

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
	C		1

Q2.

Question Number	Answer	Mark
	$\bar{u}d$ (1)	1

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C <i>A is not correct because lepton number is not conserved</i> <i>B is not correct because charge conservation is not obeyed</i> <i>D is not correct because charge conservation is not obeyed</i>	$p \rightarrow n + \beta^+ + \nu$	1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not the correct answer, as a baryon has three quarks. B is not the correct answer, as leptons are fundamental particles D is not the correct answer, as a nucleon is a proton or neutron		1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Three quarks (1) (s) u u (1)		2

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Correct symbol for pion and neutron (1) - Pion marked positive (1)	Do not award MP1 if an additional symbol appears <u>Example</u> $(\Sigma^+) \rightarrow \pi^+ + n$ Ignore 0 if written next to n	2

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• See $u\bar{d}s$ (1) • Comment that charge is zero (1)	If a meson or an incorrect baryon is given which has zero charge, MP2 can be awarded for comment of zero charge.	2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• $p : u u d$ (1) • $n : u d d$ (1) • $\pi^- : u \bar{d}$ (1)	Accept labelled $\pi^- : \bar{u} d$	3

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	$\Lambda^0 \rightarrow e^+ + e^-$ (no 2) (1) baryon number not conserved (1) $\Lambda^0 \rightarrow n$ only (no 4) (1) momentum or energy cannot be conserved (1) $\Lambda^0 \rightarrow p$ and π^0 (no 5) (1) charge not conserved (1)	More than 3 decays identified as not possible max 2 marks for the decays.	6

Q11.

Question Number	Answer	Mark
(a)(i)	Three quarks Or three antiquarks (accept the letter q to represent quarks) (1)	1
(a)(ii)	Quark and an antiquark (accept the letter q to represent quarks) (1)	1
(b)	Similarity: they have the same mass Or same magnitude of charge (1) Difference: opposite charge (1)	2
(c)(i)	Up and antistrange (in words or symbols, and can be in either order) (1)	1
(c)(ii)	μ^- (1) $+\square_{\mu}$ (1) $K^- \rightarrow \mu^- + \square_{\mu}$	2
(c)(iii)	Energy = $2 \times 494 \text{ MeV}$ (1) eV to J conversion (1) Energy = $1.58 \times 10^{-10} \text{ (J)}$ (1) (division by c^2 and subsequent multiplication by c^2 is not penalised) <u>Example of calculation</u>	3
	Energy = $2 \times 494 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1}$ Energy = $1.58 \times 10^{-10} \text{ J}$	
	Total for question	10

Q12.

Question Number	Acceptable Answers	Additional guidance	Mark
a	- fundamental – quarks and leptons (1) - Baryons made of 3 q (1) - Mesons made of quark and antiquark (1) 6 quark Or 6 leptons (1) - Each particle has an antiparticle (1)	MP2 and 3 could be given for a named particle and its quark composition Can be inferred if either set named	5

Question Number	Acceptable Answers	Additional guidance	Mark
b	• Use of $\Delta E = \Delta mc^2$ (1) • Conversion of J to eV (1) • mass = 120 GeV/c² (1)	Example of calculation: $E = 2.2 \times 10^{-25} \text{ kg} \times (3.0 \times 10^8)^2 (\text{ms}^{-1})^2$ $E = 1.98 \times 10^{-8} \text{ J}$ $E = 1.98 \times 10^{-8} \text{ J} \div 1.6 \times 10^{-19} \text{ J eV}^{-1}$ $E = 124 \times 10^9 \text{ eV}$	3

Question Number	Acceptable Answers	Additional guidance	Mark
c(i)	• Energy (of protons) converted to mass (of Higgs) (1) Or Energy is required to overcome electrostatic repulsion between protons • Reference to $E = mc^2$ (can be written in any form) (1) • Because c^2 is very large (E must be large) (1) Or Higgs particle is massive so needs a lot of energy to create it	Alternative based on numerical values: Observation that Higgs mass is 120 GeV/c ² This requires an energy of at least 120 GeV Each beam of protons would need an energy of at least 60 GeV	3
c(ii)	• Use of circumference = $2\pi r$ (1) • Use of $p = Bqr$ (1) • $p = 5.7 \times 10^{-15} \text{ N s}$ (1)	Example of calculation: $r = 27000 \div 2\pi$ $r = 4300 \text{ m}$ $p = 8.3 \text{ T} \times 1.6 \times 10^{-19} \text{ C} \times 4300 \text{ m}$ $p = 5.7 \times 10^{-15} \text{ N s}$	3
ciii	0 (1)	zero	1

Question Number	Acceptable Answers	Additional guidance	Mark
d	• High speeds (1) Or relativistic • Mass (of proton) increases (1) • Or this equation is only valid at non-relativistic speeds	Alt: speeds close to speed of light	2