# A-level
# PHYSICS
# 7408/2

Paper 2

**Mark scheme**

June 2023

Version: 1.0 Final

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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.

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

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# 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.

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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' –



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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.

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| 01.1 | total kinetic energy of the particles ✓ | Condone "molecules" or "atoms" for "particles"<br>Kinetic energy will be taken to mean total kinetic energy but do not accept use of mean kinetic energy or reference to kinetic energy of a single particle.<br>Do not allow any reference that implies there is potential energy or any other energy added to the kinetic energy. | 1 | AO1 |

| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| 01.2 | (the speed before and after a collision is the same in the elastic collision)<br>$\Delta p\ (= p_f - p_i) = -mc - mc = -2mc$ ✓ | Use of subscripts i and f or before and after do not need explanation.<br>$\Delta$ will be assumed to mean (final – initial).<br>Either the initial momentum or the final momentum must be described clearly enough to justify the negative final answer | 1 | AO1 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **01.3** | Time between colliding with **W** $(=\frac{s}{c}) = \frac{2l}{c}$<br><br>$f = \frac{1}{T}\left(=\frac{c}{2l}\right)$ ✓ | Must show evidence of a time calculation using distance and speed<br><br>Do not allow any attempted use of $v = f\lambda$ | 1 | AO1 |

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **01.4** | Reference to a Newton law **AND** $P = \frac{F}{A}$ ✓1<br><br>$P\left(= \frac{F}{A} = \frac{mc^2}{l} \times \frac{1}{l^2}\right) = \frac{mc^2}{V}$ ✓2 | The reference to Newton law could be a simple link between Newton's name and an equation. | 2 | AO1 ×2 |

| Total | | | 5 |
|---|---|---|---|

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **02.1** | Attempt to calculate either volume using correct equation ✓1 | ✓1<br>Condone POT.<br>$\frac{\pi h d^2}{4} = \frac{\pi \times 370 \times 10^{-3} \times \left(660 \times 10^{-3}\right)^2}{4} = \left(0.1265\ \text{m}^3\right)$<br>OR<br>$\frac{\pi h d^2}{4} = \frac{\pi \times 370 \times 10^{-3} \times \left(330 \times 10^{-3}\right)^2}{4} = \left(0.0316\ \text{m}^3\right)$ | 5 | AO1 ×2<br>AO2 ×3 |
| | Subtracts their two volumes ✓2 | ✓2 $V = 0.1265 - 0.0316 = 0.0949\ (\text{m}^3)$<br>Correct answer will be given ✓1 ✓2 | | |
| | $n$ = 3.09 **OR** 6.46 **OR** attempt to find one $n$ using $\frac{pV}{RT}$ with correct temperature ✓3 | ✓3 Correct answer will be given ✓1 ✓2<br>$\frac{pV}{RT} = \frac{1.01\times10^5 \times 0.0949}{8.31\times(100+273)} = (3.09)$ or<br>$\frac{pV}{RT} = \frac{2.11\times10^5 \times 0.0949}{8.31\times(100+273)} = (6.46)$ | | |
| | Calculates $\Delta n$ = 3.37 (mol)<br>**OR**<br>Determines both values of $n$ with correct $T$ and $p$ **AND** calculates their $\Delta n$ ✓4 | ✓4 $\Delta n = 6.46 - 3.09 = 3.37$ (mol)<br>Correct answer will be given ✓3 ✓4 | | |
| | Molar mass = 0.028 ($\text{kg mol}^{-1}$) ✓5 | ✓5 molar mass = $\frac{14.991 - 14.897}{3.37} = \frac{0.094}{3.37}$<br>= 0.028 ($\text{kg mol}^{-1}$) | | |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **02.2** | (Carrying out the check) at a higher temperature increases the pressure in the tyre. ✓1<br><br>(Thus) the tyre could pass the check with a smaller amount of gas in the tyre.<br>**OR**<br>(When the tyre is hot) you can achieve the same pressure but with less gas. ✓2 | ✓1 For linking pressure to temperature.<br>Condone comments suggesting $p \propto T$<br><br>✓2 For linking less gas/smaller $n$ to a passing check. **OR** For a comparison between the amount of gas in the tyre that produces a certain pressure when the tyre is hot and cold | 2 | AO2 ×2 |

