Marking Scheme

1.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)	Quarks **and** leptons **and** mesons – all required	1			1		
		(ii)	Quarks **and** mesons	1			1		
	(b)	(i)	Anti-[electron] neutrino Accept: [electron] anti-neutrino		1		1		
		(ii)	**Lepton number:** 0 = 0 + 1 -1 must be in this order or described: lepton number is 0 on LHS. Electron has lepton number of +1, anti-electron neutrino has a lepton number of -1. [1] Accept 4 = 4 + 1 -1 must be in this order. **Charge:** B has one more proton than Be, but appearance of e^- means that charge is conserved **or** +4 = +5 – 1 [+ 0] must be in this order **Or:** 0 →1 -1 + 0 must be in this order or described **or** $n = p + e^-$ + anti-neutrino so $d = u + e^-$ + anti-neutrino so $-\frac{1}{3} = \frac{2}{3} - 1 + 0$ [1]		2		2		
	(c)	(i)	$^{10}_{4}Be$ has 6 neutrons **and** $^{10}_{5}B$ has 5 neutrons	1			1		
		(ii)	LHS: udd [1] RHS: uud [1] **N.B.** bod if udd → uud + e^- + anti-neutrino seen Award **1 mark** if above seen with quarks assigned to either the e^- and/or anti-neutrino Award **1 mark** for d→u or d in n→u in p or similar Award **1 mark** if equation written the wrong way around		2		2		
			Question 1 total	**3**	**5**	**0**	**8**	**0**	**0**

2.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		Protons and neutrons are each made up of 3 quarks (1) Quarks and neutrinos are not made up of other particles (1)	2			2		
	(b)	(i)	No strong force / no electromagnetic force /only interact by weak force (1) They are uncharged (1)	2			2		
		(ii)	Conservation of charge 0 + 1 → 1 + 1 **–1** (1) Conservation of lepton 1 + 0 → 0 + 0 + **1** (1) x is an electron (1)		1 1	1	3		
	(c)		Electromagnetic (1) Presence of photons / gamma rays (1)		1	1	2		
			Question 7 total	**4**	**3**	**2**	**9**	**0**	**0**

3.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		E = [2×] $9.11 \times 10^{-31} \times c^2$ or $m = \frac{9.11 \times 10^{-31}}{1.66 \times 10^{-27}}$ [= 0.000549 u] [1] Conversion to eV i.e. dividing by 1.6×10^{-19} or × 931 [1] 1.025 MeV seen or $2 \times 9.11 \times 10^{-31} \times \frac{(3 \times 10^8)^2}{1.6 \times 10^{-19}}$ or $2 \times 0.000549 \times 931$ [1]		3		3	3	
	(b)		Excess energy or 0.01 MeV [1] Equal amounts shared by electrons & positron due to equal (light) masses [1]		2		2		
	(c)		$0.5 \times 9.11 \times 10^{-31} \times v^2 = 0.005 \times 10^6 \times 1.6 \times 10^{-19}$ seen or equivalent: $(0.5 \times 9.11 \times 10^{-31} \times (4.2 \times 10^7)^2$ giving 0.005 MeV or 4.19×10^7 seen [1] Momentum of gamma ray [= $\frac{E}{c}$] = 5.49×10^{-22} [N s] [1] Momentum of electron or positron = $9.11 \times 10^{-31} \times 4.2 \times 10^7$ = 3.8×10^{-23} or 7.6×10^{-23} [1] $5.49 \times 10^{-22} - 2 \times 4.2 \times 10^7 \times 9.11 \times 10^{-31}$ seen [1]		4		4	3	
	(d)		KE calculated (3.35×10^{-19} J or 2.1 eV) [1] Correct conclusion – negligible [1] **No ecf**			2	2	1	
			Question 5 total	**0**	**9**	**2**	**11**	**7**	**0**

