Particle Physics MS

M1. (a) (i) quark antiquark pair OR $q\bar{q}$ OR named quark antiquark pair ✓

1

(ii) 0 ✓

1

(iii) $\bar{u}s$ ✓

1

(b) (i) Weak ✓ any of the following also score 1 mark:

weak interaction

weak interaction force

weak nuclear

weak nuclear interaction

weak decay

weak force

weak nuclear force

1

(ii) conserved: baryon number, charge, lepton number, spin ✓ ✓

not conserved: strangeness ✓

3

(iii) $K^- \rightarrow \pi^0 + e^- + \overline{\nu}_{(e)}$ ✓ ✓

OR $K^- \rightarrow \pi^0 + \mu^- + \overline{\nu}_{(\mu)}$

2

[9]

M2. (a)

interaction	exchange particle
weak	W^+ OR W^- OR Z° ✓
electromagnetic	photon OR γ ✓

2

(b) *uud* ✓

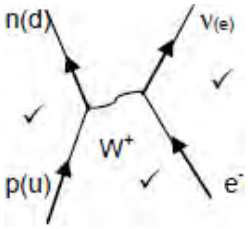
1

(c) (i) an **atomic/orbital/shell** electron ✓

interacts with a proton in the **nucleus** (via the weak interaction) ✓

3

(ii) neutron formed **or** u quark changes to d quark (and neutrino released) ✓



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[9]

M3. (a) (i) Z^0 with the weak interaction
gluons or pions with the strong nuclear force
γ photons with electromagnetic interaction
gravitons with gravity
(any exchange particle **(1)** and corresponding interaction **(1)**)

(ii) transfers energy
transfers momentum
transfers force
(sometimes) transfers charge any two **(1)(1)**

4

(b) $p\ \bar{n}\ \pi^0$ **(1)**

$V_e e^+ \mu^-$ **(1)**

$\bar{n}\ e^+$ (1)

$pe^+\mu^-$ (1)

4

[8]

M4. (a) baryon number 0 + 1 = 1 + 0 **(1)**
lepton number 0 + 0 = 0 + 0 **(1)**
charge 0 + 1 = 0 + 1 **(1)**

3

(b) K° $\bar{s}d$ **(1)**

π^+ $u\bar{d}$ **(1)**

p udu **(1)**

correct number of quarks and antiquarks in each **(1)**

4

[7]

M5. (a)

particle	quark structure	charge	strangeness	baryon number
proton ✓	uud	+ 1 ✓	0	1 ✓
sigma$^+$	uus	+1	-1 ✓	1 ✓
π^+ ✓	$u\bar{d}$	+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

[11]

M6. (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]

M7. (a) (i) positron, neutron, neutrino, positive pion **(1) (1)** (if all correct)
(lose **(1)**for each error)

(ii) electron, proton, negative muon **(1) (1)** (if all correct)
(lose **(1)**for each error)

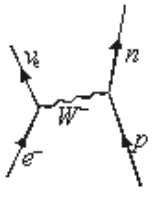
4

(b) (i) $(\mu^-) \rightarrow e^- + \overline{\nu_e} + \nu_\mu$ **(1)**

(ii) difference: mass or half-life or generation of lepton **(1)**
similarity: both leptons or both negatively charged **(1)**

3

(c)



ν_e **(1)**
n **(1)**
p **(1)**

3

[10]

M8. (a) (i) leptons do not experience the strong interaction but hadrons do **or** hadrons not fundamental/made of quarks and leptons are not **(1)**

1

(ii) hadron eg proton, neutron, pion **(1)**

lepton eg electron, neutrino **(1)**

2

(iii) baryons **(1)**

mesons **(1)**

baryons made from **three quarks** (or **3 antiquarks**), mesons a **quark**, **antiquark** pair **or** baryons, baryon number is **+1 or –1** mesons 0 **(1)**

3

(b) baryon number, lepton number, charge, strangeness, energy or momentum **(1)**

demonstration of conservation (before and after considered and number appropriate to particle quoted) **(1)**

2

[8]

M9. (a) (i) particles that experience the strong (nuclear) force/interaction **(1)**

1

(ii) particles composed of **three quarks (1)**

1

(iii) particles composed of a quark and an antiquark **(1)**

1

(b) similarity: but the same (rest) mass **or** rest energy **(1)**

difference: **opposite** quantum states eg charge **(1)**

2

(c)

	charge/C	baryon number	quark structure
antiproton	-1.6×10^{-19}	–1	$\overline{u}\,\overline{u}\,\overline{d}$

–1 for each error

2

(d) (i) weak interaction **(1)**

strange not conserved or there is a change/decay of quark (flavour) **(1)**

2

(ii) **any two**

eg charge

baryon number

(muon) lepton number

2

[11]

M10. (a) (i) $q\bar{q}$; qqq; $\overline{qqq}$

(1)(1) (**(1)** for just two combinations)

(ii) $\pi^+ = u\bar{d}$ **(1)**

$\bar{p} = \bar{d}\overline{uu}$ **(1)**

4

(b) (i) strangeness = –3

charge = –1

baryon number = +1

lepton number = 0

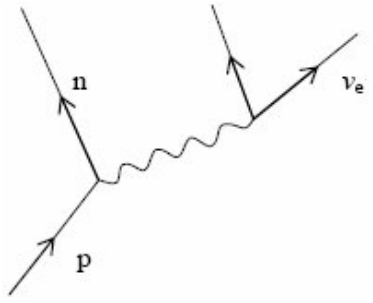
(1)(1)(1) if all correct – lose one for each error

(ii) the proton **(1)**

4

[8]

M11. (a) n **(1)**
p **(1)**
ν_e **(1)**



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(b) (i) γ photon **(1)**

(ii) γ is massless
γ has infinite range
γ does not carry charge

(1)(1) any two

3

(c) (i) all properties/quantum numbers (e.g. charge, strangeness) are opposite **(1)**

but the masses are the same **(1)**

(ii) π° **(1)**

$\bar{K}^\circ$ **(1)**

γ **(1)**

5

[11]

M12. (a) (i) (named force) from weak (nuclear), electromagnetic or gravity **(1)**
uses a mediating/exchange particle, named particle from $W^{(\pm)}$ (boson), (γ) photon or graviton **(1)**
to transfer energy/momentum **(1)**
when electron emits/receives exchange particle, disappearance/creation of new particle occurs **(1)**

QWC 1

(ii) anti proton **(1)**

max 4

(b) (i) 3 (quarks) **(1)**

(ii) weak (nuclear) **(1)**

(iii) proton **(1)**

3

[7]