A-level
PHYSICS
7408/2

Paper 2

Mark scheme

June 2025

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256A7408/2/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

No student should be disadvantaged on the basis of their gender identity and/or how they refer to the gender identity of others in their exam responses.

A consistent use of 'they/them' as a singular and pronouns beyond 'she/her' or 'he/him' will be credited in exam responses in line with existing mark scheme criteria.

Further copies of this mark scheme are available from aqa.org.uk

Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1
In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.

2.2
A bold **and** is used to indicate that both parts of the answer are required to award the mark.

2.3
Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists
This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error/contradiction negates each correct response. So, if the number of errors/contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.
However, if the answer is incorrect, mark(s) can usually be gained by correct substitution/working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do not allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf −1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' – answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb m^{-2} would both be acceptable units for magnetic flux density but 1 kg m^2 s^{-2} A^{-1} would not.

3.10 Level of response marking instructions

Level of response mark schemes are broken down into three levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are two marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

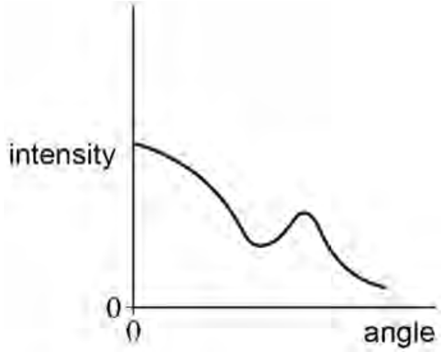
You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional comments/Guidance	Mark	AO
01.1	Any **one** from: ✓ • $(\Delta\ )E_k = (\Delta)E_P$ seen • $E_k = 1.60 \times 10^{-19} \times 5.59 \times 10^6$ or 8.94×10^{-13} seen • $Q_\alpha = 2e$ and $Q_{\text{Au}} = 79e$ An energy $= \frac{Q_\alpha Q_{\text{Au}}}{4\pi\varepsilon_0 r}$ seen in any form ✓ $r\left(= \frac{2 \times 1.60 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 5.59 \times 10^6 \times 1.60 \times 10^{-19}}\right)$ (<) 4.1×10^{-14} (m) ✓ (allow 1 sf) cao	MP1 may be seen in substitution for r Condone PoT error in MP1 and MP2. In MP2: Allow use of $E = QV$ **and** $V = \frac{Q}{4\pi\varepsilon_0 r}$ with Q_α and Q_{Au} in either order. Condone use of k for $\frac{1}{4\pi\varepsilon_0}$ unless contradicted by use of 1.38×10^{-23} Condone use of E_k in MeV. Condone 10^{-14} if supported by some correct substitution. Correct answer to at least 1 SF gains all 3 marks.	3	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	Any **two** from: ✓✓ • Idea that alpha particles give an upper limit on size of the nucleus / estimate is larger than nuclear radius • Idea that (distance of closest approach) depends on the energy of the alpha particle • Idea that recoil of nucleus is ignored • Idea that alpha particle has finite size	Ignore references to shape of nucleus. bullet 1: condone idea that it does not hit the nucleus. Referencing the distance of closest approach is not enough. bullet 2: is for the idea that the closest approach method does not give a single value • Condone does not take into account neutrons / only considers charge / only considers number of protons. If no other mark awarded allow **max 1** for reference to not taking into account the effect of the strong nuclear force.	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	When angle = 0 there is a maximum **and** first minimum is not zero **and** at least one subsequent smaller maximum ✓ Idea that nuclear radius is determined from (first diffraction) minimum ✓	 Allow subsequent peaks Condone the line meeting the intensity axis at non-zero but negative gradient. Do **not** allow double slit (even superposed with single slit) or diffraction grating (light-like) patterns. Allow suitable annotation of diagram for answer Ignore any equation given.	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	Any **one** of: ✓ • volume of a nucleus is (approximately) spherical • $V = \frac{4}{3}\pi R^3$ or $V = \frac{4}{3}\pi R_0^3 A$ • volume is proportional to A • mass = A × mass of nucleon • mass (/kg) = $A \times 1.661 \times 10^{-27}$ • mass is proportional to A Density $\left(=\frac{m}{V}\right) = \frac{Am_{(n)}}{\frac{4}{3}\pi R_0{}^3 A} = \frac{m_{(n)}}{\frac{4}{3}\pi R_0{}^3}$ **AND** where all are constants / equation is independent of A. **OR** Combining of two proportional statements and cancelling of A ✓	Do **NOT** accept bullets 3, 4,5 or 6 when A is referred to as area, activity or any other incorrect quantity. $R \propto A^{\frac{1}{3}}$ or $R^3 \propto A$ is not enough. Accept alternative values or u in bullet 5	2	AO1

