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) $\overline{p}$

First mark is for the proton

1

$n \rightarrow p$ ✓ $+ \beta^- + \nu_e$ ✓

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))/Z_o (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

baryon <u>number</u>

B1

lepton <u>number</u>

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) ✓

1

(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 ≠ 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]