PH2012 - Physics 2B

Credits:	30.0	**Semester:**	2
Number of Lectures:	48	**Lecturer:**	Dr Paul Cruickshank (module co-ordinator), Dr Bruce Sinclair, Dr Charles Baily and Dr Cameron Rae (lab co-ordinator)
Academic Year:	2018-19		

Overview
This module covers the subjects of classical waves, quantum physics and electricity and magnetism. It is suitable for those who have taken the specified first year modules in physics and mathematics, or have good Advanced Higher or A-level passes or equivalent in physics and mathematics. It includes lectures on mechanical and acoustic and electromagnetic waves, basic concepts from quantum physics in the context of two-level systems, solutions of the Schrödinger equation for simple one-dimensional potentials, and an elementary introduction to the electromagnetic field comprising electrostatics, magnetostatics, electromagnetic induction and DC circuit theory. Tutorials and teaching labs also assist students in developing relevant understanding, knowledge, and skills.

Aims & Objectives
To present a broad and mathematically founded introductory account of classical waves, electricity and magnetism and quantum physics, in particular:

- The ability to reason through scientific concepts, to relate different concepts to one another and to solve qualitative and quantitative problems in the areas covered in the courses with a toolkit of problem-solving techniques.
- Laboratory skills, including the planning of experimental investigations, the use of modern test equipment, and the construction of electronic circuits.
- An appreciation of the value of learning of physics as a transformative experience in terms of motivated use (using physics beyond the course e.g. in everyday situations) and expansion of perception (seeing the world through the lens of physics).
- To place the development of quantum physics in historical context, and develop the basic concepts of quantum mechanics, such as the quantum state, eigenfunctions and eigenvalues, and probabilistic measurements.
- To solve the Schrödinger equation for simple 1-D potentials, and apply the results to phenomena such as quantum tunnelling.
- To develop an understanding of concepts in electrostatics, magnetostatics, basic DC circuit theory and induction, and to apply these concepts to a range of charge and current distributions
- To develop an understanding of classical mechanical waves including interference, energy transport and the behaviour at boundaries, and to give an introductory account of electromagnetic waves and wave optics.
- The practical work of the module will develop a competence in using some of the standard equipment in physics laboratories, the analysis of experimental uncertainties and the presentation of experimental data in scientific reports.
- The module will develop the ability to reason through scientific concepts and to solve quantitative problems in the areas of classical waves, electricity and magnetism and quantum physics with a toolkit of problem-solving techniques.

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

- Represent transverse and longitudinal waves and waves in one and two dimensions physically, mathematically and graphically and explain the connections between these representations.
- Explain similarities and differences between different types of mechanical waves, and between mechanical and electromagnetic waves.
- Explain how to calculate Fourier series to represent arbitrary periodic waveforms, and to calculate Fourier series to represent selected periodic waveforms.

- Use the concepts of wave interference, energy transport and the behaviour at boundaries to calculate wave properties.
- Compare and contrast classical and quantum descriptions of light and matter, give examples where one description or the other is valid, and summarise experimental evidence that support the use of either description.
- Represent quantum states with basic Dirac notation, and manipulate these representations to determine probabilities for outcomes of measurements performed on two-level systems.
- Solve the Schrödinger equation for simple 1-D systems, and use these wave functions to calculate expectation values and measurement probabilities for observables such as energy, position and momentum.
- State Coulomb's Law and the Biot-Savart Law, Faraday's Law and Lenz's Law, the definitions of electric field, electric potential, capacitance, and inductance.
- Be able to use the above laws and definitions along with other physics and maths concepts to be able to model and solve a range of examples in electrostatics, magnetostatics, and electromagnetic induction. - Be able to use the above ideas to justify aspects of DC circuit theory and apply this to solving simple electrical circuit problems.
- Be able to use the above definitions and laws to justify Gauss' Law and Ampere's Law, and use these two laws on a range of electrostatic and magnetostatic examples.
- Qualitatively describe how relativity and electrostatics can be brought together to explain electromagnetism.
- State descriptions of paramagnetism, diamagnetism, and ferromagnetism.
- Appreciate how the concepts in the electricity and magnetism course may be applied to particle accelerators, fusion tokomaks, atom traps, optical tweezers, modern electronics, and electrical engineering.
- State concepts of pn junctions, design circuits using AC circuit theory, build and investigate electronic circuits.
- Use computer code to run stand-alone programs on microcontrollers.
- Use the instrumentation and tools necessary to perform experimental work, including: soldering, bench supplies, oscilloscope and signal generator.
- Clearly communicate observations and analysis through a structured formal report.

