GCE

Physics A

H556/03: Unified physics

A Level

Mark Scheme for June 2024

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM AssessorAssessorOnline Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded.*(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:

- there is nothing written in the answer space

Award Zero '0' if:

- anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	At bottom of level
Meets the criteria but with some slight inconsistency	At top of level
Consistently meets the criteria for this level	At top of level

11. **Annotations**

Annotation		Meaning
	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in numerical answers only, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. **Penalised only once in the paper.**

Annotation		Meaning
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.
XP	Wrong physics or equation	Used in numerical answers only, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
Reject	Used to indicate an incorrect answer or a point where a mark is lost.
Not	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject Specific Marking Instructions**

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

M marks These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

A marks These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

C marks These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

B marks These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

SIGNIFICANT FIGURES

If the data given in a question is to 2 sf, then allow an answer to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

Question			Answer	Mark	Guidance
1	(a)		$\lambda = \frac{v}{f}$ $(= \frac{340}{262})$	B1	Formula may be implied by substitution **Allow** *c* for *v*
			$\lambda = 2L$	B1	Relationship may be inferred from a correct diagram of fundamental drawn in a tube open at both ends, or from a statement such as 'half a wavelength fits inside the tube'
			$(L =) \frac{1.30}{2} = 0.65$ (m)	B1	Some working leading to correct answer must be shown; don't accept a bald answer **Allow** *L* = 0.649 (0.64885) as evidence of working Do not allow working backwards from the answer
	(b)	(i)	Any **two** from	B1 × 2	Mark as for Short Answer Questions (requiring only a list by way of a response) and contradictory responses see page 3. **Allow** zero / no / none for negligible throughout
			• particles occupy negligible volume (compared to volume of container/gas)		**Ignore** particles occupy negligible space **Ignore** particles are very small
			• collisions are (perfectly) elastic		**Allow** <u>kinetic</u> energy is conserved (during collisions)
			• time of collisions is negligible (compared to the time between collisions)		
			• negligible <u>forces</u> exist between particles (except during collisions)		**Allow** the particles move at constant velocity (in between collisions) **Ignore** type of force if specified

Question			Answer	Mark	Guidance
1	(b)	(ii)	$M = 4.00 \times 10^{-3}$ (kg mol^{-1})	C1	This C1 mark is for converting M into kg mol^{-1} **Allow ECF** for an incorrect POT in M
			$T = 263$ (K)	C1	T = -10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of T.
			$v^2 = \frac{1.67 \times 8.31 \times 263}{4.00 \times 10^{-3}}$ $v = 955$ (m s^{-1})	C1	This C1 mark is for correct substitution into the given formula; v^2 does not need to be calculated for the mark but seeing $v = 955$ implies the mark **Allow** M given to 1sf **Allow** 8.3 or R for 8.31 If a value for γ or M is taken from the wrong row of the table, this is a TE (M must be in kg/mol). If both wrong values are used, count this as a single TE.
			$f = (\frac{v}{\lambda} =) \frac{955}{1.30}$ = 730 (Hz)	A1	**ECF** candidate's value of λ or L ($\lambda = 2L$) from 1a **Allow** f = 740 (Hz) For reference, POT error in M gives v = 30.2 (ms^{-1}) and f = 23 (Hz)
			Alternative method using ratios		

Question			Answer	Mark	Guidance
			$\frac{f_1}{f_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ or $\frac{v_1}{v_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$	**C1**	
			T = 263 (K)	**C1**	T = -10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of T
			$\left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2} = \left(\frac{1.67 \times 263 \times 29}{1.4 \times 293 \times 4}\right)^{1/2}$ = 2.786	**C1**	This C1 mark is for substitution and the ratio 2.786 does not need to be calculated for the mark The values for M may be given in kg/mol or left in g/mol as long as there is consistency **Allow** M = 4 to 1sf
			f (= 2.786 x 262) = 730 (Hz)	**A1**	**Allow** f = 740 (Hz) If using $\frac{v_1}{v_2}$ then v = 2.786 x 340 = 947 giving f (= v / λ = 947 / 1.3) = 730 (Hz) but **ECF** candidate's own value of λ or L ($\lambda = 2L$) from 1a
			Total	**9**	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>2</td><td>(a)</td><td></td><td>$x = x_0 e^{-t/RC}$ or $\frac{x_o}{2} = x_0 e^{-T/RC}$
and
(total) resistance = NR and (total) capacitance = NC

