Mark Scheme (Results)

June 2017

Pearson Edexcel

Advanced Level in Physics (9PH0/03)

Paper 3 General and Practical Principles in Physics

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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.
- All eaminers 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 means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be 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 mean that one mark will not be awarded. (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 Bald (i.e. no working shown) correct answers score full marks unless in a ‘show that’ question.

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

4.3 ‘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.

4.4 recall of the correct formula will be awarded when the formula is seen or implied by substitution.

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

Question Number			Additional Guidance	Mark
1(a)	• An error is the difference between the (measured) result and the true value • An uncertainty is the interval/range in which the (true) value can be considered to lie	**(1)** **(1)**	Accept calculated/their for measured result/value Accept theoretical/actual value for true value	**2**
1(b)	Any **two** valid reasons that relate to • the instrument being used to make the measurement • the way in which the measurement is made • the quantity measured not being constant	 **(1)** **(1)**	Examples: resolution of instrument, zero error, parallax error, reaction time Vague statements that there will be random errors or there might be systematic errors not acceptable.	**2**

(Total for Question 1 = 4 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)	• Use a micrometer to measure y and/or z **(1)** • Use Vernier/digital calipers to measure x and/or z **(1)** • Mass of slide(s) measured using (top pan) balance/scales **(1)** • Repeat and determine mean for at least one measurement **(1)**	**(Part (a) and (b) to be marked holistically** **MP1** accept <u>digital</u> calipers for a single slide Accept Vernier calipers if it is clear that the thickness of a number of slides is being measured. To award both MP1 & 2, *x, y* & *z* must all be referred to. MP4 can be awarded for a reference to averaging any of the measurements.	**4**
2(b)	Check zero error on micrometer/callipers/balance **Or** measure *x/y/z* of slide in different places **Or** measure thickness/mass of multiple slides **(1)**	Accept 'tare' for zero error check on balance	**1**

(Total for Question 2 = 5 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3	• The deflection/fields experiments indicate that electrons have a mass (and a charge) **Or** the deflection/fields experiments indicate that electrons have particle behaviour. **(1)** • The diffraction experiments indicate that electrons must have a wave nature **(1)** • Idea that a model of electron behaviour must include wave-particle duality **(1)**	In MP1 allow a description of deflection e.g. electrons are deflected by (electric and magnetic) fields indicating that they have a mass (and charge)	**3**

(Total for Question 3 = 3 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
4(a)	• Use of $T = 2\pi\sqrt{\frac{L}{g}}$ • $L = 0.994$ m	**(1)** **(1)**	Example of calculation: $L = \frac{(2.00\,\text{s})^2 \times 9.81\,\text{m}\,\text{s}^{-2}}{4\pi^2} = 0.994\,\text{m}$	**2**
4(b)	A description that makes reference to the following points: • Record nT (where n is at least 5) **and** divide by n (to find T) • Time oscillations from equilibrium position of bob using a (fiducial) marker **Or** repeats timings for multiple oscillations and calculate mean	**(1)** **(1)**		**2**
4(c)	• Using the stopwatch there would be reaction time • The uncertainty in the measurement of the time is larger with the stopwatch than with the data logger. • Timing multiple swings (with stopwatch) reduces %U • Light gates are difficult to use with a pendulum bob.	**(1)** **(1)** **(1)** **(1)**	MP2 dependent on MP1	**4**

(Total for Question 4 = 8 marks)

<table>
<tr>
<td>*5</td>
<td>This question assesses a student’s ability to show a coherent and logical structured answer with linkage 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><td>Number of indicative points seen in answer</td><td>Number of marks awarded for indicative points</td></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>
Indicative content:
Newton’s 3rd law pair of forces must be of the same type
Or Newton’s 3rd law pair of forces must act on different bodies
The two forces mentioned are not a 3rd Law pair
Or gravity is not a good description of force
The lift on the plane should be paired with the push of the plane on the air
Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
If the vertical resultant force is zero the plane will not accelerate vertically
So the plane could be ‘at rest’ or moving with uniform velocity in the vertical direction
There must be some horizontal motion so plane can’t be in same place</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table><tr><td></td><td>Number of marks awarded for structure and lines of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkage 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 linkage between points and is unstructured</td><td>0</td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table>
Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark</td>
<td>6</td>
</tr>
</table>

