Mark Scheme (Results)

Summer 2021

Pearson Edexcel International Advanced Level
In Physics (WPH14)
Paper 01 Further Mechanics, Fields and Particles

Question number	Answer	Mark
1	The only correct answer is B muon Incorrect answers A antiproton is made of antiquarks C neutron is made of quarks D Pion is made of quark-antiquark	(1)

Question number	Answer	Mark
2	The only correct answer is B The nucleus of the atom is positively charged because the deflection could have been caused by a concentration of negative charge Incorrect answers A,C,D these are clear conclusions	(1)

Question number	Answer	Mark
3	The only correct answer is C because lepton number and charge are equal before and after the interaction Incorrect answers A lepton number is not conserved B charge is not conserved D lepton number is not conserved and charge is not conserved	(1)

Question number	Answer	Mark
4	The only correct answer is A Incorrect answers B a baryon cannot mix q and anti-q, a mson cannot be qq C both have the wrong number of quarks D both have the wrong number of quarks	(1)

Question number	Answer	Mark
5	The only correct answer is B increase the anode potential V because this will increase momentum and decrease de Broglie wavelength and decrease the angle Incorrect answers A this does not affect the angle C this does not affect the angle, just the intensity D this will increase the angle	(1)

Question number	Answer	Mark
6	The only correct answer is D because this will decrease the rate of change of flux linkage and therefore the induced emf and therefore the current Incorrect answer A, B, C these will all increase the rate of change of flux linkage and therefore the induced emf and therefore the current	(1)

Question number	Answer	Mark
7	The only correct answer is B because each sphere has half of the original kinetic energy and if ke is decreased by a factor of ½, speed is decreased by the square root of this Incorrect answers A,C,D	(1)

Question number	Answer	Mark
8	The only correct answer is C because $E = V/d$ so these changes decrease the electric field strength and therefore the force on the particle and therefore the acceleration and therefore the angle Incorrect answers A,B,D – these all increase the electric field strength	(1)

Question number	Answer	Mark
9	The only correct answer is B because $F = Bqv$ so $v=F/Bq$ Incorrect answers A,C,D	(1)

Question number	Answer	Mark
10	The only correct answer is D because short de Broglie wavelengths are needed to investigate the structure of nucleons at smaller scales Incorrect answers A these experiments are not about the creation of new particles B negative electrons do not experience repulsive electrostatic forces from positive protons or neutral neutrons C particle lifetime is not relevant as all of the particles involved are believed to be stable, as long as neutrons are in a nucleus	(1)

Question number	Answer		Mark
11(a)	• Calculate period = 8.3 s ÷ 10 = 0.83 s **or** calculate f = 10/ 8.3 s = 1.2 Hz • Use of $\omega = 2\pi / T$ **or** Use of $\omega = 2\pi f$ • ω = 7.6 rad s^{-1} <u>Example of calculation</u> T = 8.3 s ÷ 10 = 0.83 s Use of $\omega = 2\pi / T$ ω = 7.6 rad s^{-1}	 (1) (1) (1)	3
11(b)	• Use of $F = BIl \sin\theta$ • $F = 2.0 \times 10^{-3}$ N • direction is out of page <u>Example of calculation</u> F = 0.053 T × 1.1 A × 3.5 × 10^{-2} m × sin 80º = 2.0 × 10^{-3} N	(1) (1) (1)	3
	Total for question 11		**6**

Question number	Answer		Mark
12 (a)	• Evidence of $E_k = ½\ mv^2$ **and** $p = mv$ • Correct algebraic link to $E_k = p^2/2m$ <u>Example of derivation</u> $E_k = ½\ mv^2$ $[= m \times mv^2 / 2 \times m]$ $= (mv)^2 / 2m$ $[p = mv]$ $E_k = p^2/2m$	(1) (1)	2
12(b)	• Use of $F = Eq$ • Use of $W = Fs$ • Use of $E_k = p^2/2m$ **Or** Use of $E_k = ½\ mv^2$ **and** $p = mv$ in conjunction • Momentum = 9.33×10^{-20} kg m s^{-1} <u>Example of calculation</u> $F = 7.64 \times 10^6$ V m^{-1} $\times 1.60 \times 10^{-19}$ C $= 1.22 \times 10^{-12}$ N $W = 1.22 \times 10^{-12}$ N $\times 5.50 \times 10^{-3}$ m $= 6.72 \times 10^{-15}$ J 6.72×10^{-15} J $+ 6.42 \times 10^{-15}$ J $= 1.31 \times 10^{-14}$ J 1.31×10^{-14} J $= p^2 / 2 \times 3.32 \times 10^{-25}$ kg $p = 9.33 \times 10^{-20}$ kg m s^{-1}	(1) (1) (1) (1)	4
	Total for question 12		6

