Student Academic Conduct Policy, consult the UMBC Student Handbook, the Faculty Handbook, or the UMBC Policies section of the UMBC Director.

## **Enrollment Dates and Deadlines**

Students must be familiar with the academic policies and enrollment dates and deadlines as published in the [Undergraduate Catalog](#) and the [Academic Calendar](#). They are also responsible for managing their course enrollment(s) accordingly.

## **Accessibility and Disability Accommodations, Guidance and Resources**

Accommodations for students with disabilities are provided for all students with a qualified disability under the Americans with Disabilities Act (ADA & ADAAA) and Section 504 of the Rehabilitation Act who request and are eligible for accommodations. The Office of Student Disability Services (SDS) is the UMBC department designated to coordinate accommodations that creates equal access for students when barriers to participation exist in University courses, programs, or activities.

If you have a documented disability and need to request academic accommodations in your courses, please refer to the SDS website at [sds.umbc.edu](http://sds.umbc.edu) for registration information and office procedures.

SDS email: [disAbility@umbc.edu](mailto:disAbility@umbc.edu)

SDS phone: 410-455-2459

**If you will be using SDS approved accommodations in this class, please an appointment to meet with me to discuss implementation of the accommodations. During remote instruction requirements due to COVID, communication and flexibility will be essential for success.**

## Sexual Assault, Sexual Harassment, and Gender Based Violence and Discrimination

UMBC Policy in addition to federal and state law (to include Title IX) prohibits discrimination and harassment on the basis of sex, sexual orientation, and gender identity in University programs and activities. Any student who is impacted by sexual harassment, sexual assault, domestic violence, dating violence, stalking, sexual exploitation, gender discrimination, pregnancy discrimination, gender-based harassment, or related retaliation should contact the University's Title IX Coordinator to make a report and/or access support and resources. The Title IX Coordinator can be reached at [titleixcoordinator@umbc.edu](mailto:titleixcoordinator@umbc.edu) or 410-455-1717.

You can access support and resources even if you do not want to take any further action. You will not be forced to file a formal complaint or police report. Please be aware that the University may take action on its own if essential to protect the safety of the community.

If you are interested in making a report, please use the Online Reporting/Referral Form. Please note that, if you report anonymously, the University's ability to respond will be limited.

## Notice that Faculty and Teaching Assistants are Responsible Employees with Mandatory Reporting Obligations

All faculty members and teaching assistants are considered Responsible Employees, per UMBC's Policy on Sexual Misconduct, Sexual Harassment, and Gender Discrimination. Faculty and teaching assistants therefore required to report all known information regarding alleged conduct that may be a violation of the Policy to the Title IX Coordinator, even if a student discloses an experience that occurred before attending UMBC and/or an incident that only involves people not affiliated with UMBC. Reports are required regardless of the amount of detail provided and even in instances where support has already been offered or received.

While faculty members want to encourage you to share information related to your life experiences through discussion and written work, students should understand that faculty are

required to report past and present sexual harassment, sexual assault, domestic and dating violence, stalking, and gender discrimination that is shared with them to the Title IX Coordinator so that the University can inform students of their rights, resources, and support. While you are encouraged to do so, you are not obligated to respond to outreach conducted as a result of a report to the Title IX Coordinator.

If you need to speak with someone in confidence, who does not have an obligation to report to the Title IX Coordinator, UMBC has a number of Confidential Resources available to support you:

Retriever Integrated Health (Main Campus): 410-455-2472; Monday – Friday 8:30 a.m. – 5 p.m.; For After-Hours Support, Call 988.

Center for Counseling and Well-Being (Shady Grove Campus): 301-738-6273; Monday-Thursday 10:00a.m. – 7:00 p.m. and Friday 10:00 a.m. – 2:00 p.m. (virtual) Online Appointment Request Form

Pastoral Counseling via The Gathering Space for Spiritual Well-Being: 410-455-6795; i3b@umbc.edu; Monday – Friday 8:00 a.m. – 10:00 p.m.

### Other Resources

Women's Center (open to students of all genders): 410-455-2714; womenscenter@umbc.edu; Monday – Thursday 9:30 a.m. – 5:00 p.m. and Friday 10:00 a.m. – 4 p.m.

Shady Grove Student Resources, Maryland Resources, National Resources.

## Child Abuse and Neglect

Please note that Maryland law and UMBC policy require that faculty report all disclosures or suspicions of child abuse or neglect to the Department of Social Services and/or the police even if the person who experienced the abuse or neglect is now over 18.

