



PHYS3180

Condensed Matter and Statistical Physics

Session 1, In person-scheduled-weekday, North Ryde 2022

School of Mathematical and Physical Sciences

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General Information

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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://www.mq.edu.au/study/calendar-of-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.

General Faculty Policy on assessment submission deadlines and late submissions:

Online quizzes, in-class activities, scheduled tests and exams must be undertaken at the time indicated in the unit guide. Should these activities be missed due to illness or misadventure, students may apply for Special Consideration.

All other assessments must be submitted by 5:00 pm on their due date.

Should these assessments be missed due to illness or misadventure, students should apply for Special Consideration.

Assessments not submitted by the due date will receive a mark of zero unless late submissions are specifically allowed as indicated in the unit guide or on iLearn.

If late submissions are permitted as indicated in the unit guide or on iLearn a consistent penalty will be applied for late submissions as follows:

A 12-hour grace period will be given after which the following deductions will be applied to the awarded assessment mark: 12 to 24 hours late = 10% deduction; for each day thereafter, an additional 10% per day or part thereof will be applied until five days beyond the due date. After this time, a mark of zero (0) will be given. For example, an assessment worth 20% is due 5 pm on 1 January. Student A submits the assessment at 1 pm, 3 January. The assessment received a mark of 15/20. A 20% deduction is then applied to the mark of 15, resulting in the loss of three (3) marks. Student A is then awarded a final mark of 12/20.

Specific assessment information regarding 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
<u>Final exam</u>	40%	No	during examination period
<u>Assignments</u>	30%	No	Issued approximately fortnightly and due 7-10 days later.
<u>Lab reports</u>	30%	No	week 7 & week 13

Final exam

Assessment Type **1**: Examination

Indicative Time on Task **2**: 20 hours

Due: **during examination period**

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: **Issued approximately fortnightly and due 7-10 days later.**

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: **week 7 & week 13**

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.

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 [Writing Centre](#) 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: Macrostates and microstates, thermodynamic equilibrium, the equilibrium state, and the zeroth law
- week 2: State and path variables; work, heat and the first law
- week 3: Ideal gas processes and heat capacity
- week 4: The second law, reversibility and engines
- week 5: Principles of statistical mechanics and the Boltzmann distribution
- week 6: Free energy and the partition function; The Planck distribution
- 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 t
- week 5: experiment 2

- week 6: experiment 2
- week 7: free week
- week 8: experiment 3
- week 9: experiment 3
- week 10: free week
- 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: 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. See above **General Faculty Policy on assessment submission deadlines and late submissions**.

Policies and Procedures

Macquarie University policies and procedures are accessible from [Policy Central \(https://policies.mq.edu.au\)](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](#)
- [Assessment Procedure](#)
- [Complaints Resolution Procedure for Students and Members of the Public](#)
- [Special Consideration Policy](#)

Students seeking more policy resources can visit [Student Policies \(https://students.mq.edu.au/support/study/policies\)](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 \(https://policies.mq.edu.au\)](https://policies.mq.edu.au)

[du.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

Academic Integrity

At Macquarie, we believe [academic integrity](#) – honesty, respect, trust, responsibility, fairness and courage – is at the core of learning, teaching and research. We recognise that meeting the expectations required to complete your assessments can be challenging. So, we offer you a range of resources and services to help you reach your potential, including free [online writing and maths support](#), [academic skills development](#) and [wellbeing consultations](#).

Student Support

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

The Writing Centre

[The Writing Centre](#) provides resources to develop your English language proficiency, academic writing, and communication skills.

- [Workshops](#)
- [Chat with a WriteWISE peer writing leader](#)
- [Access StudyWISE](#)
- [Upload an assignment to Studiosity](#)
- [Complete the 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 Services and Support

Macquarie University offers a range of [Student Support Services](#) including:

- [IT Support](#)

- [Accessibility and disability support](#) with study
- Mental health [support](#)
- [Safety support](#) to respond to bullying, harassment, sexual harassment and sexual assault
- [Social support including information about finances, tenancy and legal issues](#)

Student Enquiries

Got a question? Ask us via [AskMQ](#), or contact [Service Connect](#).

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 refine and further develop the newly established teaching experiment on 2D materials. This option will be discussed in the introductory lab session.