Unit 4: Further Mechanics, Fields and Particles - Mark scheme

Question number	Answer	Mark
1	**D**	1
2	**C**	1
3	**A**	1
4	**B**	1
5	**C**	1
6	**B**	1
7	**D**	1
8	**B**	1
9	**D**	1
10	**D**	1

Question number	Answer		Mark
11	• Use of $E = Q/4\pi\varepsilon_0 r^2$ • $E = 1.1 \times 10^5$ N C^{-1} • Direction is towards the point charge <u>Example of calculation</u> $E = Q/4\pi\varepsilon_0 r^2$ $E = 3.7 \times 10^{-9}$ C/ ($4\pi \times 8.85 \times 10^{-12}$ F m^{-1} (0.055 m)^2) $E = 1.1 \times 10^5$ N C^{-1}	(1) (1) (1)	3
	Total for Question 11		**3**

Question number	Answer		Mark
12	• Identifies meson structure quark – antiquark • 1 correct combination 1 mark • 2 or 3 correct combinations 2 marks • All four correct combinations 3 marks <u>Combinations are</u> $(+\tfrac{2}{3}e) + (-\tfrac{2}{3}e) = 0$ $(+\tfrac{2}{3}e) + (+\tfrac{1}{3}e) = +e$ $(-\tfrac{1}{3}e) + (-\tfrac{2}{3}e) = -e$ $(-\tfrac{1}{3}e) + (\tfrac{1}{3}e) = 0$	(1) (3)	4
	Total for Question 12		**4**

Question number	Answer		Mark
13(a)	• Use of $v^2 = u^2 + 2as$ with $v = 0$ **Or** use of equivalent pair of equations • Initial speed = 7.3 (m s^{-1}) <u>Example of calculation</u> $0 = u^2 + 2 \times (-2.4\ \text{m s}^{-2}) \times 11\ \text{m}$ $u = 7.3\ \text{m s}^{-1}$	(1) (1)	2
13(b)	• Use of $p = mv$ (allow ecf of value from (a)) • Use of correct trigonometrical function for East−West momentum • Use of correct trigonometrical function for North−South momentum • Initial speed of car A = 7.8 m s^{-1} • Initial speed of car B = 11.5 m s^{-1} • So neither car was speeding **Or** conclusion consistent with their calculated values <u>Example of calculation</u> $p = (1100\ \text{kg} + 1400\ \text{kg}) \times 7.3\ \text{m s}^{-1}$ $= 18250\ \text{kg m s}^{-1}$ $p_A = 18250\ \text{kg m s}^{-1} \times \cos 62°$ $= 8570\ \text{kg m s}^{-1}$ $u_N = 8570\ \text{kg m s}^{-1} \div 1100\ \text{kg} = 7.8\ \text{m s}^{-1}$ $P_B = 18250\ \text{kg m s}^{-1} \times \sin 62°$ $= 16100\ \text{kg m s}^{-1}$ $u_B = 16100\ \text{kg m s}^{-1} \div 1400\ \text{kg} = 11.5\ \text{m s}^{-1}$ $7.8\ \text{m s}^{-1} < 8.3\ \text{m s}^{-1}$ and $11.5\ \text{m s}^{-1} < 13.9\ \text{m s}^{-1}$ So neither car was speeding	(1) (1) (1) (1) (1) (1)	6
	Total for Question 13		**8**

Question number	Answer		Mark
14(a)	• Initially a straight line with a positive gradient **Or** reference to $s = vt$ • Then an upward curve that does not reach $v = 3.0 \times 10^8$ m/s	(1) (1)	2
14(b)	• Initially distance proportional to speed • At higher speeds there is a relativistic increase in the lifetime of the particles • So the particles travel further as their lifetime is extended	(1) (1) (1)	3
	Total for Question 14		**5**

Question number	Answer	Mark
15(a)	• Use of factor 1.6×10^{-19} C to convert eV to J (1) • Use of $\Delta m = \Delta E / c^2$ (1) • mass = 1.9×10^{-28} kg (1) <u>Example of calculation</u> $E = 106 \times 10^6$ eV $\times 1.6 \times 10^{-19}$ C = 1.7×10^{-11} J $m = 1.7 \times 10^{-11}$ J $\div (3.0 \times 10^8$ m s$^{-1})^2$ = 1.9×10^{-28} kg	**3**
15(b)	• the minimum value assumes no kinetic energy is carried away by the particle (1) • a particle with kinetic energy would require more energy from the black hole and hence a greater mass decrease from the black hole (1)	**2**
	Total for Question 15	**5**

