PHYS3180

Condensed Matter and Statistical Physics

Session 1, Special circumstances, North Ryde 2021

Department of Physics and Astronomy

Contents

Notice

As part of Phase 3 of our return to campus plan, most units will now run tutorials, seminars and other small group activities on campus, and most will keep an online version available to those students unable to return or those who choose to continue their studies online.

To check the availability of face-to-face activities for your unit, please go to timetable viewer. To check detailed information on unit assessments visit your unit's iLearn space or consult your unit convenor.

General Information

Unit convenor and teaching staff Lecturer and Unit Convenor Thomas Volz thomas.volz@mq.edu.au Contact via 8261 Senior Scientific Officer Gina Dunford regina.dunford@mq.edu.au Contact via 8971
Credit points 10
Prerequisites (PHYS201 or PHYS2010) and (PHYS202 or PHYS2020) and (MATH235 or MATH2010)
Corequisites PHYS301 or PHYS3010
Co-badged status

Unit description

This unit introduces basic thermodynamic principles and connects them with the physical laws and the statistical nature of the microscopic world governing the behaviour of the matter around us. We start out with the concept of temperature and investigate the emergence of the Boltzmann factor in the canonical ensemble. We then proceed with the kinetic theory of gases and discuss transport properties and thermal diffusion. The first and second law of thermodynamics form the foundation for understanding the basic working principles of thermodynamic engines. We next introduce three key pillars of statistical physics: the equipartition theorem, partition functions and the influence of distinguishability on the counting statistics of particles. This sets us up for a discussion of basic solid-state phenomena as they were known in early 20th century, including Debye theory of the heat capacity of solids, the basics of Drude transport theory and Sommerfeld's electron model.

In order to understand more intricate properties of solid crystals, the periodic nature of the underlying crystal lattice must be considered. The unit will first introduce the 1D solid as a model system for illustrating the basic consequence of having a periodic lattice. The powerful concept of reciprocal lattice is introduced and subsequently generalized to all three dimensions, with specific examples given for the different cubic lattice structures. Wave scattering by crystals and its connection to the reciprocal lattice is discussed with particular view to the X-ray experiment on offer in the labs. Electronic properties are mapped to the existence of band structure and the emergence of band-filling patterns in different materials. Finally, the unit concludes with a discussion of a couple of cutting-edge research topics in modern solid-state physics.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://students.mq.edu.au/important-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

ULO1: demonstrate an understanding of fundamental thermodynamic principles and their connection to the microscopic dynamics of matter, particularly for gases and crystalline solids.

ULO2: describe how the periodicity of a crystal affects measurable quantities such as heat capacity or conductivity, demonstrating insight into the concept of crystal momentum and its implications for band structures and scattering experiments.

ULO3: use mathematical descriptions based in real- and momentum-space to solve problems in scattering theory.

ULO4: discuss the connection between electronic band structure and certain material properties, with specific examples of low-dimensional electronic systems.

ULO5: carry out advanced labs, analysing, interpreting and reporting results in accordance with professional standards.

General Assessment Information

The 'estimated time on task' for each assessment item is an estimate of the *additional* time needed to complete each assessment outside of all scheduled learning activities. These estimates assume that you actively engage with all scheduled learning activities *and* spend an additional 31 hours of self-led study during the session.

If you receive special consideration for the final exam, a supplementary exam will be scheduled after the end of the normal exam period. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. Approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

Lab experiments and reports

Students will have to conduct four out of the seven following experiments available in the practical part of PHYS3180:

- Debye Temperature
- X-ray Diffraction
- Properties of Semiconductors
- Nuclear Magnetic Resonance
- Superconductors
- Peltier Cooling
- Fabrication and Imaging of 2D materials

Please note the following points

1. You are required to complete four of the experiments.
2. Students should make a booking for two lab sessions for each experiment they undertake. A booking gives priority provided the students arrive punctually at the start of the laboratory session.
3. A resource folder is available for each project, containing useful background information. These may be taken away from the lab, but must be returned within two weeks for other students to use.
4. You should refer to the document *Recommendations for Laboratory Report Writing* when preparing reports. Please ensure that your reports conform to these guidelines, and feel

free to discuss this with any of the staff. You are required to write reports for two of the four experiments, one for experiment 1 or 2, and one for experiment 3 or 4.

5. Reports should not contain text that has been copied from the instructional notes. You should provide background and discussion material in your own words. It is expected that you produce your own original figures wherever possible, either hand-drawn or computer generated. Anything taken from another source must be clearly acknowledged.
6. Besides two formal reports, you are required to write *extensive* (Python-based) electronic lab notes that provide the base for the lab report writing. After each 2-week experimental session, the electronic lab notes will be pulled and assessed (worth half of the total lab mark, that is 15% in total). The lab notes should reflect the in-class prac work.

Assessment Tasks

Name	Weighting	Hurdle	Due
Final exam	40%	No	to be determined
Assignments	30%	No	announced on iLearn
Lab reports	30%	No	announced on iLearn

Final exam

Assessment Type [1]: Examination
Indicative Time on Task [2]: 20 hours
Due: **to be determined**
Weighting: **40%**

Examination in the university exam period, covering the entire content from the unit.