Total			Mark
			9

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	There is a range of speeds / kinetic energies ✓ Idea of no preferred direction ✓	Any suggestion that particles do not follow Newton's laws, are not deterministic, or the motion is unpredictable, is incorrect and restricts to **MAX 1.** Ignore references to Brownian motion and collisions. Allow velocity for speed in MP1. A reference to average speed is not enough for MP1. Must express the idea that all directions are equally likely not just that there is a range of directions. Allow $\overline{v}_x = \overline{v}_y = \overline{v}_z$ or similar for MP2	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Any **two** from: ✓✓ • particle volume << gas volume / particle volume is negligible / point masses • time for collisions << time between collisions / collisions are instantaneous • no non-contact / intermolecular forces between the particles • all collisions (between particles / between particles and wall) are elastic • the particles follow Newton's laws / have no wave behaviour	Mark using list principle Particles are (very) small is insufficient Time for collisions is (very) short/small is insufficient Ignore (as included in assumption given in **02.1**): • there is no preferred direction • there is a range of speeds	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	**Any two from** ✓✓ • greater **mean** speed / c_{rms} / **mean** kinetic energy • (mean) change in momentum / Δmv (per collision) increases • more frequent collisions (with walls, for the same volume) • force increases because force is the rate of change of momentum / $F = \frac{\Delta(mv)}{(\Delta)t}$ Larger volume increases the (surface) area **and** pressure = $\frac{\text{force}}{\text{area}}$ (if the force increases so must the area to keep pressure the same) **OR** Larger volume increases the (mean) time between collisions or decreases the number of collisions per second / frequency of collisions ✓ (decreasing the total rate of change of momentum and hence force)	Ignore reference to equations of state. Do **not** allow greater mean velocity in bullet point 1. Other marks can be awarded. Ignore references to particles colliding with each other. **Alternative route** (all marks must come from same route) (Increase in temperature means) c_{rms} increases ✓ Use of $pV = \frac{1}{3}Nm(c_{\mathrm{rms}})^2$ to justify increase of V ✓ p N and m named and stated as constant ✓	3	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.4	$\Delta E_{\mathrm{k}}\left(=\frac{3}{2}k\Delta T=\frac{3}{2}\times1.38\times10^{-23}\times(77-27)\right)=1.0(35)\times10^{-21}$ (J) ✓		1	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.5	Calculation of number N of water molecules in $1\ \mathrm{kg}$ **or** use of $\frac{3}{2}kT$ **or** use of $\frac{3}{2}RT$ for their ΔT ✓ Use of $mc\Delta\theta$ for their $\Delta\theta$ ✓ Valid comparison of quantities leading to no ✓	$N = \frac{1}{3.0\times10^{-26}}$ Allow $N = \frac{N_A}{0.018}$ Allow MP1 for **quoting** their answer to **02.4** if $\Delta\theta = 50\ \mathrm{K}$ in MP2. Allow for MP2: $c = \frac{3}{2}k\Delta T \times N = \frac{3}{2}\times1.38\times10^{-23}\times1\times$ their N **Max 1** when different ΔT and $\Delta\theta$ used for MP1 and MP2. e.g. $c = 690\ (\mathrm{J\ kg^{-1}\ K^{-1}}) \neq 1400$ so no, water vapour does not behave as an ideal gas e.g. for change in temperature of **50 K**: $Q = 2.1\times10^{-21}$ (J) and $\Delta E_k = 1.0(35)\times10^{-21}$(J) Condone comparison involving 1 sf **Alternative method** $mc\Delta\theta = \frac{3}{2}k\Delta T$ ✓ $c = \left(\frac{3k}{2m} = \right)\frac{3\times1.38\times10^{-23}}{2\times3.0\times10^{-26}}$ ✓ Comparison of quantities leading to no ✓	3	AO3

