GCE

Physics A

H556/02: Exploring 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.

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 Assessor 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 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	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
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.

Annotation		Meaning
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).

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

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.

SECTION A

Question	Answer	Marks	Guidance
1	C	1	
2	D	1	
3	C	1	
4	B	1	
5	B	1	
6	B	1	
7	B	1	
8	D	1	
9	A	1	
10	D	1	
11	C	1	
12	C	1	
13	D	1	
14	C	1	
15	C	1	
	Total	15	

SECTION B

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

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>16</td><td>(a)</td><td></td><td>Connect the <u>voltmeter</u> in parallel with the thermistor</td><td>B1</td><td>Allow correctly drawn on diagram
Allow “across” for “in parallel with”
Allow voltmeter in parallel with cell</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>Points plotted correctly, within ½ small square</td><td>B1</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Smooth curve passing within 1 vertical small square of plotted points</td><td>C1</td><td>No credit for straight line
If thick line drawn, all width of line must lie within 1 vertical small square</td></tr>
<tr><td></td><td>(c)</td><td></td><td>Current increases as temperature increases (and voltage is constant)

Use of at least two sets of data to calculate resistance

The resistance decreases, therefore it is ntc thermistor</td><td>B1

M1

A1</td><td>Accept standard symbols (T, I , θ etc) for variables in explanation

<table>
<tr><td>Temp / °C</td><td>Resistance / kΩ</td></tr>
<tr><td>30</td><td>4.0</td></tr>
<tr><td>40</td><td>2.7</td></tr>
<tr><td>50</td><td>2.0</td></tr>
<tr><td>60</td><td>1.4</td></tr>
<tr><td>70</td><td>1.1</td></tr>
<tr><td>80</td><td>0.82</td></tr>
<tr><td>90</td><td>0.63</td></tr>
</table>
Allow 1sf for resistance values from calculations
Ignore POT error for M mark</td></tr>
</table>

Question			Answer	Mark	Guidance
16	(d)		In circuit 1, p.d. (across the thermistor) will remain (almost) constant (with varying temperature)	M1	**Allow** voltage for p.d.
			In circuit 2, p.d. (across the thermistor) will vary (with varying temperature)	M1	**Allow** variation of pd to be increase or decrease
			Hence, circuit 2 will be best to choose / circuit 1 is not suitable	A1	Both M marks required for A mark
			Correct potential divider argument OR explanation of operation of circuit	B1	e.g. Use of $V_{out} = V_{in}$ x (R / R + 10 000) / the ratio of the resistances will vary (with temperature) e.g. as the milk gets hotter, the rate of heating reduces B mark is for qualifying statement

Question			Answer	Mark	Guidance
17	(a)		At P_1 (and / or P_3), waves (arrive) in phase and undergo constructive interference	B1	**Allow** maxima / loud areas for at P_1 and P_3 **Allow** phase difference of 0 or $2n\pi$ (rad) or 360° **Allow** explanation in terms of path difference (path difference = $n\lambda$ and undergo constructive interference) **Allow** superposition for interference
			At P_2, waves (arrive) in antiphase and undergo destructive interference	B1	**Allow** minimum / quiet areas for P_2 **Not just** "out of phase" **Allow** completely out of phase / out of phase by $(2n+1)\pi$ (rad) or 180° **Allow** explanation in terms of path difference (path difference = $(n+1/2)\lambda$ and undergo destructive interference) **Allow** superposition for interference **Do not allow** deconstructive for destructive
	(b)		$\lambda = (\frac{ax}{D} =) \frac{0.70 \times 2.5}{4}$	C1	
			= 0.4375 (m)	C1	
			$f = \frac{v}{\lambda} = \frac{340}{0.4375} = 780$ (Hz)	A1	**Allow** λ = 0.44 (m), then f = 770 (Hz) Correct to at least 2sf **Special case**: use of *x* as 1.25 leading to *f* = 1554 (Hz) for 1 mark
	(c)		Amplitude / maximum (of the signal) larger than previous amplitude seen at P_1 (and at P_3)	B1	**Ignore** numerical value of how much the amplitude is larger **Allow** reference to P_3 alone **Allow** height or signal for amplitude throughout

Question			Answer	Mark	Guidance
			Non-zero amplitude seen <u>at P_2</u>	**B1**	**Ignore** "louder"
	(d)	**(i)**	power per unit area (perpendicular to the direction of energy transfer)	**B1**	**Allow** energy per unit time for power **Allow** equation in words, or in symbols with all symbols defined **Do not allow** power per area or power over area
		(ii)	intensity is proportional to (amplitude)^2 amplitude in (a) = 2 and amplitude in (c) = 3 (ratio of amplitudes = 3/2) so factor = 9/4 (or 2.25)	**C1** **C1** **A1**	**Allow** *A* (or *a*) for amplitude and *I* (or i) for intensity in both C marks **Allow** any valid ratio e.g. 9:4

