Pearson Edexcel

Mark Scheme (Results)

October 2023

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.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. **It is not a set of model answers.**

1. Mark scheme format

1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. '<u>resonance</u>'

1.2 Bold lower case will be used for emphasis e.g. '**and**' when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. "(hence) distance is increased".

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.

2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.

2.5 The mark scheme will indicate if no unit error is to be applied by placing brackets around the unit.

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will be penalised by one mark (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 **use of** the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.

4.2 If a ‘show that’ question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

4.3 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

Question Number	Answer	Mark
1	**A is the correct answer** B is not correct because the number of neutrons N is on the top line C is not correct because Z is on the top line and N is on the bottom line D is not correct because Z is on the top line	1
2	**C is the correct answer** because $\Delta(mv) = F\Delta t$	1
3	**D is the correct answer** A is not correct because the frequency of the applied p.d. does not change B is not correct because the frequency of the applied p.d. does not change C is not correct because the particles do not experience a force inside the tubes	1
4	**A is the correct answer** because $\phi = B.A$	1
5	**B is the correct answer** because the scattering is independent of any neutrons	1
6	**D is the correct answer** A is not correct because we do not know the sign of the charge on each particle B is not correct because we do not know the direction of the magnetic field C is not correct because we do not know the direction of the magnetic field	1
7	**B is the correct answer because $r = \frac{mv}{BQ}$**	1
8	**B is the correct answer** because $\omega = 2\pi \times$ (revolutions per second)	1
9	**D is the correct answer** because $Q = Q_o e^{-\frac{t}{RC}}$ and RC = 5 s	1
10	**C is the correct answer** because $mg - R = \frac{mv^2}{r}$	1

Question Number	Answer		Mark
11	Use of $\omega = \frac{2\pi}{T}$	**(1)**	
	Use of $v = \omega r$	**(1)**	
	$v = 1.9 \text{ m s}^{-1}$	**(1)**	**3**
	<u>Example of calculation</u> $\omega = \frac{2\pi}{\left(\frac{12 \text{ s}}{2}\right)} = 1.05 \text{ rad s}^{-1}$ $v = 1.05 \text{ rad s}^{-1} \times 1.8 \text{ m} = 1.89 \text{ m s}^{-1}$		
	Total for question 11		**3**

Question Number	Answer	Mark
12	**EITHER** Use of $E_k = \frac{p^2}{2m}$ **(1)** Use of $\lambda = \frac{h}{p}$ **(1)** $\lambda = 1.8 \times 10^{-11}$ m **(1)** **OR** Use of $E_k = \frac{1}{2}mv^2$ **and** $p = mv$ **(1)** Use of $\lambda = \frac{h}{p}$ **(1)** **(1)** $\lambda = 1.8 \times 10^{-11}$ m <u>Example of calculation</u> $p = \sqrt{2 \times 7.2 \times 10^{-16}\text{ J} \times 9.11 \times 10^{-31}\text{ kg}} = 3.62 \times 10^{-23}$ N s ($v = 4.0 \times 10^{7}$ m s^{-1}) $\lambda = \dfrac{6.63 \times 10^{-34}\text{ J s}}{3.62 \times 10^{-23}\text{ N s}} = 1.83 \times 10^{-11}$ m	3
	Total for question 12	**3**

Question Number	Answer		Mark
13	Use of $W = mg$	**(1)**	
	Use of $F = BIL\sin\theta$	**(1)**	
	$L = 0.064$ m	**(1)**	**3**
	<u>Example of calculation</u> $W = 2.8 \times 10^{-3}$ kg $\times$ 9.81 N kg^{-1} = 0.02747 N $L = \dfrac{0.027\text{ N}}{120 \times 10^{-3}\text{ T} \times 3.6\text{ A}} = 0.0636$ m		
	Total for question 13		**3**

