Mark Scheme (Results)

January 2024

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

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Question Number	Answer	Mark
1	**B is the correct answer,** as $N = A - Z$	**1**
2	**D is the correct answer,** as this is a description of thermionic emission	**1**
3	**C is the correct answer,** as $F = Bqv \sin\theta$ and $\sin\theta = 1$	**1**
4	**C is the correct answer,** as a short wavelength gives a high resolution	**1**
5	**A is the correct answer,** as the electric field between parallel plates is uniform	**1**
6	**D is the correct answer** A is not correct because lepton number is not conserved B is not correct because charge is not conserved C is not correct because charge is not conserved	**1**
7	**D is the correct answer,** as each capacitor stores a charge Q	**1**
8	**B is the correct answer** A is not correct because the poles at X and Y must be opposite C is not correct because this would not oppose the change in flux linkage D is not correct because the poles at X and Y must be opposite	**1**
9	**D is the correct answer,** as $F\Delta t = \Delta p$ and $\Delta p = -2mv$	**1**
10	**C is the correct answer** A is not correct because the alpha must be repelled from the nucleus B is not correct because the alpha doesn't deflect enough D is not correct because the alpha deflects in the wrong direction	**1**

Question Number	Answer		Mark
11	Use of tolerance as +20%. (see anywhere)	(1)	
	Use of $W = \frac{1}{2}CV^2$	(1)	
	$W = 0.83$ J	(1)	3
	<u>Example of calculation</u> Maximum $C = 1.2 \times 2200\ \mu\text{F} = 2640\ \mu\text{F}$ $W = \frac{1}{2} \times 2640 \times 10^{-6}\text{F} \times (25\ \text{V})^2 = 0.825\ \text{J}$		
	Total for question 11		**3**

Question Number	Answer		Mark
12	There are no tracks after P	(1)	
	(Only) charged particles leave tracks **Or** Uncharged /neutral particles leave no tracks	(1)	
	'V' points on photograph identified as subsequent decays	(1)	3
	Total for question 12		**3**

Question Number	Answer		Mark
13(a)	Use of $F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ **or** Use of $F = \frac{kQ_1Q_2}{r^2}$	(1)	
	$F = 7.4 \times 10^{-8}$ N	(1)	2
	<u>Example of calculation</u> $F = \frac{(2 \times 1.6 \times 10^{-19}\ \text{C}) \times (1.6 \times 10^{-19}\ \text{C})}{4\pi \times 8.85 \times 10^{-12}\ \text{F m}^{-1} \times (7.9 \times 10^{-11}\ \text{m})^2} = 7.38 \times 10^{-8}\ \text{N}$		
13(b)	Use of $E = \frac{F}{Q}$ **Or** Use of $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (Allow use of $E = \frac{kQ}{r^2}$)	(1)	
	$E = 4.6 \times 10^{11}\ \text{N C}^{-1}$ (ecf from (a))	(1)	2
	<u>Example of calculation</u> $E = \frac{7.38 \times 10^{-8}\ \text{N}}{1.6 \times 10^{-19}\ \text{C}} = 4.61 \times 10^{11}\ \text{N C}^{-1}$		
	Total for question 13		**4**

Question Number	Answer		Mark
14	Most alphas went straight through **Or** Most alpha particles were undeviated	**(1)**	
	So atom is mainly empty (space) (MP2 dependent on MP1)	**(1)**	
	A few alpha particles were deflected by small angles	**(1)**	
	very few alpha particles had a deflection > 90° **Or** Very few alpha particles came straight back	**(1)**	
	There is a concentration of charge in the atom (MP5 dependent on MP3 or MP4) **Or** There is a concentration of mass in the atom (MP5 dependent on MP4)	**(1)**	**5**
	Total for question 14		**5**

