OCR
Oxford Cambridge and RSA

GCE

Physics A

H556/03: Unified physics

A Level

Mark Scheme for June 2022

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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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RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online 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 available in RM Assessor.

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

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% 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 via the RM Assessor messaging system in the first instance.

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.

   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. On each blank page the icon BP must be inserted to confirm that the page has been checked. For additional objects (if present), a tick must be inserted on each page to confirm that it has been checked.
Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there.

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 the Principal Examineror 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 RM Assessor messaging system.

9. Assistant Examiners should send a brief report on the performance of candidates to the Principal Examiner by the end of the marking period. Please submit a short, bulleted report using Word.

10. **Levelof response(LoR)**

    Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

    Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1 (L1), Level 2 (L2) or Level 3 (L3), **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

    Once the level is located, award the higher or lower mark.

    The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. **The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

    In summary:
    - the **science** content determines the **level**
    - the **communication statement** determines the **mark within a level**.

    Levels of response questions on this paper are**3(b)** and **5(b)**.

11. Here are the subject specific instructions for this question paper.

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.

12. Annotations available in RM Assessor

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.**
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
/	alternative and acceptable answers for the same marking point
Reject	Answers which are not worthy of credit
Not	Answers which are not worthy of credit
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

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

Question			Answer	Marks	Guidance
1	(a)		$g = GM/r^2$ $g = \frac{6.67 \times 10^{-11} \times 4.87 \times 10^{24}}{(6\,050 \times 10^{3})^{2}}$ g = 8.87 (N kg^{-1})	C1 C1 A1	**Allow** m for M **Allow** d or D or x or X or R for r Full substitution needed **Allow** r = 6 050 for this C1 mark **Allow** a negative answer Answer must be to exactly 3sf for the A1 mark. Do not use the **SF** penalty for the paper here
	(b)	(i)	$a = \omega^2 r$ **and** $\omega = 2\pi / T$ **or** $a = v^2/r$ **and** $v = 2\pi r / T$ **Either** $\omega = \frac{2\pi}{5830 \times 3600}$ **or** $v = \frac{2\pi \times 6050 \times 10^3}{5830 \times 3600}$ **or** $a = \frac{4\pi^2}{(5830 \times 3600)^2} \times 6050 \times 10^3$ a = 5.42 × 10^{-7} (m s^{-2})	C1 C1 A1	**Allow** use of $T^2 = 4\pi^2 r^3/(GM)$ **and** $v = 2\pi r / T$ ω = 2.99 × 10^{-7} (rad s^{-1}) v = 1.81 (m s^{-1}) $a = \omega^2 r$ = (2.99 × 10^{-7})^2 × 6050 × 10^3 $a = v^2/r$ = 1.81^2 / (6050 × 10^3) **Do not allow** incorrect or omitted conversion of T **Allow** answer given to 2sf **Allow** any answer which rounds to 5.4 × 10^{-7} Do **not** penalise incorrect km conversion (giving a = 5.42 × 10^{-10}) if already penalised in **(a)**

Question			Answer	Marks	Guidance
1	b	(ii)	(Mass of fluid displaced = $\rho \times V =$) 65 x 1.7	C1	
			(Weight of fluid displaced = $\rho \times V \times g =$) 65 x 1.7 x 8.87	C1	Possible **ECF** from **(a)** but **do not allow** g = 9.81 N kg^{-1}
			U (= weight of fluid displaced) = 980 (N)	A1	
		(iii)	Any 2 from: • Forces are balanced at **A** /there is no centripetal force at **A** / forces are unbalanced at **B** / there is a resultant **or** centripetal force at **B** • correct balanced forces equation at **A** • correct expression of Newton's second law at **B** • calculation of centripetal force at **B** • calculation of normal contact force at **A** • calculation of normal contact force at **B**	B1 x 2	**Allow** the pole for **A** and the equator for **B** throughout **Allow** weight provides the centripetal force but **do not allow** normal contact force/upthrust provides the centripetal force **Allow** acceleration in place of force **Ignore** any statement that suggests that centripetal force is a separate or additional force e.g. $R_A = W - U$ e.g. ($mr\omega^2$ **or** ma **or**) $F = W - U - R_B$ Centripetal force (= ma = 760 x 5.4 x 10^{-7}) = 4.1 x 10^{-4} (N) Possible **ECF** from **(b)(i)** R_A (= $W - U$ = *(680 x 8.87) – 980)* = 5760 (N) Possible **ECF** from **(a)** and **(b)(ii)** R_B (= $W - U - ma$ = 5760 - 4.1 x 10^{-4}) Possible **ECF** from **(a), (b)(i)** and **(b)(ii)**
			<u>therefore</u> reaction force (must be) greater on **A**	B1	Conclusion must follow some valid and relevant reasoning in which upthrust is mentioned **Allow** reverse argument **Allow** CF is negligible therefore reaction force is same at A and B
			Total	12	