Question Number	Answer	Mark
14	An explanation that makes reference to the following points: Application of Newton's 1st law to the path of the car/passenger, e.g. if no force the car/passenger would continue in a straight line **Or** a force is required to change direction for the car/passenger **(1)** A force was exerted on the car/passenger towards the centre of the circle **Or** an inwards force was exerted on the car/passenger at right angles to the motion **Or** a centripetal force was exerted on the car/passenger **(1)** The inward force is exerted by the car on the passenger **(1)** There is no outward force (on the passenger) so the passenger's claim is incorrect **(1)**	**4**
	Total for question 14	**4**

Question Number	Answer		Mark
15(a)	Use of conversion factor of 1 eV = 1.6×10^{-19} J Equate kinetic energy to electric potential energy at distance of closest approach **Or** equates potential at point of closest approach to E_k/Q Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ with $W = QV$ [must be correct values of Q] $r = 4.1 \times 10^{-14}$ m 1 <u>Example of calculation</u> $E_\mathrm{k} = 5.52 \times 10^6 \times 1.6 \times 10^{-19}\ \mathrm{J\ MeV^{-1}} = 8.83 \times 10^{-13}\ \mathrm{J}$ $r = \frac{79 \times 1.6 \times 10^{-19}\ \mathrm{C} \times 2 \times 1.6 \times 10^{-19}\ \mathrm{C}}{4\pi \times 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}} \times 8.83 \times 10^{-13}\ \mathrm{J}} = 4.12 \times 10^{-14}\ \mathrm{m}$	**(1)** **(1)** **(1)** **(1)**	**4**
15(b)	Use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ **or** $F = \frac{kQ_1Q_2}{r^2}$ $F = 11$ N <u>Example of calculation</u> $F = \frac{79 \times 1.6 \times 10^{-19}\ \mathrm{C} \times 2 \times 1.6 \times 10^{-19}\ \mathrm{C}}{4\pi \times 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}} \times (5.68 \times 10^{-14}\ \mathrm{m})^2} = 11.3\ \mathrm{N}$	**(1)** **(1)**	**2**
	Total for question 15		**6**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*16</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 There is a change in flux linkage (with the coil)
Or the wires cut the magnetic field (lines) ignore magnet cuts lines no marks, but doesn’t prevent subsequent marks, e.g. for change in flux linkage.

IC2 The greater the rate of change of flux linkage the larger the induced e.m.f.

IC3 After the south pole reaches the coil the flux linkage (starts to) decrease
Or When the south pole reaches the coil, by Lenz’s law the polarity of the coil changes to continue to resist the motion of the magnet
Or As the south pole reaches the coil the rate of change of flux linkage is zero
(Not direction of field lines opposite)(reference to wires move along field lines for no change in flux linkage)

IC4 As the south pole of the magnet passes through the coil the (induced) e.m.f. is negative

IC5 The (downwards) speed of the magnet increases

IC6 Emf is zero before magnet enters coil
Or Emf is zero when midpoint of magnet in coil
Or Maximum negative value is greater than maximum positive value
Or Time for which emf is negative is greater than time for which emf is positive
Or emf is zero when magnet totally leaves coil
</td><td>6</td></tr>
<tr><td></td><td>Total for question 16</td><td>6</td></tr>
</table>

Question Number	Answer		Mark
17(a)	Use of $\varphi = BA$ with $A = dl$ and $l = vt$	**(1)**	
	Use of $\varepsilon = -\frac{d(N\varphi)}{dt}$	**(1)**	
	$\varepsilon = 3.9 \times 10^{-4}$ V	**(1)**	**3**
	<u>Example of calculation</u> $\varphi = BA = B \times d \times l = B \times d \times v \times t$ $N = 1$ $\varepsilon = \frac{d\varphi}{dt} = \frac{B \times d \times v \times t}{t} = B \times d \times v$ $\varepsilon = 0.15 \text{ T} \times 7.5 \times 10^{-2} \text{ m} \times 3.5 \times 10^{-2} \text{ m s}^{-1} = 3.94 \times 10^{-4} \text{ V}$		
17(b)	(By Lenz's law, if there were a complete circuit) the (direction of the) induced e.m.f. is such as to oppose the change that produces it	**(1)**	
	(With a current) there would be a force to the right (opposing the motion) **Or** There would be a force in the direction opposite to the motion	**(1)**	
	So e.m.f. is from P to Q	**(1)**	**3**
	Total for question 17		**6**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>18(a)</td><td>Two corresponding pairs of values of V and t read from graph