(Total for Question 5 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
6(a)	• The measurement of resistance has an uncertainty of 0.6 % • The measurement of the length has an uncertainty of 4 % • The measurement of the diameter has an uncertainty of 4 % • The % uncertainty in diameter is doubled giving the greatest amount of uncertainty into the value for the resistivity	(1) (1) (1) (1)	MP1 accept use of 0.05 giving 0.3 % Example of calculation: Uncertainty in $R = \frac{0.1\,\Omega}{18.2\,\Omega} \times 100\% = 0.55\,\%$ Uncertainty in $L = \frac{0.05\,\text{m}}{1.25\,\text{m}} \times 100\% = 4.0\,\%$ Uncertainty in $d = \frac{0.01\,\text{m}}{0.27\,\text{m}} \times 100\% = 3.7\,\%$	4
6(b)	• Measured diameter in multiple places / orientations **and** calculate a mean • Calculating a mean reduces the effect of random error	(1) (1)	Treat references to resolution of instrument and thickness of wire as neutral	2
6(c)	• Use of $A = \pi r^2$ with r • Use of $R = \frac{\rho L}{A}$ • With at least one of the following values $R = 18.1\ \Omega \quad L = 1.30\ \text{m} \quad A = \pi \times (0.13 \times 10^{-3}\,\text{m})^2$ • $\rho = (7.3 \rightarrow 7.4) \times 10^{-7}\,\Omega\,\text{m}$	(1) (1) (1) (1)	MP3 accept $R = 18.15\ \Omega$ MP3. Allow calculation of ρ using given values and subtraction of total % uncertainty. Example of calculation: $A = \pi r^2 = \pi \times (0.13 \times 10^{-3}\,\text{m})^2 = 5.31 \times 10^{-8}\,\text{m}^2$ $\rho = \frac{RA}{L} = \frac{18.1\,\Omega \times 5.31 \times 10^{-8}\,\text{m}^2}{1.30\,\text{m}} = 7.39 \times 10^{-7}\,\Omega\,\text{m}$	4

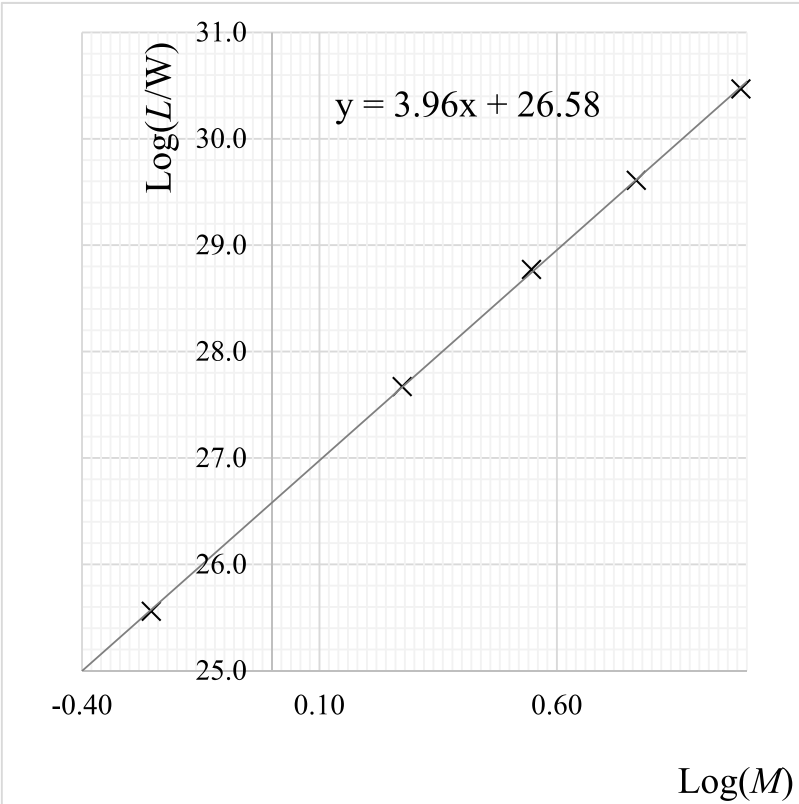
(Total for Question 6 = 10 marks)

