Conceptual Questions

33.3 Accelerators Create Matter from Energy

1.

The total energy in the beam of an accelerator is far greater than the energy of the individual beam particles. Why isn't this total energy available to create a single extremely massive particle?

2.

Synchrotron radiation takes energy from an accelerator beam and is related to acceleration. Why would you expect the problem to be more severe for electron accelerators than proton accelerators?

3.

What two major limitations prevent us from building high-energy accelerators that are physically small?

4.

What are the advantages of colliding-beam accelerators? What are the disadvantages?

33.4 Particles, Patterns, and Conservation Laws

5.

Large quantities of antimatter isolated from normal matter should behave exactly like normal matter. An antiatom, for example, composed of positrons, antiprotons, and antineutrons should have the same atomic spectrum as its matter counterpart. Would you be able to tell it is antimatter by its emission of antiphotons? Explain briefly.

6.

Massless particles are not only neutral, they are chargeless (unlike the neutron). Why is this so?

7.

Massless particles must travel at the speed of light, while others cannot reach this speed. Why are all massless particles stable? If evidence is found that neutrinos spontaneously decay into other particles, would this imply they have mass?

8.

When a star erupts in a supernova explosion, huge numbers of electron neutrinos are formed in nuclear reactions. Such neutrinos from the 1987A supernova in the relatively nearby Magellanic Cloud were observed within hours of the initial brightening, indicating they traveled to earth at approximately the speed of light. Explain how this data can be used to set an upper limit on the mass of the neutrino, noting that if the mass is small the neutrinos could travel very close to the speed of light and have a reasonable energy (on the order of MeV).

9.

Theorists have had spectacular success in predicting previously unknown particles. Considering past theoretical triumphs, why should we bother to perform experiments?

10.

What lifetime do you expect for an antineutron isolated from normal matter?

11.

Why does the η^0 meson have such a short lifetime compared to most other mesons?

12.

(a) Is a hadron always a baryon?

(b) Is a baryon always a hadron?

(c) Can an unstable baryon decay into a meson, leaving no other baryon?

13.

Explain how conservation of baryon number is responsible for conservation of total atomic mass (total number of nucleons) in nuclear decay and reactions.

33.5 Quarks: Is That All There Is?

14.

The quark flavor change $d \rightarrow u$ takes place in β^- decay. Does this mean that the reverse quark flavor change $u \rightarrow d$ takes place in β^+ decay? Justify your response by writing the decay in terms of the quark constituents, noting that it looks as if a proton is converted into a neutron in β^+ decay.

15.

Explain how the weak force can change strangeness by changing quark flavor.

16.

Beta decay is caused by the weak force, as are all reactions in which strangeness changes. Does this imply that the weak force can change quark flavor? Explain.

17.

Why is it easier to see the properties of the c, b, and t quarks in mesons having composition W^- or $t\bar{t}$ rather than in baryons having a mixture of quarks, such as udb?

18.

How can quarks, which are fermions, combine to form bosons? Why must an even number combine to form a boson? Give one example by stating the quark substructure of a boson.

19.

What evidence is cited to support the contention that the gluon force between quarks is greater than the strong nuclear force between hadrons? How is this related to color? Is it also related to quark confinement?

20.

Discuss how we know that π-mesons (π^+, π, π^0) are not fundamental particles and are not the basic carriers of the strong force.

21.

An antibaryon has three antiquarks with colors $\bar{R}\bar{G}\bar{B}$. What is its color?

22.

Suppose leptons are created in a reaction. Does this imply the weak force is acting? (for example, consider β decay.)

23.

How can the lifetime of a particle indicate that its decay is caused by the strong nuclear force? How can a change in strangeness imply which force is responsible for a reaction? What does a change in quark flavor imply about the force that is responsible?

24.

(a) Do all particles having strangeness also have at least one strange quark in them?

(b) Do all hadrons with a strange quark also have nonzero strangeness?

25.

The sigma-zero particle decays mostly via the reaction $\Sigma^0 \to \Lambda^0 + \gamma$. Explain how this decay and the respective quark compositions imply that the Σ^0 is an excited state of the Λ^0.

26.

What do the quark compositions and other quantum numbers imply about the relationships between the Δ^+ and the proton? The Δ^0 and the neutron?

27.

Discuss the similarities and differences between the photon and the Z^0 in terms of particle properties, including forces felt.

28.

Identify evidence for electroweak unification.

29.

The quarks in a particle are confined, meaning individual quarks cannot be directly observed. Are gluons confined as well? Explain

33.6 GUTs: The Unification of Forces

30.

If a GUT is proven, and the four forces are unified, it will still be correct to say that the orbit of the moon is determined by the gravitational force. Explain why.

31.

If the Higgs boson is discovered and found to have mass, will it be considered the ultimate carrier of the weak force? Explain your response.

32.

Gluons and the photon are massless. Does this imply that the W^+, W^-, and Z^0 are the ultimate carriers of the weak force?