| Total | | | 7 |
|---|---|---|---|



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **03.1** | Any **one** from: ✓1<br>• region in which a mass experiences force due to another mass<br>• (the field is conservative so) any change in potential energy only depends on the initial and final positions and not on path taken OWTTE<br>• the force is always attractive **OR** field lines point to the (centre of) mass **OR** the equipotential surfaces are spherical about the (centre of ) mass<br>• gravitational force is a non-contact force<br><br>The field strength/force has an inverse-square variation (with distance). ✓2 | ✓1 is a general point about gravitational fields<br><br>✓2 is specific to a radial gravitational field<br><br>The 'force is attractive' is insufficient<br><br>When required the term "force" must be used rather than words like "effect", "gravity" etc.<br><br>When required the word 'mass' must be used rather than object or similar.terms<br><br>Condone reference to "circular" for "spherical" in describing an equipotential surface | 2 | AO1 ×2 |

| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **03.2** | The shaded area corresponds to:<br>the (minimum) energy needed/work done to launch the space probe to a height of $8 \times 10^6$ m<br><br>**OR**<br><br>the change in GPE of the probe when moved from Earth's surface to a height of $8 \times 10^6$ m ✓ | | 1 | AO2 |

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **03.3** | Evaluates the gravitational field strength due to the Sun = $5.90 \times 10^{-3}$ (N kg$^{-1}$)<br>OR shows substitution into a valid equation ✓1<br><br>Evaluates $\frac{g_S}{g_E}$( = $\frac{5.90 \times 10^{-3}}{9.81}$ = ) $6.0 \times 10^{-4}$ or 0.060% ✓2 | ✓1 $g_S = \frac{GM_S}{r^2} = \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{(1.50 \times 10^{11})^2}$<br>✓1 ALTERNATIVE<br>The Universal gravitational equation for both bodies may be used:<br>$\frac{g_{Sun}}{g_{Earth}} = \frac{M_{Sun}}{M_{Earth}} \times \left(\frac{r_{Earth}}{r_{Sun}}\right)^2$<br><br>✓2 Answer needed to at least 2 sf. If 3+ sf are seen, the answer must round to (6.01 or 6.02)$\times 10^{-4}$. | 2 | AO2 ×2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **03.4** | The force from Earth because of its smaller mass, is less than the force from the Sun at a similar distance.<br><br>**OR**<br><br>The total work done in moving a long way from the Sun is much greater than that in moving a long way from the Earth because $m_E \ll m_S$. | Condone reference to "edge of Solar System" as "a similar distance". | 1 | AO2 |

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **03.5** | change in kinetic energy or kinetic energy per unit mass formulated ✓1 allow 2 sf | ✓1 $\frac{1}{2}m\left(v^2{}_B - v^2{}_A\right)$ **OR** $1.18 \times 10^{10}$ (J) **OR** $\frac{\Delta E_k}{m} = \frac{1}{2}\left(v^2{}_B - v^2{}_A\right)$ **OR** $m \times 2.40 \times 10^5$ J | 4 | AO1<br>AO1<br>AO2<br>×2 |
| | change in gravitational potential energy / potential formulated ✓2 | ✓2 $\Delta E_p = GMm\left(\frac{1}{1.7\times10^5} - \frac{1}{6.0\times10^6}\right)$<br>= $GMm \times 5.72 \times 10^{-6}$<br>OR $\frac{\Delta E_p}{m} = GM\left(\frac{1}{1.7\times10^5} - \frac{1}{6.0\times10^6}\right)$ | | |
| | evidence of intention to equate their $\Delta E_k$ and $\Delta E_p$ (even if not carried through; allow ecf) ✓3 | Loss and gain may be replaced with change or Δ's for this mark.<br>✓3 $\frac{1}{2}\left(v^2{}_B - v^2{}_A\right) = \frac{-GM}{r_A} - \frac{-GM}{r_B}$ and substitution of data into working equation.<br>This can be seen anywhere in the solution. | | |
| | mass of **X** = $6.3 \times 10^{20}$ kg ✓4 | | | |