Total			**11**	

Question	Answers	Additional comments/Guidance	Mark	AO
03.1	$238 \times 1.661 \times 10^{-27}$ or 3.953×10^{-25} seen OR their mass $\times 3.23 \times 10^{24}$ ✓ 1.28 (kg) ✓ **Alternative method`** $n = \frac{3.23\times10^{24}}{6.02\times10^{23}}$ or 5.37 mol seen OR their number of moles × 238 ✓ 1.28 (kg) ✓	Allow use of 1.67×10^{-27} kg Allow inclusion of electron masses. Allow use of 1.673×10^{-27} and 1.675×10^{-27} leading to 1.29	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.2	A_0 (= λN) = 8.11×10^{14} (Bq) ✓ Any **three** from: ✓✓✓ • dividing an output power / A / N / m by 0.0458 or multiplying an input power / α energy / A_0 / N_0 / m_0 by 0.0458 • Use of $A = \frac{\text{any power}}{8.94\times10^{-13}}$ or $\frac{\text{any power}}{8.94\times10^{-13}\times0.0458}$ to calculate P or A • use of $t = \frac{\ln\left(\frac{A}{A_0}\right)}{-\lambda}$ or $t = \frac{\ln\left(\frac{N}{N_0}\right)}{-\lambda}$ or $t = \frac{\ln\left(\frac{m}{m_0}\right)}{-\lambda}$ or $t = \frac{\ln\left(\frac{P}{P_0}\right)}{-\lambda}$ • convert time to years (divide a time by 365 × 24 × 60 × 60) or decay constant to yr^{-1}. Time = 14.5 (Earth years) ✓	Condone small rounding errors. $\frac{29.6}{0.0458} = 646\text{ W}$ $\frac{646}{8.94\times10^{-13}} = 7.23\times10^{14}\text{ Bq}$ $t = \frac{\ln\frac{7.23}{8.11}}{-2.51\times10^{-10}} = 4.58\times10^{8}\text{ s}$ Allow use of $0.5^{\frac{t}{t_{0.5}}}$ **and** $t_{0.5} = \frac{\ln 2}{\lambda}$ instead of $e^{-\lambda t}$. Allow conversion of half-life to years. Allow ecf for their A_0 Accept answers that round to 14 or 15 years based on working seen. Missing efficiency results in 404 y.	5	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.3	Any **three** from: ✓✓✓ • valid $Q = mc\Delta\theta$ substitution or answer • valid $Q = mL$ substitution or answer • 3 valid Q calculations • energy provided by laser between charges (= 1000 × 3) = 3000 (J) OR a valid power calculation for their Q Total energy required = 2900 (J) < 3000 (J) so yes ✓	Ignore PoT in bullet points Heat ice to 0.0 °C: $10^{-3} \times 2100 \times 25 = 52.5$ J Melt ice at 0.0 °C: $10^{-3} \times 334 \times 10^{3} = 334$ J Vaporise water at 0.0 °C: $10^{-3} \times 2500 \times 10^{3} = 2500$ J Allow $(L_f + L_v)$ in $Q = mL$ as two calculations. Allow any correct comparison for MP4 e.g. Energy required: 2887 < 3000 J Powers: 962 < 1000 W Mass of ice: 0.00104 > 0.001 kg time: 2.8865 < 3 s Δθ: 79.0 > 25 K Allow other valid comparisons.	4	AO3

Energy required	2887	<	3000	J
Powers	962	<	1000	W
Mass of ice	0.00104	>	0.001	kg
time	2.8865	<	3	s
Δθ	79.0	>	25	K

