



# PHYS702

## Statistical Physics

S1 Day 2018

*Dept of Physics and Astronomy*

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#### **Disclaimer**

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## General Information

Unit convenor and teaching staff

Unit convener and Lecturer

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Credit points

4

Prerequisites

Admission to MRes

Corequisites

Co-badged status

### Unit description

This unit presents an introduction to thermodynamics and statistical physics. The first half of the course begins with a definition of state functions and macroscopic variables such as temperature, pressure, and volume which characterise the state of a system, introducing the equation of state. Entropy is introduced via an information theoretic argument and applied to counting microstates of a system. We define the zeroth through the third laws of Thermodynamics and introduce the  $T dS$  relations. The role of potentials in simplifying thermodynamic predictions is explored. The concepts of reversible and irreversible engines and refrigeration cycles are covered in detail. We cover the ideal gas law and first order corrections for the Van der Waals gas. In the second half we introduce thermodynamical equilibrium as a postulate of statistical mechanics. We derive the partition function via the principle of maximum entropy. The Gibbs paradox is described as are macro, micro and grand canonical ensembles with examples using the ideal gas and Van der Waals gas. A short introduction is given to quantum statistical mechanics and Fermi-Dirac and Bose-Einstein distributions are derived. A range of interacting statistical systems such as ferromagnetism are explored and we introduce the study of order parameters and phase transitions.

## 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:

Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics

Understand the different levels of description of thermodynamics and statistical mechanics and how the former may be explained in terms of the latter. Construct models for selected physical systems using these descriptions.

Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.

Use the properties and mathematical descriptions of key systems including ideal gases, quantum gases, Bose and Fermi statistics and apply the concepts to physical systems

Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## General Assessment Information

If you receive [special consideration](#) for the final exam, a supplementary exam will be scheduled in the interval between the regular exam period and the start of the next session. 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. You can check the supplementary exam information page on FSE101 in iLearn ([bit.ly/FSESup](http://bit.ly/FSESup)) for dates, and approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

## Assessment Tasks

Name	Weighting	Hurdle	Due
<a href="#">Assignments</a>	20%	No	See Unit Schedule
<a href="#">Tutorial engagement</a>	10%	No	Weekly
<a href="#">Mid-semester test</a>	20%	No	Week 7
<a href="#">Final Examination</a>	50%	No	University Examination Period

## Assignments

Due: **See Unit Schedule**

Weighting: **20%**

Problem-solving is an essential aid to understanding the physical concepts and the mathematical tools that must be used in this unit. Regular assignments will be set and the problems marked and returned within two weeks. There will be six assignments over the semester.

Informal group discussion regarding the assignment problems is encouraged, but students should present their own solutions and should explicitly acknowledge those they have worked with on the assignment. The examinations may contain material related to the assignment work.

Students' individual engagement with assignment questions will be tested through the in-class tutorial presentations.

All marking is performed according to principles of standards-based assessment. Marks are awarded for evidence of correct understanding and analysis of problems. Marks are not normalized to any set distribution.

700-level students should not need to be reminded that working on problems is an essential part of any physics course. It is only by attempting problems that an understanding of new (and sometimes strange) concepts is obtained. Do not hesitate to seek help if you are having difficulties with the assignment problems.

**Extension Requests:** Given the importance we place on assignments as an aid to learning we expect assignments to be submitted on time. In turn, we undertake to return your assignments (provided they were submitted on time), marked and with feedback within two weeks of their due date. Extensions will only be considered if requested with valid reasons **prior to the due date**.

If for any reason a student is unable to submit an assignment by the due date, the student

should contact the relevant staff member as soon as possible, explain the situation, and request an extension.

On successful completion you will be able to:

- Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics
- Understand the different levels of description of thermodynamics and statistical mechanics and how the former may be explained in terms of the latter. Construct models for selected physical systems using these descriptions.
- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
- Use the properties and mathematical descriptions of key systems including ideal gases, quantum gases, Bose and Fermi statistics and apply the concepts to physical systems
- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Tutorial engagement

Due: **Weekly**

Weighting: **10%**

Each tutorial session, several students will present their attempts at either previous assignment questions or tutorial problems at the whiteboard.

