UNSW Course Outline

PHYS3118 Quantum Physics of Solids and Devices - 2024

Published on the 22 May 2024

General Course Information

Course Code : PHYS3118
Year : 2024
Term : Term 2
Teaching Period : T2
Is a multi-term course? : No
Faculty : Faculty of Science
Academic Unit : School of Physics
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Undergraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

The coupling of Solid State Physics and Quantum Physics is the basis for virtually all technological aspects of modern life. Quantum mechanics plays an important role in the properties of solids, and will be central to new generations of electronic devices across the

coming decades, e.g., quantum computers. Existing devices, such as laser diodes and superconducting quantum interference devices (SQUIDs), also exploit quantum phenomena for their operation. The course will appeal to those seeking a better contextual understanding of quantum mechanics and to learn about its real world applications: past, present and future. Through a series of lecture, tutorial and laboratory classes, this course covers three main areas. The first is 'The Quantum Physics of Solids', with topics including crystal structure, phonons as quantum oscillations, electrons as quantum particles in solids, band structure and unconventional materials. The second is 'Interactions in Quantum Systems', with topics including paramagnetism, diamagnetism and ferromagnetism, electron-electron interactions and their role in screening and plasmonic effects, and superconductivity. The third is 'From Semiconductors to Quantum Devices', with topics including charge carriers in semiconductors, p-n junctions and diodes, finite solids and heterojunctions, quantum confinement and low-dimensional devices, nanoelectronics.

Course Aims

This course aims to give an overview of the basic concepts of solid state physics. It will introduce a number of essential physics concepts that underlie the operation of all electronic, magnetic and superconducting devices.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : Describe the essential concepts of basic solid state physics.
CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.
CLO3 : Interpret the physics of particle-particle interactions in solids and explain how these interactions produce effects such as magnetism and superconductivity.
CLO4 : Explain the physics of semiconductors and how this is translated into modern functional electronic and magnetic device structures.
CLO5 : Produce and record quality experimental results in associated lab experiments, maintaining an accurate laboratory record of the process.

Course Learning Outcomes	Assessment Item
CLO1 : Describe the essential concepts of basic solid state physics.	• Laboratory • Assignment 1 • Weekly quiz • Final exam
CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.	• Laboratory • Assignment 1 • Weekly quiz • Final exam
CLO3 : Interpret the physics of particle-particle interactions in solids and explain how these interactions produce effects such as magnetism and superconductivity.	• Laboratory • Weekly quiz • Final exam
CLO4 : Explain the physics of semiconductors and how this is translated into modern functional electronic and magnetic device structures.	• Weekly quiz • Final exam
CLO5 : Produce and record quality experimental results in associated lab experiments, maintaining an accurate laboratory record of the process.	• Laboratory

Learning and Teaching Technologies

Moodle - Learning Management System

Learning and Teaching in this course

This course is taught by two lecturers A/Prof Rajib Rahman (Weeks 1-5) and Dr Maja Cassidy (Weeks 7-10).

Monday 10th June (Week 3) is a public holiday. There will be no lecuture on this day but a make-

up lecture will be scheduled at another time during the term. Please check Moodle announcements.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Laboratory Assessment Format: Individual	10%	
Assignment 1 Assessment Format: Individual	20%	Due Date: Week 5: 24 June - 30 June
Weekly quiz Assessment Format: Individual	20%	
Final exam Assessment Format: Individual	50%	

Assessment Details

Laboratory

Assessment Overview

You will complete 2 four-hour laboratory experiments over the term. Labs will be scheduled throughout the term. You will work in pairs. Assessments will be based on an oral assessment of the completion of preparation work, participation in the lab, and the written account. Marks will be allocated based on (i) an understanding of the underlying physical principles, (ii) the quality of the experimental results and analysis, and (iii) the presentation of the lab book.

Course Learning Outcomes

- CLO1 : Describe the essential concepts of basic solid state physics.
- CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.
- CLO3 : Interpret the physics of particle-particle interactions in solids and explain how these interactions produce effects such as magnetism and superconductivity.
- CLO5 : Produce and record quality experimental results in associated lab experiments, maintaining an accurate laboratory record of the process.