4.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	<table><tr><th>Particle</th><th>Symbol</th><th>Quark Combination</th><th>Charge/e</th><th>Baryon Number</th></tr><tr><td>Proton</td><td>p</td><td>uud</td><td>+1</td><td>1</td></tr><tr><td>Delta particle</td><td>Δ^{++}</td><td>uuu</td><td>+2</td><td>1</td></tr><tr><td>Electron</td><td>e^-</td><td>No quarks present</td><td>-1</td><td>0</td></tr><tr><td>Pion</td><td>π^-</td><td>$\bar{u}d$ or $d\bar{u}$</td><td>-1</td><td>0</td></tr></table>[3 × 1] marks for each correct row (ignoring row for proton)		3		3		
		(ii)	Electron	1			1		
	(b)		**Charge:** LHS: -1 +1 (=0) RHS: -1 +2 -1 (=0) [must be shown how 0 is determined on both sides] (1) **Lepton Number:** LHS: 1 + 0 (= 1) RHS: 1 + 0 + 0 (=1) [must be shown how 1 is determined on both sides] (1)		2		2		
	(c)	(i)	Up Quark: Δ^{++} contains 3 up quarks (uuu) = proton contains 2 up quarks (uud) + pion contains 1 up quark ($u\bar{d}$) (1) Down Quark: Δ^{++} contains 0 down quarks = proton contains 1down quark (uud) + pion contains 1 antidown quark ($u\bar{d}$). (1) Alternative for first mark: equation in quark form $uuu \rightarrow uud + u\bar{d}$		2		2		
		(ii)	**Any 2 × (1) from:** • Very short lifetime / decays quickly / ref to 6×10^{-24} s • No change in u or d quark number (or flavour) • Only quarks or hadrons involved • No γ (or photon) or no neutrino involvement	2			2		
	(d)		No practical use for electron or proton or both when they were discovered (1) Now many uses **and** one example given for either electron or proton (1)			2	2		
			Question 4 total	**3**	**7**	**2**	**12**	**0**	**0**

5.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		**Differences** **Hadrons** H1 Made up of quarks H2 Affected by strong interaction H3 e.g. protons / neutrons / mesons **Leptons** L1 Fundamental particles L2 Not affected by strong interaction L3 e.g. electron / electron neutrino **Similarities** S1 Both have a rest mass / gravitational attraction S2 Both can be affected by the weak interaction S3 Both can be affected by the electromagnetic interaction **Sub group** G1 Hadrons can be split into Baryons and mesons G2 Baryons contain 3 quarks G3 Mesons contain a quark antiquark pair **5 – 6 marks** 2 points from each of H L S and G *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3 – 4 marks** 1 point from each of H L S and G *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1 – 2 marks** 3 points from any group *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*	6			6		
	(b)	(i)	Charge +1 -1 = 0 + 0 (1) Lepton number 0 +1 = 0 +1 (1) Hence, x is an uncharged lepton, … … Hence Particle identified as an electro neutrino (1)		3		3		
		(ii)	u changes to d / uud to udd		1		1		
		(iii)	Weak interaction because of the presence of a neutrino / change in quark flavour	1			1		
			Question 5 total	**7**	**4**	**0**	**11**	**0**	**0**

6.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		$-\frac{2}{3}-\frac{2}{3}-\frac{2}{3}=-2$ seen or statement that this is the only way to get a charge of -2(e)		1		1		
	(b)		$\overline{uuu} \rightarrow \overline{uud} + \overline{ud}$ **or** $\overline{uuu} + \overline{uu}$ **or** $\overline{uuu} + \overline{dd}$ [1] [any order of quarks in the baryon and meson] Anti-proton or anti- Δ^+ and π^- OR anti- Δ^{++} and π^0 [1]			2	2		
	(c)		Strong force [1] **no ecf** Short time or conservation of u and d **and** no photon or accept ONLY quarks / hadrons involved **or** no neutrinos **and** no photons **or** no flavour change **and** no photons [1]			2	2		
	(d)		**Any 3 x (1) valid points:** -contradicts current theories (relativity) or can't travel faster than the speed of light ✓ -current theories well established ✓ -further experiments ✓ -by other groups / scientists / peer review ✓ -due to instrument problems (timing delay) / systematic errors ✓			3	3		
			Question 6 total	**0**	**1**	**7**	**8**	**0**	**0**

7.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		Mass can be converted to energy (or vice versa or $E = mc^2$) (1) So mass-energy cons used if change of mass (1) i.e. short concluding comment stating briefly mass-energy conservation (rather than simple energy conservation) also accept $m_0c^2 + E$ conserved (or similar)	2			2		
	(b)		Baryon number OK [1+1 = 5-3+1-1+0+0+0] or 2=2 (1) Accept U and D conservation : 4U + 2D = 4U + 2D Or Quark number: 6 = 6 Lepton number not OK [0+0 ≠ 0+0+0+0+0+0+4] or 0≠4 (1) Charge conservation OK [1+1 = 5-3+0+0+2-2+0] or 2=2] (1) Mass energy not OK not enough energy to produce products (1) If not 4 correct conclusions 3max.			4	4		
			Question 7 total	**2**	**0**	**4**	**6**	**0**	**0**