Use of $V = V_0 e^{-\frac{t}{RC}}$ Or Use of ln V = ln $V_0 - \frac{t}{CR}$

C= 497 (µF) (Range 463 µF to 520 µF)

Comparison of calculated value to tolerance calculated using 10% and conclusion as to whether it is in tolerance
Or use of difference between calculated and labelled value to calculate percentage difference and conclusion as to whether it is in tolerance

<u>OR</u>
Use of $V = V_0 /e$ (4.4 V) to find time constant (74 s)
Or intercept with t axis using initial tangent to find time constant

Use of time constant = RC

C= 493 (µF) (Range 463 µF to 520 µF)

Comparison of calculated value to tolerance calculated using 10% and conclusion as to whether it is in tolerance
Or use of difference between calculated and labelled value to calculate percentage difference and conclusion as to whether it is in tolerance

<u>Example of calculation</u>
$\frac{4.1\text{ V}}{12\text{ V}} = \mathrm{e}^{-\frac{80\text{ s}}{150\times10^3\ \Omega\times C}}$

$C = -\frac{80\text{ s}}{150\times10^3\ \Omega\times\ln\left(\frac{4.1\text{ V}}{12\text{ V}}\right)} = 4.97\times10^{-4}\text{ F}$

Largest C = 1.1 × 470 µF = 517 µF
The capacitance is 497 µF which is less than the maximum value of 517 µF, so value is within tolerance</td><td>(1)

(1)

(1)

(1)

(1)

(1)

(1)

(1)</td><td>4</td></tr>
</table>

18(b)	Use of $W = \frac{1}{2}.\frac{Q^2}{C}$ Use of $W = \frac{1}{2}CV^2$ Calculates ratio of energies stored and makes comparison to 1000 and suitable conclusion **Or** Applies factor of 1000 to one calculated energy and makes comparison to the other energy and suitable conclusion <u>Example of calculation</u> $W = \frac{1}{2}.\frac{(56\ \text{C})^2}{47\ \text{F}} = 33.4\ \text{J}$ $W = \frac{1}{2} \times 470 \times 10^{-6} \times (12\ \text{V})^2 = 0.0338\ \text{J}$ $\text{Ratio} = \frac{33.4\ \text{J}}{0.0338\ \text{J}} = 987$ Ratio of energies stored is 990 which is close to 1000, so claim is accurate	**(1)** **(1)** **(1)**	**3**
	Total for question 18		**7**

