Past-paper walk-through

Fundamental particles ▪ 11.2

eXercise

Questions in this set

- 9702/11 N25 Q40 ▪ 1 mark
- 9702/12 N25 Q38 ▪ 1 mark
- 9702/14 N25 Q40 ▪ 1 mark
- 9702/22 N25 Q6 ▪ 9 marks
- 9702/11 J25 Q38 ▪ 1 mark
- 9702/11 J25 Q40 ▪ 1 mark
- 9702/12 J25 Q39 ▪ 1 mark
- 9702/12 J25 Q40 ▪ 1 mark
- 9702/13 J25 Q33 ▪ 1 mark
- 9702/13 J25 Q38 ▪ 1 mark

Questions in this set

- 9702/13 J25 Q39 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 40

9702/11 N25 ▪ Q40 ▪ 1 mark

Which particle is a lepton? **[1]**

A meson

B positron

C proton

D quark

Solution 40

A meson

B positron ✓

C proton

D quark

Why

- Leptons are fundamental particles that feel no strong force: electrons, positrons, muons and neutrinos.
- A meson and a proton are both hadrons, built from quarks.
- A quark is fundamental too, but it belongs to its own family, not the leptons.

Question 38

9702/12 N25 ▪ Q38 ▪ 1 mark

An up quark in a hadron changes to a down quark.
The elementary charge is *e*.
What is the magnitude of the change in the charge of the hadron? **[1]**

A $\frac{1}{3}e$

B $\frac{2}{3}e$

C e

D zero

Solution 38

A $\frac{1}{3}e$

B $\frac{2}{3}e$

C e ✓

D zero

Why

- An up quark carries $+\frac{2}{3}e$ and a down quark $-\frac{1}{3}e$.
- The change is $-\frac{1}{3}e - (+\frac{2}{3}e) = -1e$.
- So the magnitude is e – which is exactly the charge change in β^+ decay.

Question 40

9702/14 N25 ▪ Q40 ▪ 1 mark

Which combination of three quarks has no overall charge? **[1]**

A down, strange, strange

B up, charm, strange

C up, charm, top

D up, down, strange

Solution 40

A down, strange, strange

B up, charm, strange

C up, charm, top

D up, down, strange ✓

Why

- Up, charm and top each carry $+\frac{2}{3}e$; down and strange each carry $-\frac{1}{3}e$.
- D gives $+\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$.
- A comes to $-1e$, B to $+1e$ and C to $+2e$.

Question 6

9702/22 N25 ▪ Q6 ▪ 9 marks

(a) State what is meant by a fundamental particle. **[1]**

(b)(i) Particle Q is a meson with a charge of 0.

Determine a possible quark composition for Q. **[2]**

(b)(ii) Particle Q has a mass of 0.67 u and a kinetic energy of 2.1×10^{-16} J.

Calculate the speed of particle Q. **[3]**

(c)(i) State the number of electrons in a neutral atom of radium-228. **[1]**

(c)(ii) A nucleus of radium-228 undergoes a series of decays to form nucleus X.

During the process, 5 α-particles and 4 β^- particles are emitted.

Determine the number of protons and the number of neutrons in nucleus X. **[2]**

Solution 6

(a)

Mark scheme

- (a particle that) cannot be divided / subdivided (into smaller particles) **B1**

Solution 6

(b)(i) Worked steps

A meson is **one quark and one antiquark**, and the pair must add to zero charge.

- Pair a quark with the antiquark of its own type: up with anti-up, or down with anti-down.
- Charges then cancel: $+\frac{2}{3} + (-\frac{2}{3}) = 0$, or $-\frac{1}{3} + (+\frac{1}{3}) = 0$.
- So "up and anti-up" is a valid answer (charm, top, strange or bottom pairs work equally).

Solution 6

Mark scheme

- any combination of one quark and one antiquark **C1**
- up / charm / top and antiup / anticharm / antitop or down / strange / bottom and antidown / antistrange / antibottom **A1**

Solution 6

(b)(ii) Worked steps

Convert the mass into kilograms before anything else: $1\ \text{u} = 1.66 \times 10^{-27}$ kg.

- $m = 0.67 \times 1.66 \times 10^{-27} = 1.11 \times 10^{-27}$ kg
- $E_\text{K} = \frac{1}{2}mv^2$, so $v = \sqrt{\dfrac{2E_\text{K}}{m}}$
- $v = \sqrt{\dfrac{2 \times 2.1 \times 10^{-16}}{1.11 \times 10^{-27}}}$
- $v = 6.1 \times 10^{5}$ m s^{-1}

Solution 6

Mark scheme

- E(K) = 1
- 2 mv2 C1
- 2.1 × 10–16 = 1
- 2 × 0.67 × 1.66 × 10–27 × v 2 C1
- v = 6.1 × 105 m s–1 A1

Solution 6

(c)(i)

Mark scheme

- number of electrons $= 88$ **A1**

Solution 6

(c)(ii) Worked steps

Track the two numbers separately, remembering what each decay does.

