School of Physics

# Course Outline 2022

# PHYS3113

# Thermal Physics and Statistical Mechanics

School of Physics

Faculty of Science

T1, 2022

# 1. Staff

| Position | Name | Email | Consultation times and locations | Contact Details |
|---|---|---|---|---|
| Course Convenor | Prof. Paul Curmi | p.curmi@unsw.edu.au | Consultation times: by arrangement via email | |
| Lecturer | Assoc. Prof. Julian Berengut | julian.berengut@unsw.edu.au | Consultation times: by arrangement via email | |
| Laboratory Staff | Tamara Reztsova | t.reztsova@unsw.edu.au | School of Physics, Higher Year Lab, Room 142, Old Main Building | (02) 9385 4577 |
| Teaching Support Officer | Zofia Krawczyk-Bernotas | z.krawczyk-bernotas@unsw.edu.au | School of Physics office G06, Old Main Building | (02) 9065 5719 |
| Tutor | TBA | TBA | | |

# 2. Course information

Units of credit: 6

Pre-requisite(s): PHYS2111 or PHYS2110 Exclusion: PHYS2210, PHYS3021

Teaching times and locations:

http://timetable.unsw.edu.au/2022/PHYS3113.html

## 2.1 Course summary

Thermal physics and statistical mechanics is concerned with the study of macroscopic and mesoscopic systems. Both aim to understand the properties of systems and processes that occur in such systems. 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 foundation of mechanics. Its importance in the development of modern physics, from the understanding of stars to the smallest transistor, cannot be overestimated. Topics to be covered include: Classical thermodynamics. Kinetic theory of gases, ideal gas, van der Waals gas. First law of thermodynamics. Heat engines, Carnot cycle, Carnot's theorem. Classical entropy, second law of thermodynamics. Third law of thermodynamics. Postulate approach to classical thermodynamics, fundamental relation and its consequences. Alternative formulations, thermodynamic potentials, Legendre transforms, Maxwell's relations. Phase transitions stability criteria, Clausius-Clapeyron equation, Gibbs phase rule. Thermodynamic probability, Boltzmann entropy. Boltzmann distribution, Fermi-Dirac and Bose-Einstein distributions. Partition function. Micro-canonical, canonical and grand canonical ensembles. Heat capacity of diatomics, Einstein

and Debye models, phonons. Paramagnetism. Blackbody radiation. Bose-Einstein condensation, liquid helium. Fermi energy, free electrons and the Fermi gas.

## 2.2 Course aims

By the end of this course, students will have gained an understanding of the microscopic considerations underpinning concepts such as entropy and the vast difference in the statistical properties of fermions and bosons. They will have acquired an in-depth knowledge of 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 will prepare students for the study of advanced physics and research into modern sciences.

**Graduate Attributes Developed in this Course**

- Research, inquiry and analytical thinking abilities
- Capability and motivation for intellectual development
- Information literacy

## 2.3 Course learning outcomes (CLO)

At the successful completion of this course you (the student) should be able to:

1. Apply the principles of classical thermodynamics and statistical mechanics to solve problems in physics.
2. Explain the concept of entropy from a classical and statistical perspective.
3. Identify the collective properties of systems of matter and radiation at various scales.
4. Explain the link between microscopic physics (classical and quantum mechanics) and macroscopic and mesoscopic processes.
5. Acquire and interpret experimental data.

## 2.4 Relationship between course and program learning outcomes and assessments

Course learning outcomes 1-3 are assessed by the midsession test, assignment and final exam. These assessments are largely of a problem-solving nature designed to determine students' ability to deploy acquired knowledge to new situations, which is a key graduate attribute for successful physics-trained graduates. Course learning outcomes 1 and 4 are also assessed via the laboratory component of the assessment.

