PX265-7.5 Thermal Physics II

21/22

Department
Physics
Level
Undergraduate Level 2
Module leader
Paul Goddard
Credit value
7.5
Module duration
10 weeks
Assessment
Multiple
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Any macroscopic object we meet contains a large number of particles, each of which moves according to the laws of mechanics (which can be classical or quantum). Yet we can often ignore the details of this microscopic motion and use a few average quantities such as temperature and pressure to describe and predict the behaviour of the object. Why we can do this, when we can do this and how to do it are the subject of this module.

The most important idea in the field is due to Boltzmann, who identified the connection between entropy and disorder. The empirical laws of thermodynamics required the existence of entropy, but there was no microscopic definition for it. The module shows how the structure of equilibrium thermodynamics follows from Boltzmann's definition of the entropy and shows how, in principle, any observable equilibrium quantity can be computed. This microscopic theory (now called statistical mechanics) provides the basis for predicting and explaining all thermodynamic properties of matter.

[Module web page]

Module aims

The module introduces statistical mechanics and its central role in physics. It should give you an appreciation of Boltzmann's insights into the nature and role of entropy. You will see many of the ideas introduced here used in the description of the properties of matter in solid state, nuclear and astrophysics modules in the third and fourth years.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

1. Introduction to Statistical Mechanics: Systems and states: microstates. Fundamental assumptions of stat. mech.
2. Equilibrium State: Definition of entropy for closed system in equilibrium. Maximization of entropy of a closed system in equilibrium. Fluctuations and Large Systems
3. Boltzmann distribution and Lagrange multipliers: Partition function, Z. Evaluation of Z for a spin-half system in a magnetic field and harmonic oscillator and system with degeneracy. Relationship of Z to thermodynamic quantities E, S and F=E-TS. Minimization of F in equilibrium for systems at fixed T and V. Microscopic basis for thermodynamics and relation to statistical mechanics.
4. Classical Thermodynamics of Gases: Thermal equilibrium, quasistatic and reversible changes. Statistical Mechanics of Classical Gases. Thermodynamic potentials G and H. The ideal gas law, the Gibbs paradox.
5. Grand-Canonical ensembles: system not closed (possibility of particle exchange between systems). Bose- Einstein and Fermi- Dirac distribution functions. Density of states. Chemical potential. Fermi energy. Relevance of Fermi-Dirac and Bose-Einstein to matter. Phonons: Einstein model, Debye model and dispersive phonons, role of elastic modulus, phonon heat capacity, thermal expansion. Thermal properties of the free Fermi gas.

Learning outcomes

By the end of the module, students should be able to:

- Give the definitions of thermal equilibrium, the ergodic hypothesis and the various ensembles
- Explain importance of the partition function and calculate thermodynamic averages from it (this includes the Fermi-Dirac and Bose-Einstein distributions)
- Discuss the structure of statistical mechanics and explain its relation to classical thermodynamics
- Explain the notion of degeneracy and the density of states.

Indicative reading list

Concepts in Thermal Physics by S. J. Blundell and K. M. Blundell (OUP, 2010).
Further reading: Statistical mechanics: a survival guide by A. M. Glazer and J. S. Wark (OUP, 2001);
Statistical Physics by A. M. Guenault (Springer, 2007).

[View reading list on Talis Aspire]

Subject specific skills

Knowledge of mathematics and physics. Skills in modelling, reasoning, thinking.

Transferable skills

Analytical, communication, problem-solving, self-study

Study

Study time

Type	Required
Lectures	20 sessions of 1 hour (27%)
Other activity	5 hours (7%)
Private study	50 hours (67%)
Total	75 hours

Private study description

Working through lecture notes, solving problems, wider reading, discussing with others taking the module, revising for exam, practising on past exam papers

Other activity description

4 problem classes

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Assessment group D1

	Weighting	Study time	Eligible for self-certification
Assessed Problems	15%		No

	Weighting	Study time	Eligible for self-certification
Assessed work as specified by department			
In-person Examination Answer 2 questions	85%		No

- Answerbook Green (8 page)
- Students may use a calculator

Assessment group R

	Weighting	Study time	Eligible for self-certification
In-person Examination - Resit	100%		No

- Students may use a calculator
- Answerbook Green (8 page)

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX265

Availability

Courses

This module is Core for:

- Year 2 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)
- Year 2 of UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
  - Year 2 of GF13 Mathematics and Physics
  - Year 2 of FG31 Mathematics and Physics (MMathPhys)
- Year 2 of UPXA-F300 Undergraduate Physics (BSc)
- UPXA-F303 Undergraduate Physics (MPhys)
  - Year 2 of F300 Physics
  - Year 2 of F303 Physics (MPhys)
- Year 2 of UPXA-F3N1 Undergraduate Physics and Business Studies
- Year 2 of UPXA-F3F5 Undergraduate Physics with Astrophysics (BSc)
- Year 2 of UPXA-F3FA Undergraduate Physics with Astrophysics (MPhys)
- Year 2 of UPXA-F3N2 Undergraduate Physics with Business Studies