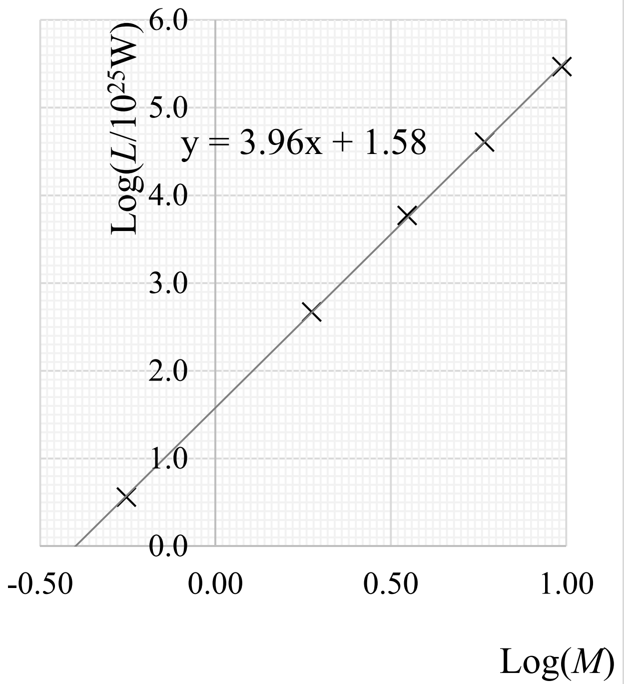
Question Number	Acceptable Answer		Additional Guidance	Mark
7(a)	An explanation that makes reference to the following: • The time interval is very short • the idea of a high sample rate (with the datalogger) **Or** (Percentage) uncertainty in measurement would be small (when using the datalogger).	**(1)** **(1)**	MP2 examples: time interval between measurements is small Many recordings/sec	2
7(b)(i)	• Correct time(s) read from graph • Use of $v = \frac{s}{t}$ • $v = 5900\ (\mathrm{m\,s^{-1}})$	**(1)** **(1)** **(1)**	<u>Example of calculation:</u> $t = (1400 - 1000) \times 10^{-6}$ s $v = \frac{2L}{t} = \frac{2 \times 1.18\ \mathrm{m}}{400 \times 10^{-6}\ \mathrm{s}} = 5900\ \mathrm{m\,s^{-1}}$	3
7(b)(ii)	• Substitution into $E = v^2 \rho$ ecf from (b)(i) • $E = 2.7 \times 10^{11}$ Pa	**(1)** **(1)**	MP2 accept N $\mathrm{m^{-2}}$ for units 'show that value' gives $E = 2.8 \times 10^{11}$ Pa <u>Example of calculation:</u> $E = v^2 \rho = (5900\ \mathrm{m\,s^{-1}})^2 \times 7850\ \mathrm{kg\,m^{-3}}$ $\therefore E = 2.73 \times 10^{11}\ \mathrm{Pa}$	2

(Total for Question 7 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)	• Ammeter in series with LED **and** voltmeter in parallel with LED **(1)**		1
8(b)(i)	• The IV graph of an ohmic conductor is a straight line through the origin **Or** V is directly proportional to I **(1)** • Hence Ohm's law is not obeyed for the LED **(1)**	MP1 accept converse argument MP2 dependent on MP1	2
8(b)(ii)	**Either** • $V_{\text{LED}} = 2\text{ V}$ (from graph) **(1)** • Use of $V_{\text{LED}} + V_{\text{R}} = 5\text{ V}$ **(1)** • Use of $R = \frac{V}{I}$ **(1)** • R = 170 Ω **(1)** **Or** • Use of $R = \frac{V}{I}$ **(1)** • $V_{\text{LED}} = 2\text{ V}$ (from graph) **(1)** • Use of $R_{\text{LED}} + R = 278\ \Omega$ **(1)** • R = 170 Ω **(1)**	Example of calculation: $2\text{ V} + V_{\text{R}} = 5\text{ V}$ $\therefore V_{\text{R}} = 3\text{ V}$ $R = \frac{3\text{ V}}{18 \times 10^{-3}\text{ A}} = 167\ \Omega$	4

