PHYS702

Statistical Physics

S1 Day 2014

Physics and Astronomy

Contents

General Information

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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 ferrormagnetism 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 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.
- Apply mathematical approaches to solve ideal and practical problems in thermal and statistical physics.
- Understand the properties and mathematical descriptions of key systems including ideal gases, quantum gases, Bose and Fermi statistics and apply the concepts to e.g. condensed matter systems.
- Present physical arguments in thermostatistics through explanation of tutorial and assignment questions at the whiteboard.

Assessment Tasks

Name	Weighting	Due
Assignments	15%	See Unit Schedule
Tutorial engagement	15%	Weekly
Mid-semester test	20%	Week 7
Final Examination	50%	University Examination Period

Assignments

Due: **See Unit Schedule**
Weighting: **15%**

As for all physics units, problem solving is an essential aid to understanding the physical concepts involved and the mathematical tools that must be used. Regular assignments will be set and the problems marked and returned within two weeks. There will be five 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. You should also note that the examination in general contains 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 a key 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. This will allow us to provide you feedback in time to aid your ongoing learning through the course. 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. If such contact is not made, then the student will be penalised 20% for each working day that the assignment is late (ie an assignment due on a Friday and handed in on a Monday is penalised as if it is one day late). As complete solutions for an assignment are usually handed out to the class a week after the assignment is due, an extension beyond a week is generally not possible, and in any case would receive a grade of zero.

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Tutorial engagement

Due: **Weekly**
Weighting: **15%**

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. We also expect students to be able to give a content summary of the previous lecture at the beginning of each class. These summaries are also assessed and will form part of the tutorial mark.

Grades will be announced periodically as we cycle through the class. The grading scheme is as follows:

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

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Mid-semester test

Due: **Week 7**
Weighting: **20%**

An in-class test will be held around 6-7 weeks into the course of 60 minutes duration.

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

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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.

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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 PHYS310. It will be used as a frequent reference but will not be followed through in a chapter-by-chapter approach.

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, the student liaison committee meeting, 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. Review of basic thermodynamic concepts: open/closed/isolated, microstates and macrostates, thermodynamic equilibrium and statistical entropy. The Zeroth law.
2. Counting microstates and statistical temperature, microcanonical ensemble, explanation of equilibrium state.
3. Macroscopic thermodynamics: ideal gas, system and environment, types of processes, state variables, internal energy and first law
4. Heat capacity. Law of Dulong and Petit. Irreversibility, extracting work, and the second law. Entropy and temperature. Heat engines and efficiency.
5. The Stirling engine in detail. Fundamental relation and Maxwell relations. Canonical ensemble and ensemble averages. Maxwell-Boltzmann distribution.
6. Equipartition. Thermodynamic potentials. Theory of paramagnetism. Indistinguishability and Gibbs paradox. Planck distribution and cosmic background radiation. Phonons and the Debye theory.
7. Chemical potential. Definition, particle exchange, grand potential, phase boundaries, chemical reactions.
8. Real gases. Van der Waals gas, isotherms of the vdW gas, Maxwell construction, law of corresponding states, Virial expansion, Lennard-Jones potential, Cooling real gases, Joule expansion, Joule-Kelvin expansion, liquefaction of gases, helium phase diagram.
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. Intermezzo from the research world: Seminar on atomic and molecular quantum gases, how to make an atomic BEC, optical potentials/lattices, Feshbach resonances, lattice systems as quantum simulators.
11. Fermi gases; degenerate Fermi gases, Sommerfeld expansion, heat capacity of metals, Fermi pressure, Pauli paramagnetism.
12. Ising model, 2x2 toy model, exchange interactions, Ising Hamiltonian, Mean-field approximation, isotherms of the Ising model, compare vdW gas to Ising system, Critical exponents.
13. Landau theory, LT of the Ising model, 1st order transitions, symmetry breaking, Landau-

Ginzburg, Fluctuations and Correlations near a phase transition. Revision.

Assignments

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

Assignment No.	Date available on iLearn	Date due
1 Steel 1	Friday March 14	Tuesday March 25
2 Steel 2	Friday March 28	Tuesday April 8
3 Steel 3	Friday April 11	Tuesday April 29
4 Volz 1	Friday May 2	Tuesday May 13
5 Volz 2	Friday May 16	Tuesday May 27

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. Students should be aware of the following policies in particular with regard to Learning and Teaching:

Academic Honesty Policy http://mq.edu.au/policy/docs/academic_honesty/policy.html

Assessment Policy http://mq.edu.au/policy/docs/assessment/policy.html

Grading Policy http://mq.edu.au/policy/docs/grading/policy.html

Grade Appeal Policy http://mq.edu.au/policy/docs/gradeappeal/policy.html

Grievance Management Policy http://mq.edu.au/policy/docs/grievance_management/policy.html

Disruption to Studies Policy http://www.mq.edu.au/policy/docs/disruption_studies/policy.html *The Disruption to Studies Policy is effective from March 3 2014 and replaces the Special Consideration Policy.*

In addition, a number of other policies can be found in the Learning and Teaching Category of 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/support/student_conduct/

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) 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

IT Help

For help with University computer systems and technology, visit http://informatics.mq.edu.au/help/.

When using the University's IT, you must adhere to the Acceptable Use Policy. The policy applies to all who connect to the MQ network including students.

Feedback

Student Liaison Committee

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 the Student Liaison Committee. Please consider being a member of this committee, which meets once during the semester (lunch provided), with the purpose of improving teaching via student feedback. The class will be asked to nominate two students as representatives for the PHYS301 unit on the student liaison committee. This nomination process will be conducted during lectures and the lecturer will forward the names to the Head of Department. The SLC meetings are minuted and student representatives receive copies of the minutes from the two preceding SLC meetings prior to the meeting. An update on the responses that have been made by the department to the feedback obtained at the two preceding SLC meetings are reported by the Head of Department at the beginning of each SLC meeting. These responses are also minuted. The feedback is acted upon in a number of ways mostly initiated via Department of Physics and Astronomy meetings, where decisions on actions are taken.

Requirements in order to complete the unit satisfactorily

To pass the course unit you must:

- achieve a satisfactory standard overall
- achieve a satisfactory standard in each component of the unit, i.e. in assignments, tutorial participation, mid-semester test, and the final examination.

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.