

Study guide for Particle Physics

1. Kinematics: Lorentz transform, invariants, notation, 4-vectors, dot product, using dot product with 4-velocity to find quantities in a given particle's reference frame.
2. Basic concepts: Forces, force carriers; particles and anti-particles; relativistic wave equation, Klein-Gordon wave equation, spinors, Feynman diagrams; interactions, initial and final states; forces as momentum transfer, connection to Feynman diagrams; event rates, general expression, decay rates, cross sections.
3. Leptons, quarks, and hadrons: conserved quantities, lepton numbers L_e, L_μ, L_τ , quark numbers B, S, C, B_c, T_c ; flavor-changing weak interactions.
4. Experimental methods: how particles and properties discovered; accelerators, linacs, rings, RF acceleration, synchrotron radiation, fixed target vs. beam-beam collisions; interactions of particles with matter, nuclear interactions, ionization, multiple scattering, bremsstrahlung, pair production, Compton scattering, photoelectric effect, electromagnetic and hadronic showers, Cerenkov effect, scintillation; particle detection, gas ionization detectors, wire chambers, drift chambers, scintillators, solid state ionization, Cerenkov detectors, calorimeters, calorimeter read-out.
5. Space-time symmetries: continuous symmetries, translation, rotation, time, connection to conservation laws; Noether's theorem, classical Lagrangian motivation, Hamiltonian motivation; intrinsic spin; discrete symmetries, parity, intrinsic parity, parity of photon and pion, charge conjugation parity, C-parity in pion and positronium decays, time inversion.
6. QCD and hadron physics: hadron quantum numbers, isospin; quark states and color; hadron spectroscopy, isospin-strangeness pattern of lightest hadrons, color antisymmetric wavefunction, color charges, confinement; QCD, running coupling constant, screening, asymptotic freedom, jets, form factors.
7. Weak interactions: W and Z bosons, charged current reactions, symmetries, low energy limit, quark mixing, CKM matrix, neutrino mixing, PMNS matrix, neutrino oscillations, double beta decay; neutral currents, unification, Z0 decay limit on number of neutrinos.
8. Gauge symmetries: gauge transformation, gauge symmetry in quantum mechanics; Lagrangian formulation. Higgs boson. Electroweak unification.
9. C, P, and CP-violation in weak interactions: beta decay parity asymmetry, muon decay asymmetries and symmetries, left-handed neutrinos, right-handed antineutrinos, symmetries and asymmetries in pion and muon decays; neutral kaons, K0 mixing, K0-short and -long, CP-violation, strangeness oscillations.
10. Beyond the standard model: grand unified theories, expanded gauge symmetries, Georgi-Glashow model, proton decay; cosmic matter-antimatter asymmetry, Sakharov's idea, leptogenesis; dark matter; supersymmetry.