Question Number	Answer		Mark
15	Use of $\lambda = \frac{h}{p}$	**(1)**	
	Use of $E_\mathrm{k} = \frac{p^2}{2m}$ **Or** Use of $E_\mathrm{k} = \frac{1}{2}mv^2$ and $p = mv$	**(1)**	
	Use of $V = \frac{W}{Q}$ with $W = E_\mathrm{k}$	**(1)**	
	$V = 2300$ V	**(1)**	**4**
	Example of calculation $p = \frac{6.63 \times 10^{-34}\ \mathrm{Js}}{2.55 \times 10^{-11}\ \mathrm{m}} = 2.60 \times 10^{-23}\ \mathrm{N\ s}$ $E = \frac{(2.60 \times 10^{-23}\ \mathrm{N\ s})^2}{2 \times 9.11 \times 10^{-31}\ \mathrm{kg}} = 3.71 \times 10^{-16}\ \mathrm{J}$ $V = \frac{3.71 \times 10^{-16}\ \mathrm{J}}{1.6 \times 10^{-19}\ \mathrm{C}} = 2320\ \mathrm{V}$		
	Total for question 15		**4**

Question Number	Answer		Mark
16	Use of $\frac{dA}{dt} = Lv$ **Or** In 1 second, area swept out by wings = Lv	**(1)**	
	Use of $\varphi = BA$	**(1)**	
	Use of $\varepsilon = -\frac{d(N\varphi)}{dt}$	**(1)**	
	$v = 280\ (\mathrm{m\ s^{-1}}) > 250\ (\mathrm{m\ s^{-1}})$ so the pilot's statement is not correct **Or** emf = 0.36 (V) < 0.40 (V) so the pilot's statement is not correct	**(1)**	4
	<u>Example of calculation</u> $\varepsilon = -\frac{d(N\varphi)}{dt} = \frac{d(NBA)}{dt} = B\frac{dA}{dt}$ $\frac{dA}{dt} = 35\ \mathrm{m} \times v$ $0.40\ \mathrm{V} = 41 \times 10^{-6}\ \mathrm{T} \times 35\ \mathrm{m} \times v$ $v = \frac{0.40\ V}{41 \times 10^{-6}\ \mathrm{T} \times 35\ \mathrm{m}} = 279\ \mathrm{m\ s^{-1}}$		
	Total for question 16		**4**

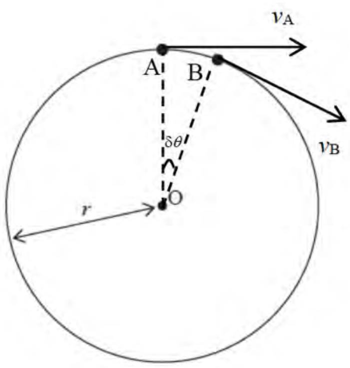
<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>17(a)</td><td>
Correct vector diagram showing velocity at the two positions and the corresponding velocity change **(1)**

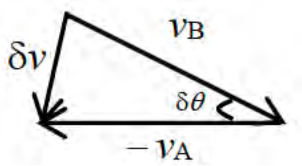
Use small angle approximation, so $\delta\theta \approx \delta v / v$ **(1)**

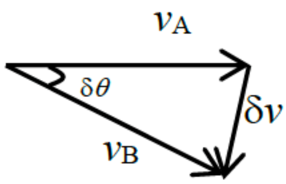
Use of $\delta\theta / \delta t = \omega$ and $v = r\omega$
Or Use of similar triangles and $\delta\theta = \delta s / r$ and $\delta s / t = v$ **(1)**

Use of $\delta v / \delta t = a$ **(1)**

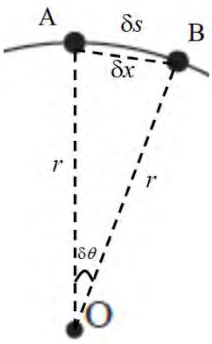
Algebra to show $a = v^2/r$ **(1)**

<u>Example of derivation</u>






$v_A = v_B = v$
Small angle, so $\delta\theta = \delta v / v$
$\delta\theta = \omega\delta t$
$\delta\theta = v\delta t / r$
$v\delta t / r = \delta v / v$
$\delta v / \delta t = v^2 / r$
$a = v^2 / r$