<table>
<tr><th>Question number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>13</td><td>

Use of $\Delta E_{grav} = mg\Delta h$
Idea that centripetal force at top of loop equals weight for minimum speed
Use of $F = mv^2/r$
Use of $E_k = ½\ mv^2$
Add E_{grav} at top of loop and required E_k
Or Subtract E_{grav} at top of loop from E_{grav} at launch
Or Subtract required E_k from E_{grav} at launch
(ΔE_{grav} at start of) 0.081 J is less than 0.089 J (for sum of E_{grav} at top of loop and required E_k, so insufficient energy), so it does not complete the loop
Or (Height required of) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop
Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop
Or v at height of top of loop would be 0.77 m s^{-1} which is less than the required 1.04 m s^{-1} so it does not complete the loop
Or mv^2/r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop

Do not credit parts of calculation or derivation unambiguously using the formula for uniform acceleration $v^2 = 2as$, i.e. if the symbols are seen and substitution is from them and not from $mg\Delta h = ½\ mv^2$

<u>Example of calculation</u>
ΔE_{grav} at release point = 0.033 kg × 9.81 N kg^{-1} × 0.25 m = 0.0809 J
W = 0.033 kg × 9.81 N kg^{-1} = 0.324 N
At minimum speed $W = mv^2/r$
0.324 N = 0.033 kg × v^2 / 0.11 m
v = 1.04 m s^{-1}
E_k = ½ × 0.033 kg × (1.04 m s^{-1})^2 = 0.0178 J
ΔE_{grav} at top of loop = 0.033 kg × 9.81 N kg^{-1} × 0.22 m = 0.0712 J
Total energy required to complete loop
= 0.0178 J + 0.0712 J = 0.089 J
0.0809 J < 0.089 J
</td><td>(1)
(1)
(1)
(1)
(1)
(1)</td><td>6</td></tr>
<tr><td></td><td>Total for question 13</td><td></td><td>6</td></tr>
</table>

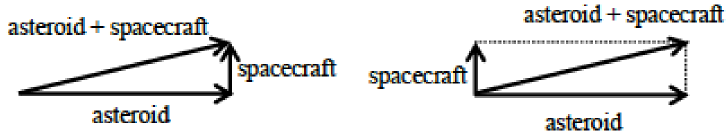
Question number	Answer	Mark
*14	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content	

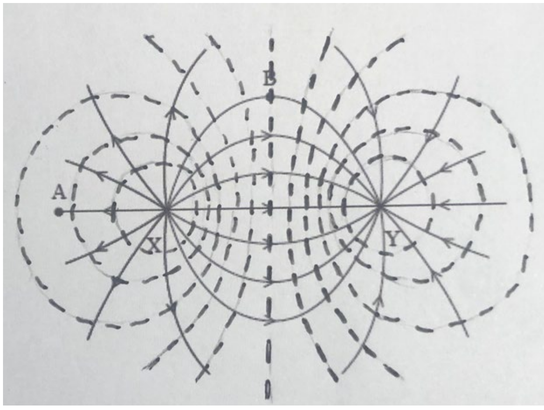
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max linkage mark available	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). **Indicative content:** • change of flux linked to surrounding metal **Or** change of flux linked to copper tube • e.m.f induced • full conducting path available, so current in metal • current produces magnetic field • (by Lenz's law the) magnetic field (due to the induced current) produces a force (on the magnet) that opposes the motion of magnet causing it • upward force on magnet, so (increased) downward force on tube	**6**
	Total for question 14	**6**