Question Number	Answer		Mark
19(a)	Use of $p = mv$ Use of trigonometrical function for x or y component of momentum for either stone Applies conservation of momentum in x direction or y direction $v = 1.32$ (m s^{-1}) (3 sf reqd) if x components considered Or $v = 1.33$ (m s^{-1}) (3 sf reqd) if y components considered <u>Example of calculation</u> $p = 19.1 \text{ kg} \times 0.87 \text{ m s}^{-1} = 16.6 \text{ kg m s}^{-1}$ y component for upper stone $= 16.6 \text{ kg m s}^{-1} \times \sin 50^{\circ} = 12.7 \text{ kg m s}^{-1}$ y component for lower stone $= 12.7 \text{ kg m s}^{-1} = 19.1 \text{ kg} \times v \sin 30^{\circ}$ $v = \dfrac{12.7 \text{ kg m s}^{-1}}{0.5 \times 19.1 \text{ kg}} = 1.33 \text{ m s}^{-1}$	(1) (1) (1) (1)	4
19(b)	Use of $E_k = \frac{1}{2}mv^2$ **Or** use of $E_k = \frac{p^2}{2m}$ Correct calculation of one kinetic energy (e.c.f from (a)) Comparison and conclusion consistent with correctly calculated values of kinetic energy <u>Example of calculation</u> $E_{\text{k}} = \frac{1}{2} \times 19.1 \text{ kg} \times (1.7 \text{ m s}^{-1})^2 = 27.6 \text{ J}$ before $E_{\text{k}} = \dfrac{1}{2} \times 19.1 \text{ kg} \times (0.87 \text{ m s}^{-1})^2 + \dfrac{1}{2} \times 19.1 \text{ kg} \times (1.33 \text{ m s}^{-1})^2$ $\therefore E_k = 7.2 \text{ J} + 16.9 \text{ J} = 24.1 \text{ J}$ after Initial $E_{\text{k}} = 28$ J so kinetic energy is not the same and collision is not elastic	(1) (1) (1)	3
	Total for question 19		**7**

Question Number	Answer		Mark
20(a)	Use of $C = 4\pi\varepsilon_0 r$ Use of $Q = CV$ Use of $E = \frac{V}{d}$ Use of $F = EQ$ $F = 1.6 \times 10^{-3}$ N <u>Example of calculation</u> $C = 4\pi \times 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}} \times 3.5 \times 10^{-2}\ \mathrm{m} = 3.89 \times 10^{-12}\ \mathrm{F}$ $Q = 3.89 \times 10^{-12}\mathrm{F} \times 4500\ \mathrm{V} = 1.75 \times 10^{-8}\ \mathrm{C}$ $E = \dfrac{4500\ \mathrm{V}}{5.0 \times 10^{-2}\ \mathrm{m}} = 9.0 \times 10^{4}\ \mathrm{V\ m^{-1}}$ $F = 9.0 \times 10^{4}\ \mathrm{N\ C^{-1}} \times 1.75 \times 10^{-8}\ \mathrm{C} = 1.58 \times 10^{-3}\ \mathrm{N}$	(1) (1) (1) (1) (1)	5
20(b)	When the sphere touches the plate it is charged with the same polarity The force on the sphere due to the electric field is away from that plate so it moves towards the opposite plate **Or** the sphere is repelled from the plate with the charge of the same sign **Or** the sphere is attracted towards the plate with opposite charge When the sphere touches the charged plate opposite the first it becomes oppositely charged and is repelled from that charged plate (and so on) **Or** When the sphere touches the oppositely charged plate it becomes oppositely charged and is attracted to the first plate (and so on)	(1) (1) (1)	3
20(c)	(The bell connected to the lightning conductor becomes positively charged so) <u>electrons</u> are attracted to the right-hand side of the sphere The sphere is attracted to the positively charged bell [MP2 dependent on award of MP1]	(1) (1)	2
	Total for question 20		**10**

Question Number	Answer	Mark
21(a)	$u\bar{d}$ **Or** $d\bar{u}$ **Or** $u\bar{u}$ **Or** $d\bar{d}$ **(1)**	1
21(b)	MAX 2 conservation laws (Conservation of) charge **(1)** $-1 \rightarrow -1 + 0$ **(1)** Dependent on MP1 (Conservation of) lepton number **(1)** $0 \rightarrow 1 + -1$ **(1)** Dependent on MP3 (Conservation of) baryon number **(1)** $0 \rightarrow 0 + 0$ **(1)** Dependent on MP5	4
21(c)	Conversion of eV to J **(1)** Use of $\Delta E = c^2 \Delta m$ **(1)** $m = 1.9 \times 10^{-28}$ (kg) **(1)** <u>Example of calculation</u> $m = 106 \text{ MeV} \times 10^6 \times 1.6 \times 10^{-19} \text{J eV}^{-1} = 1.70 \times 10^{-11}$ J $m = \frac{1.70 \times 10^{-11} \text{ J}}{(3.0 \times 10^8)^2} = 1.88 \times 10^{-28}$ kg	3
21(d)	(When $v = 0.99c$) relativistic effects will be significant **(1)** **Or** (When $v = 0.99c$) time dilation occurs The lifetime (of high energy pions) would be longer (than for pions at rest) MP2 dependent on MP1 **(1)**	2
	Total for question 21	**10**