Assignment 1

Assessment Overview

You will receive an assignment in the first half of the course, based on the materials covered in the course up to that point.

You will have one week to complete the assignment, which is due one week after being made available.

The assignments will be marked and returned to you within two weeks.

Course Learning Outcomes

- CLO1 : Describe the essential concepts of basic solid state physics.
- CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.

Assignment submission Turnitin type

This is not a Turnitin assignment

Weekly quiz

Assessment Overview

You will complete 8 weekly quizzes over the term, with the content based on the previous week of lectures. The quizzes will be held in person in the 2 hour lecture block, and will go for 10 minutes. You will be able to bring hand written notes or print outs of the lecture slides. You will not be able to use a computer or an internet connected device, and must complete the quiz yourself without discussion.

The best 6 of 8 quiz marks will count towards your final grade.

Course Learning Outcomes

- CLO1 : Describe the essential concepts of basic solid state physics.
- CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.
- CLO3 : Interpret the physics of particle-particle interactions in solids and explain how these interactions produce effects such as magnetism and superconductivity.
- CLO4 : Explain the physics of semiconductors and how this is translated into modern functional electronic and magnetic device structures.

Final exam

Assessment Overview

You will sit a 20 minute oral examination on the complete course material (excluding laboratory work) with both academics present.

The exam will consist of 4 questions. You will be provided with a bank of questions similar to the exam questions at least 2 weeks in advance, and may include past exams, tutorials, and assignments.

In the oral examination you will be expected to concisely explain how you would go about solving the questions, if you were in a written examination. You may be asked to write any relevant

equations, and draw relevant diagrams on a whiteboard. Your examiners may ask follow-up questions to guide your answer. The exam will be recorded. Feedback is available after your final marks are released via direct consultation with the Course Convenor.

Course Learning Outcomes

- CLO1 : Describe the essential concepts of basic solid state physics.
- CLO2 : Apply the concepts and methods of solid state physics to analyse the structural, thermal and electronic properties of solids.
- CLO3 : Interpret the physics of particle-particle interactions in solids and explain how these interactions produce effects such as magnetism and superconductivity.
- CLO4 : Explain the physics of semiconductors and how this is translated into modern functional electronic and magnetic device structures.

General Assessment Information

Please see Moodle for details on how feedback will be provided for each assessment task.

Grading Basis

Standard

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 27 May - 2 June	Topic	Intro: What solids are, why they form, what the types are (crystal, amorphous, etc), basic structures. Bravais lattices, introduce k-space and reciprocal lattices. Phonons – 1D chain model. Group and phase velocities. Phonons in 3D, x-rays and neutrons as analytical techniques.
Week 2 : 3 June - 9 June	Topic	Specific heat – Debye and Einstein models. Electron heat capacity, Fermi distribution (what happens when you have lots of electrons). Bloch's theorem and what electrons see inside a crystal (very large finite quantum well). Nearly free electron model and where band structure comes from.
	Assessment	Quiz 1
Week 3 : 10 June - 16 June	Topic	Bands in solids, metals, semiconductors & insulators, effective mass, etc. Non-conventional crystals: molecular crystals, amorphous materials, quasi-crystals, graphene, layered 2Ds.
	Assessment	Quiz 2
Week 4 : 17 June - 23 June	Topic	The failure of band theory in describing magnetism: Magnetism and magnetic materials – basic properties, classifications. Paramagnetism and diamagnetism.
	Assessment	Quiz 3
Week 5 : 24 June - 30 June	Topic	Spin interactions continued: Ising models, ferromagnetism and antiferromagnetism. Dielectrics.
	Assessment	Quiz 4
	Assessment	Assignment 1 due
Week 6 : 1 July - 7 July	Activity	No lectures - reading week
Week 7 : 8 July - 14 July	Topic	Superconductivity: Properties of material (e.g., Meissner), basics of BCS. Josephson effect, SQUIDs, qubits and quantum sensors.
	Assessment	Quiz 5
Week 8 : 15 July - 21 July	Topic	Semiconductors: Density of states, bandstructure, intrinsic, doping, scattering, drift and diffusion, generation and recombination, continuity equation
	Assessment	Quiz 6
Week 9 : 22 July - 28 July	Topic	Semiconductor devices: p-n junctions, diodes, bipolar transistor, light emission, photovoltaics. Schottky barriers, MOSCAPs and MOSFETs
	Assessment	Quiz 7
Week 10 : 29 July - 4 August	Topic	Advanced semiconductor devices: Heterojunctions - HEMTs and semiconductor quantum well lasers. Quantum effects in devices with reduced dimensions. Quantum hall effect (2D), quantized conductance (1D), coulomb blockade (0D)
	Assessment	Quiz 8

