Particle Physics exam topics

1. Scales in nature. Natural units $\hbar = c = 1$. Special relativity.
   Lecture notes: Sections 1 and 2.

2. Fundamentals of quantum theory, symmetries. Parity, time reversal, charge conjugation. Space-time translations, charge conservation and U(1) symmetry. Classification of particles based on their interactions and conserved quantities.
   Lecture notes: Section 3.

3. Relativistic quantum mechanics. The Klein-Gordon equation and its properties.
   Lecture notes: Section 4.

4. Dirac equation: derivation, relativistic covariance and spinors. Conserved current and probabilistic interpretation.
   Lecture notes: Sections 5.1-3 and 5.5. (5.4 recommended).

5. Dirac equation: Plane wave solutions. Dirac sea and antiparticles. Weyl spinors.
   Lecture notes: Sections 5.6 and 5.7 (5.8 recommended, 5.9 optional material).

6. Fundamentals of weak interactions. Beta decay, neutrino. Parity and CP violations. CPT symmetry.
   Lecture notes: Section 6.

7. Hadrons, isospin. Strangeness and hypercharge. The SU(3) quark model.
   Lecture notes: Sections 7 (7.1.3, 7.1.4 and 7.3.5 are optional material).

8. Relativistic fields. Euler-Lagrange equations, Noether theorem. Actions for free scalaar and Dirac fields. Relativistic formulation of the electromagnetic field, gauge invariance.
   Lecture notes: Section 8 and 9. (8.3.2 and 8.3.3: optional material).

9. Elements of quantum field theory. Canonical quantisation of free fields. Free particles. Perturbation theory, Dyson-Schwinger expansion. Fundamentals of Feynman diagrams.
   Lecture notes: Section 10.

10. Lepton number conservation. Direct detection of the neutrino, evidence for $\nu_e \neq \nu_\mu$. Charged current interactions, the Cabibbo angle.
    Lecture notes: Sections 11.1-11.2, 11.3.1.

11. Flavour changing neutral current, GIM mechanism. Discovery of charm. Third generation, CKM flavour mixing and CP violation. Neutrino mixing.
    Lecture notes: Sections 11.3.2-11.4.

12. Nonabelian gauge theories. Global non-Abelian symmetry groups. Local gauge invariance, covariant derivative and the gauge fields. Gauge field action.
    Lecture notes: Section 12.1.

13. Discovery of colour. Quantum chromodynamics. Confinement and asymptotic freedom. Jet physics and evidence for gluons.
    Lecture notes: Section 12.2-12.4.

14. Intermediate vector bosons. Lagrangian for massive vector field. $SU(2)_L \times U(1)_Y$ gauge theory of weak interactions, fermion multiplets.
Lecture notes: Sections 13.1 and 13.3.1.

15. Spontaneous symmetry breaking and Higgs mechanism. Masses of the W and Z bosons. Fermion masses and mixing angles.
Lecture notes: Sections 13.2.1, 13.2.3, 13.3.3 and 13.3.4.