PH4040 - Nuclear and Particle Physics with Advanced Skills

Credits:	15.0	**Semester:**	1
Number of Lectures:		**Lecturer:**	Dr Antje Kohnle and Dr Bruce Sinclair
Academic Year:	2018-19		

Overview

This module is for students on certain joint degrees.
The first aim of this module is to describe in terms of appropriate models, the structure and properties of the atomic nucleus, the classification of fundamental particles and the means by which they interact. The syllabus includes: nuclear sizes, binding energy, spin dependence of the strong nuclear force; radioactivity, the semi-empirical mass formula; nuclear stability, the shell model, magic numbers; spin-orbit coupling; energetics of beta decay, alpha-decay and spontaneous fission; nuclear reactions, resonances; fission; electroweak and colour interactions, classification of particles as intermediate bosons, leptons or hadrons. Standard model of leptons and quarks, and ideas that go beyond the standard model.
The second aim of this module is to develop research skills, and oral and written communication skills in science. Participants will be given training in the use of bibliographic databases, use of the scientific literature, oral and written communication skills, and will develop these skills through structured assignments.

Aims & Objectives

To present an introductory account of nuclear physics and elementary particle physics, including

- scattering experiments, observational aspects of nuclei, including their binding energy, size, spin and parity - nuclear models: liquid drop and shell models
- the semi-empirical mass formula and deductions from it concerning nuclear stability
- the classification of fundamental particles and their interactions according to the Standard Model - quark structure of mesons and baryons
- properties of the strong and weak interactions.
- To develop advanced skills in scientific information retrieval, analysis, and communication.

Learning Outcomes

By the end of the module, students should have a comprehensive knowledge of the topics covered in the lectures and be able to

- Explain methods used to extract information about nuclei and particles through scattering experiments, and be able to derive quantitative information through calculations for simple cases.
- Apply concepts from special relativity, quantum mechanics and atomic physics to describe subatomic systems.
- Explain the assumptions, limitations and ranges of applicability of the liquid drop model and shell models of the nucleus.
- Use the liquid drop model and the law of radioactive decay to describe alpha-decay, beta-decay, fission and fusion, predict decay reactions and calculate the energy release in nuclear decays.
- Determine nuclear properties such as binding energy, spin and parity in the framework of the liquid drop model and the shell model of the nucleus.
- Articulate a considered and differentiated view on nuclear power generation founded on the physical principles of induced fission.
- Apply principles of relativistic kinematics to calculate kinematic quantities in reactions and decays.
- Describe interactions arising from fundamental forces in terms of Feynman diagrams and apply conservation laws to predict the type of interaction.
- Explain the experimental evidence for quarks, gluons, quark confinement and colour charge.
- State the key ideas of the Standard Model of particle physics, and name some currently unsolved problems in particle physics.
- Name important current particle accelerators and state their centre-of-mass energies.
- Apply the concepts of quark generation mixing, helicity and parity violation to weak interactions.

Students should also be able to search the scientific literature in an effective way, and find and analyse relevant information. They should be able to communicate complicated scientific topics in oral and written formats.

Synopsis

- Binding energy of nuclei, liquid drop model of the nucleus - Stability of nuclei, alpha-decay, beta-decay, fission, fusion - nuclear shell model
- Scattering, relativistic kinematics, cross section, luminosity, Fermi's second golden rule, resonances
- The four fundamental interactions and Feynman diagrams
- The standard model of particle physics: Quarks, gluons and hadrons
- The standard model of particle physics: Phenomenology of the weak interaction
- The Scientific Literature and Publishing
- Web of Science and Information Retrieval
- Critical Analysis of Scientific Writing
- Oral and Written Communication Skills

Pre-requisites

PH3061, PH3062, Entry to BSc Honours in Philosophy and Physics or Computer Science and Physics or Mathematics and Physics or Theoretical Physics and Mathematics

Anti-requisites

PH3014, PH4041

Assessment

Coursework = 40%, 2-hour Written Examination = 60%

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 made up of learning opportunities from parts of first semester PH3014 and the latter ~2/3 of PH4041, i.e. the Nuclear and Particle sections

The continuous assessment is made up of 36% from the PH3014 component, and 4% from the PH4041 component. Thus the breakdown is

Nuclear and Particle Physics web quizzes that are due in in weeks 7, 8, 10, and 11 -- 4%
TSfP Compare two papers submission 6%
TSfP Compare two papers discussion 1.5%
TSfP talk 7%
TSfP input to peer review of article plan 2.0%
TSfP review article 19.5%

Accreditation Matters

This module contains material that is or may be part of the IOP “Core of Physics”. This includes
Energy momentum relationship
Nuclear masses and binding energies
Radioactive decay, fission and fusion
Pauli exclusion principle, fermions, bosons, and elementary particles
Fundamental forces and the Standard Model

Recommended Books

Please view University online record:
http://resourcelists.st-andrews.ac.uk/modules/ph4040.html

General Information

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