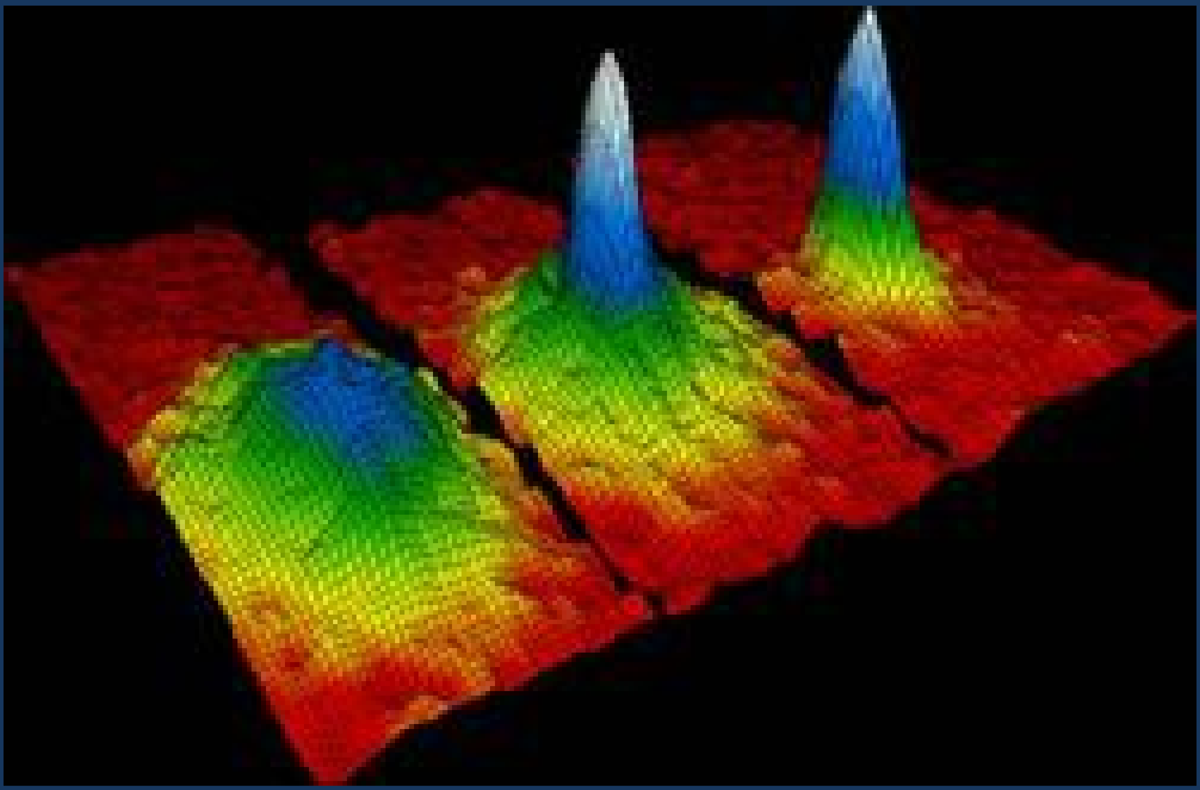
University of Glasgow | School of Physics & Astronomy



Velocity-distribution data for a gas of rubidium atoms,
showing the evolution of a Bose-Einstein condensate.

PHYS5016 Statistical Mechanics

Course Information Guide

1 Course Details

PHYS5016 Statistical Mechanics is a level 5M Physics Honours course. It consists of 18 lectures and 2 full class tutorials. Full details of how this course contributes to the physics degree options are given in the Honours Course Guide for Physics.

Lecturer: Professor D Ireland
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Recommended Reading:

A single text book is not chosen for this course, because there are several undergraduate texts which offer excellent insights and treatments. Some examples are given below; it may be possible to pick them up second hand on the web or find them in libraries. In addition, links will be given to electronic resources available via the University Library.

- Statistical Physics 2nd Ed, Tony Guenault, Springer ISBN 9781402059742 (GUL Physics TN40 1988-G)
- Introductory Statistical Mechanics, DS Betts and RE Turner, Addison Wesley ISBN 0201544210 (GUL Physics TN40 1992-B)
- Introductory Statistical Mechanics, Bowley and Sanchez, Oxford ISBN 0198505760 (pbk) (GUL Physics TN40 1999-B)
- Introduction to Statistical Physics, K. Huang, Chapman & Hall/CRC, ISBN 9781420079029
- Statistical Mechanics: A Survival Guide, A.M. Glazer and J.S. Wark, Oxford University Press ISBN 0198508166 (GUL Physics TN40 2001-G)

Course notes, supplementary material, and question sheets (with hints and full answers) are made available on Moodle.

2 Assessment

The course will be assessed via an examination in the April/May diet. It provides 10 M-level credits.

3 Required Knowledge

Students are expected to have completed thermodynamics lecture courses earlier in their career, and should be confident in mathematical analysis.

4 Intended Learning Outcomes

On completion of this course, students should have a quantitative understanding of the key concepts of statistical mechanics (detailed below in the course outline). Students should have demonstrable ability to apply the associated core techniques to complex physical systems in order to quantify their macroscopic properties in terms of a consideration of microscopic states. Students should be confident in deriving fundamental aspects of the course, including the definitions of the system energy, partition function, and entropy.

5 Course Outline

General overview: Statistical Mechanics investigates how the laws of thermodynamics and bulk properties of matter (the macroscopic observables) are related, via probabilistic assumptions, to the microscopic properties of the atomic and molecular constituents as described by quantum mechanics. The first half of the course addresses the solid state (in which particles are distinguishable), and the second half is concerned with gases.

5.1 Fundamental concepts

The fundamental steps in the statistical method are introduced, for an isolated system containing a fixed number of particles and a fixed total energy. Concepts of entropy, system energy and statistical temperature are developed. Microcanonical and canonical ensembles are defined, along with the canonical partition function. Relation to laws of thermodynamics. Connection between the partition function and temperature, entropy, energy, heat capacity, Helmholtz free energy, chemical potential. Energy fluctuations.

5.2 Canonical Partition function for simple systems

Starting with simple distinguishable particle systems, basic examples are studied that inform a broad range of physics. Two-state system, dipole in magnetic field, simple harmonic oscillator, rotor, single particle in a box. Multiplicative property of partition functions.

5.3 Lattice heat capacity of solids

An analysis of the Einstein and Debye models of a crystal, based on oscillators, and introducing the concept of the density of states, and the cut-off frequency for crystal lattices.

5.4 Distinguishable particles: the Statistical Mechanics of gases

The concept of counting of states for a gas of indistinguishable particles is introduced, along with the statistics of ensembles of fermions and bosons. The concept of a dilute gas is defined, and the Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann distribution functions are derived.

5.5 Classical Maxwell Boltzmann gas

Partition function, dilution validity, speed distribution, energy per particle, entropy, Sackur-Tetrode equation, Helmholtz free energy, pressure and connection with thermodynamics.

5.6 Fermi-Dirac and Bose-Einstein gases

Exploring the low-temperature extremes, define Fermi Temperature, zero-point energy, degeneracy pressure and relevance to compact objects in astrophysics. Fermi integrals for non-zero temperature, energy, pressure & heat capacity. Low temperature limit of Bose-Einstein gases, failure of the simple density of states description, formation of condensate, occupation number of the ground state, anomalies in specific heat & the lambda point. Photons as a boson gas, Planck radiation law, radiation energy density and pressure.