Question Number	Answer		Mark
22(a)	There is a (resultant) force on the electrons in the vertical direction	**(1)**	
	So the electrons are accelerated vertically	**(1)**	
	But in the horizontal direction the electrons have a constant speed	**(1)**	**3**
22(b)(i)	Use of $W = QV$	**(1)**	
	Use of $E_K = \frac{1}{2}mv^2$	**(1)**	
	$v = 1.73 \times 10^7$ (m s^{-1})(minimum 3 sf required)	**(1)**	**3**
	Example of calculation $E_K = 1.6 \times 10^{-19}\ \text{C} \times 850\ \text{V} = 1.36 \times 10^{-16}\ \text{J}$ $v = \sqrt{\dfrac{2 \times 1.6 \times 10^{-19}\ \text{C} \times 850\ \text{V}}{9.11 \times 10^{-31}\ \text{kg}}} = 1.73 \times 10^7\ \text{m s}^{-1}$		
22(b)(ii)	Use of $s = ut$	**(1)**	
	Use of $F = EQ$	**(1)**	
	Use of $F = ma$	**(1)**	
	Use of $s = ut + \frac{1}{2}at^2$	**(1)**	
	$s = 0.028$ m (Allow ecf from (b)(i))	**(1)**	**5**
	Example of calculation $t = \dfrac{7.5 \times 10^{-2}\ \text{m}}{1.73 \times 10^7\ \text{m s}^{-1}} = 4.34 \times 10^{-9}\ \text{s}$ $F = 1.7 \times 10^4\ \text{V m}^{-1} \times 1.6 \times 10^{-19}\ \text{C} = 2.72 \times 10^{-15}\ \text{N}$ $a = \dfrac{2.72 \times 10^{-15}\ \text{N}}{9.11 \times 10^{-31}\ \text{kg}} = 2.99 \times 10^{15}\ \text{m s}^{-2}$ $s = \dfrac{1}{2} \times 2.99 \times 10^{15}\ \text{m s}^{-2}\ (4.34 \times 10^{-9}\ \text{s})^2 = 0.028\ \text{m}$		

22(b)(iii)	Use of $F = BQv \sin\theta$ with $F = \frac{mv^2}{r}$ to obtain $\frac{e}{m} = \frac{v}{Br}$ **Or** Use of $p = mv$ with $r = \frac{p}{BQ}$ to obtain $\frac{e}{m} = \frac{v}{Br}$ **(1)** $\frac{e}{m} = 1.65 \times 10^{11}$ C kg^{-1} (ecf from (b)(i)) **(1)** Substitutes standard values into $\frac{e}{m}$ **(1)** Standard value of $\frac{e}{m} = 1.76 \times 10^{11}$ C kg^{-1} calculated **and** comparison with experimental value **and** clear conclusion **(1)** <u>Example of calculation</u> $\frac{e}{m} = \frac{1.73 \times 10^{7}\ \text{m s}^{-1}}{3.0 \times 10^{-3}\ \text{T} \times 3.5 \times 10^{-2}\ \text{m}} = 1.65 \times 10^{11}\ \text{C kg}^{-1}$ $\frac{e}{m} = \frac{1.6 \times 10^{-19}\ \text{C}}{9.11 \times 10^{-31}\ \text{kg}} = 1.76 \times 10^{11}\ \text{C kg}^{-1}$	**4**
	Total for question 22	**15**