Imperial College London

Module Specification (Curriculum Review)

Basic details

UID		Cohorts covered	Earliest cohort: 2023-24; Latest cohort:
Long title	Advanced Particle Physics		
New code	PHYS70012	New short title	

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

This module covers advanced concepts in particle physics. Building on the formalism of Lagrangian and Hamiltonian mechanics it illustrates how the Standard Model of particle physics was constructed, with some emphasis on how experimental input guided the structure of the Standard Model. Students will understand QED, and the weak and strong forces and be able to perform various calculations related to these forces. The shortcomings of the Standard Model are also discussed qualitatively and extensions proposed to the Standard Model are introduced.

551 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	7.5	15	N

HECOS codes:

FHEQ level: Level 7

Allocation of study hours

	Hours	
Lectures	26	
Group teaching	10	*Incl. seminars, tutorials, problem classes.*
Lab/ practical	0	
Other scheduled	10	*Incl. project supervision, fieldwork, external visits.*
Independent study	141.5	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement	0	*Incl. work-based learning and study that occurs overseas.*
Total hours	187.5	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term		Other	Term 2, 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		Michael	McCann

Learning and teaching

Module description

Learning outcomes

On completing the Advanced Particle Physics module, students will:
•Understand the meaning and importance of the terms: quark, lepton and boson propagators, Feynman diagrams, quantum numbers, charge, colour, weak charge, flavour, symmetries and conservation laws.
•Understand the conceptual design of particle physics detectors, with reference to the functioning of the main sub-detectors.
•Understand the form and consequences of the Dirac equation.
•Understand the use of gauge theories within particle physics, with particular reference to local U(1) invariance, the QED Lagrangian, non-Abelian gauge theories and the QCD Lagrangian.
•Understand weak interactions, in particular: Parity violation, charged and neutral weak currents, Weinberg angle, spontaneous symmetry-breaking, Higgs bosons, and the Standard-Model Lagrangian.
•Understand the concept of CP violation, and its relation to the CKM matrix and oscillations in the B and K systems.
•Understand the limitations of the Standard Model, using neutrino oscillations, SUSY, dark matter and GUTs as examples.
•Understand the relation between theory and experiment in determining the Standard Model of particle physics.

Module content	**Module Overview and Basics (1 Lecture):** Lecture overview, office hours, books. Introduction to particles. Tensor notation. Relativistic particles, energy and momentum conservation. Spin, helicity and angular momentum conservation. **Experiments and Detectors (2 Lectures):** How to build a particle physics experiment. Detection of charged particles from reactions, Bethe-Bloch formula. Gas drift chambers, Si tracking, Scintillators. Photon detectors, EM calorimeters and showers. Particle ID detectors. **The Dirac Equation (3 Lectures):** Relativistic wave equation for all the matter (fermion spin 1/2) particles. Solutions; spin, helicity, antiparticles. **The Electromagnetic Force (5 Lectures):** The photon wavefunction and Maxwell's equations. Photon-electron coupling; in the Dirac equation (minimal substitution), in Maxwell's equations as a conserved current and as a Feynman diagram. Massless, implying infinite range, Yukawa couplings. Lagrangians, U(1) gauge invariance and Nöther's theorem. Decays, Fermi's Golden Rule, phase space, cross-sections. **The Strong Force (4 Lectures):** QCD; SU(3) gauge invariance. Massless but not infinite range; gluons carry their own charge; “confinement" and “asymptotic freedom". Colourless hadrons as bound states of quarks; baryons, mesons, multiplets. Reactions, hadronisation and jets. **The Weak Force (5 Lectures):** C and P violation, CPT conservation. Neutral Current interactions; Charged Current Interactions. W, Z massive force bosons, spontaneously broken symmetry, left handed coupling. Approximate (Yukawa) point interaction, GF. V-A structure and Dirac equation LH coupling, neutrinos. Handedness and helicity. Muon decay; tau decay; pion decay. CKM matrix, K0, B0 mixing. K0 and B0 CP violation. **Electroweak Theory and the Higgs (3 Lectures):** Mixing with hypercharge U(1) gives Z and photon. Reactions, e+e- → Z. The Higgs and mass generation. Spontaneous symmetry breaking. **Neutrinos and Beyond the Standard Model (3 Lectures):** Neutrino oscillations, mixing. Massive neutrinos. Dark matter. Supersymmetry, GUT's.
Learning and Teaching Approach	Students will be taught over one term using a combination of lectures, office hours and directed exercises on theoretical work.
Assessment Strategy	100% of summative assessment is based on a final exam: written exam of 2h that will evaluate competences in the topics described above.
Feedback	Problem sheets are provided weekly (9 in total) with questions and examples students can practise with. Out of these questions, one or two are marked as Rapid Feedback questions. Students can hand in their answers to these questions which will be reviewed and annotated (no formal mark) for formative feedback. Rapid Feedback questions are then reviewed during a Rapid Feedback session with a teaching assistant.
Reading list	Lecture notes are provided to students. The notes are designed to be self-contained, and there is no designated textbook required for this module; however, we recommend the following to the students: (1) Modern Particle Physics, Mark Thompson, Cambridge University Press. In addition we recommend: (2) Introduction to Elementary Particles, David Griffiths, Wiley and (3) Quarks and Leptons, Halzen and Martin, Wiley, as helpful for further reading on some topics.

Quality assurance

Date of first approval	
Date of last revision	
Date of this approval	
Module leader	Michael McCann

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Notes/ comments	

Template version 16/06/2017

Programme structure

Associated modules

UID	Legacy code	Module title	Requisite type

UID	Legacy code	Module title	Requisite type

Assessment details

Grading method	Numeric	Pass mark
		50%

Assessments

Assessment type	Assessment description	Weighting	Pass mark	Must pass?
Final exam	2 hour written examination	100%	50%	N
		100%		