Questions

1. Give a reaction between two nucleons, similar to Eq. 32–4, that could produce a π^-.

2. If a proton is moving at very high speed, so that its kinetic energy is much greater than its rest energy (m_0c^2), can it then decay via $p \rightarrow n + \pi^+$?

3. What would an "antiatom," made up of the antiparticles to the constituents of normal atoms, consist of? What might happen if *antimatter*, made of such antiatoms, came in contact with our normal world of matter?

4. What particle in a decay signals the electromagnetic interaction?

5. Does the presence of a neutrino among the decay products of a particle necessarily mean that the decay occurs via the weak interaction? Do all decays via the weak interaction produce a neutrino? Explain.

6. Why is it that a neutron decays via the weak interaction even though the neutron and one of its decay products (proton) are strongly interacting?

7. Which of the four interactions (strong, electromagnetic, weak, gravitational) does an electron take part in? A neutrino? A proton?

8. Check that charge and baryon number are conserved in each of the decays in Table 32–2.

9. Which of the particle decays in Table 32–2 occur via the electromagnetic interaction?

10. Which of the particle decays in Table 32–2 occur by the weak interaction?

11. By what interaction, and why, does $\Sigma^\pm$ decay to Λ^0? What about Σ^0 decaying to Λ^0?

12. The Δ baryon has spin $\frac{3}{2}$, baryon number 1, and charge $Q = +2,\ +1,\ 0,$ or -1. Why is there no charge state $Q = -2$?

13. Which of the particle decays in Table 32–4 occur via the electromagnetic interaction?

14. Which of the particle decays in Table 32–4 occur by the weak interaction?

15. Quarks have spin $\frac{1}{2}$. How do you account for the fact that baryons have spin $\frac{1}{2}$ or $\frac{3}{2}$, and mesons have spin 0 or 1?

16. Suppose there were a kind of "neutrinolet" that was massless, had no color charge or electrical charge, and did not feel the weak force. Could you say that this particle even exists?

17. Is it possible for a particle to be both (*a*) a lepton and a baryon? (*b*) a baryon and a hadron? (*c*) a meson and a quark? (*d*) a hadron and a lepton? Explain.

18. Using the ideas of quantum chromodynamics, would it be possible to find particles made up of two quarks and no antiquarks? What about two quarks and two antiquarks?

19. Why do neutrons decay when they are free but not when they are inside the nucleus?

20. Is the reaction $e^- + p \rightarrow n + \bar{\nu}_e$ possible? Explain.

21. Occasionally, the Λ will decay by the following reaction: $\Lambda^0 \rightarrow p^+ + e^- + \bar{\nu}_e$. Which of the four forces in nature is responsible for this decay? How do you know?

Problems

32–1 Particles and Accelerators

1. (I) What is the total energy of a proton whose kinetic energy is 6.35 GeV?

2. (I) Calculate the wavelength of 35-GeV electrons.

3. (I) What strength of magnetic field is used in a cyclotron in which protons make 2.8×10^7 revolutions per second?

4. (I) What is the time for one complete revolution for a very high-energy proton in the 1.0-km-radius Fermilab accelerator?

5. (I) If α particles are accelerated by the cyclotron of Example 32–2, what must be the frequency of the voltage applied to the dees?

6. (II) (*a*) If the cyclotron of Example 32–2 accelerated α particles, what maximum energy could they attain? What would their speed be? (*b*) Repeat for deuterons $\left({}^2_1H\right)$. (*c*) In each case, what frequency of voltage is required?

7. (II) Which is better for picking out details of the nucleus: 30-MeV alpha particles or 30-MeV protons? Compare each of their wavelengths with the size of a nucleon in a nucleus.

8. (II) The voltage across the dees of a cyclotron is 55 kV. How many revolutions do protons make to reach a kinetic energy of 25 MeV?

9. (II) What is the wavelength (= maximum resolvable distance) of 7.0-TeV protons?

10. (II) A cyclotron with a radius of 1.0 m is to accelerate deuterons $\left({}^2_1H\right)$ to an energy of 12 MeV. (*a*) What is the required magnetic field? (*b*) What frequency is needed for the voltage between the dees? (*c*) If the potential difference between the dees averages 22 kV, how many revolutions will the particles make before exiting? (*d*) How much time does it take for one deuteron to go from start to exit. (*e*) Estimate how far it travels during this time.

11. (II) The 4.25-km-radius tunnel that will be used to house the magnets for the Large Hadron Collider (LHC) calls for proton beams of energy 7.0 TeV. What magnetic field will be required?

12. (II) The 1.0-km radius Fermilab Tevatron takes about 20 seconds to bring the energies of the stored protons from 150 GeV to 1.0 TeV. The acceleration is done once per turn. Estimate the energy given to the protons on each turn. (You can assume that the speed of the protons is essentially c the whole time.)

13. (III) Show that the energy of a particle (charge e) in a synchrotron, in the relativistic limit $(v \approx c)$, is given by $E\ (\text{in eV}) = Brc$, where B is magnetic field strength and r the radius of the orbit (SI units).

14. (III) What magnetic field intensity is needed at the 1.0-km-radius Fermilab synchrotron for 1.0-TeV protons?