Physics 365: HEP Exam 1 8 October 1987

Complete no more than 6 of the following 10 problems

1. Free neutrons decay with a mean life of about 900 s, yet they are stable in many nuclei. Why? Λ^0 particles are similiar to the neutron but have a mass of 1116 MeV (c.f., neutron mass = 939.6 MeV and proton mass = 938.3 MeV). Are there any stable nuclei containing Λs? (In short, what condition determines if a particle is stable in a nucleus.)

2. Sketch the curve of binding energy vs. the mass number A for stable nuclei. Why does it look the way it does?

3. Show quark flow diagrams for the following reactions:

$$\begin{aligned} \Omega^- &\rightarrow \Lambda^0 + K^- \qquad (\tau = 10^{-10}\text{s}) \\ \gamma + p &\rightarrow \Delta^+ \\ K^- + p &\rightarrow \Omega^- + K^+ + K^0 \\ \pi^- + n &\rightarrow \Delta^- + \pi^0 \end{aligned}$$

4. Define and give an example of: lepton, meson, hadron, gauge particle, strange particle, baryon, isospin multiplet (report the I value for the multiplet) and hypercharge.

5. Explain Yang-Mills fields, Goldstone bosons and the Higgs mechanism for making particles with mass.

6. What is Cabibbo rotation? What observations necessitated its use?

7. For each of the following particles list all forces the particle feels: n, π, μ, ν, and γ. Why does the weak force have a short range whereas the electromagnetic force has a long range? Explain how the nuclear force relates to the strong (color) force.

8. Draw feynman diagrams for the following cases: Compton scattering, neutron decay, "dressed" (renormalized) electrons, and bremsstrahlung.

9. Explain K_s regeneration.

10. Draw the pseudoscaler meson nonet and the baryon decuplet. Label axes! Show and application of the Gell-Mann–Nishijima formula. Show the quark content of 3 particles.

Do 3 of the following 5 problems.

11. Consider the case of a beam particle with mass m_1 incident on a target particle with mass m_2. What beam-particle energy E_1 is needed to form a single particle with mass M in the reaction? (Prove the result using 4-vectors.)

12. Prove that in the above case the energy in the cm frame is

$$E_{cm}^{tot} = \left[m_1^2 + m_2^2 + 2E_1 m_2\right]^{\frac{1}{2}}$$

Apply this formula to the production of $\overline{p}$ from p on p, i.e., what E_{cm} is needed to produce $\overline{p}$ from p on p.

13. A Carbon target 1 mm thick is hit by a .1 mA proton beam producing 2×10^{12} scatterings per sec. What is the cross section for Carbon?

14. In the above case a circular detector, $r = .5$ cm, placed 1 m from the target detects 10^7 scatterings per sec. What is the differential crosssection at this angle? Is the scattering isotropic?

15. The Rutherford scattering crosssection is

$$\frac{d\sigma}{d\Omega} = \frac{Z^2\alpha^2}{4k^2\beta^2 \sin^4(\theta/2)}$$

At what rate will protons from question #14 Rutherford scatter into the detector if the protons have an energy of 40 MeV and the detector is placed at $\theta = 90°$?