



# PHYS3180

## Condensed Matter and Statistical Physics

Session 1, In person-scheduled-weekday, North Ryde 2024

*School of Mathematical and Physical Sciences*

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#### Disclaimer

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## General Information

### Unit convenor and teaching staff

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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

### Planning your time

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.

### Requirements to Pass the Unit

There are no hurdle tasks specified in this unit. Consequently, the requirement to pass is to obtain an overall mark of at least 50% across the three assessment components.

#### Late Assessment Submission Penalty

Unless a Special Consideration request has been submitted and approved, a 5% penalty (of the total possible mark of the task) will be applied for each day a written assignment or laboratory report is not submitted, up until the 7th day (including weekends and holidays). After the 7th day, a grade of 0 will be awarded even if the assessment is submitted. The submission time for all uploaded assessments is 11:55 pm. A 1-hour grace period will be provided to students who experience a technical concern. For any late submission of time-sensitive tasks, such as scheduled tests/exams, and/or scheduled labs, please apply for Special Consideration.

### Specific assessment information regarding lab experiments and reports

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

- Debye Temperature
- X-ray Diffraction
- Properties of Semiconductors
- Nuclear Magnetic Resonance
- Superconductors

**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 set of resources folder is available for each project which can be downloaded from iLearn.
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.

**Special Consideration**

The Special Consideration Policy aims to support students who have been impacted by short-term circumstances or events that are serious, unavoidable and significantly disruptive, and which may affect their performance in assessment. If you experience circumstances or events that affect your ability to complete the written assessments in this unit on time, please inform the convenor and submit a Special Consideration request through [ask.mq.edu.au](http://ask.mq.edu.au).

**Assessment Tasks**

Name	Weighting	Hurdle	Due
<a href="#"><u>Assignments</u></a>	30%	No	2 weeks after release
<a href="#"><u>Final exam</u></a>	40%	No	Final examination period
<a href="#"><u>Lab reports</u></a>	30%	No	as advised in week 1

**Assignments**

Assessment Type **1**: Problem set

Indicative Time on Task <sup>2</sup>: 24 hours

Due: **2 weeks after release**

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.

## Final exam

Assessment Type <sup>1</sup>: Examination

Indicative Time on Task <sup>2</sup>: 20 hours

Due: **Final 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.

## Lab reports

Assessment Type <sup>1</sup>: Lab report

Indicative Time on Task <sup>2</sup>: 12 hours

Due: **as advised in week 1**

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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<sup>1</sup> 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.

<sup>2</sup> 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 weeks 1-7:

- *Oxford Solid State Basics*, by Steven H. Simon.

Reference book covering weeks 8-13:

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

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

## Communication

We will communicate with you via your university email or through announcements on iLearn. Queries to convenors can either be placed on the iLearn discussion board or emailed to your lecturers from your university email address.

## Unit Schedule

### Lecture content

- week 1: Electron transport in solids, Drude model
- week 2: Sommerfeld theory of electrons
- week 3: 1D solid: phonons and electrons
- week 4: Crystal Structure & Reciprocal Lattice
- week 5: Wave Scattering by crystals
- week 6: Electrons in solids – bandstructure
- week 7: Topics from modern solid-state physics
- week 8: Macrostates and microstates, thermodynamic equilibrium, the equilibrium state, and the zeroth law
- week 9: State and path variables; work, heat and the first law
- week 10: Ideal gas processes and heat capacity
- week 11: The second law, reversibility and engines
- week 12: Principles of statistical mechanics and the Boltzmann distribution
- week 13: Free energy and the partition function; The Planck distribution

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

### Labs schedule (location E7B 252)

- week 1: free week
- week 2: experiment 1
- week 3: experiment 1
- week 4: experiment 2
- week 5: experiment 2
- week 6: experiment 3
- week 7: free week (Easter)
- week 8: experiment 3
- week 9: experiment 4
- week 10: free week
- week 11: experiment 4
- week 12: free week
- week 13: no experiments.

## Policies and Procedures

Macquarie University policies and procedures are accessible from [Policy Central \(https://policie](https://policie)



[s.mq.edu.au](https://www.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) 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](https://ask.mq.edu.au) or if you are a Global MBA student contact [globalmba.support@mq.edu.au](mailto: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 Advocacy](#) provides independent advice on MQ policies, procedures, and processes

## 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/](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

We have changed the order of the topics, so that we begin with condensed matter, which leads to thermodynamics. This lays the basis for a natural development of the topics.

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Unit information based on version 2024.02 of the [Handbook](#)