# PH3012 - Thermal and Statistical Physics

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| **Credits:** | 15.0 | **Semester:** | 2 |
| **Number of Lectures:** | 27 | **Lecturer:** | Prof Steve Lee and Dr Irina Leonhardt |
| **Academic Year:** | 2018-19 | | |

## Overview

Thermodynamics and Statistical Physics provide complementary approaches to understanding many-body states of matter. This course introduces the fundamental ideas and methods of both approaches and applies these to systems in thermal equilibrium, covering systems of both quantum mechanical and classical particles. Physical examples are used throughout to develop the ideas in a concrete way.

## Aims & Objectives

To present the fundamental ideas and methods of Thermodynamics and Statistical Physics, and to develop these through simple examples and applications. The presentation includes:

- Laws of thermodynamics
- Thermodynamic potentials and Maxwell's relations
- Application to simple thermodynamic systems
- Phase transitions and introduction to Landau theory
- Statistical ensemble of distinguishable particles and Boltzmann entropy
- Counting for particles with quantum statistics
- Important examples of statistical physics: paramagnets, heat capacity in crystals, ideal classical and quantum gases, Bose-Einstein condensation, and electrons in metals. White dwarfs and neutron stars.

## Learning Outcomes

By the end of the course the students will be expected to:

- State the laws of thermodynamics in their various forms and explain their physical significance.
- Derive and state Maxwell's relations and apply them to problems in thermodynamics.
- State the thermodynamic potentials and recognize the most appropriate potential for application to a particular problem.
- Have a basic appreciation of the thermodynamics of first and second order phase transitions.
- Derive and state the Boltzmann, Fermi-Dirac and Bose-Einstein distributions.
- Know the key links between thermodynamics and statistical physics and apply these to problems.
- Be able to explain the importance and significance of the partition function, and be able to construct partition functions for systems and extract thermodynamic properties from them.

## Synopsis

Zeroth and first laws of thermodynamics, ideal gas illustrating a simple equation of state, thermal equilibrium, quasistatic and reversible processes. Second law of thermodynamics. Maxwell’s relations. Overview of the thermodynamic potentials. Conditions for equilibrium. 3rd law of thermodynamics. Phase transitions.
Microstate, macrostate, statistical weight, postulate of equal a priori probability, equilibrium postulate, Boltzmann form for the entropy. Statistics of distinguishable particles, Boltzmann distribution, partition function, general definition of the entropy, Helmholtz free energy. The statistical mechanics of a two level system. Quantum statistics: Bose-Einstein and Fermi-Dirac, density of states, black-body radiation, Bose-Einstein condensation, Fermi energy. De Broglie wavelength and quantum behaviour, gases in the classical limit, Maxwell-Boltzmann distribution.

## Pre-requisites

PH3081 or PH3082 or (MT2506 and MT2507)

## Anti-requisites

None

**Assessment**
Continuous Assessment = 20%, 2 Hour Examination = 80%

**Additional information on continuous assessment etc.**

Please note that the definitive comments on continuous assessment will be communicated within the module. This section is intended to give an indication of the likely breakdown and timing of the continuous assessment.

This module is part of the core JH programme, and as such there is a summary of deadlines etc on the School's Students and Staff web pages. Students have compulsory tutorials every two weeks, with hand-in tutorial work counting for 20% of the module mark.

**Accreditation Matters**
This module contains material that is or may be part of the IOP "Core of Physics". This includes
Probability distributions
Black body radiation
Entropy, free energies and the Carnot Cycle
Kinetic theory of gases and the gas laws to Van der Waals equation
Statistical basis of entropy
Maxwell-Boltzmann distribution
Bose-Einstein and Fermi-Dirac distributions
Density of states and partition function

**Recommended Books**
Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph3012.html

**General Information**
Please also read the general information in the School's honours handbook.