Question			Answer	Marks	Guidance
2	(a)		use of stopclock (**or** stopwatch **or** timer) time *n* oscillations **and** divide by *n*	**B1** **B1**	 If *n* is specified then $n \geq 5$
	(b)	(i)	$f = 1/T$ working shown to give $T^2 = \left(\frac{8\pi^2}{3g}\right)L$	**B1** **B1**	**Allow** $T = 2\pi\left(\frac{2L}{3g}\right)^{\frac{1}{2}}$ **or** $f^2 = 1/T^2$ Subject must be T^2 **Allow** $T^2/L = 8\pi^2/3g$
		(ii)	$g = \left(\frac{8\pi^2}{3 \times 2.64}\right)$ $g = 9.97$ (m s^{-2})	**C1** **A1**	 Answer must be given to at least 3sf
		(iii)	line of worst fit drawn	**B1**	Steepest or shallowest possible line that passes through all the error bars (allow ±½ small square tolerance vertically) If two lines are drawn then they must both be correct
		(iv)	gradient of worst line calculated with large triangle working to find percentage uncertainty in *g* answer consistent with candidate's worst line	**B1** **M1** **A1**	$\Delta L \geq 0.06$m Shallowest gradient ≈ 2.1(s^2 m^{-1}) and steepest ≈ 2.9 (s^2 m^{-1}) $\frac{\text{worst value of g} - 9.97}{9.97}$ (x 100%) **Allow** % uncertainty in gradient = $\frac{\text{gradient of wfl} - 2.64}{2.64}$ (x 100%) Expect answer ≈ 10% (steepest wfl) and ≈ 27% (shallowest wfl) **Allow** a negative answer
		(v)	percentage difference = $\frac{9.97 - 9.81}{9.81}$ x 100% = 1.6% **or** absolute difference = 9.97 - 9.81 = 0.16 **or** absolute uncertainty = (9.97 – value of *g* from wfl*)* conclusion consistent with candidate's answer to **(b)(iv)**	**M1** **A1**	Possible **ECF** from **(b)(ii)** Value for *g* is accurate if % uncertainty >% difference **or** if absolute uncertainty > absolute difference **or** if 9.81 lies within the uncertainty range for *g*
			Total	**12**	

Question			Answer	Marks	Guidance
3	(a)		p → n **or** proton → neutron	**M1**	**Allow** u→d or uud→udd **Ignore** A/Z values for the M1 mark
			(p → n +) e^+ + ν **or** positron + (electron) neutrino	**A1**	**Allow** β+ or ${}^{0}_{1}\beta$ or $\bar{e}$ or ${}^{0}_{1}e$ (but **not** e) for e^+ **Allow** ν_e (but **not** $\bar{\nu}$) for ν **Allow** ${}^{1}_{1}\mathrm{H}$ for ${}^{1}_{1}p$ Where A/Z values are given then they must be correct i.e. ${}^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{1}e^{+} + {}^{0}_{0}\nu$

Question			Answer	Marks	Guidance
3	(b)*		**Level 3 (5–6 marks)** Detailed method **and** analysis which clearly distinguishes between gamma, beta-plus and beta-minus *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)** Some method **and** analysis which clearly distinguishes between any two of the sources *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 method **or** limited analysis *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× 6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Method** • Measure background count and subtract from source count • Clamp source pointing away from you • Safety precautions (handle source with tongs, limit time etc.) • Record count over fixed time period • Investigate variation of count rate with range • Place aluminium sheets between source and radiation counter • Set up magnetic field at right angles to emission direction in order to investigate deflection of charged particles • Move radiation counter to find direction of deflection **Analysis** • Gamma has longest range in air, beta minus and beta plus have similar range (or β^+ has shortest range due to annihilation in air) • Gamma penetrates aluminium which is (more than a few mm) thick whereas beta does not • Gamma is undeflected by magnet (because neutral) • Beta radiation is deflected by magnet (because charged particles) • Beta plus and beta minus are deflected in opposite directions • because they have opposite charges / beta plus particle is a positron and beta minus particle is an electron • Use Fleming's left-hand rule to determine charge on beta particle through the direction of its deflection • With beta-plus, current is in same direction as motion of particle (opposite for beta-minus)
			Total	**8**	