| Total | | | 10 |
|---|---|---|---|



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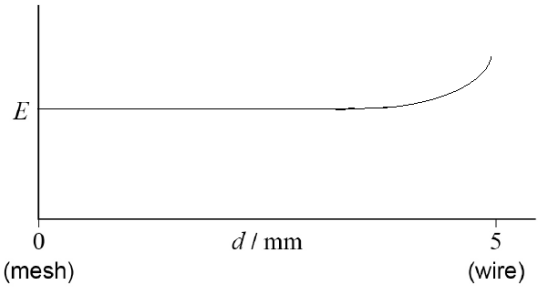
| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **04.1** | Horizontal line above zero for > half the distance ✓<br><br>(then) curves upwards ✓ |  <br><br>Marks are independent. | 2 | AO2<br>×2 |

| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **04.2** | statement that (kinetic) energy is the same<br><br>**OR**<br><br>correct substitution of data into equation/ratio ✓<br><br>ratio $\left(=\sqrt{\frac{6.64\times10^{-26}}{9.11\times10^{-31}}}\right)=270$ ✓ | Some factors (e.g. ½) that cancel may be absent. | 2 | AO3<br>×2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **04.3** | Due to collisions argon loses more energy / speed / momentum (than electron)<br>**OR**<br>Electron is less ionising (than argon) /<br>Argon is more ionising (than electron)<br><br>so ratio is larger. ✓ | Mark is for the explanation<br>Do not allow explanations that suggests the particles have different distances to travel.<br>Do not allow references to air resistance.<br>Accept idea that "argon has higher probability of collision (than electron)"<br>Accept reverse arguments | 1 | AO3 |

