

Solutions

Each answer shows the steps, then the **result**.

2.1

- strange quark: $-\frac{1}{3}\mathbf{e}$
- anti-charm quark: the charm quark is $+\frac{2}{3}e$, so its antiquark is $-\frac{2}{3}\mathbf{e}$

2.2

- write each charge: $+\frac{2}{3}e$, $+\frac{2}{3}e$, $-\frac{1}{3}e$

$$\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +\mathbf{e}$$

2.3

- a meson is one quark and one antiquark; take d and $\bar{\mathbf{u}}$

$$-\frac{1}{3}e - \frac{2}{3}e = -\mathbf{e}$$

- $\bar{\mathbf{s}}\mathbf{u}$ or $\bar{\mathbf{b}}\mathbf{u}$ would do just as well

2.4

- **electron** and **quark**
- a neutron is three quarks and a meson is a quark with an antiquark, so neither is fundamental

2.5

- an antineutron is the antiparticle of the neutron (u d d), so it is $\bar{\mathbf{u}}\bar{\mathbf{d}}\bar{\mathbf{d}}$
- each antiquark has the opposite charge to its quark

$$-\frac{2}{3}e + \frac{1}{3}e + \frac{1}{3}e = \mathbf{0}$$

3.1 B

- u u u gives $\frac{2}{3} + \frac{2}{3} + \frac{2}{3} = +2$
- A gives +1, C gives 0 and D gives +1

3.2

- a meson is one quark and one antiquark
- the largest charge a quark can carry is $+\frac{2}{3}e$ and the largest an antiquark can carry is $+\frac{1}{3}e$
- the most they can add to is $+e$, so $+2e$ is impossible

3.3

- (a) an **up** quark changes into a **down** quark, so a proton becomes a neutron
- (b) the lepton emitted with a positron is a neutrino

$$\mathbf{u} \rightarrow \mathbf{d} + \beta^+ + \nu_{\mathbf{e}}$$

(c) the nucleon is still there: it has only changed one of its quarks, so a proton has become a neutron

- the number of nucleons is therefore unchanged, though the proton number falls by one

(d) an (electron) **antineutrino** is emitted in β^- decay

- it is the **antiparticle** of the neutrino emitted in β^+ decay: the same mass, and it is matter's counterpart rather than the particle itself

3.4

- **proton**: not fundamental, a **baryon** (three quarks)
- **positron**: **fundamental** (a lepton)
- π^+ **meson**: not fundamental, a **meson** (a quark and an antiquark)
- **electron antineutrino**: **fundamental** (a lepton)

3.5

(a) three quarks, so a possible set is d, d, d

$$-\frac{1}{3}e - \frac{1}{3}e - \frac{1}{3}e = -e$$

- d d s and d s s also give $-e$

(b) a **baryon**

- a baryon is three quarks, while a meson is one quark and one antiquark