

PHY680 — PARTICLE PHYSICS

1. Course Information

Course code and title	PHY680 — Particle Physics
Credits / contact pattern	3-1-0-0 (11); two 90-minute lectures and one 60-minute tutorial per week
Semester	Semester II, 2027
Instructor-in-charge	Goutam Das, Assistant Professor Email: gkdgoutam@iitk.ac.in Office: FB-253 Office hours: By appointment via email
Lecture schedule / venue	Monday and Wednesday, 15:30–17:00 Venue: To be announced
Tutorial schedule / venue	Friday, 11:00–12:00 Venue: To be announced
Teaching assistant(s)	To be announced
Course duration	Full semester

2. Course Description and Prerequisites

This course develops a field-theoretic understanding of the Standard Model and its phenomenology. It begins with relativistic kinematics and Lorentz-invariant phase space, then uses scattering amplitudes, symmetries, gauge theories, & symmetry breaking to build a coherent account of QED, QCD, and electroweak physics. The emphasis is on deriving results, understanding assumptions and approximations, and connecting formal calculations to measurable observables at colliders. Students are expected to have passed Quantum Field Theory-I and to be comfortable with relativistic field theory, Lorentz covariance, Lagrangian methods, propagators, Feynman rules, and tree-level amplitudes.

3. Syllabus and Tentative Lecture Plan

The final order and number of meetings may be adjusted to the approved semester calendar.

Topic	Brief description	Tentative no. of lectures
Relativistic Kinematics and Phase Space	Natural units, four-vectors, Lorentz invariants, centre-of-mass and laboratory frames, Mandelstam variables, two- and three-body phase space, Dalitz plots, and crossing symmetry.	2
Symmetries, Conservation Laws, and Isospin	Continuous and discrete symmetries, Noether's theorem, charge conjugation, parity and time reversal, parity violation, isospin SU(2), strangeness, and hadronic quantum numbers.	3
Flavour SU(3) and the Quark Model	Flavour symmetry, SU(3) representations and tensor products, the Eightfold Way, meson and baryon multiplets, quark quantum numbers, and the classification of hadrons.	2
Hadron Spectroscopy and the Colour Degree of Freedom	Hadron wavefunctions, spin-flavour structure, baryon statistics, magnetic moments, the need for colour, colour representations, evidence for quarks, and the ratio R in e^+e^- annihilation.	2
Weak Interactions and Parity Violation	Fermi's theory, beta decay and muon decay, the Fermi constant, maximal parity violation, the V–A structure of weak interactions, helicity and chirality, and the motivation for intermediate vector bosons.	2
Gauge Principles and Quantum Field Theories	Global and local symmetries, gauge invariance, covariant derivatives, the QED Lagrangian, the connection with Maxwell theory, and non-Abelian Yang–Mills theories based on SU(2) and SU(3).	2
Spontaneous Symmetry Breaking and the Higgs Mechanism	Spontaneous symmetry breaking in scalar field theories, the Goldstone theorem, Abelian and non-Abelian examples, the Higgs mechanism, and the origin of masses for gauge bosons.	2

Electroweak Unification and the Standard Model	The $SU(2)_L \times U(1)_Y$ gauge structure, weak isospin and hypercharge, electric charge, electroweak mixing, the photon, $W^\pm$ and Z bosons, fermion masses, Yukawa couplings, and experimental tests.	4
Quantum Chromodynamics: The Theory of Strong Interactions	The QCD Lagrangian, gluons and colour, non-Abelian self-interactions, colour factors, confinement, running coupling, asymptotic freedom, and experimental evidence for QCD.	2
Parton Model, Deep-Inelastic Scattering, and Collider Physics	The parton model, deep-inelastic scattering, Bjorken scaling, structure functions, parton distribution functions, factorization, Drell–Yan processes, jet production, and heavy-quark production.	4
Higgs Physics and Precision Tests of the Standard Model	Higgs production and decay, branching fractions, coupling measurements, precision electroweak observables, the Z pole, the W -boson mass, the weak mixing angle, and tests of Standard Model consistency.	2
Flavour Physics, CP Violation, and Neutrino Oscillations	Yukawa matrices, CKM mixing, the GIM mechanism, neutral-meson mixing, CP violation, neutrino masses, PMNS mixing, neutrino oscillations, and matter effects.	2
Beyond the Standard Model and Synthesis	Unresolved questions including dark matter, baryogenesis, the hierarchy problem, strong CP, and neutrino masses; an introduction to effective field theory and SMEFT, precision constraints, new-physics searches, and a synthesis of the course.	1

4. Tutorials and Computational Component

The weekly tutorial is intended for analytical problem-solving and guided discussion, with computational exercises where appropriate. Active student’s interaction is required during the tutorials.

5. Evaluation and Grading

Component	Weight	Notes
Assignments, class performance, quizzes, and engagement	25%	Criteria to be announced.
Mid-semester examination	25%	Date, duration, coverage, and permitted materials to be announced.
End-semester examination	50%	Under the applicable Institute examination rules.
Total	100%	Final letter grade assigned under applicable IITK procedures.

6. Assignment and Academic Integrity Policy

- **Assignments:** Deadlines, submission format/channel, collaboration rules, and late-submission policies will be specified for each assignment. Unless collaboration is explicitly permitted, solutions must be students’ own work. Discussion is allowed, but derivations must be independently written and understood. Part of tutorial component will involve discussing the problems among students with possible presentation when required.
- **Academic integrity:** Plagiarism, copying, impersonation, and fabricated data may invite action under applicable IITK rules. Generative AI, code assistants, symbolic tools, and online solutions may be used only as permitted for each task. Required use must be disclosed; students remain responsible for correctness and attribution.
- **Attendance and exceptional circumstances:** Students are expected to attend lectures and tutorials and keep up with course material. Illness, emergencies, missed examinations, and other exceptional circumstances should be reported promptly and handled under current IITK regulations and procedures.

7. Recommended Texts and Resources

1. M. Peskin and D. Schroeder, An Introduction to Quantum Field Theory.
2. M. D. Schwartz, Quantum Field Theory and the Standard Model.
3. T. D. Lee, Particle Physics and Introduction to Field Theory.
4. F. Halzen and A. D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics.
5. P. B. Pal, An Introductory Course of Particle Physics.
6. I. J. R. Aitchison and A. J. G. Hey, Gauge Theories in Particle Physics (Vols. I–II).
7. Additional lecture notes and papers will be recommended topic-wise during the semester.