Or
$v_A = v_B = v$
Small angle, so $\delta v / v \approx \delta\theta$
$\delta s / r \approx \delta\theta$
Similar triangles, so $\delta v / v = \delta s / r$
$\delta v / t = v\,\delta s / tr$
$\delta v / t = v^2 / r$
$a = v^2 / r$


</td><td>5</td></tr>
</table>

17(b)	Use of $F = \frac{mv^2}{r}$ **(1)** Use of $F = mg$ **(1)** Use of Pythagoras **Or** Use of trigonometry sufficient to determine tension **(1)** $T = 31$ (N), which is less than 35 (N) so the wire will not break **(1)** <u>Example of calculation</u> $F = \frac{1.55\text{ kg} \times (22.5\text{ m s}^{-1})^2}{28.5\text{ m}} = 27.5\text{ N}$ $F = 1.55\text{ kg} \times 9.81\text{ N kg}^{-1} = 15.2\text{ N}$ $T = \sqrt{(27.5\text{ N})^2 + (15.2\text{ N})^2} = 31.4\text{ N}$ **Or** $F = \frac{1.55\text{ kg} \times (22.5\text{ m s}^{-1})^2}{28.5\text{ m}} = 27.5\text{ N}$ $F = 1.55\text{ kg} \times 9.81\text{ N kg}^{-1} = 15.2\text{ N}$ $\tan\theta = \frac{15.2\text{ N}}{27.5\text{ N}}$ $\theta = 28.9°$ $T \sin 28.9° = 15.2\text{ N}$ $T = 31.45\text{ N}$		**4**
	Total for question 17		**9**

Question Number	Answer		Mark
18(a)(i)	Corresponding pair of values read from graph line Substitution into $V = V_0\left(1 - e^{-\frac{t}{RC}}\right) \ldots$ …with $V_0 = 6.0$ V $C = 2.2 \times 10^{-4}$ F (220 μF) (Allow answers in the range 2.1×10^{-4} to 2.3×10^{-4} F) MP4 dependent on MP3 **OR** Read time for $V_0\left(1 - \frac{1}{e}\right)$ or 63 % × V_0 from graph, Use of time constant = RC …with $V_0 = 6.0$ V $C = 2.2 \times 10^{-4}$ F (220 μF) MP4 dependent on MP3 (Allow answers in the range 2.1×10^{-4} to 2.3×10^{-4} F) MP4 dependent on MP3 <u>Example of calculation</u> $V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$ $5.1\text{ V} = 6.0\text{ V}\left(1 - \mathrm{e}^{-\frac{70\text{ s}}{168 \times 10^3\ \Omega \times C}}\right)$ $\frac{5.1\text{ V}}{6.0\text{ V}} = 1 - \mathrm{e}^{-\frac{70\text{ s}}{168 \times 10^3\ \Omega \times C}}$ $\mathrm{e}^{-\frac{70\text{ s}}{168 \times 10^3\ \Omega \times C}} = 1 - 0.85$ $\frac{70\text{ s}}{168 \times 10^3\ \Omega \times C} = 1.90$ $C = \frac{70\text{ s}}{168 \times 10^3\ \Omega \times 1.90} = 2.19 \times 10^{-4}$ F	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
18(a)(ii)	Use of $I = \frac{V}{R}$ $I = 3.6 \times 10^{-5}$ A and marked on current axis at time $t = 0$ Exponential decreasing curve <u>Example of calculation</u> $I = \frac{6.0\text{ V}}{168 \times 10^3\ \Omega} = 3.57 \times 10^{-5}$ A	**(1)** **(1)** **(1)**	**3**
18(b)	Resistance in circuit would decrease So current in circuit would increase **Or** so time constant will decrease **Or** so T = RC will decrease (Hence) capacitor would charge more quickly MP2 dependent on MP1, MP3 dependent on MP2	**(1)** **(1)** **(1)**	**3**
	Total for question 18		**10**