$\frac{1}{2} = e^{-\frac{T}{NR \times NC}}$ with clear steps leading to T = (ln2)N^{2}RC</td><td>M1

A1</td><td>Allow $x = x_0 e^{-T/RC}$
Allow any letter for x except N
Allow τ for RC
Not $x = x_0$ (1 - $e^{-t/RC}$)
Not $R_T C_T = N^2 CR$ alone but allow $R_T C_T = NR \times NC$

Intermediate working must be shown in full e.g.
ln½ = $-\frac{T}{NR \times NC}$ so $\frac{T}{NR \times NC}$ = ln2
Do not allow incorrect negative signs in working or in answer</td></tr>
<tr><td></td><td>(b)</td><td></td><td>a measurement is precise if repeat readings are closely clustered (or reverse argument)

quantitative data used to support their conclusion</td><td>B1

B1</td><td>Allow if there is a small spread (of results about the mean value) / small range / small uncertainties (or small error bars on graph)
Ignore comments about number of sig figs

Either range, absolute or % error calculated correctly for at least one stated value of N
<table>
<tr><td>N</td><td>Range /s</td><td>abs unc/s)</td><td>%unc</td></tr>
<tr><td>1</td><td>0.6</td><td>+/- 0.3</td><td>2.1 or 4.2</td></tr>
<tr><td>2</td><td>0.7</td><td>+/- 0.4</td><td>0.8 1.6</td></tr>
<tr><td>3</td><td>1.4</td><td>+/- 0.7</td><td>0.6 1.2</td></tr>
<tr><td>4</td><td>1.6</td><td>+/- 0.8</td><td>0.4 0.8</td></tr>
<tr><td>5</td><td>10.5</td><td>+/- 5.3</td><td>1.5 3.0</td></tr>
<tr><td>6</td><td>13.2</td><td>+/- 6.6</td><td>1.3 2.6</td></tr>
</table></td></tr>
</table>

Question			Answer	Mark	Guidance
2	(c)		14.4 and 50.0	B1	Both values given to 1dp Mark entries in first table (on page 4) **only** if second table (on page 6) is left blank
	(d)	(i)	y-axis labelled "*T* / s"	B1	**Allow** suitable equivalent e.g. *T* (s), Time in secs
			y-axis scale completed correctly	B1	Scales markings of 100, 200, 300, 400 and 500 every 2 cm
			all six x-co-ordinates correctly plotted	M1	Check at 1, 4, 9, 16, 25 and 36; ±½ small square tolerance.
			all six data points plotted accurately	A1	Check visually by fit to bfl; ±½ small square tolerance. **ECF** candidate's values for *N* = 1 and 2
		(ii)	suitable best fit line	B1	There must be an even scatter of points above and below the line
2	(d)	(iii)	evidence of use of at least half of the width of the drawn line	B1	Evidenced by triangle drawn on graph **or** by Δx in working for gradient

Question			Answer	Mark	Guidance
			Gradient =14 (s)	**B1**	Correct line should have Δx ≥ 17.5 **Allow** any answer between 13 and 15(s) **ECF** candidate's own best fit line
		(iv)	$R = \frac{gradient}{C\ ln\ 2}$ Value of *R* is in the range 19 – 22 (kΩ) uncertainty is 5% of *R* with value given to same number of dp as *R*	**B1** **B1**	For reference, *R* in kΩ = $\frac{\text{gradient value in } \mathbf{d(iii)}}{0.69}$ **ECF** candidate's gradient value in **d(iii)** **Allow** answer given in Ohms if unit clearly stated **Allow** answer given to 1sf i.e. 20 (kΩ) **Expect** 1 (kΩ) **Allow** to more than 1 s.f. but uncertainty must be given to same number of d.p. as candidate's value for *R* If answer given in Ohms, **allow** uncertainty also given in Ohms to same number of d.p. as *R*
	(e)	**(i)**	systematic	**B1**	
		(ii)	(smaller T value for N = 6 so) smaller gradient and therefore smaller R value	**B1**	**Ignore** references to smaller or bigger *C*
			Total	**16**	