(Total for Question 8 = 7 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>9(a)</td><td>An explanation that makes reference to the following points:
• Shows expansion $\log L = p \log(M) + \log(L_{Sun})$ (1)
• Compares with y = mx+ c (1)</td><td></td><td>2</td></tr>
<tr><td>9(b)(i)</td><td>• Log values correct and consistent to 3/4 SF (1)
• Labels and unit (1)
• Scales (1)
• Plots (1)
• Line of best fit (1)

</td><td><table>
<tr><th>Log (L /W)</th><th>Log (L /10^{25} W)</th><th>Log (M /M_{Sun})</th></tr>
<tr><td>25.56</td><td>0.560</td><td>−0.254</td></tr>
<tr><td>27.67</td><td>2.67</td><td>0.274</td></tr>
<tr><td>28.77</td><td>3.77</td><td>0.547</td></tr>
<tr><td>29.61</td><td>4.61</td><td>0.767</td></tr>
<tr><td>30.47</td><td>5.47</td><td>0.988</td></tr>
</table>
<table>
<tr><th>Ln (L /W)</th><th>Ln (L /10^{25} W)</th><th>Ln (M /M_{Sun})</th></tr>
<tr><td>58.85</td><td>1.29</td><td>−0.585</td></tr>
<tr><td>63.72</td><td>6.15</td><td>0.631</td></tr>
<tr><td>66.25</td><td>8.69</td><td>1.26</td></tr>
<tr><td>68.18</td><td>10.6</td><td>1.77</td></tr>
<tr><td>70.16</td><td>12.6</td><td>2.27</td></tr>
</table></td><td>5</td></tr>
</table>

			
9(b)(ii)	• Determines gradient using large triangle –Δx ≥ 0.6 **(1)** • gradient = (3.9→ 4.0) to 2/3 SF and no units **(1)** • reads intercept on *y*-axis and takes antilog to give a value for L_{Sun} **(1)** • States $L = 4 \times 10^{26} M^4$ **(1)**	$L_{Sun} = 4 \times 10^{26}$ W (accept any value that rounds to 4)	**4**

(Total for Question 9 = 11 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	A description that makes reference to the following: • (Remove the source and) record background count for specified time and subtract from equivalent quantity **(1)** • Divide by time to give a count rate. **(1)**	There needs to be two clear steps. Subtract a count from a count, or a count rate from a count rate and divide a count by time to obtain a count rate.	**2**
10(b)(i)	**Either** • The GM-tube has a low efficiency for γ-ray detection **Or** there is an increased area exposed to γ-rays **(1)** • (So) placing the tube side on to the radiation would increase the count rate **(1)** **Or** • The γ-radiation could be detected anywhere inside the GM-tube **(1)** • So placing the tube side on to the radiation would reduce the uncertainty in the distance measurement **(1)**	For low efficiency, accept GM tube poor at detecting γ-rays.	**2**
10(b)(ii)	• Record the count (at least) twice and then determine an average count rate **Or** record the count for a much longer time **(1)** • This reduces the effect of (random) errors in the measurement of the count rate **(1)**		**2**