## Pregnant and Parenting Students

UMBC's Policy on Sexual Misconduct, Sexual Harassment and Gender Discrimination expressly prohibits all forms of discrimination and harassment on the basis of sex, including pregnancy. Resources for pregnant, parenting and breastfeeding students are available through the University's Office of Equity and Civil Rights. Pregnant and parenting students are encouraged to contact the Title IX Coordinator to discuss plans and ensure ongoing access to their academic program with respect to a leave of absence – returning following leave, or any other accommodation that may be needed related to pregnancy, childbirth, adoption, breastfeeding, and/or the early months of parenting.

In addition, students who are pregnant and have an impairment related to their pregnancy that qualifies as disability under the ADA may be entitled to accommodations through the Office of Student Disability Services.

## **Religious Observances & Accommodations**

UMBC Policy provides that students should not be penalized because of observances of their religious beliefs, and that students shall be given an opportunity, whenever feasible, to make up within a reasonable time any academic assignment that is missed due to individual participation in religious observances. It is the responsibility of the student to inform the instructor of any intended absences or requested modifications for religious observances in advance, and as early as possible. For questions or guidance regarding religious observances and accommodations, please contact the Office of Equity and Civil Rights at [ecr@umbc.edu](mailto:ecr@umbc.edu).

## **Hate, Bias, Discrimination and Harassment**

UMBC values safety, cultural and ethnic diversity, social responsibility, lifelong learning, equity, and civic engagement.

Consistent with these principles, UMBC Policy prohibits discrimination and harassment in its educational programs and activities or with respect to employment terms and conditions based on race, creed, color, religion, sex, gender, pregnancy, ancestry, age, gender identity or expression, national origin, veterans' status, marital status, sexual orientation, physical or mental disability, or genetic information.

Students (and faculty and staff) who experience discrimination, harassment, hate, or bias based upon a protected status or who have such matters reported to them should use the online reporting/referral form to report discrimination, hate, or bias incidents. You may report incidents that happen to you anonymously. Please note that, if you report anonymously, the University's ability to respond may be limited.

## Individual Paper grading rubric

	Not addressed	Novice	Intermediate	Proficient
<b>Abstract</b>	•	<ul style="list-style-type: none"> <li>Not coherent or complete.</li> <li>Does not make you want to read the paper.</li> </ul>	<ul style="list-style-type: none"> <li>Complete but too long/short.</li> <li>Boring.</li> </ul>	<ul style="list-style-type: none"> <li>Informative, complete, concise.</li> <li>Makes you want to read the paper.</li> </ul>
<b>Formatting</b>	•	<ul style="list-style-type: none"> <li>Sloppy and/or no "look and feel of journal article".</li> <li>Hard to read.</li> </ul>	<ul style="list-style-type: none"> <li>Overall "journal article layout"</li> <li>Mediocre figures</li> <li>Mediocre eq's</li> </ul>	<ul style="list-style-type: none"> <li>Overall "look and feel" of a journal article.</li> <li>High-quality figures.</li> <li>Clear equations.</li> </ul>
<b>Organization</b>	•	<ul style="list-style-type: none"> <li>No use of sections</li> <li>Illogical ordering</li> </ul>	<ul style="list-style-type: none"> <li>Coherent chunks but non-optimal order.</li> <li>Hard to follow.</li> <li>Figures/equation use non-optimal.</li> </ul>	<ul style="list-style-type: none"> <li>Great use of sections.</li> <li>Coherent and logical flow of information.</li> <li>Excellent use and placement of figures and equations</li> </ul>
<b>Writing</b>	•	<ul style="list-style-type: none"> <li>Excessive typos.</li> <li>Poor sentence-level writing.</li> <li>Hard to read</li> </ul>	<ul style="list-style-type: none"> <li>Average grammar, and sentence-level writing.</li> <li>Few typos</li> <li>Logical and coherent</li> </ul>	<ul style="list-style-type: none"> <li>Perfect grammar, sentence structure, and paragraphs.</li> <li>Smooth transitions</li> <li>Easy to read</li> </ul>
<b>Physics</b>	•	<ul style="list-style-type: none"> <li>Incorrect physics.</li> <li>Gaps in explanation.</li> <li>Impossible to follow.</li> </ul>	<ul style="list-style-type: none"> <li>Correct but not particularly well-explained.</li> <li>Incomplete coverage.</li> <li>Hard to follow.</li> </ul>	<ul style="list-style-type: none"> <li>Well-explained, correct, interesting.</li> <li>Complete coverage of intended material.</li> <li>Easy to follow</li> </ul>