On successful completion you will be able to:

- demonstrate an understanding of fundamental thermodynamic principles and their connection to the microscopic dynamics of matter, particularly for gases and crystalline solids.
- describe how the periodicity of a crystal affects measurable quantities such as heat capacity or conductivity, demonstrating insight into the concept of crystal momentum and

its implications for band structures and scattering experiments.

- use mathematical descriptions based in real- and momentum-space to solve problems in scattering theory.
- discuss the connection between electronic band structure and certain material properties, with specific examples of low-dimensional electronic systems.

Assignments

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 24 hours
Due: **announced on iLearn**
Weighting: **30%**

Problem sets, released every two weeks.

On successful completion you will be able to:

- demonstrate an understanding of fundamental thermodynamic principles and their connection to the microscopic dynamics of matter, particularly for gases and crystalline solids.
- describe how the periodicity of a crystal affects measurable quantities such as heat capacity or conductivity, demonstrating insight into the concept of crystal momentum and its implications for band structures and scattering experiments.
- use mathematical descriptions based in real- and momentum-space to solve problems in scattering theory.
- discuss the connection between electronic band structure and certain material properties, with specific examples of low-dimensional electronic systems.

Lab reports

Assessment Type [1]: Lab report
Indicative Time on Task [2]: 12 hours
Due: **announced on iLearn**
Weighting: **30%**

Documentation of experiments, including formal reports and digital labbook record.

On successful completion you will be able to:

- carry out advanced labs, analysing, interpreting and reporting results in accordance with professional standards.

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[1] If you need help with your assignment, please contact:

- the academic teaching staff in your unit for guidance in understanding or completing this type of assessment
- the Learning Skills Unit for academic skills support.

[2] Indicative time-on-task is an estimate of the time required for completion of the assessment task and is subject to individual variation

Delivery and Resources

Required textbook covering the week 1-6:

Concepts in Thermal Physics, 2nd edition, by S.J. & K.M. Blundell

Required textbook covering the week 7-13:

Oxford Solid State Basics, by Steven H. Simon.

Note: Lecture materials, additional reading and assignments will be posted to iLearn

Unit Schedule

Lecture content

- week 1: Temperature, Boltzmann Factor, kinetic theory of gases
- week 2: Kinetic theory of gases, transport and thermal diffusion
- week 3: 1st law and expansion process
- week 4: 2nd law and Carnot engine
- week 5: Equipartition theorem, partition function and distinguishability
- week 6: Heat capacity of solids, Debye theory
- week 7: Electron transport in solids, Drude model
- week 8: Sommerfeld theory of electrons
- week 9: 1D solid: phonons and electrons
- week 10: Crystal Structure & Reciprocal Lattice
- week 11: Wave Scattering by crystals
- week 12: Electrons in solids – band structure
- week 13: Topics from modern solid-state physics

Note: The division by week and topics is only approximate and will change depending on progress.

Labs schedule (location E7B 252)

- week 1: short online (ZOOM) intro session to introduce electronic lab books and the suite of experiments on offer
- week 2: experiment 1
- week 3: experiment 1
- week 4: free week to write draft report for experiment 1
- week 5: experiment 2
- week 6: experiment 2
- week 7: free week to write final report for experiment 1
- week 8: experiment 3
- week 9: experiment 3
- week 10: free week to write final report for experiment 2 or 3
- week 11: experiment 4
- week 12: experiment 4
- week 13: no experiments.

Schedule of assessable tasks and related materials

Assignments

The assignments will be handed out bi-weekly with the exact dates announced on iLearn.

Labwork

The due dates for lab reports will be announced in class and on iLearn well in advance.

NOTE:

We understand that at times due dates for assignments from several different units can collide and we are happy to accommodate changes in due dates, ***provided the request occurs well in advance of the due date***. Once the change has been agreed on, it cannot be moved again. A late penalty (-5% per day) applies after the due dates.

You are required to carry out four experiments, each taking no more than two weeks to complete, and to submit reports on two of them according to the deadlines announced in class and on iLearn. These dates are ***not negotiable except in cases of serious illness or misadventure***.

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://policies.mq.edu.au). Students should be aware of the following policies in particular with regard to

Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy

Students seeking more policy resources can visit Student Policies (https://students.mq.edu.au/support/study/policies). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

To find other policies relating to Teaching and Learning, visit Policy Central (https://policies.mq.edu.au) and use the search tool.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/admin/other-resources/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to help you improve your marks and take control of your study.

- Getting help with your assignment
- Workshops
- StudyWise
- Academic Integrity Module

The Library provides online and face to face support to help you find and use relevant information resources.

- Subject and Research Guides
- Ask a Librarian

Student Enquiry Service

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

Equity Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Changes from Previous Offering

For interested students, there might be the possibility to help set up a new teaching experiment on 2D materials. This option will be discussed in the introductory lab session.