UNSW Course Outline

# PHYS3113 Thermal Physics and Statistical Mechanics - 2024

Published on the 05 Feb 2024

## General Course Information

**Course Code :** PHYS3113
**Year :** 2024
**Term :** Term 1
**Teaching Period :** T1
**Is a multi-term course? :** No
**Faculty :** Faculty of Science
**Academic Unit :** School of Physics
**Delivery Mode :** Multimodal
**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

Thermal physics and statistical mechanics are concerned with the study of macroscopic and mesoscopic systems. Both aim to understand the properties and processes that occur in such systems with large numbers of particles. Statistical mechanics links mesoscopic and macroscopic properties of systems of matter and radiation with the fundamental microscopic physics (classical and quantum mechanics). It puts the concepts of thermodynamics on a firm mechanical foundation. Its importance in the development of modern society, from engines to refrigeration to the smallest transistor, cannot be overestimated. Topics to be covered include: classical thermodynamics; kinetic theory of gases; laws of thermodynamics; heat engines, Carnot cycle, Carnot's theorem; classical entropy; thermodynamic potentials, Legendre transforms, Maxwell's relations; thermodynamic probability, Boltzmann entropy; Boltzmann distribution, Fermi-Dirac and Bose-Einstein distributions; partition functions, micro-canonical, canonical and grand canonical ensembles; heat capacity, phonons, paramagnetism; blackbody radiation; Bose-Einstein condensation; Fermi energy, free electrons and the Fermi gas. This course consists of lectures, tutorials, and laboratory work. While not a prerequisite, students who have studied classical mechanics may find some interesting parallels.

## Course Aims

The aim of this course is to provide a deep understanding of the probabilistic foundations of statistical mechanics and how large numbers of particles in a system changes its physics. Thermal physics introduces the fundamental concept of entropy, which is central to understanding energy transduction and the arrow of time. Statistical mechanics allows us to understand the microscopic considerations underpinning concepts such as entropy, and the vast difference in the statistical properties of fermions and bosons. Applications of these concepts include such diverse topics as blackbody radiation, paramagnetism and ferromagnetism, Bose-Einstein condensation and liquid helium. Theoretical methods will be emphasised throughout the course. The course is an ideal springboard to more advanced topics such as quantum transport theory and many-particle physics. This subject aims to prepare students for the study of advanced physics and research into modern sciences.

## Relationship to Other Courses

Pre-requisite(s): PHYS2111 or PHYS2110. You are expected to know the content of these courses, it is assumed knowledge.

Exclusion: PHYS2210, PHYS3021

# Course Learning Outcomes

| Course Learning Outcomes |
| --- |
| CLO1 : Apply the principles of classical thermodynamics and statistical mechanics to solve problems in physics |
| CLO2 : Explain the concept of entropy from a classical and statistical perspective. |
| CLO3 : Identify the collective properties of systems of matter and radiation at various scales. |
| CLO4 : Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic processes where many particles are involved. |
| CLO5 : Acquire and interpret experimental data on heat, work, and real gases in a modern laboratory setting. |

| Course Learning Outcomes | Assessment Item |
| --- | --- |
| CLO1 : Apply the principles of classical thermodynamics and statistical mechanics to solve problems in physics | • Mid-session test<br>• Weekly quizzes<br>• Final exam |
| CLO2 : Explain the concept of entropy from a classical and statistical perspective. | • Mid-session test<br>• Weekly quizzes<br>• Final exam |
| CLO3 : Identify the collective properties of systems of matter and radiation at various scales. | • Mid-session test<br>• Weekly quizzes<br>• Final exam |
| CLO4 : Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic processes where many particles are involved. | • Mid-session test<br>• Weekly quizzes<br>• Final exam |
| CLO5 : Acquire and interpret experimental data on heat, work, and real gases in a modern laboratory setting. | • Laboratory |

# Learning and Teaching Technologies

Moodle - Learning Management System

# Assessments

## Assessment Structure

| Assessment Item | Weight | Relevant Dates |
|---|---|---|
| Mid-session test<br>Assessment Format: Individual | 15% | |
| Weekly quizzes<br>Assessment Format: Individual | 15% | |
| Final exam<br>Assessment Format: Individual | 60% | |
| Laboratory<br>Assessment Format: Individual | 10% | |

## Assessment Details

### Mid-session test

<u>Assessment Overview</u>

A 50-minute in-class test to take place around [Week 4]. The test will consist of a few questions (with sub-parts) based on topics covered in the first few weeks of the lectures and tutorials. You will be expected to solve analytical problems as well as display understanding of the concepts covered to that point.

<u>Course Learning Outcomes</u>

- CLO1 : Apply the principles of classical thermodynamics and statistical mechanics to solve problems in physics
- CLO2 : Explain the concept of entropy from a classical and statistical perspective.
- CLO3 : Identify the collective properties of systems of matter and radiation at various scales.
- CLO4 : Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic processes where many particles are involved.

<u>Assessment Length</u>

50 minutes

### Weekly quizzes

<u>Assessment Overview</u>

Quizzes will be held in lectures most weeks to provide you with regular feedback about progress in the course. The best six quiz marks will be counted towards your the final grade.