Question Number	Answer		Mark
19(a)	Use of $E = hf$ with $c = f\lambda$	**(1)**	
	Use of $E_k = \frac{1}{2}mv^2$ **Or** Use of $E_k = \frac{p^2}{2m}$ and $p = mv$	**(1)**	
	$v = 8.8 \times 10^5\ \text{m s}^{-1}$	**(1)**	**3**
	<u>Example of calculation</u> $f = \frac{c}{\lambda} = \frac{3.0 \times 10^8\ \text{m s}^{-1}}{560 \times 10^{-9}\ \text{m}} = 5.36 \times 10^{14}\ \text{Hz}$ $E = hf = 6.63 \times 10^{-34}\ \text{J s} \times 5.36 \times 10^{14}\ \text{Hz}$ $E = 3.55 \times 10^{-19}\ \text{J}$ $v = \sqrt{\frac{2 \times 9.11 \times 3.55 \times 10^{-19}\ \text{J}}{9.11 \times 10^{-31}\ \text{kg}}} = 8.83 \times 10^5\ \text{m s}^{-1}$		

19(b)	Use of $p = mv$ Use of $r = \frac{p}{BQ}$ Use of $v = \frac{2\pi r}{T}$ and $f = \frac{1}{T}$ **Or** Use of $\omega = \frac{v}{r}$ and $\omega = \frac{2\pi}{T}$ and $f = \frac{1}{T}$ Use of $c = f\lambda$ λ = 224 (m) ≈ 220 (m), so the radiation emitted by the electron would cause interference with the radio station broadcast **Or** f = 1.34×10^6 (Hz) ≈ 1.36×10^6 (Hz), so the radiation emitted by the electron would cause interference with the radio station broadcast **OR** Use of $F = Bqv$ Use of $F = \frac{mv^2}{r}$ Use of $v = \frac{2\pi r}{T}$ and $f = \frac{1}{T}$ **Or** Use of $\omega = \frac{v}{r}$ and $\omega = \frac{2\pi}{T}$ and $f = \frac{1}{T}$ Use of $c = f\lambda$ λ = 224 (m) ≈ 220 (m), so the radiation emitted by the electron would cause interference with the radio station broadcast **Or** f = 1.34×10^6 (Hz) ≈ 1.36×10^6 (Hz), so the radiation emitted by the electron would cause interference with the radio station broadcast <u>Example of calculation</u> $p = 9.11 \times 10^{-31}\ \text{kg} \times 1.65 \times 10^6\ \text{m s}^{-1} = 1.50\ \times 10^{-24}\ \text{kg m s}^{-1}$ $r = \frac{1.50\ \times 10^{-24}\ \text{kg m s}^{-1}}{48 \times 10^{-6}\ \text{T} \times 1.6 \times 10^{-19}\ \text{C}} = 0.196\ \text{m}$ $f = \frac{1.65 \times 10^6\ \text{m s}^{-1}}{2\pi \times 0.196\ \text{m}} = 1.34 \times 10^6\ \text{Hz}$ **Either** $f = \frac{3.0 \times 10^8\ \text{m s}^{-1}}{220\ \text{m}} = 1.36 \times 10^6\ \text{Hz}$ **Or** $\lambda = \frac{3.0 \times 10^8\ \text{m s}^{-1}}{1.34 \times 10^6\ \text{Hz}} = 224\ \text{m}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **5**
	Total for question 19		**8**