Total			11

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	Calculation of either radius by adding radius of Saturn to height ✓ Use of $\frac{T_1}{r_1^{\frac{3}{2}}} = \frac{T_2}{r_2^{\frac{3}{2}}}$ **OR** use of $T^2 = \frac{4\pi^2 r^3}{GM}$ **OR** Calculation of constant of proportionality (k) ✓ 1.36 (Earth days) ✓	Ignore PoT for first 2 marks $r_{\text{Mimas}} = 1.86 \times 10^8$ m $r_{\text{Enceladus}} = 2.38 \times 10^8$ m $k = \frac{T}{r^{1.5}}$ or $\frac{T^2}{r^3}$ or $\frac{T^{\frac{2}{3}}}{r}$ Allow ecf for MP2 and MP3 for ignoring radius of Saturn to give 1.57 (Earth days)	3	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	Variation of potential with distance is (approximately) a straight / linear line / constant gradient **AND** the field strength is equal to the (potential) gradient ✓	Do **NOT** allow (directly) proportional Allow range shown on graph is much smaller than the distance from Saturn with support from a suitable equation.	1	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	12.025×10^8 to 12.045×10^8 (m) ✓ (field = potential gradient, distance at which gradient = 0)	≥ 4 SF required Do **not** allow 12.02 or 12.05. **For non-standard papers:** MLP18A4 as main mark scheme MLP18A3 12.015×10^8 to 12.050×10^8 (m)	1	AO2

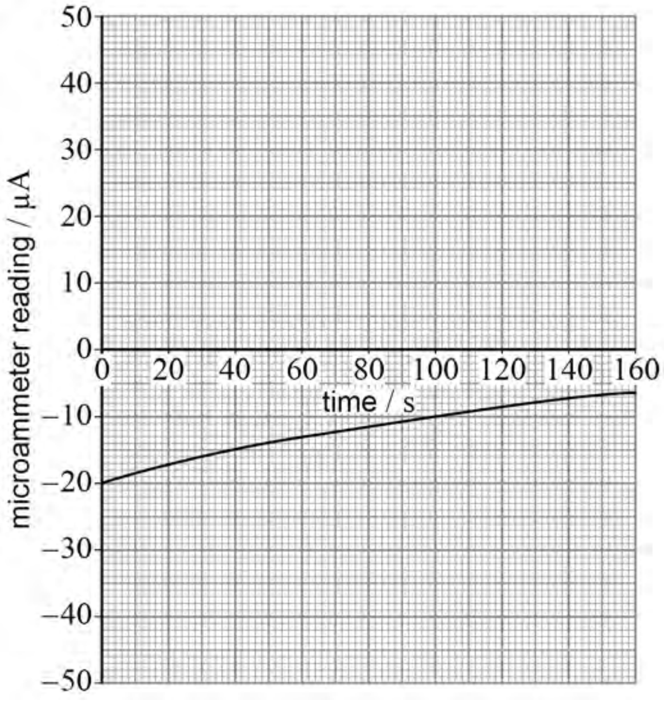
Question	Answers	Additional comments/Guidance	Mark	AO
04.4	Gravitational potential from Titan = value from dashed line − value from solid line at consistent distance $= -3.2(00) \times 10^{7} - -3.135 \times 10^{7} = -6.5 \times 10^{5}$ (J kg^{-1}) ✓	ignore PoT for MP1 and MP2 Allow $-3.2(00) \times 10^{7}$ to -3.203×10^{7} Allow -3.135×10^{7} to -3.138×10^{7} Allow -6.2×10^{5} to -6.8×10^{5} **For non-standard papers:** MLP18A4 as main mark scheme MLP18A3 allow variation in read offs but answer in same range.	3	AO2
	Any **one** from: ✓ • distance from Titan = $12.22 \times 10^{8} - 12.08 \times 10^{8}$ $(= 1.4 \times 10^{7})$ • use of $V = -\frac{GM}{r}$ (including with data taken directly from either line or their distance from Titan)			
	Correct answer for their V ✓	their V due to Titan (or -7×10^{5}) $\times 2.1 \times 10^{17}$ 1.36×10^{23} (kg) from -6.5×10^{5} 1.47×10^{23} (kg) from -7×10^{5}		