Question			Answer	Mark	Guidance
3	(a)				**Ignore** incorrect numbering or general statements of Newton's Laws throughout
			the rocket exerts a (backwards) force on the (hot) gas	**B1**	**Allow** engine for rocket **Allow** (burning) fuel for gas but **not** air Note that 'rocket expels gas backwards' is in the stem and so gains no credit
			(so) the gas exerts a (forwards) force on the rocket	**B1**	**Allow** engine for rocket **Allow** gas pushes the rocket forwards
			(this forwards) force must be greater than the weight of the rocket / there is a resultant force (which causes acceleration / a change in momentum)	**B1**	**Allow** net or unbalanced for resultant

3	**(b)**	*	**Level 3 (5–6 marks)** Expect a correct calculation of *H* with correct assumptions **and** a clear evaluation supported with a calculation *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect **Either** a correct calculation of *H* but no evaluation **or** Some calculation **and** some evaluation **or** Incorrect calculations but a clear evaluation *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect **Either** Limited calculation (e.g. 3100 sin 75° seen, A*B* **or** *BC* calculated but not *H*, use of suvat but with wrong *v*) **or** Limited assumptions stated (note that 'g is always 9.81' is in stem) **or** Limited evaluation (e.g. *g* would be smaller at **C** than **A**) *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1 x 6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Calculation** vertical component of velocity at **B** = 3100 sin 75° (= 2994 m s^{-1}) AB • Assume (force and mass constant so) constant acceleration • Use of suvat, $u = 0$, $v = 2994$, $t = 50$ • $s = 74.9$ km BC • Assume no air resistance • Use of suvat, $u = 2994$, $v = 0$, $a = -9.81$ • $s = 457$ km Total $H = 457 + 74.9 \approx 530$ km **Evaluation** • $g \propto \frac{1}{r^2}$ • $\frac{g_C}{g_A} = \frac{r_A^2}{r_C^2} = \frac{6400^2}{(6400+530)^2} = 0.85$ • 15% drop in g from **A** to **C** (or 17% increase from **C** to **A**) but use ECF for *H* • therefore constant *g* is a poor assumption • $g_C \approx 8.3$ or 8.4 if $g_A = 9.81$ but use ECF for *H* • If g is smaller, then H would increase
			Total	**9**	

Question			Answer	Mark	Guidance
4	(a)		3 out of the following 4: • Extension (or length) measured using a ruler • Extension = stretched length – original length • Force (weight of load) determined using a forcemeter **or** W = mg • (k is) gradient of graph of force against extension	**B1 x 3**	**Ignore** any incorrect statements unless contradictory **Allow** tape measure Could be shown on a labelled diagram **Allow** 4cm or 0.04m for original length **Allow** extension is change in length from original This mark may be scored by saying a graph of mass against extension would give gradient = k/g **Allow** k = gradient of graph of force against length **Allow** k/g = gradient of graph of mass against extension **Allow** *k* = load divided by extension, calculated for a single load

4	(b)	(i)	**Method 1** *d* = *8.5 – 3.2* (= 5.3(cm))	**C1**	**Mark whichever method leads to the most marks** *d* = 5.3cm does not need to be calculated explicitly but seeing 5.3 implies first C1 mark
			(*F* = *kd* so) *F* = 0.62 × 5.30 (= 3.3 (N))	**C1**	*F* = 3.3N does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 3.2 (N) …
			$a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$		
			a = 17 (m s^{-2})	**A1**	**…** and *a* = 16 (m s^{-2})
			Method 2 (*F* = *kd* so) *F* = 0.62 × 8.50 (= 5.27(N))	**(C1)**	*F* = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 5.19 (N)
			F_R = (0.62 × 8.50) – (0.20 × 9.81) (= 3.3 (N))	**(C1)**	*F* = 3.3(N) does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 3.2 (N) …
			$a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$		
			a = 17 (m s^{-2})	**(A1)**	… and *a* = 16 (m s^{-2})
			Method 3 (*F* = *kd* so) *F* = 0.62 × 8.5 (= 5.27(N))	**(C1)**	*F* = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 5.19 (N)
			$\left(a = \frac{F}{m} \text{ so}\right) a = \frac{5.27}{0.20}$ = 26 (m s^{-2})	**(C1)**	Note: *a*= 26 (ms^{-2}) is an intermediate calculation for $a_{initial}$ in this method only and is **not** the A1 mark
			$a_{initial}$ = 26.35 – 9.81 = 17 (m s^{-2})	**(A1)**	**Allow** *k* = 0.61 leading to *F* = 5.19 and *a* = 16