Students will be assessed on the degree to which they have engaged with the problem, their ability to explain their thinking, and ability to draw on ideas and techniques from the course. The correctness of the final answer is secondary to these other issues.

Each student will be expected to present at the whiteboard on at least 3 to 4 occasions. All students will be expected to engage in the class discussion around these problems.

Grades will be announced periodically during the semester. The grading scheme is as follows:

0 - nil or near nil contribution and engagement  
1 - some ability to explain a tutorial problem - reasonably complete explanation of problem  
3 - very strong explanation capturing almost all ideas or featuring unexpected/creative insights into the issues.

On successful completion you will be able to:

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- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
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## Mid-semester test

Due: **Week 7**

Weighting: **20%**

An in-class test will be held in week 6 or 7 of 60 minutes duration.

This will test the principles and applications studied in the first part of the course.

On successful completion you will be able to:

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- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
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- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Final Examination

Due: **University Examination Period**

Weighting: **50%**

You should have a scientific calculator for use during the final examination. Note that calculators with text retrieval are not permitted for the final examination.

You are expected to present yourself for the final examination at the time and place designated in the University examination timetable (<http://www.timetables.mq.edu.au/exam/>). The timetable will be available in draft form approximately eight weeks before the commencement of examinations and in final form approximately four weeks before the commencement of examinations.

On successful completion you will be able to:

- Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics
- Understand the different levels of description of thermodynamics and statistical mechanics and how the former may be explained in terms of the latter. Construct models for selected physical systems using these descriptions.
- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
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- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Delivery and Resources

### Classes

Mixed Lecture and Tutorial/discussion

The timetable for classes can be found on the University web site at: <http://www.timetables.mq.edu.au/>

## Required and Recommended Texts and/or Materials

### Recommended Text

*Concepts in Thermal Physics* by Blundell & Blundell.

This is the same text as used in PHYS202. It will be used as a frequent reference but will not be followed through in a chapter-by-chapter approach.

### Additional References

*Statistical Mechanics* by K Huang, Wiley.

*Fundamentals of Statistical and Thermal Physics* by F Reif, McGraw-Hill

### Technology Used and Required

### Unit Web Page

This unit will be administered through iLearn at <http://ilearn.mq.edu.au/course/view.php?id=12028>. Please check this site regularly for lecture and extension material available for downloading and look out for announcements. We will run one or more discussion fora through the iLearn page for both technical physics and administrative issues. Staff will ignore emails and discussion questions about issues which are already explained in this document or which have been covered in the announcements and discussion features of the iLearn page.

## Teaching and Learning Strategy

The theoretical aspects of this unit are taught in lectures and tutorials with fortnightly assignments to strengthen the understanding of the material. The theoretical material is heavily mathematical in nature, and often abstract, and true understanding can only be achieved through testing and refining understanding through problem solving.

## Schedule of topics

A detailed plan of topics to be covered and learning goals for each of them will be available early in the session.

## Changes since the last offering of this unit

- We appreciate your feedback through the unit questionnaires, student-staff meetings, and any individual comments you may have.

## Unit Schedule

### Schedule of assessable tasks and related materials

#### Course structure

The topics of the course are roughly as follows week by week:

1. Brief introduction to large numbers, and principles of kinetic theory of gases. The Maxwell Boltzmann distribution.
2. Molecular velocity distribution and collisions. The Boltzmann Equation. Boltzmann's H theorem.
3. Molecular effusion and transport properties - viscosity, conductivity and diffusion.
4. Basic thermodynamic concepts: open/closed/isolated systems, microstates and macrostates, thermodynamic equilibrium and statistical entropy. Counting microstates and statistical temperature, microcanonical ensemble, explanation of equilibrium state.
5. Macroscopic thermodynamics: ideal gas, processes, state variables, internal energy and first law. Heat capacity. Law of Dulong and Petit. Irreversibility, extracting work, and the second law.
6. Entropy. Fundamental relation and Maxwell relations. Thermodynamic potentials. Chemical potential. Cooling real gases, Joule expansion, Joule-Kelvin expansion. Phase diagrams. Van der Waals gas, isotherms of the vdW gas, vdW gas-liquid transitions, Maxwell construction.
7. Introduction to Statistical Mechanics. Microcanonical, Canonical and Grand Canonical Ensembles. Partition functions.
8. Approximate methods of Statistical Mechanics.