# 3. Strategies and approaches to learning

## 3.1 Learning and teaching activities

## Assumed Knowledge

PHYS2111 or PHYS2110

## Timetable

Lectures: 3 lectures per week: 1 x 2hr (Week 1-5, 7-9), 2 x 1hr (Weeks 1-5, 7-8, 10)

Tutorial: 1 x 1 hr per week (Weeks 1-5, 7-10)

Laboratory: 2 x 4 hr per term

**Lecture Timetable**

***Lecturer:*** This course is taught by two lecturers teaching 20 hours each.

| ***Day*** | ***Time*** | ***Location*** | ***Weeks*** |
|---|---|---|---|
| Monday | 0900-1100 | Webster Theatre B (K-G15-290) | 1-4, 5, 7-9 |
| Thursday | 1300-1400 | Physics Theatre (K-K14-19) | 1-4, 5, 7-9, 10 |
| Friday | 1300-1400 | Keith Burrows Theatre (K-J14-G5) | 1-4, 5, 7-8, 10 |

**Other:**

| | | | |
|---|---|---|---|
| Tuesday | 1000-1200 | Webster Theatre B (K-G15-290) | 10 |

**Tutorial:**

| ***Day*** | ***Time*** | ***Location*** | ***Weeks*** |
|---|---|---|---|
| Monday | 1200-1300 | Keith Burrows Theatre (K-J14-G5) | 1-5, 7- 9 |

**Note:** Zoom link will be provided for any students who cannot come to campus, and will also be made available for students to access in their own time.

## Laboratory Information

| ***Day*** | ***Time*** | ***Location*** | ***Weeks*** |
|---|---|---|---|
| Wednesday | 0900-1300; 1400-1800 | Old Main Building (K-K15-142) | 1-5, 7-10 |
| Thursday | 0900-1300; 1400-1800 | Old Main Building (K-K15-142) | 1-5, 7-10 |

The laboratory component of the course will be held in the Physics Laboratory, Room 142, Old Main Building. For details about labs, see http://timetable.unsw.edu.au/2022/PHYS3113.html or contact Laboratory Staff or Student Advisor. The laboratory manager is Tamara Reztsova (t.reztsova@unsw.edu.au).

## 3.2 Expectations of students

Students are expected to attend 80% of all classes.

Academic misconduct will not be tolerated in any form in this course. Substantiated instances of cheating, plagiarism or copying of answers may result in a failure grade or significant deduction of marks. Please ensure you are fully familiar with the University's requirements and rules on plagiarism, which are detailed at http://student.unsw.edu.au/plagiarism. Claims of being unaware of the rules and/or the requirement for you to meeting them will not be accepted as mitigating circumstances.

The School endorses interactive group learning and fully understands that you may discuss the content of your courses including tutorial and assignment problems during your studies. However, submitted assignments should be your own work outlining your own reasoning and demonstrating your own knowledge related to the assessment. Copying will not be tolerated (we are good at spotting it); please ensure you know where the line between studying together and cheating on assessments lies. We will expect you to stay firmly on the correct side of that line.

# 4. Course schedule and structure

## Detailed Syllabus

| Week | Topic |
|---|---|
| Week 1: | Introduction, concepts and definitions, processes, kinetic theory of gases. Ideal gas, temperature, thermal equilibrium. |
| Week 2: | Work, heat, first law of thermodynamics & applications, heat engines, efficiency, Carnot cycle, Carnot theorem, magnetic systems. |
| Week 3: | Second law of thermodynamics, entropy, formal framework of thermodynamics, thermodynamic potentials, van der Waals gas, phase transitions |
| Week 4: | 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: | 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 6: | Flexibility week. |
| Week 7: | 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: | 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: | 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. |

# 5. Assessment

## 5.1 Assessment tasks

## Assessment

Course assessment comprises assignments, in-session test, laboratory and final examination.

| Assessment task | Length | Weight | Mark | Due date *(normally midnight on due date)* |
|---|---|---|---|---|
| **Assessment 1: Mid-session test** | 50 mins | 15% | | Thursday 17th March (Week 5) |
| **Assessment 2: Assignment** | | 15% | | Wednesday 20th April (Week 10) |
| **Assessment 3: Laboratory** | | 10% | | See note below regarding laboratory classes |
| **Assessment 4: Final Exam** | 2 hours | 60% | | See Exam Schedule – TBA |

**Laboratory Information**

2 labs for a total of 8 hours of lab in the term (2 x 4 hours) + laboratory report(s), marked in the week following the experiment. Marking will be done via Zoom.