10(c)(i)	• Mean straight line with positive intercept on the y-axis **(1)**		**1**
10(c)(ii)	• $C = \dfrac{K}{4\pi d^2}$ used to show $\dfrac{1}{\sqrt{C}} \propto d$ **(1)** **Or** identifies gradient as $\sqrt{\dfrac{4\pi}{K}}$ which is constant **(1)** • Since graph is a straight line, data is consistent with this **(1)** • However, line doesn't pass through the origin **(1)** • This indicates a <u>systematic</u> error in measuring the distance **(1)**		**4**
10(d)	• α-particles would only travel a few cm (in air), and so wouldn't reach the GM-tube **(1)** • β-particles would probably not pass through the sides of the GM-tube, and so wouldn't be detected so suggestion is correct. **(1)**	Accept a reference to α-particles not passing through the side of the tube (even if they reached it when d was small) and so not contributing to the count (rate) For 2 marks expect a valid conclusion, as well as a statement of the likelihood of the α-particles and β-particles contributing to the count (rate)	**2**

(Total for Question 10 = 13 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
11(a)	• Data not recorded to the same sf/dp **(1)** • Positions of mass holder not recorded **(1)**		**2**
11(b)	• Attempt to calculate gradient **(1)** • $k = (24.0 \rightarrow 25.0)$ N m^{-1} **(1)**	Accept $k = (0.24 \rightarrow 0.25)$ N cm^{-1} <u>Example of calculation:</u> gradient= $\dfrac{(1.6\text{-}0)\text{ N}}{(6.5\text{-}0)\times10^{-2}\text{m}}$ =24.6 N m^{-1}	**2**
11(c)	• new spring constant = 11 N m^{-1} **(1)** • Use of $T = 2\pi\sqrt{\dfrac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • f = 1.5 Hz **(1)**	<u>Example of calculation:</u> k = 22/2 = 11 N m^{-1} $T = 2\pi\sqrt{\dfrac{0.12\,\text{kg}}{11\,\text{N m}^{-1}}} = 0.66\,\text{s}$ f = 1/0.66 s = 1.5 Hz	**4**

***11(d)**

This question assesses a student's ability to show a coherent and logical structured answer with linkage 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 points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

Indicative content:

- As magnet A moves, its coil experiences a change of magnetic flux (linkage)
- The change in magnetic flux linkage induces an emf in the coil
- The (induced) emf causes a current in both coils
- The current in the second coil causes a force to act on magnet B, driving magnet B into oscillation
- Because both mass-spring systems have the same period/frequency
- Resonance occurs (and magnet B oscillates with increasing amplitude)

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

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

Linkage Marks

IC points 1 – 4
Three of these points could score one linkage mark

IC points 5 & 6 could score one linkage mark

.

6

(Total for Question 11 = 14 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
12(a)	• use of $\frac{\Delta\lambda}{\lambda}=\frac{v}{c}$ with λ = 656.2 nm • $v = 9 \times 10^4$ m s^{-1} • the star is moving towards the Earth	**(1)** **(1)** **(1)**	<u>Example of calculation:</u> $v=\left(\frac{(656.2-656.0)\times10^{-9}\,\text{m}}{656.2\times10^{-9}\,\text{m}}\right)\times3.00\times10^{8}\,\text{m s}^{-1}$ $=9.14\times10^{4}\,\text{m s}^{-1}$	**3**
12(b)(i)	• set up diffraction grating at right angles to light from laser **Or** set up grating parallel to screen • measure the distance between the diffraction grating and the screen • measure the distance between 1st order images on the screen	**(1)** **(1)** **(1)**	An annotated diagram could score these marks MP3 accept between other correct specified orders.	**3**
12(b)(ii)	• use of $d\sin\theta=n\lambda$ • Calculation of one of the diffraction angles (for any n) • Attempt to calculate a difference in the angles **Or** statement that the two angles are very similar • So (accurate) measurement would be very difficult **Or** the difference in wavelength could not be determined with this grating	**(1)** **(1)** **(1)** **(1)**	MP4 dependent on MP3 <u>Example of calculation:</u> $\sin\theta_1=\frac{656.2\times10^{-9}\,\text{m}}{2.2\times10^{-6}\,\text{m}}$ $\sin\theta_2=\frac{656.0\times10^{-9}\,\text{m}}{2.2\times10^{-6}\,\text{m}}$ $\therefore\theta_1=17.354^{\circ}$ $\therefore\theta_1=17.348^{\circ}$ $\therefore\Delta\theta=17.354^{\circ}-17.348^{\circ}=0.006^{\circ}$	**4**
12(c)(i)	• Use of $\frac{1}{2}m\langle c^2\rangle=\frac{3}{2}kT$ • $\text{mean kinetic energy}=6.4\times10^{-20}\,\text{J}$	**(1)** **(1)**	<u>Example of calculation:</u> $\frac{1}{2}m\langle c^2\rangle=\frac{3}{2}kT$ $=\frac{3}{2}\times1.38\times10^{-23}\,\text{J K}^{-1}\times3100\,\text{K}=6.42\times10^{-20}\,\text{J}$	**2**
12(c)(ii)	• There are electron transitions between energy levels in the atoms, • When electrons return to a lower level they emit energy in the form of <u>photons</u>	**(1)** **(1)**		**2**

