Imperial College London

Advanced Particle Physics

Module Code	PHYS97003	FHEQ Level	Level 7
Pre-requisites	Physics of the Universe, Advanced Classical Physics	Co-requisites	None
Primary Department	Physics		
Module Leader	Dr Antonin Vacheret and Dr Michael McCann		
Additional Teaching Departments	None		
Teaching Staff	Dr Antonin Vacheret, Dr Michael McCann + Course Associates		
Programmes on which the Module is delivered			Core/Elective
All UG Physics programmes (F300, F303, F309, F325, F390, F3W3)			Elective
Learning Outcomes	On completing the Advanced Particle Physics course, 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. • Be able to describe 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		
Description of Content	**Course 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. Reactions $\mu^-e^- \rightarrow \mu^-e^-$, $e^+e^- \rightarrow \mu^+\mu^-$. **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, G_F. V-A structure and Dirac equation LH coupling, neutrinos. Handedness and helicity. Muon decay; tau decay; pion decay. CKM matrix, K^0, B^0 mixing. K^0 and B^0 CP violation. **Electroweak Theory and the Higgs (3 Lectures):** Mixing with hypercharge U(1) gives Z and photon. Reactions, $e^+e^- \rightarrow Z^0$. 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.

Assessment		Assessment Type	Weighting
Written Exam		Exam	100%
Learning & Teaching Hours	Independent Study Hours	Placement Hours	Total Hours
57	93	0	150
ECTS Credit	6	CATS Credit	12
Date of introduction	October 2016	Date of Last Revision	04/05/2020