PX284-15 Statistical Mechanics, Electromagnetic Theory and Optics

24/25

Department
Physics
Level
Undergraduate Level 2
Module leader
Paul Goddard
Credit value
15
Module duration
20 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 discussed in the first half of this module.

In the second half of the module, we develop the ideas of first year electricity and magnetism into Maxwell's theory of electromagnetism. Establishing a complete theory of electromagnetism has proved to be one the greatest achievements of physics. It was the principal motivation for Einstein to develop special relativity, it has served as the model for subsequent theories of the forces of nature and it has been the basis for all of electronics (radios, telephones, computers, the lot...).

Module web page

Module aims

The module should study Maxwell's equations and their solutions and introduce statistical mechanics and its central role in physics.

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.

I. Electromagnetic Theory and Optics: Ampere's law, Faraday/Lenz's law, Gauss's law in differential form. Need for the displacement current. Statement of Maxwell's equations. Maxwell equations in vacuum and in matter. Magnetisation and polarization of materials. Relation of E and P, B and M. Solutions to Maxwell equations in vacuum. Electromagnetic waves, Poynting vector, intrinsic impedance, polarisation. Boundary conditions. Interfaces between dielectrics, separation into perpendicular and parallel components. Refractive index. Ohm's law. Interface with a metal, skin effect.
Optics: reflection and refraction. Wavefronts at plane and spherical surfaces. Lenses. Basics of optical instruments, resolution.

II. Statistical Mechanics: Systems and states: microstates. Fundamental assumptions of stat. mech. Equilibrium State. Definition of entropy for closed system in equilibrium. Maximization of entropy of a closed system in equilibrium. Fluctuations and Large Systems. 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. 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. 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.

Learning outcomes

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

- Write down and manipulate Maxwell's equations in integral or differential form and derive the boundary conditions at boundaries between linear isotropic materials
- Derive the plane-wave solutions to Maxwell's equations in free space, dielectrics and ohmic conductors
- Describe the interaction of light with optical materials and explain the basics of geometrical optics
- Explain the ergodic hypothesis and define thermal equilibrium for various ensembles
- Define 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

Indicative reading list

Young and Freedman, University Physics 11th Edition
IS Grant and WR Phillips, Electromagnetism
E Hecht, Optics
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	40 sessions of 1 hour (27%)
Other activity	20 hours (13%)
Private study	90 hours (60%)
Total	150 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

14 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
Coursework Assessed work as specified by department	15%	
Statistical Mechanics, Electromagnetic Theory and Optics Answer 4 questions	85%	

- Answerbook Pink (12 page)
- Students may use a calculator

Assessment group R1

	Weighting	Study time
In-person Examination - Resit Answer 4 questions	100%	

- Answerbook Pink (12 page)
- Students may use a calculator

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX284

Availability

Courses

This module is Core for:

- UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
  - Year 2 of GF13 Mathematics and Physics
  - Year 2 of GF13 Mathematics and Physics
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
  - Year 2 of FG31 Mathematics and Physics (MMathPhys)
  - Year 2 of FG31 Mathematics and Physics (MMathPhys)

- UPXA-F300 Undergraduate Physics (BSc)
    - Year 2 of F300 Physics
    - Year 2 of F300 Physics
    - Year 2 of F300 Physics
- UPXA-F303 Undergraduate Physics (MPhys)
    - Year 2 of F300 Physics
    - Year 2 of F303 Physics (MPhys)
- UPXA-F3F5 Undergraduate Physics with Astrophysics (BSc)
    - Year 2 of F3F5 Physics with Astrophysics
    - Year 2 of F3F5 Physics with Astrophysics
- Year 2 of UPXA-F3FA Undergraduate Physics with Astrophysics (MPhys)
- Year 2 of UPXA-F3N2 Undergraduate Physics with Business Studies

This module is Optional for:

- Year 2 of UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
- UMAA-G100 Undergraduate Mathematics (BSc)
    - Year 2 of G100 Mathematics
    - Year 2 of G100 Mathematics
    - Year 2 of G100 Mathematics
- UMAA-G103 Undergraduate Mathematics (MMath)
    - Year 2 of G100 Mathematics
    - Year 2 of G103 Mathematics (MMath)
    - Year 2 of G103 Mathematics (MMath)
- Year 2 of UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
- Year 2 of UMAA-G1NC Undergraduate Mathematics and Business Studies
- Year 2 of UMAA-G1N2 Undergraduate Mathematics and Business Studies (with Intercalated Year)
- Year 2 of UMAA-GL11 Undergraduate Mathematics and Economics
- Year 2 of UECA-GL12 Undergraduate Mathematics and Economics (with Intercalated Year)
- Year 2 of UMAA-G101 Undergraduate Mathematics with Intercalated Year