4	**(b)**	**(ii)**			The two C1 marks are independent and XP in one does not imply XP in the other
			Use of $a = (-)\omega^2 x$	**C1**	**Not** just formula alone Expect *a* = 17 but **allow ECF** of *a* from **(b)(i)** **Allow** any value for *x*
			Use of $f = \frac{\omega}{2\pi}$	**C1**	**Not** just formula alone Use *of* $a = (-)(2\pi f)^2 x$ scores both C1 marks
			f = 2.8 (Hz)	**A1**	**Allow** *f* = 2.9 (Hz)
			Alternative method: *(a = F / m = kx / m* and *a = (-) ω²x* gives)		
			$\omega^2 = \frac{k}{m}$	**(C1)**	**Allow** $T = 2\pi\sqrt{\frac{m}{k}}$ $f = \frac{1}{T}$
			$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $= \frac{1}{2\pi}\sqrt{\frac{0.62 \times 100}{0.2}}$	**(C1)**	
			f = 2.8 (Hz)	**(A1)**	**Allow** *f* = 2.9 (Hz)

4	**(c)**	**(i)**	(motion of magnet M causes) a change of flux (linkage) in coil Y (inducing an e.m.f.)	**B1**	**Allow** field (lines of M) cuts (turns of) coil Y **Allow** the coil or Y or solenoid for coil Y
			there is an (induced) <u>current</u> in (or through) coil X	**B1**	**Allow** the coils or the wire(s) or X for coil X **Ignore** (induced) e.m.f.
			alternating current / field / flux in coil X interacts with the field of magnet L (causing an alternating force)	**B1**	**Not** changing or varying or oscillating for alternating **Allow** current / field / flux in coil X interacts with field of magnet L **to c**ause an alternating force **Allow** changing direction for alternating **Allow** combines for interacts **Allow** cuts across for interacts with
	(c)	**(ii)**	frequency of magnet L (always) equals (forcing/driving) frequency of vibration generator / magnet M	**B1**	**Allow** frequency of magnet increases with frequency of vibration generator
			resonance occurs at / close to 2.5 Hz	**B1**	May be seen from a **labelled** graph of amplitude against frequency **Allow** resonance occurs when forcing / driving frequency = natural frequency
			amplitude is maximum at resonance	**B1**	May be seen from a labelled graph of amplitude against frequency
			Total	**15**	

Question			Answer	Mark	Guidance
5	(a)	(i)	Resistance (which causes a loss of energy) as charges pass through the cell	B1	**Allow** current passes for charges pass **Allow** resistance inside the cell or resistance produced by materials or chemicals in the cell **Allow** lost volts per (unit) current **Allow** resistance which leads to a drop in terminal p.d. when current is drawn from the cell **Ignore** resistance *of* the cell
		(ii)	energy transferred <u>per (unit) charge</u> (from chemical energy / some other form of energy) into <u>electrical</u> energy	B1	**Allow** work (done) for energy **Allow** energy transferred <u>per (unit) charge</u> to charge carriers **Allow** (maximum) p.d./voltage across a cell when no current is drawn
	(b)		$\epsilon = I(R + r)$ or $\epsilon = V + Ir$ Rearranging V = 5.6 - 1.2I gives $I = 4.7 - 0.83V$ drawn as a line on the graph I = 2.8 (A)	C1 C1 A1	**Allow** V = 5.6 - 1.2I **Allow** evidence of a trial and improvement method (could be inferred from graph) **Allow** answer in the range 2.70 – 2.90 (A)

5	**(c)**	*	**Level 3 (5–6 marks)** Clear description **and** clear uncertainties *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description (eg correct circuit, valid method for varying temperature, r found from graph) **or** clear uncertainties (eg adds error bars to graph and uses a wfl to find uncertainties) **or** Some description **and** limited uncertainties *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description (eg thermistor symbol correct, range of temperatures used, *V* and *I* measured) **or** Limited uncertainties (eg uncertainties not related to graph, uncertainty in *r* found from Δintercepts rather than Δgradients) *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1 x 6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • correct circuit symbols and diagram • vary resistance of thermistor, record *V* and *I* • method to vary resistance of thermistor, e.g. water bath and thermometer, start from 0°C • Plot V (y-axis) against *I* (x-axis) • e.m.f. = y-intercept; r = – gradient • alternatively, *P = IV, R = V/I* • plot *P (*y-axis) against *R* (x-axis) • maximum power occurs when *r = R* • e.m.f. found from $\epsilon = V + Ir$ **Uncertainties** • Gather repeat readings of *V* and *I* at each temperature if possible and estimate uncertainty in *V* and *I* from half the range of the repeated values • If no repeats, use accuracy (or (half) resolution) of ammeter and voltmeter for uncertainty in *V* and *I* • Add error bars to graph and draw a wfl • Find gradient and y-intercept of wfl • Uncertainty in r / e.m.f. is difference between gradients / y-intercepts of best and worst line • For alternative method, estimate width of peak to find uncertainty in *r* and find uncertainty in e.m.f. using $\epsilon = V + Ir$
			Total	**11**	

