

M1.(a)

1 ✓

0 ✓ 1 ✓

⋮

ud ✓ uud ✓

1 mark each

5

(b) Strong nuclear circled ✓

1

(c) Charge $1 + 1 = 1 + X$ $X = 1$ ✓

1

Baryon number $0 + 1 = 0 + X$ $X = 1$ ✓

1

Strangeness $0 + 0 = 1 + X$ $X = -1$ ✓

1

Any order

(d) Weak nuclear circled ✓

1

(e) Strangeness of X is -1,
First mark is for showing that strangeness changes

The strangeness of the pion and neutron are both zero

1

The strangeness changes from -1 to 0 ✓

This can only occur in weak interactions. ✓

Second is for stating that this can only happen if the interaction is weak.

1

(f)

$\bar{\nu}$
First mark is for the proton

1

$n \rightarrow p \checkmark + \beta^- + \bar{\nu}_e \checkmark$

Second is for the beta minus and antineutrino.

1

(g) The only particles remaining are electrons / positrons and neutrinos / antineutrinos which are stable ✓

1

1

And a proton which is the only stable baryon ✓

1

1

[16]

M2.C

[1]

M3. (a) γ / (pair of) gamma (ray(s))/Z₀ (particles) (followed by gamma rays) / photon(s) of electromagnetic radiation

B1

1

- (b) (i) mass can be converted to energy and vice versa
- B1
- 1
- (ii) charge
- B1
- B1
- B1
- B1
- minus 1 for each incorrect answer **if more than 3 answers are given**
- 3
- [5]**

- M4.** (a) (i) any two eg proton, neutron ✓✓
- 2
- (ii) $u\bar{d}$ ✓
- 1
- (b) (i) contains a strange quark
- or** longer half life than expected
- or** decays by weak interaction ✓
- 1
- (ii) the second one is not possible ✓
- because lepton number is not conserved ✓
- 2
- (c) (i) weak (interaction) ✓

- (ii) mention of charge conservation
or charge conservation demonstrated by numbers ✓✓ 1
- (iii) X must be a baryon ✓✓
 baryon number on right hand side is +1 ✓✓ 2
- (iv) proton/p ✓✓ 1

[11]

M5. (a) electron/neutrino/tau/muon

B1

proton/neutron

B1

kaon/k particle/k meson/pion/pi meson

B1

3

(b) (i) charge

M1

correct equation: $1 + 0 \neq 1 + (-1)$

1 mark lost for additional conservation law stated as broken

A1

2

(ii) any other correct conservation (lepton: $0 + 0 = 0 + 0$;
 baryon: $0 + 1 = 1 + 0$; strangeness: $0 + 0 = 0 + 0$)

B1 1

(c) annihilation

B1

release of energy/pair of gamma rays

B1 2

[8]

M6. (a) (i) three (1)
one (1)

2

(b) (i) charge (1)
baryon number (1)
lepton number (1)
mass (1)
energy (1)
momentum (1)

max 2

(ii) strangeness (1)
(iii) weak interaction/(nuclear) force (1)
(iv) proton (1)

5

[7]