Information about Special Consideration is available from https://student.unsw.edu.au/special-consideration

**Further information**

UNSW grading system: student.unsw.edu.au/grades

UNSW assessment policy: student.unsw.edu.au/assessment

## 5.2 Assessment criteria and standards

Please see Moodle for a marking rubric for each assessment task

## 5.3 Submission of assessment tasks

Unless otherwise specified, assignments should be submitted to your lecturer or posted in the School of Physics assignment box by 5pm on the due date. Assignments will not be accepted by email. Marks will be deducted for late assignments, at a rate of 10% of the maximum possible mark for the assignment per day. A weekend will count as two days. An assignment submitted after the solutions have been posted will automatically receive 0%.

A downloadable assignment cover sheet is available from https://www.physics.unsw.edu.au/current-students/cover-sheet

## 5.4. Feedback on assessment

Please see Moodle for details on how feedback will be provided for each assessment task

# 6. Academic integrity, referencing and plagiarism

**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 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.[1] 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 and **plagiarism** can be located at:

- The *Current Students* site student.unsw.edu.au/plagiarism**,** and
- The *ELISE* training site subjectguides.library.unsw.edu.au/elise

The *Conduct and Integrity Unit* provides further resources to assist you to understand your conduct obligations as a student: student.unsw.edu.au/conduct.

# 7. Readings and resources

**Prescribed:** M. J. Hoch, *Statistical and Thermal Physics*, CRC Press, available from UNSW Bookstore $102.

**Other textbook references**:

`H. B. Callen, *Thermodynamics*

`A H Carter, *Classical and Statistical Thermodynamics*

E. Fermi, *Thermodynamics*

F. Mandl, *Statistical Physics*

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

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*

[1] International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013.

## Other Resources

Lecture notes will be posted on the PHYS3113 Moodle page.

# 8. Administrative matters

**Communications**

Students should check their UNSW email account regularly as all official university communication will be sent to that address. Students should use their university email account when writing to UNSW staff and should always include their name and student number.

**Health and Safety**

The School of Physics is actively committed to the health, safety and welfare of its staff and students. Information on relevant UNSW Occupational Health and Safety policies and expectations is available at: www.ohs.unsw.edu.au and https://www.physics.unsw.edu.au/about/safety

**Recommended Internet Sites**

The School of Physics website is www.physics.unsw.edu.au. Under the "Current Students" link students will find information about degrees, courses, and assessment.

The University website my.unsw.edu.au provides links to the UNSW Handbook, Timetables, Calendars and other student information.

**Student Complaint Procedures**

UNSW has procedures for dealing with complaints. These aim to solve grievances as quickly and as close to the source as possible. Information is available here: student.unsw.edu.au/complaints. Staff who can assist include:

**School Contacts:**

Zofia Krawczyk-Bernotas
Teaching Support Manager
School of Physics
Room G06, OMB
z.krawczyk-bernotas@unsw.edu.au
Tel: 9065 5719

Prof Adam Micolich
Teaching Director
School of Physics
Room G57A, OMB
adam.micolich@gmail.com

Prof Susan Coppersmith
Head of School
School of Physics
s.coppersmtih@unsw.edu.au

A/Prof Julian Berengut
Honours Coordinator
School of Physics
julian.berengut@unsw.edu.au

# 9. Additional support for students

- The *Current Students* Gateway: student.unsw.edu.au
- Academic Skills and Support: student.unsw.edu.au/skills

- Student Wellbeing, Health and Safety: student.unsw.edu.au/wellbeing
- Disability Support Services: student.unsw.edu.au/disability
- UNSW IT Service Centre: www.it.unsw.edu.au/students