Question			Answer	Mark	Guidance
18	**(a)**		**Level 3 (5–6 marks)** Clear description **and** clear analysis *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 **or** clear analysis **or** some description **and** some analysis	**B1 x 6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** Expect to see use of ac for clear description **Description** • labelled circuit diagram • smaller number of turns on primary • a.c. supply on primary

Question			Answer	Mark	Guidance
			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 **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.		• load resistor on output • a.c. ammeter to measure current • measurement of number of turns on secondary • keep number of turns on primary constant • keep input ac voltage constant • increase number of turns on secondary each time **Analysis** • algebra to get to N_s α $1/I_s$ • graph drawn $1/I_s$ against N_s / I_s against $1/N_s$ • expect straight line through origin **or** • lg I_s against lg N_s • expect straight line to show gradient = -1 • therefore N_s α $1/I_s$ **or – if load resistor in circuit only** • use of Ohm's law applied to load resistor to explain why presence of load resistor increases primary current • plotting graph drawn I_s against N_s • expect straight line through origin
	(b)(i)		The (magnitude of the induced) e.m.f. is (directly) proportional/equal to the rate of change of (magnetic) flux linkage	**B1**	**Allow** electromotive force for e.m.f **Do not allow** electromagnetic force for e.m.f. **Allow** change per unit time for rate of change **Allow** cutting flux for change of flux linkage **Do not allow** flux density for flux linkage

Question			Answer	Mark	Guidance
	(b)(ii)		Use of $Ns / N_p = Vs / Vp$ N_s / 920 = 5.0 / 230 so N_s = 20	**C1** **A1**	Expect to see attempt at substitution following the equation Correct substitution and correct algebra into any arrangement
	(b)(iii)		Use of N = 20 $3.4 = 20 \times \Delta\phi / 1.2 \times 10^{-3}$ $\Delta\phi = 2.0 \times 10^{-4}$ Unit: Wb / weber(s)	**C1** **C1** **A1** **B1**	Expect to see factor of 20 correctly used Correctly calculated to 2sf (2.04) **Special cases**: for two marks from the calculation Use of N = 1 gives 4.08 x 10^{-3} correct to 2sf Use of N = 920 gives 4.43 x 10^{-6} correct to 2sf **Allow** T m^2 **Ignore** V s **Allow** correct base unit (kg m^2 s^{-2} A^{-1})

Question			Answer	Mark	Guidance
19	**(a)**		Calculation in eV: $E_{\text{light photon}} = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 510 \times 10^{-9}$ $= 3.90 \times 10^{-19}$ (J)	**C1**	Calculation in J: $E_{\text{light photon}} = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 510 \times 10^{-9}$ $= 3.90 \times 10^{-19}$ (J)
			$E_{\text{light photon}} = 3.9 \times 10^{-19} / 1.6 \times 10^{-19}$ $= 2.44$ (eV)	**C1**	$E_{\text{X-ray photon}} = 32 \times 10^{3} \times 1.6 \times 10^{-19}$ $= 5.12 \times 10^{-15}$ (J)
			Number of photons = ($E_{\text{X-ray photon}}/E_{\text{light photon}}$) x efficiency		Number of photons = ($E_{\text{X-ray photon}}/E_{\text{light photon}}$) x efficiency
			= (32 000 / 2.44) x 0.15	**C1**	= ($5.12 \times 10^{-15} / 3.90 \times 10^{-19}$) x 0.15
			= 1969	**A0**	= 1969 Answer to at least 3sf **Allow** use of 2.4eV for energy of light photon to give 2000 in either method
	(b)	**(i)**	(The work function is) the minimum energy required to release an electron (from the surface of a metal)	**B1**	**Allow** minimum work done for minimum energy **Do not allow** idea of energy needed to release multiple electrons **Do not allow** release of electron from atom **Do not allow** idea of ionisation energy
		(ii)	$\phi = 2.3 \times 1.6 \times 10^{-19}$ (= 3.68×10^{-19} J)	**C1**	Or $\phi = 2.44 - 2.3$ (= 0.14 eV)
			$KE_{\text{max}} = (3.90 - 3.68) \times 10^{-19} = 2.2 \times 10^{-20}$ (J)	**A1**	$KE_{\text{max}} = 0.14 \times 1.6 \times 10^{-19} = 2.2 \times 10^{-20}$ (J) Answer to at least 2sf **Allow** use of 2.4 eV to give 1.6×10^{-20} (J) ecf light photon energy from (a)