Total			8

Question	Answers	Additional comments/Guidance	Mark	AO
05.1	Idea that capacitance / charge stored with dielectric is seven times greater than with vacuum / air / free space (for same geometry and pd) ✓	Allow material for dielectric. Allow $\frac{\text{permittivity of dielectric}}{\text{permittivity of free space}} = 7.0$ Allow ε or $\varepsilon_{\text{dielectric}}$ (but not ε_r) only if it is named as the permittivity of the dielectric. Allow the permittivity of the dielectric is seven times greater than the permittivity of free space/vacuum/air. Do **NOT** allow the **relative** permittivity of the dielectric is seven times greater than the permittivity of free space. Do **NOT** allow $\frac{\varepsilon_r}{\varepsilon_0} = 7.0$	1	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
05.2	Attempt at a valid method ✓ (allow minor read-off errors) 73 ± 2 (s) ✓	**Valid methods** Measuring time until $\frac{40}{\mathrm{e}} = 14.7\ \mu\mathrm{A}$ Condone 14-15 microammeter read off for MP1. Measuring one or two half-lives with $\frac{t_{0.5}}{\ln 2}$ Picking a point and substituting into $I = I_0 \mathrm{e}^{-\frac{t}{T}}$ Some working must be seen for MP1 and may be seen on graph only for a direct read off of the time constant.	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
05.3	Use of e^{-5} **or** use of $I = I_0\, e^{-\frac{5T}{T}}$ with their I_0 and T ✓ (convert to a percentage) 0.67% ✓	Condone 0.37^5 for MP1… …leading to 0.69% for MP2.	2	1 × AO1 1 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
05.4	**Award MAX 3 for ✓✓✓** The magnitude of the current generally decreases with time, together with • Starts at (−)20 μA • Half-life of 100 ± 4 s $I_0 = \pm 20\ \mu A$: check (100, ±10) $I_0 = \pm 40\ \mu A$: check (100, ±20) • Line to at least 120 s with correct shape including: decreasing gradient **throughout** does **not** have a non-zero asymptote • Negative current shown for all times	When **increasing** magnitude of current seen, **MAX 1** for either: • correct half life: shown by passing through (0,0) **AND** either $(100, \pm 10)$ or $100, \pm 20)$ • negative current shown for all times. Award MAX 2 when two curves given and one is not clearly deleted/erased.  	3	AO3

Total			8	

Question	Answers	Additional comments/Guidance	Mark	AO
06.1	$a = \frac{v^2}{r} = \frac{(74.2\times10^3)^2}{4.22\times10^8}$ **OR** 13.0 (m s^{-2}) seen ✓ $g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\times1.90\times10^{27}}{(4.22\times10^8)^2}$ **OR** 0.712 (m s^{-2}) seen ✓ (for ballistic objects $ma = mg$ so $a = g$ and) $0.71\ \text{m s}^{-2} \neq 13\ \text{m s}^{-2}$ so the suggestion is not correct ✓	POT must be correct in MP1 and MP2 If no working, correct units must be seen somewhere for MP3 Allow calculation and comparison of centripetal force and weight if consistent mass used. Condone 1SF answers. Correct answers to calculations required for MP3. **Alternative** Evidence of $T^2 = \frac{4\pi^2 r^3}{GM}$ **or** $v^2 = \frac{GM}{r}$ **or** $\omega^2 = \frac{GM}{r^3}$ ✓ Calculation of any relevant quantity or combination of quantities e.g. $v = 17.3$ km s^{-1} ✓ Comparison of a relevant quantity to conclude that suggestion is not correct ✓	3	AO3

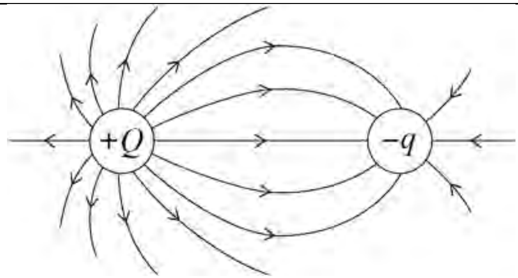
Question	Answers	Additional comments/Guidance	Mark	AO
06.2	Arrow starting at dot, pointing vertically down the page ✓	Condone a downwards vertical arrow where the line of action passes through the point. The line of action of the arrow must travel through the plasma torus near to the ion. Ignore arrows that are outside this area. When more than one arrow is drawn within the scoring area, then which arrow is B must be indicated unambiguously. Allow a line that looks vertical taking into account the 3D nature of the diagram.	1	AO2