Question number	Answer		Mark
15 (a)	• Resultant on correct triangle or parallelogram including arrows with a clear right angle between initial asteroid momentum and initial spacecraft momentum • Fully labelled (dependent on MP1) Example of diagram:  	(1) (1)	2
15 (b)	• Use of $p = mv$ • $p = 1.1 \times 10^{7}$ (N s) (minimum 2 s.f.) Example of calculation $p = 920\ \text{kg} \times 12\ 000\ \text{m s}^{-1} = 1.1 \times 10^{7}\ \text{N s}$	(1) (1)	2
15 (c)	• Use of correct trigonometry • Angle = 1.5×10^{-7} (rad) (minimum 2 s.f.) Allow ecf from (b) Example of calculation $\tan\theta = 1.1 \times 10^{7}\ \text{N s} \div 7.6 \times 10^{13}\ \text{N s} = 1.45 \times 10^{-7}$ ($\theta = 8.3 \times 10^{-6}\,°$) $\theta = 1.45 \times 10^{-7}$ rad (Answer depends on rounding from (b), accept 1.4 or 1.5 rad)	(1) (1)	2
15 (d)	• Apply principle of conservation of momentum along path at 90° to original path of asteroid • Component of velocity = $3.9 \times 10^{-3}\ \text{m s}^{-1}$ Allow ecf from (b) or (c) Example of calculation Component of velocity = spacecraft momentum ÷ (mass of spacecraft + mass of asteroid) $= 1.1 \times 10^{7}\ \text{N s} \div (920\ \text{kg} + 2.8 \times 10^{9}\ \text{kg})$ $= 3.9 \times 10^{-3}\ \text{m s}^{-1}$	(1) (1)	2
15 (e)	• Use of impulse = $F\,\Delta t = \Delta p$ • Concludes 1.8×10^{9} N s change in momentum from rocket engines is greater than 1.1×10^{7} N s change from impact Allow ecf from (b) Example of calculation Impulse = $5.1 \times 10^{6}\ \text{N} \times 6 \times 60\ \text{s} = 1.8 \times 10^{9}\ \text{N s}$	(1) (1)	2
	Total for question 15		10

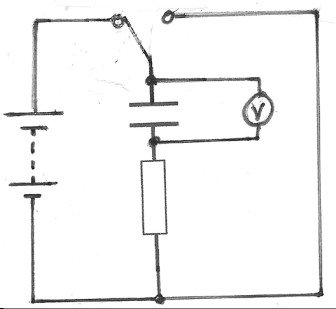
Question Number	Answer		Mark
16 (a)	• Use of $E = Q / 4\pi\varepsilon_0 r^2$ **Or** Use of $E = kQ / r^2$ • Adds E due to X to E due to Y • $E = 2.8 \times 10^6\ \mathrm{V\ m^{-1}}$ <u>Example of calculation</u> E due to X = $2.5 \times 10^{-7}\ \mathrm{C} / 4 \times \pi \times 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}} \times (4.0 \times 10^{-2}\ \mathrm{m})^2$ $= 1.4 \times 10^6\ \mathrm{V\ m^{-1}}$ (towards Y) E due to Y = $2.5 \times 10^{-7}\ \mathrm{C} / 4 \times \pi \times 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}} \times (4.0 \times 10^{-2}\ \mathrm{m})^2$ $= 1.4 \times 10^6\ \mathrm{V\ m^{-1}}$ (towards Y) $E = 1.4 \times 10^6\ \mathrm{V\ m^{-1}} + 1.4 \times 10^6\ \mathrm{V\ m^{-1}} = 2.8 \times 10^6\ \mathrm{V\ m^{-1}}$	(1) (1) (1)	3
16 (b) (i)	• Central straight line equidistant from X and Y **and** at least one of the diverging lines between X and the central line **and** at least one of the diverging lines between the central line and Y • At least one line looping X **and** one line looping Y • Line spacing between X and Y smaller than line spacing to the left of X **and** to the right of Y <u>Example of diagram</u>  	(1) (1) (1)	3

