Solutions

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

2.1

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

2.2

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

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

2.3

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

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

- $\text{s}\bar{\text{u}}$ or $\text{b}\bar{\text{u}}$ 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 $\mathbf{\bar{u}\bar{d}\bar{d}}$
- each antiquark has the opposite charge to its quark

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

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

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

(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

$$-\tfrac{1}{3}e - \tfrac{1}{3}e - \tfrac{1}{3}e = \mathbf{-e}$$

- 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