Question number	Answer	Mark
16	• Energy conversion using 1.6×10^{-19} C (1) • Use of $E_p = Vq$ (1) • Use of $Q/4\pi\varepsilon_0 r$ with $Q = 79e$ (1) • $r = 2.9 \times 10^{-14}$ m (1) • This is about 10 000 times smaller than the atom, so it is consistent with the conclusion that there is a massive nucleus in an atom that is mostly empty space **Or** conclusion consistent with their calculated values (1) <u>Example of calculation</u> Initial $E_k = 7.7 \times 10^6 \times 1.6 \times 10^{-19}$ C = 1.23×10^{-12} J $V = 7.36 \times 10^{-13}$ J $\div (2 \times 1.6 \times 10^{-19}$ C = 3.85×10^6 V $r = 79 \times 1.6 \times 10^{-19}$ C $\div (4 \times \pi \times 8.85 \times 10^{-12}$ F m$^{-1} \times 3.85 \times 10^6$ V) $r = 2.9 \times 10^{-14}$ m	**5**
	Total for Question 16	**5**

Question number	Answer		Mark
17(a)	• Electrons produced by thermionic emission (at the filament) • Electrons are accelerated by an electric field between the anode and the cathode	(1) (1)	**2**
17(b)(i)	• Use of $E = V/d$ **and** $F = EQ$ • Use of $F = ma$ • Use of $v = s/t$ • Use of $s = ut + \frac{1}{2}at^2$ with $u = 0$ • $s = 0.013$ m • which is less than 0.025 m so it doesn't hit the plate **Or** give credit for answer consistent with calculated value <u>Example of calculation</u> $E = 550\text{ V} / 0.05\text{ m} = 11\ 000\text{ V m}^{-1}$ $F = 11\ 000\text{ V m}^{-1} \times 1.6 \times 10^{-19}\text{ C}$ $F = 1.76 \times 10^{-15}\text{ N}$ $a = F/m = 1.76 \times 10^{-15}\text{ N} / 9.11 \times 10^{-31}\text{ kg}$ $a = 1.93 \times 10^{15}\text{ m s}^{-2}$ $t = 0.10\text{ m} / 2.7 \times 10^{7}\text{ m s}^{-1} = 3.70 \times 10^{-9}\text{ s}$ $s = \frac{1}{2} \times 1.93 \times 10^{15}\text{ m s}^{-2} \times (3.70 \times 10^{-9}\text{ s})^2$ $s = 0.013$ m	(1) (1) (1) (1) (1) (1)	**6**
17(b)(ii)	• Use of $\lambda = h/p$ • $\lambda = 2.7 \times 10^{-11}$ m <u>Example of calculation</u> $\lambda = 6.63 \times 10^{-34}\text{ J s} \div (9.11 \times 10^{-31}\text{ kg} \times 2.7 \times 10^{7}\text{ m s}^{-1})$ $\lambda = 2.7 \times 10^{-11}$ m	(1) (1)	**2**
	Total for Question 17		**10**

Question number	Answer	Mark
18(a)	For each law, states what is conserved and uses values for the particles in the equation to demonstrate conservation • baryon number is conserved (1) • neutron(1) → proton(1) + electron(0) + antineutrino(0) (1) • lepton number is conserved (1) • neutron(0) → proton(0) + electron(+1) + antineutrino(−1) (1) • charge is conserved (1) • neutron(0) → proton(+1) + electron(−1) + antineutrino(0) (1)	6
18(b)	• Attempt at calculation of mass difference (1) • eV conversion (1) • Use of $E_k = p^2/2m$ (1) • $p = 4.77 \times 10^{-22}$ kg m s^{-1} (1) <u>Example of calculation</u> $\Delta m = m_n - m_p - m_e$ $\Delta m = 939.5656 \text{ MeV/c}^2 - 938.2723 \text{ MeV/c}^2 - 0.5110 \text{ MeV/c}^2$ $= 0.7823 \text{ MeV/c}^2$ $E_k = 0.7823 \times 10^6 \text{ eV} \times 1.60 \times 10^{-19} \text{ C} = 1.25 \times 10^{-13} \text{ J}$ $p = \sqrt{(2 \times 1.25 \times 10^{-13} \text{ J} \times 9.11 \times 10^{-31} \text{ kg})}$ $p = 4.77 \times 10^{-22}$ kg m s^{-1}	4
	Total for Question 18	**10**

<table>
<tr><th>Question number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>19(a)</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is Structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning.

