PHYS702

Statistical Physics

S1 Day 2017

Dept of Physics and Astronomy

Contents

General Information

Unit convenor and teaching staff
Unit convener
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By appointment

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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, 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.
- Apply mathematical approaches to solve ideal and practical problems in kinetic theory, 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.

General Assessment Information

If you apply for Disruption to Study for your final examination, you must make yourself available for the week of July 24 – 28, 2017. If you are not available at that time, there is no guarantee an additional examination time will be offered. Specific examination dates and times will be determined at a later date.

Assessment Tasks

Name	Weighting	Hurdle	Due
Assignments	20%	No	See Unit Schedule
Tutorial engagement	10%	No	Weekly
Mid-semester test	20%	No	Week 7
Final Examination	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 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. 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. If such contact is not made, then the student will be penalised 20% for each working day that the assignment is late.

On successful completion you will be able to:

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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.

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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.

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thermal and statistical physics.
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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.

On successful completion you will be able to:
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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 PHYS202 and 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, 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.
6. Irreversibility, extracting work, and the second law. Entropy. Fundamental relation and Maxwell relations. Canonical ensemble and ensemble averages. Thermodynamic potentials.
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. 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 3	Thursday March 16
2 Dawes 2	Thursday March 16	Thursday March 30
3 Dawes 3	Thursday March 30	Thursday April 27
4 Volz 1	Thursday April 27	Thursday May 11
5 Volz 2	Thursday May 11	Thursday May 25

6 Volz 3	Thursday May 25	Thursday 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. 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_2016.html

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

Complaint Management Procedure for Students and Members of the Public http://www.mq.edu.au/policy/docs/complaint_management/procedure.html

Disruption to Studies Policy (in effect until Dec 4th, 2017): http://www.mq.edu.au/policy/docs/disruption_studies/policy.html

Special Consideration Policy (in effect from Dec 4th, 2017): https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policies/special-consideration

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/

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.

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://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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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
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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

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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 thermostatistics 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 thermostatistics through explanation of tutorial and assignment questions at the whiteboard.

Assessment task

- Tutorial engagement

Changes from Previous Offering

Some additional material on kinetic theory will be included in the first part of the unit, and magnetic properties will be taught in the second part of the unit.

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
- 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.