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| 04.4 | Evidence of suitable test for student A suggestion involving 2+ data points ✓1<br><br>Evidence of suitable test for student B suggestion involving 2+ sets of data ✓2<br><br>Both tests performed **AND** rejects both suggestions ✓3 | ✓1 test inverse square:<br>e.g. $Nh^2 =$ constant<br><br>✓2 test exponential:<br>e.g. $N$ should decrease by half in equal intervals of $h$<br>**OR** test $N = k\,e^{-h}$ : show that $N\,e^{h}$ is not constant<br><br>Accept $\log/\ln$ interpretations of the test.<br><br>✓3<br><br>Expect to see for student A $10 \times 1.0^2 = 10$ and $4 \times 1.34^2 = 7.18$ or similar<br><br>Expect to see for student B $N = 10$ to $N = 5$ changes $h$ by $0.25$ and $N = 5$ to $N = 2.5$ changes $h$ by $0.31$ or similar<br><br>reject both students' suggestions with reasons eg $Nh^2$ is not constant and $N$ does not fall by the same fraction in equal intervals of $h$<br><br>Allow answer accepting B if a reference to experimental error is made and the difference is small. | 3 | AO3 ×3 |
| **Total** | | | **8** | |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **05.1** | $V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$ with substitution attempted with $V_0$ being larger than $V$ ✓1<br><br>Time to charge to 4.0 V = $t_2 = -R_1 C \ln\left(1 - \frac{4}{6}\right)$<br><br>**OR**<br><br>Time to charge to 2.0 V = $t_1 = -R_1 C \ln\left(1 - \frac{2}{6}\right)$ ✓2<br><br>$t = t_2 - t_1 = -R_1 C \ln\left(\frac{1}{3}\right) - \left\{-R_1 C \ln\left(\frac{2}{3}\right)\right\}$<br><br>$\left(= -R_1 C\left(\ln\frac{1}{3} - \ln\frac{2}{3}\right) = -R_1 C \ln\left(\frac{\frac{1}{3}}{\frac{2}{3}}\right)\right) = -R_1 C \ln\left(\frac{1}{2}\right) = 0.69 R_1 C$<br><br>**OR**<br><br>$= R_1 C(1.10 - 0.41) = 0.69 R_1 C$ ✓3 | NB The answer can be obtained incorrectly by finding the time to charge to 2V using a 4V supply. This approach may only gain the first mark for an attempted use of the equation.<br><br>Award 0 for a solution using the discharge equation.<br><br>Condone $R$ for $R_1$<br><br>✓2 If given in an equation then then time must be the subject or be in a form that is used to obtain mp3<br><br>can be awarded for $t_2 = 1.10 \times R_1 C$ **OR** $t_1 = 0.41 \times R_1 C$<br><br>✓3 Must see $0.69\, R_1 C$ for 3 marks.<br><br>Only award MP3 for $0.69 R_1 C$ if the solution involves a time difference. | 3 | AO1<br>AO2<br>×2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **05.2** | Attempt to find usable data from **Figure 9** ✓1<br>Determine scaling factor **OR** Determine $R_1$ ✓2<br>Calculate $Q$ the charge stored at 4 V or the charging time constant **from a valid method** ✓3<br>Determine $C$ to a value that rounds to $1 \times 10^{-4}$ (F) to 2 or more sf (expect to see $1.0 \times 10^{-4}$ F) ✓4<br><br>**Method 1 (from area)**<br>✓1a Attempt at finding area under *I*–*t* graph by counting boxes<br>✓2a $1\ \text{cm}^2$ box corresponds to charge $0.5 \times 10^{-5}$ C<br>✓3a Number of $1\ \text{cm}^2$ boxes = 80 (78 to 80)<br>$Q = (80 \times 0.5 \times 10^{-5}) = (3.9 \text{ to } 4.1) \times 10^{-4}$ (C)<br>✓4a $C = \frac{\text{their } Q}{4}$ = a value that rounds to $1 \times 10^{-4}$ (F) (≥ 2 sf required)<br>Award **MAX 1** for estimating the average current by sight and using $C = \frac{IT}{V}$. | **Method 2 (from individual data points)**<br>Possible methods are shown but only final answers requested are needed to gain marks.<br>✓1b Use of a current and voltage across the resistor, e.g. $I = 2.0 \times 10^{-5}$ A and voltage across resistor = 2 V (when capacitor has 4 V)<br>**OR**<br>$I = 6.0 \times 10^{-5}$ A and voltage across resistor = 6 V (when capacitor has 0 V)<br>✓2b $R_1 = \frac{V}{I} = \frac{2.0}{2.0 \times 10^{-5}}$<br>**OR** $\left(\frac{V}{I} = \frac{6}{6 \times 10^{-5}}\right) = 1.0 \times 10^5$ (Ω)<br>✓3b Charging time constant = $R_1C$<br>Eg using $I = I_0 e^{\frac{-t}{R_1 C}}$ then $R_1C = \frac{t}{\ln\left(\frac{I_0}{I}\right)}$<br>Substituting $I = 2 \times 10^{-5}$ A and<br>$I_0 = 6 \times 10^{-5}$ A and $t = 11$ s.<br>OR<br>Graphical method must include evidence from Figure 9<br>charging time constant $(R_1C) = 10.(0)$ (s)<br>✓4b $C = \frac{\text{time constant}}{R_1} = \frac{10.0}{1.0 \times 10^5}$<br>= a value that rounds to $1 \times 10^{-4}$ (F) (≥ 2 sf required) | 4 | AO2 ×3<br>AO3 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **05.3** | Reading of relevant discharge data from **Figure 10** provided there is an attempt to use data ✓1<br><br>A valid substitution of their data into a relevant equation to find $R_1$ or $R_{\text{Total}}$ ✓2<br><br>$R_2 = R_{\text{Total}} - \text{their } R_1 = 2.0 \times 10^5\ \Omega$ ✓3<br>allow **one** ecf from either their $R_{\text{Total}}$ **or** their $R_1$<br>When $R_1$ is derived in an earlier question accept this value of $R_1$ and allow ecf for $R_{\text{total}}$<br>When $R_1$ is derived in this question, allow one ecf from either their $R_{\text{total}}$ or their $R_1$ | ✓1 From **Figure 10** this can be the time taken for the voltage to fall to half its value.<br><br>✓2 Finding $R_{\text{Total}}$ from **Figure 10**<br>4.0 V to 2.0 V in $(32 - 11)$ s using<br>$t_{\frac{1}{2}} = 0.69RC$ allow $= 0.7RC$<br>$R_{\text{Total}} = 3.0 \times 10^5\ \Omega$<br><br>Finding $R_1$ from **Figure 9**<br>6.0 A to 3.0 A in 6.8 s using<br>$t_{\frac{1}{2}} = 0.69RC$ allow $= 0.7RC$<br>$R_1 = 1.0 \times 10^5\ \Omega$<br>**OR**<br>Using<br>$I = I_o e^{\frac{-t}{R_1 C}}$<br>for example, with $I = 2 \times 10^{-5}$ A and<br>$I_o = 6 \times 10^{-5}$ A and $t = 11$ s<br><br>Note $R_1$ may be taken from **05.2** and not use the graph information. | 3 | AO3 ×3 |