Question Number	Answer	Mark
20(a)	Total momentum remains constant **Or** Total momentum before a collision = Total momentum after a collision **(1)** Provided no (resultant) external force acts **Or** In an isolated / closed system **(1)**	2
20(b)(i)	Velocities/momenta resolved into components **(1)** Use of $p = mv$ **(1)** Use of principle of conservation of momentum **(1)** $v = 5.64 \times 10^6$ (m s^{-1}) **(1)** <u>Example of calculation</u> $v \times 6.64 \times 10^{-27}\text{kg} \times \sin 70^0 = 1.55 \times 10^7 \text{ m s}^{-1} \times 6.64 \times 10^{-27}\text{kg} \sin 20^0$ $v = \dfrac{1.55 \times 10^7 \text{ m s}^{-1} \times 0.342}{0.940} = 5.641 \times 10^6 \text{ m s}^{-1}$	4
20(b)(ii)	Use of $E_k = \frac{1}{2}mv^2$ **(1)** Correct calculation of one kinetic energy **(1)** 9.04×10^{-13} (J) $\approx 9.01 \times 10^{-13}$ (J), so collision is elastic **(1)** (ecf from (b)(i) and show that value gives 9.02×10^{-13} J) <u>Example of calculation</u> $E_k = \frac{1}{2} \times 6.64 \times 10^{-27} \text{ kg} \times (1.55 \times 10^7 \text{ m s}^{-1})^2$ $+ \frac{1}{2} \times 6.64 \times 10^{-27} \text{ kg} \times (5.64 \times 10^6 \text{ m s}^{-1})^2$ $E_k = 7.98 \times 10^{-13} \text{ J} + 1.06 \times 10^{-13} \text{ J}$ $E_k = 9.04 \times 10^{-13} \text{ J}$	3
	Total for question 20	**9**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*21(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>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><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>
Indicative content
IC1 The current produces a magnetic field
IC2 Alternating current, so alternating/varying magnetic field
IC3 There is a change of flux linkage with kettle/core due to the alternating current
Or Lines of magnetic flux cut the kettle/core.
IC4 An <u>e.m.f. is induced</u> across the kettle/core
IC5 Currents circulate in (the iron of) the kettle/core
IC6 The kettle heats as energy is dissipated by the heating effect of currents
Or the core heats as energy is dissipated and the thermal energy is transferred to the kettle by conduction
</td><td>6</td></tr>
<tr><td>21(b)</td><td>
Only pan is heated
Or Surface of cooker does not get hot
Or Egg is not a conductor (1)

As current can only circulate in a conductor
Or there is no current in the surface
Or there is a current in the pan because it is a conductor (1)
</td><td>2</td></tr>
<tr><td></td><td>Total for question 21</td><td>8</td></tr>
</table>

Question Number	Answer		Mark
22(a)(i)	s $\bar{u}$ The meson must be a quark-antiquark pair and include a strange quark **Or** The meson must be a quark-antiquark pair and have a charge of −1	**(1)** **(1)**	**2**
22(a)(ii)	Use of 1 eV = 1.6×10^{-19} J Use of $\Delta E = c^2 \Delta m$ $\Delta m = 8.8 \times 10^{-28}$ (kg) Example of calculation $\Delta E = 494 \times 10^6$ eV $\times 1.6 \times 10^{-19}$ J eV^{-1} $\Delta E = 7.90 \times 10^{-11}$ J $\Delta m = \frac{7.90 \times 10^{-11}\text{ J}}{(3.0 \times 10^8 \text{ m s}^{-1})^2} = 8.78 \times 10^{-28}$ kg	**(1)** **(1)** **(1)**	**3**
22(b)(i)	**MAX 4** Electric field / p.d. accelerates particles **Or** Electric field / p.d. gives particles energy Magnetic field / force at right angles to particles path Magnetic field/force maintains circular motion (whilst in dees) **Or** Particle experiences centripetal force / acceleration (whilst in dees) p.d. switches every half cycle **Or** Polarity of dees switches every half cycle **Or** p.d. switches when particle is in dees p.d. has a constant time period **Or** p.d. has a constant frequency **Or** period is independent of speed of particle	 **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
22(b)(ii)	Use of 1 eV = 1.60×10^{-19} J Use of $E_k = \frac{p^2}{2m}$ **Or** Use of $E_k = \frac{1}{2}mv^2$ and $p = mv$ Use of $r = \frac{p}{Bq}$ B = 0.74 T Example of calculation $E_k = 80 \times 10^3$ eV $\times 1.6 \times 10^{-19}$ J eV^{-1} $E_k = 1.28 \times 10^{-14}$ J $p = \sqrt{2 \times 1.67 \times 10^{-27}\text{ kg} \times 1.28 \times 10^{-14}\text{ J}} = 6.54 \times 10^{-21}$ N s $B = \frac{6.54 \times 10^{-21}\text{ N s}}{1.6 \times 10^{-19}\text{ C} \times 0.055\text{ m}} = 0.743$ T	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 22		**13**