Imperial College London

Module Specification (Curriculum Review)

Basic details

			Earliest cohort	Latest cohort
UID		Cohorts covered	2021-22	

Long title: Nuclear and Particle Physics

New code: PHYS60001

New short title: Nuclear & Particle Physics

Brief description of module *(approx. 600 chars.)*:

In this course the students will be introduced to the physics of elementary particles and nuclei. We explore conceptually the fundamental forces and the Standard Model of particle physics, with use of basic Feynman diagrams. We introduce concepts associated with symmetries and use relativistic kinematics to calculate simple interactions. We explore the concepts of nuclear binding energy via the semi-empirical mass formula and the nuclear shell model. We explain alpha, beta and gamma decay and how these radiations interact with matter. We conclude by studying the processes of fission and fusion and their applications.

624 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	5.0	10	N

HECOS codes:

FHEQ level: Level 6

Allocation of study hours

	Hours	
Lectures	22	
Group teaching	6	*Incl. seminars, tutorials, problem classes.*
Lab/ practical	0	
Other scheduled	11	*Incl. project supervision, fieldwork, external visits.*
Independent study	86	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement	0	*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term		Other	Term 1, exam in term 3

Ownership

Primary department: Physics

Additional teaching departments: None

Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N

External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module Leader		Morgan	Wascko

Learning and teaching

Module description

Learning outcomes

On completion of this module you will be able:
1• To understand conceptually the content of the Standard Model and how the theoretical framework is informed, validated and scrutinised by experimental methods;
2• To illustrate the electromagnetic, weak and strong forces using basic Feynman diagrams and calculate simple particle interactions using relativistic energy-momentum formulae;
3• To understand conceptually the key aspects of the electromagnetic force, illustrating the idea with basic calculations of electron-electron scattering and electron-positron annihilation;
4• To understand conceptually the key aspects of the strong force, including asymptotic freedom and quark confinement, illustrating the ideas with basic calculations of the meson masses and electron-positron annihilation to quarks;
5• To understand conceptually the key aspects of the weak force, illustrating the ideas with basic calculations of muon decay and two-family neutrino mixing, the CKM matrix and its consequences;
6• To explain the origin of the various terms in the semi-empirical mass formula and in the nuclear shell model, and perform basic calculations to derive the observed stable nuclei;
7• To explain and calculate alpha, beta and gamma decays at a basic particle physics level and the interactions of the various nuclear radiations with matter;
8• To explain the concepts of fission (spontaneous and induced), chain reactions and fusion, and perform the associated calculations demonstrating energy release.

Module content	**PART I – PARTICLE PHYSICS** **• Introduction to the Standard Model** Feynman diagrams. Recalling relativistic particles, energy and momentum conservation; 4-vectors. Decay rates, cross sections. Spin and helicity. **• The Electromagnetic Force** Photons, QED Feynman diagrams. Positronium. Rutherford scattering. Reactions: μe-→μe, ee-→μμ. **• The Strong Force** Gluons and QCD Feynman diagrams. Self-interactions, “confinement”, “asymptotic freedom”. Colourless hadrons as bound states of quarks: baryons and mesons. Reaction: ee-→qq, with mention of hadronisation and jets. **• The Weak Force** Feynman diagrams. W and Z bosons, left-handed coupling. Approximate (Yukawa) point interaction, G_F. Muon decay; 3-body final state; tau decay. Neutrino oscillations. Pion decay: 2-body final state; leptonic decays. CKM matrix with mention of CP violation. Mention of Electroweak Unification and the Higgs. **PART II – NUCLEAR PHYSICS** **• The Nuclear Force and Nuclear Masses** Residual strong force. Nuclear binding, semi-empirical mass formula. Shell model, magic numbers. **• Nuclear Decays and Reactions** Gamma, beta and alpha decays **• Interactions of radiation with matter and applications** Interactions of charged particles, photons and neutrons Applications in Medicine **• Fission and Fusion** Fission, uranium and nuclear reactors. Fusion, primordial and stellar nucleosynthesis. Solar power reactions.
Learning and Teaching Approach	Students will be taught over a term using a combination of lectures (supported by office hours) and directed exercises in problem sheets to be solved as homework and in tutorials.
Assessment Strategy	An exam covering all learning outcomes will comprise the main part of the summative assessment and will comprise 75% of the module mark. In-course assessments comprising online tests and handwritten problems will comprise 25% of the mark.
Feedback	Problem Sheets are provided weekly (8 in total) with questions and examples students can practise with. There will be tutorials questions discussed with, and marked by, the tutors or their teaching assistants and students will receive feedback from those.
Reading list	High-quality, self-contained lecture notes are provided to students and lecture slides are also made available. There are excellent textbooks that are suggested as supplementary or complementary reading for those wishing to explore further some aspects of the course:

Quality assurance

Date of first approval	
Date of last revision	
Date of this approval	
Module leader	Morgan Wascko
Notes/ comments	

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Programme structure
Associated modules

UID	Legacy code	Module title	Requisite type

Programme structure
Associated programmes

UID	Legacy code	Programme title	Core?

Assessment details

Grading method	Numeric	Pass mark	40%

Assessments

Assessment type	Assessment description	Weighting	Pass mark	Must pass?
Examination	2-hr written examination	75%	40%	N
Coursework	Online and hand-written work	25%	40%	N
		100%		