Question			Answer	Marks	Guidance
4	(a)		Any two points from • (During / shortly after) the Big Bang **or** (Universe was initially) very hot **or** (Universe was initially) gamma photons • Universe expanded **or** Universe cooled (to 2.7K) • wavelength of (gamma) photons subsequently increased	**B1 x 2**	**Allow** radiation for photons throughout **Allow** cosmos / space for Universe but **not** matter / everything **Allow** frequency/energy of photons subsequently decreased **Allow** wavelength of photons/radiation has redshifted **Allow** wavelength of photons has stretched
	(b)	(i)	$\lambda_{max} \propto 1/T$ (T has decreased over time so in the past) the <u>peak</u> was at a shorter wavelength / further to the left on the graph	**B1** **B1**	**Not** $\lambda_{max} = 1/T$ May be inferred from candidate's diagram **Ignore** overall shape of spectrum
		(ii)	$E\left(= \frac{hc}{\lambda}\right) = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.1 \times 10^{-3}}$ $E = 1.8 \times 10^{-22}$(J)	**C1** **A1**	Full substitution needed if judging explicitly

Question			Answer	Marks	Guidance
4	(b)	(iii)	**EITHER** $\frac{3\ x\ 10^{-6}}{1.8\ x\ 10^{-22}}$ **or** 1.66×10^{16} (photons $m^{-2}\ s^{-1}$) **OR** $3 \times 10^{-6} \times (150 \times 10^{-4})$ **or** 4.5×10^{-8} (W)	C1	
			number of photons per second $\left(= \frac{3 \times 10^{-6} \times 150 \times 10^{-4}}{1.8 \times 10^{-22}}\right)$ $= 2.5 \times 10^{14}$ (s^{-1})	A1	**Allow** 2×10^{14} (s^{-1}) or 3×10^{14} (s^{-1}) Expect to see $1.66 \times 10^{16} \times 150 \times 10^{-4}$ **or** $\frac{4.5 \times 10^{-8}}{1.8 \times 10^{-22}}$
		(iv)	$E = Pt = IAt$ and $V = Ah$ where A is CSA of cylindrical tank and h is height of tank $\Delta\theta = \frac{E}{mc} = \frac{I \cancel{A} t}{\rho \cancel{A} h\ c} = \frac{It}{\rho hc}$ and so $\frac{\Delta\theta}{t} = \frac{I}{\rho hc}$		
			$E = mc\Delta\theta$ **and** $m = \rho V$	C1	**Allow** nonstandard letters as long as meaning is clear **Allow** 1000 ($kg\ m^{-3}$) for ρ **Allow** $\pi r^2 h$ **or** $5\pi r^2$ for V
			max temp rise s^{-1} $\left(= \frac{\Delta\theta}{t}\right) = \frac{3 \times 10^{-6}}{1000 \times 5 \times 4200}$	C1	
			max temp rise $s^{-1} = 1 \times 10^{-13}$ (°C s^{-1})	A1	**Allow** answer to more than 1s.f. (1.43×10^{-13} (°C s^{-1}))
			Total	**11**	

Question			Answer	Marks	Guidance
5	(a)	(i)			**Allow** v for v_{max} throughout
			$I_{max} = nAv_{max}e$	**B1**	**Allow** I for I_{max} **Allow** q or Q for e / a for A / V for v but **not** N for n
			$v_{max} = \frac{20 \times 10^{-3}}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.4 \times 10^{-8}}$	**M1**	Substitution must be shown in full
			$v_{max} = 1.1 \times 10^{-4}$ (m s^{-1})	**A1**	Answer must be given initially to 2 or more sf (but may later be rounded to 1sf)
		(ii)	$\omega = 2\pi f$	**C1**	May be inferred from working $\omega = 2\pi \times 11 \times 10^{9} = 6.9 \times 10^{10}$ (rad s^{-1})
			A (= v_{max}/ω) = $\frac{1.1 \times 10^{-4}}{2\pi \times 11 \times 10^{9}}$ **or** A (= v_{max}/ω) = $\frac{1.1 \times 10^{-4}}{6.9 \times 10^{10}}$	**C1**	**Allow** use of $v_{max} = 1 \times 10^{-4}$ (m s^{-1}) **Allow** v_{max} from **(a)(i)** given to more than 2sf but **not ECF** from any value which does not round to 1×10^{-4} (m s^{-1})
			$A = 1.6 \times 10^{-15}$ (m)	**A1**	**Allow** use of $v_{max} = 1 \times 10^{-4}$ (m s^{-1})^1 giving $A = 1.4 \times 10^{-15}$ (m) to 2sf or 1.45×10^{-15} (m) to 3sf Special case: **Allow** $A = 1 \times 10^{-15}$(m) to 1 sf if $v_{max} = 1 \times 10^{-4}$ (m s^{-1}) is used
		(iii)	($a_{max} = \omega^2 A$ and $v_{max} = \omega A$)		
			$a_{max} = 2\pi f v_{max}$	**M1**	**Allow** $a_{max} = \omega v_{max}$ **Allow** a for a_{max} and v for v_{max}
			Since v_{max} is constant, $a_{max} \propto f$	**A1**	

