11. Particle Physics

11.2 Fundamental particles

Paper 2

Marking Scheme

Q1.

(a)	meson(s) **or** hadron(s)	**B1**
(b)	Q: anti-up **or** anti-charm **or** anti-top	**B1**
	R: up **or** charm **or** top	**B1**

Q2.

(a)(iii)	leptons	**B1**
(b)	(alpha particle consists of) 2 protons and 2 neutrons	**C1**
	quark composition of proton = up up down **or** quark composition of neutron = up down down	**C1**
	quark composition (of alpha particle) = 6 up, 6 down	**A1**

Q3.

(a)(ii)	down (quark) changes to up (quark) **or** up down down (quarks) change to up up down (quarks)	**B1**
(b)	charm (quark charge) is (+)2/3(e) **or** 2 charm (quark charges) is (+)4/3(e) **or** bottom (quark charge) is –1/3(e)	**C1**
	charge = +2/3(e) + 2/3(e) –1/3(e) = (+)1(e)	**A1**

Q4.

(c)	neutrino classified as a lepton only and positron classified as a lepton only	**B1**
	neutron classified as a baryon and a hadron and not as a lepton	**B1**
(d)(ii)	working states or implies 3 quarks and each quark has a charge of (+) ⅔(e)	**B1**
	any combination of 3 quarks comprised of one or more of up / charm / top	**B1**

Q5.

(a)	only baryon **and** nucleon underlined	**B1**
(c)	charm antiquark (charge) = –⅔(e) **or** –⅔(e) + q = –1(e)	**B1**
	(other quark q = –⅓(e) so) down / strange / bottom	**B1**

Q6.

(b)(i)	up / u (charge) = $(+)\frac{2}{3}e$ **or** antidown / $\bar{d}$ = $(+)\frac{1}{3}e$ **or** (q)= $\frac{2}{3}e+\frac{1}{3}e$	**M1**
	q = (+)1e	**A1**
(b)(ii)	hadron(s)	**B1**
	meson(s)	**B1**

Q7.

(a)(ii)	lepton(s)	**B1**
(b)(i)	(charge of ddd / Y =) $-\frac{1}{3}(e)\ -\frac{1}{3}(e)\ -\frac{1}{3}(e) = -1(e)$	**B1**
	(charge of $\bar{u}$d / Z =) $-\frac{1}{3}(e)\ -\frac{2}{3}(e) = -1(e)$	**B1**
(b)(ii)	meson: Z / $\bar{u}$ d because consists of a quark and an antiquark	**B1**
	baryon: Y / ddd because consists of three quarks	**B1**

Q8.

(a)	particle with no internal structure / particle which cannot be broken down into anything smaller	**A1**
(b)	charges: $u = (+)\frac{2}{3}(e)$ **or** $d = -\frac{1}{3}(e)$ **or** $s = -\frac{1}{3}(e)$	**C1**
	$(+)\frac{2}{3}(e) - \frac{1}{3}(e) - \frac{1}{3}(e) = 0(e)$	**A1**
(c)(i)	• same/equal mass • same/equal (magnitude of) charge • both fundamental (particles) • opposite (sign of) charge • one is matter and the other is antimatter *Any two points, 1 mark each.*	**B2**
(c)(ii)	neutron/baryon consists of three quarks	**B1**
	pion/meson consists of one quark and one antiquark	**B1**

Q9.

(c)(i)	up down down / udd	**B1**
(c)(ii)	up up up / uuu	**B1**

Q10.

(a)(iv)	(quark structure is) up up down **or** uud	**B1**
	(2 / 3)*e* + (2 / 3)*e* – (1 / 3)*e* = (+)*e*	**B1**
(a)(v)	up up down changes to up down down **or** uud → udd **or** up changes to down **or** u → d	**B1**

Q11.

(b)	made up of quarks (so) not a fundamental particle	**B1**

Q12.

(b)(i)	neutron decays into proton and an electron / β^- particle	**B1**
(b)(ii)	down to up	**B1**

Q13.

(b)	charge of quark(s) = (+) 2*e* / 3	**B1**
	up/u (quarks)	**B1**

Q14.

(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	**B1**
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	**B1**

Q15.

(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	**B1**
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	**B1**

Q16.

(b)(i)	$-(1/3)e$	**B1**
(b)(ii)	$2q - (1/3)e = e$ so $q = (2/3)e$	**M1**
	up / u (quarks) (*allow charm or top quarks*)	**A1**

Q17.

(c)(ii)	down quark charge is $-(1/3)e$	**C1**
	$-(1/3)e + q = -1e$ so $q = -(2/3)e$	**A1**
	($-(2/3)e$ is) anti-up / $\bar{u}$ (quark) (*allow charm or top antiquark*)	**B1**

Q18.

(b)	d/down (quark charge) is $-\frac{1}{3}(e)$ **or** two d/down (quark charges) is $-\frac{2}{3}(e)$ **or** s/strange (quark charge) is $-\frac{1}{3}(e)$	**C1**
	charge = $-\frac{1}{3}(e) - \frac{1}{3}(e) - \frac{1}{3}(e)$ = $-1(e)$	**A1**

Q19.

(a)	circle(s) drawn only around β^- and $\bar{\nu}$ symbols	**B1**
(e)	up down down changes to up up down **or** udd → uud **or** down changes to up **or** d → u	**B1**

Q20.

(a)	antineutrino **and** positron both underlined (and no other particles)	**B1**