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Summary of Material Covered on Exam 1

1 Relativistic kinematics

Natural units, expressing momentum and mass as energies

- Putting in factors of $\hbar$ and c to make formulae correct
- Definition of $\alpha = e^2 / 4\pi\varepsilon_0 \hbar c \simeq 1/137$

Relations between E, p, v and m: $E^2 = p^2 + m^2$, $v = p/E$, $\gamma = E/m = 1/\sqrt{1-v^2}$
Transforming energy and momentum between reference frames
Lifetime: time dilation and average decay distance of moving particle
4-vectors and 4-momentum, definition of p^2 and $p_1 \cdot p_2$ Lorentz invariants
Two body kinematics: determining energy and momentum from masses
Center of mass and lab (fixed target) frames
Shrinking of angles wrt beam for large incident momenta in lab frame
Calculating threshold energy for particle production

2 Leptons, Quarks and fundamental forces

Fundamental forces and unification

- Force carriers for each force

Leptons and quarks

- Which forces are felt by charged leptons, neutrinos, quarks, hadrons?
- Organization of quarks and leptons into doublets covering three generations
- Lepton quantum numbers
- Quark quantum numbers (S, C, B, T); baryon number

Hadrons: mesons and baryons

- Particle multiplets, similar masses for particles differing by u and d quark
- EM splitting within a mutiplet

Composite particles (mesons, baryons) vs point particles (leptons and quarks)
Approximate masses of basic hadrons and leptons
Spin 1/2 baryons and spin 3/2 baryons:

- Quark content
- Which decay strongly and which decay weakly. Special case of the Ω^-
- Diagram of particles by charge and strangeness

Spin 0 and spin 1 mesons:

- Quark content
- Which decay strongly and which decay weakly.
- Diagram of particles by charge and strangeness

Which decays are allowed or forbidden by strong, E&M, weak forces

3 Quantum mechanics

Schrodinger's equation and the wavefunction $\psi(x,t)$ (1-D) and $\psi(\mathbf{x},t)$ (3-D)

Stationary states: $\psi(x,t) = \psi(x)e^{-iEt/\hbar}$

Quantization of energy and ang. momentum in QM from boundary conditions and normalization

Operators in QM

- Special operators such as momentum, energy, angular momentum (L^2, L_z)
- Eigenstates and eigenvalues of operators

Special potentials:

- $U = 0$ everywhere; free particle wavefunctions
- Infinite square well and its solutions (1-D, 3-D)
- Energy levels for 1-D and 3-D systems, degeneracy
- Hydrogen atom quantum numbers, energies, degeneracies

Uncertainty principle

- Using the uncertainty principle to establish minimum kinetic energies of bound systems of a specified size (atomic, nuclear, etc).

4 Cross sections and luminosity

Particle flux, total particle flux

Luminosity, integrated luminosity, cross section and scattering rates

Calculating luminosity from beam and target information

Exponential decrease of flux intensity inside target, scattering length $\lambda = 1/\sigma n_t$

Nuclear collision length, nuclear interaction length (including density adjusted value)

Solid angle differential $d\Omega = d\cos\theta d\phi = \sin\theta d\theta d\phi$

Using basic Feynman diagrams to represent fundamental processes

Exchanging heavy particles, range of interaction $r \approx 1/m$, for exchange particle mass m

Weak interactions and W exchange

Basics of Rutherford scattering