9. Quantum gases. Identical particles, permutation symmetry, spin-statistics theorem, statistics of indistinguishable particles, Fermi vs Bose statistics, ideal Bose gas at high T, BEC, heat capacity of the Bose gas
10. Fermi gases; degenerate Fermi gases. Heat capacity of metals, Fermi pressure, Pauli paramagnetism.
11. Cold atomic and molecular gases. Methods of cooling. Selected applications.
12. Ising model, 2x2 toy model, exchange interactions, Ising Hamiltonian, Mean-field approximation, isotherms of the Ising model, compare vdW gas to Ising system.
13. Phase transitions and critical phenomena. Revision.

## Assignments

The assignments will be handed out according to the following approximate timetable

Assignment No.	Date available on iLearn	Date due
1 Dawes 1	Friday March 2	Friday March 16
2 Dawes 2	Thursday March 15	Friday March 30
3 Dawes 3	Thursday March 29	Friday April 27
4 Terno 1	Thursday April 26	Tuesday May 15
5 Terno 2	Thursday May 10	Friday May 25
6 Terno 3	Thursday May 24	Friday June 8

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.*

## Policies and Procedures

Macquarie University policies and procedures are accessible from [Policy Central \(https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central\)](https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central). 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](#) (**Note:** The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.)

Undergraduate students seeking more policy resources can visit the [Student Policy Gateway](https://students.mq.edu.au/support/study/student-policy-gateway) (<https://students.mq.edu.au/support/study/student-policy-gateway>). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit [Policy Central](http://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central) (<http://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central>).

## Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: <https://students.mq.edu.au/study/getting-started/student-conduct>

## Results

Results shown in *iLearn*, 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](http://ask.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](http://mq.edu.au/learningskills)) provides academic writing resources and study strategies to improve your marks and take control of your study.

- [Workshops](#)
- [StudyWise](#)
- [Academic Integrity Module for Students](#)
- [Ask a Learning Adviser](#)

## Student Services and 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.

## Student Enquiries

For all student enquiries, visit Student Connect at [ask.mq.edu.au](http://ask.mq.edu.au)

## 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.

## Graduate Capabilities

### PG - Capable of Professional and Personal Judgment and Initiative

Our postgraduates will demonstrate a high standard of discernment and common sense in their professional and personal judgment. They will have the ability to make informed choices and decisions that reflect both the nature of their professional work and their personal perspectives.

This graduate capability is supported by:

#### Assessment task

- Tutorial engagement

### PG - Discipline Knowledge and Skills

Our postgraduates will be able to demonstrate a significantly enhanced depth and breadth of knowledge, scholarly understanding, and specific subject content knowledge in their chosen fields.

This graduate capability is supported by:

#### Learning outcomes

- Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics
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- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
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- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

#### Assessment tasks

- Assignments
- Tutorial engagement
- Mid-semester test
- Final Examination

## PG - Critical, Analytical and Integrative Thinking

Our postgraduates will be capable of utilising and reflecting on prior knowledge and experience, of applying higher level critical thinking skills, and of integrating and synthesising learning and knowledge from a range of sources and environments. A characteristic of this form of thinking is the generation of new, professionally oriented knowledge through personal or group-based critique of practice and theory.

This graduate capability is supported by:

### Learning outcomes

- Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics
- Understand the different levels of description of thermodynamics and statistical mechanics and how the former may be explained in terms of the latter. Construct models for selected physical systems using these descriptions.
- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
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- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

### Assessment tasks

- Assignments
- Tutorial engagement
- Mid-semester test
- Final Examination

## PG - Research and Problem Solving Capability

Our postgraduates will be capable of systematic enquiry; able to use research skills to create new knowledge that can be applied to real world issues, or contribute to a field of study or practice to enhance society. They will be capable of creative questioning, problem finding and problem solving.