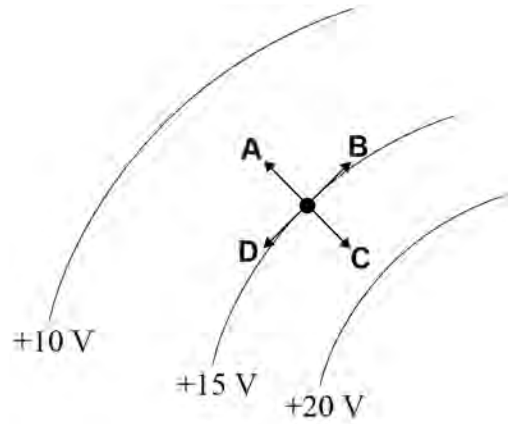
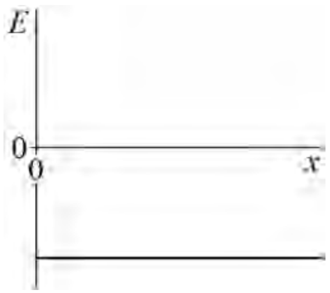
Question	Answers	Additional comments/Guidance	Mark	AO
06.3	$BQv = \frac{mv^2}{r}$ ✓ $B(= \frac{5.31\times10^{-26}\times74.2\times10^{3}}{3.2\times10^{-19}\times4.22\times10^{8}}) = 2.9\times10^{-11}$ ✓ $\text{kg A}^{-1}\text{ s}^{-2}$ ✓	Evidence for MP1 can come from substitution of candidates centripetal force as their magnetic force in second equation. Do **not** accept e for Q in MP1 when correct answer not seen. Allow ecf for use of their centripetal acceleration (expect 13.0) from question **06.1** e.g. $BQV = ma$ MP3 can be awarded with no working.	3	1 × AO1 2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
06.4	Use of $F = ma$ / $a = \frac{v^2}{r}$ **OR** use of $F = QE$ ✓ $a\left(=\frac{QE}{m}\right)=\frac{3.2\times10^{-19}\times371\times10^{-6}}{5.31\times10^{-26}}$ ✓ 2.24×10^3 (m s^{-2}) ✓	Ignore PoT in MP1 and MP2 Condone in MP1 **and** MP2 the use of **one** of either • e for 3.2×10^{-19} C or • m_e / m_p for mass Allow use of $F = QE$ **and** $F = ma$ with same F	3	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
06.5	Any **two** from: ✓✓ • Correct charges for both ions • Use of $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ for either charge • use of Pythagoras with their E values **or** $E_T = \sqrt{E_Y^2 + 4E_Y^2}$ 8.0 or 8.1×10^{-6} (V m^{-1}) ✓	Do **not** condone POT error in MP1. $2 \times 1.60 \times 10^{-19} (= 3.2 \times 10^{-19})$ (C) **and** 1.60×10^{-19} (C) $E_X = 7.2 \times 10^{-6}$ V m^{-1} $E_Y = 3.6 \times 10^{-6}$ V m^{-1} Condone use of $+1$ or $+2$ for Q in bullet 2 Correct values seen for E_X and E_Y gains bullets 1 and 2 Allow appropriate trigonometry with 63° or 27° for bullet 3. Do **not** allow use of Pythagoras with distances.	3	AO2

Total			**13**

Question	Key	Answer	AO
7	B	$\frac{\sqrt{2}}{3}v$	AO2
8	C	$16\ \text{cm}^3$	AO2
9	C	is constant as the pressure increases.	AO2
10	B	$\theta_1 - p_1\left(\frac{\theta_2 - \theta_1}{p_2 - p_1}\right)$	AO2
11	B		AO2
12	A	$4F$	AO2
13	A	qV	AO1

14	C		AO1
15	D		AO2
16	D		AO1
17	C	600 μF	AO2
18	C	233 Ω	AO2

19	B	**R** | **Q**	AO2
20	D	$4I$	AO2
21	A	0	AO2
22	D	6.25 μV	AO2
23	A	80%	AO2
24	A	34 kHz	AO2
25	D	64 cm	AO2
26	C	0.103 MeV	AO2
27	D	${}^{123}_{53}\mathrm{I} + \mathrm{e}^{-} \rightarrow {}^{123}_{52}\mathrm{Te} + \nu_{\mathrm{e}}$	AO1
28	C	4.7 MeV	AO2
29	A	to absorb neutrons released from fission	AO1
30	D	slow neutrons to thermal speeds.	AO1
31	D	**R** only	AO1

Total: 25 marks