Indicative content
• Electric field accelerates proton across gap
• Potential difference oscillates at a constant frequency so the time in the gaps is constant for each cycle
• Enters successive gaps at greater speeds so the gaps must increase in size
• Proton has constant speed within the drift tube
• Potential difference oscillates at a constant frequency so time in tubes is constant for each cycle
• Goes faster in successive tubes so the tubes must increase in length</td><td>6</td></tr>
</table>

Question number	Answer	Mark
19(b)(i)	• Force on proton due to magnetic field (BQv) = centripetal force (mv^2/r) (1) • Use $p = mv$ (1) • Correct algebraic link to $r = p/BQ$ (1)	3
19(b)(ii)	• Use of $E = pc$ (1) • Use of $r = p/BQ$ (1) • B = 7.7 T (1) Example of calculation $p = 6.5 \times 10^{12} \times 1.6 \times 10^{-19}$ C $\div 3.00 \times 10^{8}$ m s^{-1} $= 3.47 \times 10^{-15}$ Ns $B = 3.47 \times 10^{-15}$ Ns $\div$ (2800 m $\times 1.6 \times 10^{-19}$ C) B = 7.7 T	3
	Total for Question 19	**12**

Question number	Answer	Mark
20(a)(i)	• Alternating current produces an alternating/varying magnetic field (1) • Magnetic flux in first coil linked to second coil **Or** lines of flux cutting coil in second coil **Or** so there is varying flux in second coil (1) • An e.m.f. is therefore induced in the second coil (1) • There is a current in the capacitor circuit because there is a complete circuit (1)	4
20(a)(ii)	• Alternating current will charge the capacitor during one half cycle and discharge it during the other half cycle (1) • so a diode is needed to convert the ac to dc **Or** the diode only conducts during every alternate half cycle (1)	2
20(b)(i)	• Use of $C = Q/V$ (1) • $Q = 0.059$ C (1) <u>Example of calculation</u> $Q = 1.8 \times 10^{-4}$ F × 330 V $Q = 0.059$ C	2
20(b)(ii)	• Use of $W = ½ QV$ or a derived equation (1) • $W = 9.8$ J (1) <u>Example of calculation</u> $W = 0.5 \times 0.059$ C × 330 V $Q = 9.8$ J	2
20(b)(iii) 1.	• Use of $V = V_0 /e$ to find time constant **Or** intercept with t axis using initial tangent to find time constant (1) • Use of time constant = RC (1) • Use of $V = IR$ (1) • I = 270 A (1) <u>Example of calculation</u> $V_0 /e = 330$ V / e = 121 V Time constant = 217×10^{-6} s 217×10^{-6} s = $R \times 1.8 \times 10^{-4}$ F $R = 1.2$ Ω $I = 330$ V / 1.2 Ω = 274 A	4

Question number	Answer	Mark
20(b)(iii) 2.	**Either** • Use of 20% of W_0 (1) • Use of $W = ½CV^2$ (1) • Use $V = V_0 e^{\frac{-t}{RC}}$ (1) • $t = 1.7 \times 10^{-4}$ s (1) **Or** • Calculate 20% of initial energy = 1.96 J (1) • Use of $W = ½\ QV$ and $C = Q/V$ (1) • Use of graph to determine corresponding value of t (1) • $t = 1.7 \times 10^{-4}$ s (1) <u>Example of calculation</u> $V/V_0 = \sqrt{0.2} = 0.45$ $0.45\ V_0 = V_0 e^{\frac{-t}{RC}}$ $\ln 0.45 = \frac{-t}{0.00018\ \text{F} \times 1.2\Omega}$ $t = 1.7 \times 10^{-4}$ s **Or** $W = ½\ QV$ and $C = Q/V$ so $W = ½\ CV^2$ $V = \sqrt{(2 \times 1.96\ \text{J} \div 1.8 \times 10^{-4}\ \text{F})} = 148$ V $t = 1.7 \times 10^{-4}$ s	4
	Total for Question 20	**18**