Question			Answer	Marks	Guidance
5	(b)*	(i)	**Level 3 (5–6 marks)** Clear explanation **and** clear description *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 explanation **or** clear description (but not both) **or** Some explanation **and** some description *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 explanation **or** Limited description *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× 6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Explanation of pattern** • Interference / superposition occurs • Path difference a whole number of wavelengths • means waves are (exactly) in phase (or $\Delta\varphi = 0$) • giving (maximum) constructive interference • which leads to maximum intensity • Path difference an odd number of half wavelengths (or $\Delta\varphi = \pi$ radians) • means waves are in antiphase • giving (maximum) destructive interference • which leads to minimum intensity **Description of relationship between *f* and *x*** • $\lambda = ax/D$ **and** $c = f\lambda \rightarrow x = cD/af$ • so $x \propto 1/f$ (provided a and *D* remain constant) • Use ruler along QP to measure *x (or 10*x/10, say) • Connect oscilloscope to transmitter or detector to measure *f* • Vary *f (*keeping a and *D* constant) and measure corresponding *x* • Calculate *fx* which should remain constant • Or plot graph of 1/*x* against *f* (or x against 1/f) • Should give straight line <u>through the origin</u>

Question			Answer	Marks	Guidance
5	(b)	(ii)	At 90° rotation, (interference) pattern disappears	B1	**Allow** constant intensity along PQ **Not** zero intensity along PQ **Allow** from 0 to 90° the intensities of the maxima decrease (and the minimum intensities increase)
			At 180° rotation, intensities are the same as at 0° but the maximum/minimum positions are switched / reversed	B1	**Allow** from 90 ° to 180 ° the intensities of the maxima increase (and the minimum intensities decrease) but the maximum/minimum positions are switched / reversed from between 0 and 90°
			Waves with polarisations at 90° to each other do not interfere / only waves with same polarisation interfere / only waves with a component in the same plane interfere	B1	**Allow** waves must oscillate in same plane to interfere **Ignore** at 90° rotation, only waves from Y are detected at D because D can only detect vertical polarised waves
			Total	**17**	

Question			Answer	Marks	Guidance
6	(a)		time taken for current (**or** charge **or** voltage) to fall to 1/e <u>of its initial value</u>	**B1**	**Not** capacitance **Not** to fall <u>by</u> (a factor of) 1/e **Allow** to decrease <u>to</u> 37% of its initial value **Allow** to decrease <u>by</u> 63% **Ignore** time constant = *CR*
	(b)	**(i)**	f (= 1/T) = 1 / (40 × 10^{-3}) f = 25 (Hz)	**B1** **B1**	**Allow** f = 1/T **and** T = 40 × 10^{-3} (s)
		(ii)	**EITHER** Calculation of Q_o / e time constant (read from graph) = 14 (ms) **OR** Use of $Q = Q_o e^{-t/CR}$ time constant = 14 (ms)	 **C1** **A1** **(C1)** **(A1)**	**Allow** any initial value of charge e.g. 8.0 / e = 2.9 (μC) **or** 37% x 8.0 = 3.0 (μC) **Allow** 14±1 (ms) e.g. $2.0 = 8.0e^{-0.02/CR}$ gives CR = 0.02 / ln4 Using the decay equation may incur two POT errors
		(iii)	tangent drawn to graph <u>at steepest part of curve</u> maximum current in range 5.0 × 10^{-4} to 7.0 × 10^{-4} (A)	**M1** **A1**	Judge by eye, no daylight between curve and tangent **Allow** a negative answer **Allow** answer to 1sf

Question			Answer	Marks	Guidance
6	(b)	(iv)	vertical axis labelled as current with the correct unit **and** at least one positive and one negative scale marking **and** scale should allow for their maximum current to be plotted	**B1**	For example I / mA , I (mA), I /10^{-4} A, current in mA etc All scale markings shown must be correct
			exponential decay of current in each section	**M1**	**Allow** any curve with a decreasing gradient in each section **Ignore** value of minimum current but **not** zero **Ignore** sign of current for this marking point All curves should start at the correct maximum current value. However, If **B1** mark has not been scored, **allow** any value of maximum current as long as it remains consistent across all four sections
			sign of current alternates at 20, 40, 60 and 80 ms	**A1**	
			Total	**10**	

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