16 (b) (ii)	• Field lines show direction of force on a (positive) charge • (So) field line shows the direction of acceleration • Point A - Where the line is straight, a charge (initially at rest) will follow the line, so true in this case • Point B - Curved line means acceleration always changing direction but velocity is not in the direction of acceleration so statement not true	(1) (1) (1) (1)	**4**
16 (c)	• Use of $V = Q / 4\pi\varepsilon_0 r$ **Or** Use of $V = kQ / r$ • Applies potential at each point is sum of potential due to charge at X and potential due to charge at Y • Applies p.d. = sum of potentials at D – sum of potentials at C • $V = (-)\ 2.0 \times 10^5$ V <u>Example of calculation</u> V_C due to X= 5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 2.5 \times 10^{-2}$ m $= 1.8 \times 10^5$ V V_D due to X= 5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 5.5 \times 10^{-2}$ m $= 0.8 \times 10^5$ V V_D due to Y= -5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 2.5 \times 10^{-2}$ m $= -1.8 \times 10^5$ V V_C due to Y = -5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 5.5 \times 10^{-2}$ m $= -0.8 \times 10^5$ V $V_C = 1.8 \times 10^5\ \text{V} - 0.8 \times 10^5\ \text{V} = 1.0 \times 10^5$ V $V_D = -1.8 \times 10^5\ \text{V} + 0.8 \times 10^5\ \text{V} = -1.0 \times 10^5$ V $V_{CD} = V_D - V_C$ $= -1.0 \times 10^5\ \text{V} - 1.0 \times 10^5$ V $= -2.0 \times 10^5$ V	(1) (1) (1) (1)	**4**
	Total for Question 16		**14**

<table>
<tr><th>Question number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>17 (a)</td><td>

- Battery in series with capacitor and resistor
- Voltmeter/datalogger/oscilloscope in parallel with capacitor
- Appropriate switching mechanism and discharge circuit completed

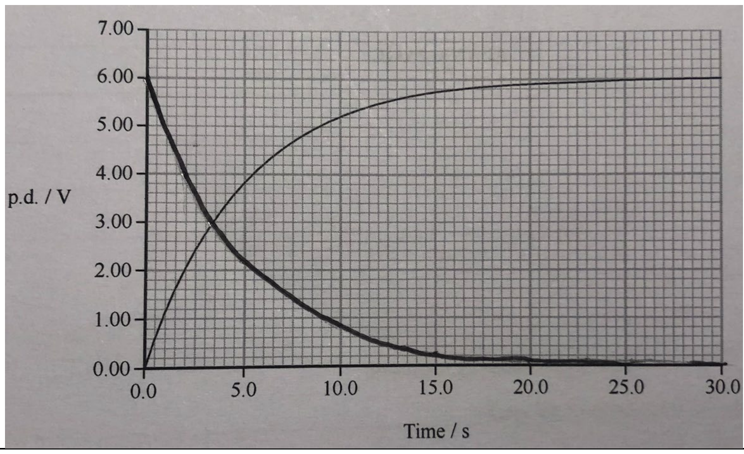
Example of diagram:



</td><td>(1)
(1)
(1)</td><td>3</td></tr>
<tr><td>17 (b) (i)</td><td>

- Exponential decline
- Symmetry with charging curve, starts at 6.00 V, curves cross at 3.00 V

Example of graph



</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td>17 (b) (ii)</td><td>

- Use of $I = I_0 e^{-\frac{t}{RC}}$ with $V = IR$
- Apply total p.d. = sum of p.d.s
- Suitable algebra

Example of derivation

$$I = I_0 e^{-\frac{t}{RC}}$$
$$V_R = R I_0 e^{-\frac{t}{RC}}$$
$$I_0 R = V_0$$
$$V_R = V_0 e^{-\frac{t}{RC}}$$
$$V_{cap} = V_0 - V_R$$
$$V = V_0 - V_0 e^{-\frac{t}{RC}}$$

</td><td>(1)
(1)
(1)</td><td>3</td></tr>
</table>

17 (b) (iii)	• Use of $V = V_0(1 - 1/e) = 0.63\ V_0$ for V at time constant (1) • Read time constant off graph = 4.9 s (allow range 4.5 s to 5.0 s) (1) • Use of time constant = RC (1) • $C = 1.5 \times 10^{-5}$ F, so choose 15 μF capacitor (1) ($C = 1.4 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) **Or** • Draws tangent to line at t = 0 s to intercept p.d. = 6.00 V line (1) • Read time constant off graph = 4.9 s (allow range 4.5 s to 5.0 s) (1) • Use of time constant = RC (1) • $C = 1.5 \times 10^{-5}$ F, so choose 15 μF capacitor (1) ($C = 1.4 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) **Or** • Record corresponding values of V and t from point (or points) on graph (1) • Use of $V = V_0 - V_0 e^{-\frac{t}{RC}}$ (1) • Convert to correct logarithmic form (1) • $C = 1.5 \times 10^{-5}$ F, so choose 15 μF capacitor (1) ($C = 1.3 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) **Or** • $\frac{V_0}{2} = V_0 e^{-\frac{t_{\frac{1}{2}}}{RC}}$ (1) • $RC = t_{½} / \ln 2$ (1) • Records time for V to increase to ½ V_0 (3.4 s) (allow range 3.0 s to 3.5 s) (1) • $C = 1.5 \times 10^{-5}$ F, so choose 15 μF capacitor (1) ($C = 1.3 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) <u>Example of calculation</u> V at time constant time = 0.63 × 6.00 V = 3.8 V Time from graph = 4.9 s 4.9 s = $C \times 3.3 \times 10^5\ \Omega$ $C = 1.48 \times 10^{-5}$ F	**4**