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

Course Resources

Recommended Resources

- Hook & Hall: "Solid State Physics" (2nd edition) - Wiley
- Ibach and Lüth: "Solid State Physics" (4th Edition) - Springer
- Simon: “The Oxford Solid State Basics” - Oxford University Press
- Kittel: “Introduction to Solid State Physics”, 8th edition, Wiley
- Sze: "Physics of Semiconductor Device" 3rd edition, Wiley

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Lecturer	Rajib Rahman				Please email lecturers only for urgent matters and arranging a consultation time. Questions about course related matters should be posted on the appropriate Moodle discussion forum	No	No
Convenor	Maja Cassidy				Please email lecturers only for urgent matters and arranging a consultation time. Questions about course related matters should be posted on the appropriate Moodle discussion forum	No	Yes
Year coordinator	Elizabeth Angstmann					No	No
Lab director	Tamara Reztsova					No	No
Administrator	Zofia Krawczyk					No	No

Other Useful Information

Academic Information

Upon your enrolment at UNSW, you share responsibility with us for maintaining a safe, harmonious and tolerant University environment.

You are required to:

- Comply with the University's conditions of enrolment.
- Act responsibly, ethically, safely and with integrity.
- Observe standards of equity and respect in dealing with every member of the UNSW community.
- Engage in lawful behaviour.
- Use and care for University resources in a responsible and appropriate manner.
- Maintain the University's reputation and good standing.

For more information, visit the UNSW Student Code of Conduct Website.

Academic Honesty and Plagarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.
Further information about referencing styles can be located at https://student.unsw.edu.au/

referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits: honesty, trust, fairness, respect, responsibility and courage. At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.
Further information about academic integrity, plagiarism and the use of AI in assessments can be located at:

- The Current Students site,
- The ELISE training site, and
- The Use of AI for assessments site.

The Student Conduct and Integrity Unit provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct

Submission of Assessment Tasks

Penalty for Late Submissions

UNSW has a standard late submission penalty of:

- 5% per day,
- for all assessments where a penalty applies,
- capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, and
- no permitted variation.

Any variations to the above will be explicitly stated in the Course Outline for a given course or assessment task.

Students are expected to manage their time to meet deadlines and to request extensions as early as possible before the deadline.

Special Consideration

If circumstances prevent you from attending/completing an assessment task, you must officially apply for special consideration, usually within 3 days of the sitting date/due date. You can apply by logging onto myUNSW and following the link in the My Student Profile Tab. Medical documentation or other documentation explaining your absence must be submitted with your application. Once your application has been assessed, you will be contacted via your student

email address to be advised of the official outcome and any actions that need to be taken from there. For more information about special consideration, please visit: https://student.unsw.edu.au/special-consideration

Important note: UNSW has a "fit to sit/submit" rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit to do so and cannot later apply for Special Consideration. This is to ensure that if you feel unwell or are faced with significant circumstances beyond your control that affect your ability to study, you do not sit an examination or submit an assessment that does not reflect your best performance. Instead, you should apply for Special Consideration as soon as you realise you are not well enough or are otherwise unable to sit or submit an assessment.

Faculty-specific Information

Additional support for students

- The Current Students Gateway
- Student Support
- Academic Skills and Support
- Student Wellbeing, Health and Safety
- Equitable Learning Services
- UNSW IT Service Centre
- Science EDI Student Initiatives, Offerings and Guidelines