

M1.(a) (90,39)

B1

(0,-1)

B1

$\bar{\nu}^e$

B1

3

(b) $d \rightarrow u$

or

Number of u quarks increases by 1 and number of d quarks decreases by 1

B1

1

(c) (i) Meson

Do not allow hadron

B1

1

(ii) Negative box ticked

B1

1

(iii) Characteristic of particles with strange quarks / they contain the strange quark / they have strangeness

B1

1

(iv) Gluon, W ($^+$ or $^-$) (boson) or Z^0

B1

1

[8]

M2.C

M3. (a)

particle	quark structure	charge	strangeness	baryon number
proton ✓	uud	+ 1 ✓	0	1 ✓
sigma ⁺	uus	+1	-1 ✓	1 ✓
π^+ ✓	ud	+1 ✓	0	0

7

(b) (i) examples:
proton, antiquarks ✓

1

(ii) consists of 3 antiquarks ✓

1

(iii) same (rest) mass (energy) ✓
difference eg baryon number/charge ✓

2

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M4. (a) one named hadron or obvious symbol

B1

1

(b) $d\bar{d}/u\bar{u}/u\bar{d}/\bar{d}u$ or words

B1

1

M5. (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)**

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M6. (a) up, down, strange (allow charm, top, bottom)
any two **(1)** any three **(1)(1)** (not u, d, s etc)

B2
2

(b) udd **(1)**

B1

$$+2/3(e) - 1/3(e) - 1/3(e) \text{ (1)}$$

B1
2

[4]

M7. (a) lepton fundamental
meson, baryon not fundamental
allow underline or crossing out wrong options **(1)**

1

(b) (i) baryon/hadron **(1)**

(ii) u u d **(1)**

$$+ \frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +1(e) \text{ (1)}$$

3

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M8. (a) baryon number $0 + 1 = 1 + 0$ **(1)**
lepton number $0 + 0 = 0 + 0$ **(1)**
charge $0 + 1 = 0 + 1$ **(1)**

3

(b) K^0 $\bar{s}d$ (1)

π^+ $u\bar{d}$ (1)

p udu (1)

correct number of quarks and antiquarks in each (1)

4

[7]

M9. (a) 22 (nucleons) (1)
11 (electrons) (1)

2

(b) charge: $+\frac{2}{3} = -\frac{1}{3} + 1 + 0$ (1)

lepton number: $0 = 0 - 1 + 1$ (1)

baryon number: $\frac{1}{3} = \frac{1}{3} + 0 + 0$ (1)

3

(c) the electron and the positron are annihilated (1)
 γ photon(s)/ γ ray(s) are produced (1)
specifying two (γ) photons/rays (1)
masses converted into energy (1)

max 2

[7]

M10. (a) baryon qqq
antibaryon $\bar{q}\bar{q}\bar{q}$

meson

qq

two names **(1)**
composition of each sub-group **(1) (1)**

3

(b) (i) $n \rightarrow p$ **(1)** + ${}_{-1}^0\beta^{-}$ **(1)** + $\bar{\nu}_{(e)}$ **(1)**

(ii) a down (d) quark changes to an up (u) quark
[or udd changes to uud] **(1)**

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[7]