(Total for Question 12 = 14 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
13(a)	• (isotopes are atoms/nuclides with the) same number of protons but different numbers of neutrons/nucleons (in the nucleus) **(1)**	Ignore references to the number of electrons in the atoms Do not credit mass number or atomic number	**1**
13(b)	• Use of $W = QV$ **(1)** • Use of $KE = \frac{1}{2}mv^2$ **(1)** • Use of $1\text{u} = 1.66 \times 10^{-27}$ kg **(1)** • $v = 2.16 \times 10^5$ (m s^{-1}) **(1)**	<u>Example of calculation:</u> $\frac{1}{2}mv^2 = eV$ $\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}\,\text{C} \times 8.5 \times 10^3\,\text{V}}{(34.97 \times 1.66 \times 10^{-27})\,\text{kg}}} = 2.16 \times 10^5\,\text{m s}^{-1}$	**4**
13(c)(i)	• Electric field vertically downwards (from top plate to bottom plate) **(1)** • Magnetic field into paper **(1)**		**2**
13(c)(ii)	• Use of $E = \frac{V}{d}$ **(1)** • Use of $F_E = EQ$ **(1)** • Use of $F_M = BQv$ **(1)** • Show that these forces are equal (if v is 2.2×10^5 m s^{-1}) and hence state that B is suitable **(1)**	Do not award MP4 if incorrect ion charge used <u>Example of calculation:</u> $E = \frac{V}{d} = \frac{135\,\text{V}}{2.5 \times 10^{-2}\,\text{m}} = 5400\,\text{V m}^{-1}$ $F = EQ = 5400\,\text{V m}^{-1} \times 1.6 \times 10^{-19}\,\text{C} = 8.6 \times 10^{-16}\,\text{N}$ $F = BQv = 24.5 \times 10^{-3}\,\text{T} \times 1.6 \times 10^{-19}\,\text{C} \times 2.2 \times 10^5\,\text{m s}^{-1}$ $= 8.6 \times 10^{-16}\,\text{N}$	**4**

13(d)(i)	• The ions experience a force perpendicular to their velocity (and the magnetic field) **(1)** • The (resultant) force on the ions causes an acceleration at right angles to their velocity **Or** There is a magnetic force acting towards the centre of the path **(1)**	For velocity accept direction of motion or direction of travel	**2**
13(d)(ii)	• Use of $r = \dfrac{mv}{BQ}$ **(1)** • $r = 0.23$ m **(1)**	<u>Example of calculation:</u> $r = \dfrac{mv}{BQ}$ $= \dfrac{(34.97 \times 1.66 \times 10^{-27})\,\text{kg} \times 2.2 \times 10^{5}\,\text{m}\,\text{s}^{-1}}{0.35\,\text{T} \times 1.6 \times 10^{-19}\,\text{C}} = 0.228\,\text{m}$	**2**
13(d)(iii)1	• path drawn with less curvature (less overall deflection) **(1)**	MP1 awarded for path in the magnetic field	**1**
13(d)(iii)2	• ions are more massive **(1)** • ions have the same charge so the radius of the path would be greater **(1)**		**2**

(Total for Question 13 = 18 marks)

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