Question			Answer	Mark	Guidance
		(iii)	$I\left(=\frac{Q}{t}\right)=\frac{12\times1969\times1.6\times10^{-19}}{60}$ = 6.3 x 10^{-17} (A)	**C1** **A1**	**Allow** full credit for use of 2000 Answer to at least 2sf (6.30) **Allow** use of *N*= 2000 to give I = 6.4 x 10^{-17} (A) **Allow** ecf on *N* from (a)
		(iv)	One from: One to one interaction between (light) photon and electron That there are no secondary electrons That the current is continuous / X-rays arrive at a constant rate within the minute (or 1 every 5s) All the electrons leave the photocathode	**B1**	

Question			Answer	Mark	Guidance
20	**(a)**		(Minimum) energy required to separate the nucleons (to infinity)	**B1**	**Allow** protons and neutrons for nucleons **Allow** energy released when the nucleus forms from the nucleons **Do not allow** mathematical descriptions such as (mass defect x c^2)
	(b)		H-1 is a single proton / nucleon AND there is no binding energy / it is not bound to anything	**B1**	
	(c)	**(i)**	The product has a higher binding energy (per nucleon)	**B1**	**Allow** the fusion of low Z number nuclei will result in a nucleus higher up the curve making it more stable **Ignore** statements regarding electrostatic repulsion
		(ii)	Energy before = (1.1 x 2) + (2.8 x 3) (= 10.6 MeV) Energy after = 7.1 x 4 (= 28.4 MeV) Energy released = 28.4 -10.6 = 17.8 MeV = 17.8 x 10^6 x 1.6 x 10^{-19} = 2.8 x 10^{-12} (J)	**C1** **C1** **A1**	**Allow** ± 0.1 MeV tolerance on binding energy values from graph Answer to at least 2sf (2.848) MAX value of energy within tolerances = 2.99 x 10^{-12} MIN value of energy within tolerances = 2.70 x 10^{-12}
		(iii)	Energy released per second = 4.3 x 10^9 x (3 x 10^8)^2 = 3.87 x 10^{26} (J) No of reactions = 3.87 x 10^{26} / 2.85 x 10^{-12} = 1.4 x 10^{38} (s^{-1})	**C1** **A1**	Alternative method: Mass per reaction = 2.85 x 10^{-12} / (3 x 10^8)^2 = 3.2 x 10^{-29} (kg) No of reactions = 4.3 x 10^9 / 3.2 x 10^{-29} = 1.4 x 10^{38} (s^{-1}) **Allow** use of 3 x 10^{-12} to give 1.29 x 10^{38}

Question			Answer	Mark	Guidance
					Allow use of (c)(ii) tolerance range for energy released value from to final answer in range 1.29 – 1.43 ($x10^{38}$) Correct to at least 2sf
	(d)	**(i)**	0 / neutral	**B1**	Unit not necessary, but penalise incorrect unit
		(ii)	(electron) neutrino	**B1**	**Do not allow** antineutrino **Ignore** symbols If answer line is blank, then the name in the missing space in the equation can be taken as the answer
		(iii)	4	**B1**	
	(e)		$d \rightarrow u$ $+ {}^{0}_{-1}e^{-} + \bar{\nu}$	**B1** **B1**	Correct change of quark **Allow** udd to uud Correct symbols for other two particles **Allow** e^- or ${}^{0}_{-1}e$ for electron **Allow** beta symbol for electron Numbers for the neutrino do not need to be present, but must be correct if given ${}^{0}_{0}\bar{\nu}$

Question			Answer	Mark	Guidance
21	(a)	(i)	Material (introduced into the body and) used so its position in the body can be detected / function of organ can be determined	B1	**Allow** "used to produce images" for "detected" **Do not allow** "trace" for "position detected" **Ignore** treatment
		(ii)	(Very) little ionisation	B1	**Allow** less ionising / least ionising **Do not allow** "zero ionisation"
			(Most can) pass through the body tissue / can be detected outside / highly penetrating	B1	**Allow** other radiation would be absorbed within the body
	(b)	(i)	$\lambda = \frac{ln2}{T_{1/2}} = \frac{ln2}{6.01 \times 3600}$ (= 3.20 x 10^{-5} s^{-1})	C1	
			$(A = \lambda N)$ 900 x 10^{6} = 3.20 x 10^{-5} x N	C1	
			N = 2.8 x 10^{13}	A1	Correct to at least 2sf (2.81) **Special case**: Calculation of decay constant in $hour^{-1}$ gives 0.115 leading to N = 7.8 x 10^{9} maximum 1 mark Calculation of decay constant in min^{-1} gives 1.9 x 10^{-3} leading to N = 4.7 x 10^{11} maximum 1 mark
		(ii)	(Correct use of $A = A_0e^{-\lambda t}$) 0.03 = $e^{-3.2 \times 10^{-5} t}$	C1	Or use of λ as 0.115 $hour^{-1}$ ecf for λ from (b)(i)
			ln(0.03)= - 3.2 ×10^{-5} t	C1	ln(0.03)= - 0.115 t
			t = 109 500 s = 30 hours	A1	**Allow** final answer that rounds to 30 or 31 hours