This graduate capability is supported by:

### Learning outcomes

- Interpret and apply the 0th-3rd laws of thermodynamics, some principal ideas from kinetic theory and the postulates of statistical mechanics
- Understand the different levels of description of thermodynamics and statistical

mechanics and how the former may be explained in terms of the latter. Construct models for selected physical systems using these descriptions.

- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, thermal and statistical physics.
- Use the properties and mathematical descriptions of key systems including ideal gases, quantum gases, Bose and Fermi statistics and apply the concepts to physical systems
- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Assessment tasks

- Assignments
- Tutorial engagement
- Mid-semester test
- Final Examination

## PG - Effective Communication

Our postgraduates will be able to communicate effectively and convey their views to different social, cultural, and professional audiences. They will be able to use a variety of technologically supported media to communicate with empathy using a range of written, spoken or visual formats.

This graduate capability is supported by:

## Learning outcome

- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Assessment tasks

- Assignments
- Tutorial engagement

## PG - Engaged and Responsible, Active and Ethical Citizens

Our postgraduates will be ethically aware and capable of confident transformative action in relation to their professional responsibilities and the wider community. They will have a sense of connectedness with others and country and have a sense of mutual obligation. They will be able to appreciate the impact of their professional roles for social justice and inclusion related to national and global issues

This graduate capability is supported by:

## Learning outcome

- Present physical arguments in thermostatics through explanation of tutorial and assignment questions at the whiteboard.

## Assessment task

- Tutorial engagement

## Changes from Previous Offering

Some additional material on kinetic theory is included in the first part of the unit, and the topic arrangement in the two halves of the unit has been adjusted. Some changes to content of the second part of the unit will be made to emphasise the fundamental principles.

## Feedback

### Feedback mechanisms

The Physics Department values quality teaching and engages in periodic student evaluations of its units, external reviews of its programs and course units, and seeks formal feedback from students via focus groups and meetings with the student group. Please consider attending such meetings, with the purpose of improving teaching via student feedback.

## Requirements in order to complete the unit satisfactorily

To pass the course unit you must achieve a satisfactory standard overall

## Standards Expectation

### Grading

An aggregate standard number grade (SNG) corresponding to a pass (P) is required to pass this unit.

**High Distinction (HD, 85-100%):** provides consistent evidence of deep and critical understanding in relation to the learning outcomes. There is substantial originality and insight in identifying, generating and communicating competing arguments, perspectives or problem solving approaches; critical evaluation of problems, their solutions and their implications; creativity in application.

**Distinction (D, 75-84%):** provides evidence of integration and evaluation of critical ideas, principles and theories, distinctive insight and ability in applying relevant skills and concepts in relation to learning outcomes. There is demonstration of frequent originality in defining and analysing issues or problems and providing solutions; and the use of means of communication appropriate to the discipline and the audience.

**Credit (Cr, 66-74%):** provides evidence of learning that goes beyond replication of content

knowledge or skills relevant to the learning outcomes. There is demonstration of substantial understanding of fundamental concepts in the field of study and the ability to apply these concepts in a variety of contexts; plus communication of ideas fluently and clearly in terms of the conventions of the discipline.

**Pass (P, 50-65%):** provides sufficient evidence of the achievement of learning outcomes. There is demonstration of understanding and application of fundamental concepts of the field of study; and communication of information and ideas adequately in terms of the conventions of the discipline. The learning attainment is considered satisfactory or adequate or competent or capable in relation to the specified outcomes.

**Fail (F, 0-49%):** does not provide evidence of attainment of all learning outcomes. There is missing or partial or superficial or faulty understanding and application of the fundamental concepts in the field of study; and incomplete, confusing or lacking communication of ideas in ways that give little attention to the conventions of the discipline.

## Changes since First Published

Date	Description
19/02/2018	Minor change to description of assignments from 5 to 6 in the semester.