Synopsis

Quantum Physics

Photoelectric effect and photodetectors. Optical devices and single-photon experiments. Probabilistic measurements, expectation values. Entanglement and the physical interpretation of quantum mechanics. Wave functions and the Schrödinger equation in one dimension. Operators and eigenvalues. The uncertainty principle. Infinite- and finite-depth square well potential. Quantum tunnelling.

Electricity and Magnetism

- Basic electrostatics: Coulomb's Law, electric field E, electric field from discrete and continuous distributions of charge. Electric potential V, relation between E and V, examples.
- DC circuit theory: electric current and drift velocity of charge-carriers. Electric potential and Kirchoff's laws. Input and output impedance of circuits, equivalent circuits.
- Gauss' law and capacitors: electric flux, Gauss' law, use to solve fields around high-symmetry charge distributions, electrostatic shielding, capacitors, role of dielectric materials in capacitors.
- Magnetic effects of currents: forces on charges moving in a magnetic field, Biot-Savart law and application to long straight wire and coil, force between two current carrying wires and the definition of the units of current, Ampere's law and examples.
- Electromagnetic Induction: Faraday's law, Lenz's law, induced electric fields, self and mutual inductance.
- Electricity and magnetism unified via relativity (qualitative). Magnetic materials.

Classical Waves

- Waves: Waves on stretched strings, the wave equation, wave velocity, transmission of energy, sound waves and light waves, the Doppler effect in sound, superposition of waves,

standing waves, Fourier series, interference and beats, phase, dispersion, phase and group velocity, reflection and transmission of waves at an interface or boundary.
Wave properties of light: Nature of electromagnetic radiation, the e-m spectrum, polarisation, dispersion, interference, Bragg scattering, diffraction.

Laboratory Work
Explore aspects of physics in a practical manner, broaden competence in various forms of experimental and diagnostic instrumentation, explore the science and develop practical skills in electronics, develop computational skills through work with microprocessors.

Pre-requisites

PH1011, PH1012 and MT1002; alternatively passes in Advanced Higher Physics and Mathematics or A-level Physics and Mathematics both normally at grade A. PH2011 Physics 2A should be done before taking this module, or permission gained from Head of School to waive this requirement.

Anti-requisites
AS1002

Assessment
3 Hour Examination = 60%, Class Test = 10%, Laboratory work = 25%, Meaningful participation in pre-lecture quizzes and in-lecture clicker questions = 5%

Additional information on continuous assessment etc.

Accreditation Matters
This module contains some material that is or may be part of the IOP “Core of Physics”. This includes

Fourier Series
Photoelectric effect
Wave-particle duality
Heisenberg’s uncertainty principle
Wave function and its interpretation
Quantum structure and spectra of simple atoms
Bragg scattering
Magnetic properties of matter
Waves in linear media to the level of group velocity
Waves on strings, sound waves, and EM waves
Doppler effect
Electrostatics and magnetostatics
DC circuit analysis
Gauss, Faraday, Ampere, Lenz laws
EM Spectrum
Dispersion by prisms and diffraction gratings
Optical cavities and laser action
Ability to work independently, to use their initiative and to organise themselves to meet deadlines
In lab –
Semiconductors and doping
AC circuit analysis to complex impedance, transients, and resonance
Geometrical optics to the level of simple optical systems (for direct entrants, others have seen in PH1011)
Interference and diffraction at single and multiple apertures (for direct entrants, others have seen in PH1011)
How to plan, execute and report the results of an experiment or investigation
How to compare results critically with predictions from theory

Recommended Books
Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph2012.html

General Information
Please also read the additional information in the School's pre-honours handbook.