Question			Answer	Mark	Guidance
					Special case: if fall of 3% ($A = 0.97A_0$) calculated, leading to 0.26 hours then max 1
	(c)		Activity is low compared to background	**B1**	**Allow** activity is very low **Allow** decays very slowly / very little decay for low activity **Allow** rate of emission for activity **Ignore** references to long half life
	(d)		**Level 3 (5–6 marks)** Clear description **and** full correct 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)** Clear description **or** full correct calculation **OR** Some description **and** some calculation *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 **or** limited calculation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant*.	**B1×6**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** Expect to see appropriate safety precaution for clear description **Description:** • Take background count • Over (at least) 3 minutes • Take count due to source • Over the same time • Measured using a stopwatch • Calculate the corrected count • Calculate the corrected count per minute • Use a Geiger-Muller tube and counter • Hold source at arms length when transferring • Keep in lead lined box at other times • Use tongs to hold source

Question			Answer	Mark	Guidance
			0 marks *No response or no response worthy of credit*		**Calculation** • $C = C_0 e^{-\lambda t}$ • $lnC = lnC_0 - \lambda t$ • e.g 7.51 = 7.81 - $(\lambda \times 6)$ • λ around 0.05 hour^{-1} • $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ • $T_{\frac{1}{2}}$ = 13.9 hours (allow any answer that round to 14 hours) • $T_{\frac{1}{2}}$ = 830 minutes or 49 900 seconds (allow some tolerance for slight graph reading discrepancies) • Or by a graphical method

Question			Answer	Mark	Guidance
22	**(a)**	**(i)**	At least 4 equidistant parallel vertical (straight) lines	**B1**	By eye **Ignore** field lines outside of plates At least one line must touch top and bottom plate
			With arrows pointing downwards	**B1**	At least one arrow, and all arrows given must be correct

Question			Answer	Mark	Guidance
		(ii)	The top and the bottom of the clouds will not be parallel / will be uneven	**B1**	**Allow** uneven charge distribution / charge density **Allow** the field is non-uniform **Allow** the cloud is a non-uniform shape **Ignore** cloud has non uniform density
		(iii)	($V = Ed$) = 4.0 x 10^5 x 3.2 x 10^3 = 1.3 x 10^9 (V)	**B1**	Values of E, d with correct powers of 10 and correct evaluation must be seen to at least 2sf (1.28) **Ignore** unit
		(iv)	$C = \left(\frac{\varepsilon_0 A}{d} =\right) \frac{8.85 \times 10^{-12} \times \pi \times \left(12 \times 10^3\right)^2}{3.2 \times 10^3}$ C = 1.3 x 10^{-6} (F)	**C1** **A1**	All values (including ε_0) substituted correctly Correct evaluation to at least 2sf (1.25 x 10^{-6}) **Note**: use of $C = 4\pi\varepsilon_o R$ (leading to 1.3 x 10^{-6} is XP)
		(v)	Q (= CV) = 1.25 x 10^{-6} x 1.28 x10^9 Q = 1600 (C)	**C1** **A1**	Ecf from (a)(iii) and (a)(iv) Correct evaluation to at least 2sf **Allow** 2sf answer of 1700 C for 2sf values used in calculation **Allow** answer of 1250C for p.d. value of 1 x 10^9
	(b)	**(i)**	$V = \frac{Q}{4 \pi \varepsilon_0 r}$ $V = \frac{155}{(4\pi\ 8.85 \times 10^{-12} \times 2 \times 10^3)}$	 **C1**	 All values substituted correctly

Question			Answer	Mark	Guidance
			= 7.0 x 10^{8} (V)	**A1**	Correct answer to at least 2sf (6.97)
		(ii)	Either		
			(I =) 155 / 25 x 10^{-3} = (6200 A)	**C1**	**Ignore** units throughout although penalise any unit on answer line
			n = 6200 / 1.6 x 10^{-19} = 3.88 x10^{22}	**C1**	
			n (in 1ms) = 3.88 x 10^{22} x 10^{-3} = 3.9 x 10^{19}	**A1**	Correct evaluation to at least 2sf (3.88)
			Or		
			(Charge flow) = 155/25 = (6.2 C ms^{-1})	**(C1)**	
			n = 6.2 / 1.6 x 10^{-19}	**(C1)**	
			n = 3.9 x 10^{19}	**(A1)**	Correct evaluation to at least 2sf (3.88)

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