Question			Answer	Mark	Guidance
6	(a)		F (= EQ) = 0.90 × 1.60 × 10^{-19} = 1.4(4) × 10^{-19} (N)	B1	Working and answer must both be shown Answer must be given to 2sf or more Unit need not be given but, if given, must be correct
	(b)	(i)	($F = BQv$ but B and Q are constant, so) (the magnitude of) the velocity is different /changes	B1	**Allow** speed **Ignore** the direction is different
6	(b)	(ii)	$v = (\frac{F_{mag}}{BQ} =) \frac{5.6 \times 10^{-19}}{5.0 \times 10^{-5} \times 1.60 \times 10^{-19}}$	C1	v = 7.0 × 10^{4} (m s^{-1}) implies first C1

Question			Answer	Mark	Guidance
			resultant force F_R= (5.6 – 1.4) × 10^{-19}	**C1**	**Allow** 10^{-19} for 1.4×10^{-19} (giving $\boldsymbol{F_R}$= 4.6 × 10^{-19}) F_R= 4.2 × 10^{-19} implies second C1 Do not credit if used as F_{mag} in F_{mag} = *BQv*
			$r = \left(\frac{mv^2}{F_R} =\right) \frac{1.673 \times 10^{-27} \times (7.0 \times 10^4)^2}{4.2 \times 10^{-19}}$	**C1**	Third C1 is for correct substitution into formula **Allow** m_p = 1.67 × 10^{-27} kg given to 3 s.f. **Not** m_p = 1.661 × 10^{-27} kg or m_p = 1.675 × 10^{-27} kg **Allow ECF** for incorrect *v* Use of $\boldsymbol{F_R}$ = 5.6 × 10^{-19} or = 1.4 × 10^{-19} is **XP**
			r = 20 (m)	**A1**	**Allow** *r* = 19 (m)
			Alternative all-in-one method:		
			$r = \frac{mF_{mag}{}^2}{F_R B^2 Q^2}$	**(C1)**	$\boldsymbol{F_R}$**= 4.2 × 10^{-19}** (4.16 ×10^{-19} to 3sf) implies second C1 An incorrect value of F_R is **XP** from this point
			resultant force F_R= (5.6 – 1.4) × 10^{-19}	**(C1)**	
			$r = \frac{1.673 \times 10^{-27} \times (5.6 \times 10^{-19})^2}{4.2 \times 10^{-19} \text{ x } (5.0 \times 10^{-5})^2 \times (1.60 \times 10^{-19})^2}$	**(C1)**	Third C1 is for correct substitution into formula
			r = 20 (m)	**(A1)**	**Allow** *r* = 19 (m)

6	**(b)**	**(iii)1**	$\lvert\text{resultant force}\rvert = (\sqrt{3.9^2 + 1.4^2}) \times 10^{-19}$	**C1**	**Ignore** attempt to calculate weight of proton **Allow** $F_E = 10^{-19}$
			$\lvert\text{resultant force}\rvert = 4.1 \times 10^{-19}$ (N)	**A1**	**Allow** $\lvert F\rvert = 4.0 \times 10^{-19}$ (N) using $F_E = 1.0 \times 10^{-19}$ **Allow** $\lvert F\rvert = 4.2 \times 10^{-19}$ (N) using $F_E = 1.44 \times 10^{-19}$
		(iii)2	<u>resultant / net</u> force is not perpendicular to velocity	**B1**	**Allow** direction of motion / path but **not** speed for velocity **Allow** acceleration / <u>resultant</u> force is not (always) towards centre (of circle) **Allow** electric force is not perpendicular to velocity / is in the same direction as velocity **Ignore** references to centripetal
			work is done on proton (therefore kinetic energy changes so speed is not constant)	**B1**	**Ignore** references to centripetal
			Total	**10**	

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