<u>Course Learning Outcomes</u>

- CLO1 : Apply the principles of classical thermodynamics and statistical mechanics to solve

problems in physics
- CLO2 : Explain the concept of entropy from a classical and statistical perspective.
- CLO3 : Identify the collective properties of systems of matter and radiation at various scales.
- CLO4 : Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic processes where many particles are involved.

### Final exam

#### Assessment Overview

Students will sit a 2-hour final exam during the exam period. It will consist of several questions requiring analytical solutions which may include diagrams or graphs. All topics from lectures and tutorials may be assessed.

#### Course Learning Outcomes

- CLO1 : Apply the principles of classical thermodynamics and statistical mechanics to solve problems in physics
- CLO2 : Explain the concept of entropy from a classical and statistical perspective.
- CLO3 : Identify the collective properties of systems of matter and radiation at various scales.
- CLO4 : Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic processes where many particles are involved.

### Laboratory

#### Assessment Overview

You will be expected to complete 2 four-hour laboratory experiments over the term. The first is generally scheduled within the first three weeks of the term, while the second Is generally scheduled during weeks 4 to 8. Each lab is worth 5%. Assessments will be based on the written account and accompanying interview with an academic marker in the week after the experiment. 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. Feedback is provided on the same day as the interview.

#### Course Learning Outcomes

- CLO5 : Acquire and interpret experimental data on heat, work, and real gases in a modern laboratory setting.

## General Assessment Information

Please note that the marks in Moodle are raw marks and may be subjected to moderation in order to calculate your final mark.

**Grading Basis**

Standard

# Course Schedule

| Teaching Week/Module | Activity Type | Content |
|---|---|---|
| Week 1 : 12 February - 18 February | Topic | Introduction, concepts and definitions, processes, kinetic theory of gases. Ideal gas, temperature, thermal equilibrium. |
| Week 2 : 19 February - 25 February | Topic | Work, heat, first law of thermodynamics & applications, heat engines, efficiency, Carnot cycle, Carnot theorem, magnetic systems. |
| Week 3 : 26 February - 3 March | Topic | Second law of thermodynamics, entropy, formal framework of thermodynamics, thermodynamic potentials, van der Waals gas, phase transitions |
| Week 4 : 4 March - 10 March | Topic | Introduction to idea of statistical mechanics, Microstates, classical phase space, quantum mechanical ideal gas, ideal spin systems, counting accessible microstates, statistical definitions of entropy and temperature, entropy of ideal systems, third law of thermodynamics and temperature |
| Week 5 : 11 March - 17 March | Topic | Introduction to probability theory, change of (random) variables, binomial and Gaussian distribution. Ensembles. Ergodic theorem. Canonical ensemble, distribution, and partition function. Thermodynamic properties for a spin system using the canonical distribution. |
| Week 7 : 25 March - 31 March | Topic | Partition function and Helmholtz potential. Fluctuations, Boltzmann entropy, partition function for ideal gas. Grand canonical distribution, application to ideal gas, mean values. Partition function and grand sum, grand potential. |
| Week 8 : 1 April - 7 April | Topic | Quantum distributions for fermions and bosons. Fluctuations. Classical limit. Equation of state. Fermi energy. Fermi sphere in momentum space. Mean energy for T=0. Pressure of Fermi gas, stars and gravitational collapse of white dwarfs. |
| Week 9 : 8 April - 14 April | Topic | Low-temperature behaviour of chemical potential for ideal Bose gas. Tc for B-E condensation. E.M. radiation in a cavity, Planck distribution, radiation laws. Radiation pressure, equation of state for radiation in an enclosure. Phonons in crystalline solids, specific heat of a solid, Debye model. |

## Attendance Requirements

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

# Course Resources

## Recommended Resources

**Recommended:** H. Gould & J. Tobochnik, *Statistical and Thermal Physics: with Computer Applications*

**Other textbook references**:

`H. B. Callen, *Thermodynamics*

`A H Carter, *Classical and Statistical Thermodynamics*

E. Fermi, *Thermodynamics*

F. Mandl, *Statistical Physics*

M. J. Hoch, *Statistical and Thermal Physics*

R. Kubo *Statistical Mechanics*

S. J. Blundell, *Concepts in Thermal Physics*

C. J. Thompson, *Mathematical and Statistical Mechanics*

F. Reif, *Fundamentals of Statistical and Thermal Physics*

M. Kardar, *Statistical Physics of Particles*

C. Kittel & H. Kroemer, *Thermal Physics*

# Staff Details

| Position | Name | Email | Location | Phone | Availability | Equitable Learning Services Contact | Primary Contact |
|---|---|---|---|---|---|---|---|
| Year coordinator | Elizabeth Angstmann | | | | | Yes | No |
| Administrator | Zofia Krawczyk | | | | | No | No |
| Lab supervisor | Tamara Reztsova | | | | | No | No |
| Lecturer | Paul Curmi | | | | | No | No |
| Convenor | Julian Berengut | | | | | No | Yes |

# 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](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