- An α decay removes 2 protons and 2 neutrons; a β^- decay turns a neutron into a proton, so protons $+1$ and neutrons -1.
- Radium-228 has $Z = 88$ and $N = 228 - 88 = 140$.
- Protons: $88 - (5 \times 2) + (4 \times 1) = 88 - 10 + 4 = 82$
- Neutrons: $140 - (5 \times 2) - (4 \times 1) = 140 - 10 - 4 = 126$

Solution 6

Check with the nucleon number: $82 + 126 = 208$, and $228 - (5 \times 4) = 208$.

Mark scheme

- (number of nucleons $= 228 - 5 \times 4 = 208$) number of protons $= 88 - (5 \times 2) + 4$
- $= 82$ **A1**
- number of neutrons$= 208 - 82 = 126$
- $= 126$ **A1**

Question 38

9702/11 J25 ▪ Q38 ▪ 1 mark

Which list contains only fundamental particles? **[1]**

A antineutrinos, baryons, neutrons, electrons

B mesons, electrons, neutrinos, protons

C positrons, quarks, hadrons, protons

D quarks, positrons, neutrinos, leptons

Solution 38

A antineutrinos, baryons, neutrons, electrons

B mesons, electrons, neutrinos, protons

C positrons, quarks, hadrons, protons

D quarks, positrons, neutrinos, leptons ✓

Why

- Fundamental means not built from anything smaller: quarks and leptons (electrons, positrons, neutrinos) qualify.
- Baryons, mesons, hadrons, neutrons and protons are all made of quarks, so none of them is fundamental.
- Only D avoids every composite particle.

Question 40

9702/11 J25 ▪ Q40 ▪ 1 mark

A hadron consists of antiquarks that are all identical.
What is a possible value, in terms of the elementary charge e, for the charge on the hadron? **[1]**

A $0e$

B $+1e$

C $+2e$

D $+3e$

Solution 40

A $0e$

B $+1e$ ✓

C $+2e$

D $+3e$

Why

- A hadron made purely of antiquarks must be an antibaryon – three of them.
- Three identical anti-down (or anti-strange) quarks give $3 \times (+\frac{1}{3}e) = +1e$.
- Three anti-up quarks would give $-2e$, so $+1e$ is the only offered value that can occur.

Question 39

9702/12 J25 ▪ Q39 ▪ 1 mark

What is the composition of a meson? **[1]**

A 1 quark and 1 antiquark

B 1 quark and 2 antiquarks

C 2 quarks and 1 antiquark

D 3 quarks

Solution 39

A 1 quark and 1 antiquark ✓

B 1 quark and 2 antiquarks

C 2 quarks and 1 antiquark

D 3 quarks

Why

- A meson is a quark–antiquark pair.
- Three quarks make a baryon, such as a proton or a neutron.
- The pairing is why a meson comes out with a whole-number charge.

Question 40

9702/12 J25 ▪ Q40 ▪ 1 mark

40 A nucleus of carbon-11 contains 6 protons and 5 neutrons.

The nucleus of carbon-11 decays by β^+ emission.

What is the total number of up and down quarks in the product of the decay of this nucleus?

	up quarks	down quarks
A	15	18
B	16	17
C	17	16
D	18	15

Solution 40

Answer: **B**

Why

- β^+ decay turns a proton into a neutron, so the product has 5 protons and 6 neutrons.
- A proton is uud (2 up, 1 down) and a neutron is udd (1 up, 2 down).
- Up: $5(2) + 6(1) = 16$; down: $5(1) + 6(2) = 17$.

Question 33

9702/13 J25 ▪ Q33 ▪ 1 mark

33 What **cannot** be the charge on a charge carrier?

A $-4.8 \times 10^{-19}\,\text{C}$

B $-3.2 \times 10^{-19}\,\text{C}$

C $-2.4 \times 10^{-19}\,\text{C}$

Question 33

D $+3.2 \times 10^{-19}\,\text{C}$

Solution 33

Answer: **C**

Why

- A free charge carrier must carry a whole-number multiple of $e = 1.60 \times 10^{-19}$ C.
- A is $3e$, and B and D are both $2e$.
- C works out at $1.5e$, which is not a whole multiple, so it cannot occur.

Question 38

9702/13 J25 ▪ Q38 ▪ 1 mark

38 A nucleus decays by emitting a β^+ particle.

Which particle **must** also be emitted from the nucleus?

A antineutrino

B β^- particle

C α-particle

Question 38

D neutrino

Solution 38

Answer: **D**

Why

- In β^+ emission a proton becomes a neutron and a positron is released.
- Lepton number has to be conserved, and the positron carries -1.
- So a neutrino, with lepton number $+1$, must be emitted with it.

Question 39

9702/13 J25 ▪ Q39 ▪ 1 mark

39 What are the charges on an antidown quark and on an antistrange quark?

	antidown quark	antistrange quark
A	$+\frac{1}{3}e$	$+\frac{1}{3}e$
B	$+\frac{1}{3}e$	$-\frac{1}{3}e$
C	$-\frac{1}{3}e$	$+\frac{1}{3}e$

Question 39

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

Solution 39

Answer: **A**

Why

- A down quark has charge $-\frac{1}{3}e$, so its antiquark carries $+\frac{1}{3}e$.
- A strange quark also has $-\frac{1}{3}e$, so the antistrange is $+\frac{1}{3}e$ as well.
- Down and strange sit in the same charge family, which is why both answers are the same.