17 (b) (iv)	• Use of $Q = CV$ (ecf for C from (iii)) (1) • $Q = 9.0 \times 10^{-5}$ C (1) <u>Example of calculation</u> 1.5×10^{-5} F $\times$ 6.00 V $= 9.0 \times 10^{-5}$ C	**2**
17 (b) (v)	• Use of $W = ½\, CV^2$ (ecf for C from (iii)) **Or** Use of $W = ½\, QV$ (ecf for Q from (iv)) **Or** Use of $W = ½\, Q^2/C$ (ecf for C from (iii), for Q from (iv)) (1) • $W = 2.7 \times 10^{-4}$ J (1) <u>Example of calculation:</u> $W = ½ \times 1.5 \times 10^{-5}$ F $\times$ (6.00 V)$^2 = 2.7 \times 10^{-4}$ J	**2**
	Total for question 17	**16**

Question number	Answer		Mark
18(a)	• Mass equal (to mass of electron) • Charge equal and opposite (to charge of electron) • Lepton number (equal and) opposite (to lepton number of electron)	(1) (1) (1)	3
18 (b)	• Curvature more in top half of picture • Particle moving slower after passing through lead plate because energy lost, so moving from lower half to top half • (Applying FLHR,) field into page (mark dependent on an indication of correct direction of positron motion)	(1) (1) (1)	3
18 (c) (i)	• Use of conversion factor 1.6×10^{-19} C • Use of $E_k = ½ mv^2$ • Calculated speed = 2.8×10^9 (m s^{-1}), which is greater than the speed of light (so it must be relativistic) <u>Example of calculation</u> $E_k = 23 \times 10^6$ eV $\times 1.6 \times 10^{-19}$ C $= 3.7 \times 10^{-12}$ J 3.7×10^{-12} J $= 0.5 \times 9.11 \times 10^{-31}$ kg $\times v^2$ $v = 2.8 \times 10^9$ m s^{-1}	(1) (1) (1)	3
18 (c) (ii)	• Use of $E = pc$ (ecf for E from (c)(i)) • Use of $r = p/Bq$ • $B = 2.1$ T Do not award MP1 if $p = mv$ calculated using v from part (i) <u>Example of calculation</u> 3.7×10^{-12} J $= p \times 3.00 \times 10^8$ m s^{-1} $p = 1.2 \times 10^{-20}$ N s 0.037 m $= 1.2 \times 10^{-20}$ N s / $B \times 1.6 \times 10^{-19}$ C $B = 2.1$ T	(1) (1) (1)	3

18 (d)	• Use of $E_k = \frac{1}{2} mv^2$ (1) • Use of $\Delta E = c^2 \Delta m$ (1) • Use of $E = hf$ (1) • $f = 1.2 \times 10^{20}$ Hz (1) <u>Example of calculation</u> $E_k = 2 \times 0.5 \times 9.11 \times 10^{-31}$ kg $\times (1.5 \times 10^7$ m s$^{-1})^2$ $= 2.0 \times 10^{-16}$ J $\Delta E = (3.00 \times 10^8$ m s$^{-1})^2 \times 2 \times 9.11 \times 10^{-31}$ kg $= 1.64 \times 10^{-13}$ J Total energy $= 1.64 \times 10^{-13}$ J $+ 2.0 \times 10^{-16}$ J $= 1.64 \times 10^{-13}$ J Energy for one gamma photon $= 8.2 \times 10^{-14}$ J 8.2×10^{-12} J $= 6.63 \times 10^{-34}$ J s $\times f$ $f = 1.2 \times 10^{20}$ Hz	**4**
	Total for question 18	**16**