| Total | | | 10 |
|---|---|---|---|



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **06.1** | Any **two** from: ✓✓<br>• using electrons gives greater resolution (as the wavelength can be made very small)<br>• electrons can get closer to the nuclei (as there is no electrostatic repulsion)<br>• electrons have less recoil (as their mass is small compared to the nucleus)<br>• free electrons are easier to accelerate **OR** give energy to (as charge-to-mass ratio is higher)<br>• electrons are easier to produce<br>• scattering distributions are easier to interpret **OR** strong nuclear interaction is not involved<br>• using alpha particles only gives the distance of closest approach/upper limit to the radius. | OWTTE on each advantage<br>Allow reverse arguments | 2 | AO1<br>AO2 |



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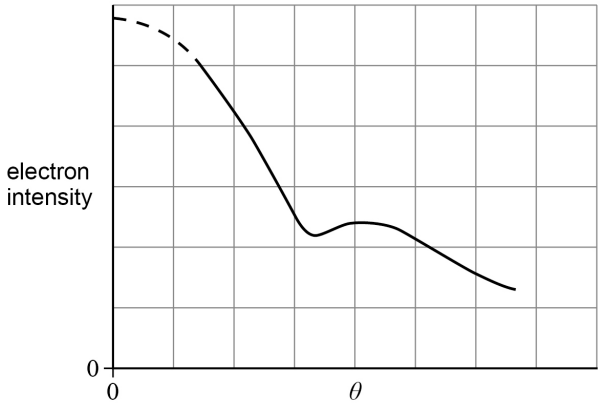
| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **06.2** | A curved line showing an decrease in intensity with increase in θ.✓<br><br>There is a single **non-zero** minimum. ✓ | Do not allow U-shaped graphs.<br>The initial part of the curve may be absent.<br><br>Award MAX 1 for a line that covers less than half the θ axis.<br><br>  <br> | 2 | AO1 ×2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **06.3** | Density (= mass÷volume) = $\frac{Am_{\text{nucleon}}}{\frac{4}{3}\pi R^3}$ ✓1<br>(substituting density = $\frac{Am_{\text{nucleon}}}{\frac{4}{3}\pi\left(R_0 A^{\frac{1}{3}}\right)^3}$ )<br>Density = $\frac{3m_{\text{nucleon}}}{4\pi(R_0)^3}$ (in which) all (terms are) constant **OR** the expression does not depend on *A* ✓2 | ✓1 Do not accept *M* unlabelled.<br>Accept *m* (ie lowercase) unlabelled.<br>Condone $m_{\text{n}}$ (mass of neutron in Data sheet) for $m_{\text{nucleon}}$.<br>Accept only $1.67 \times 10^{-27}$ (kg) for mass of nucleon (ie to 3 sf).<br>Allow ecf to MP2 for any misrepresentation of *m* provided it is clear that it signifies mass of a single nucleon.<br>✓2 If the constants are identified the equation may be converted into a ratio. The equation may be rearranged to have $R_0$ as the subject with work to show that this is a constant *when the density is constant*. | 2 | AO1<br>AO2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **06.4** | Any **one** of: ✓<br><br>The mass of the nucleus is not exactly $A \times m_{\text{nucleon}}$ (because this ignores the binding energy)<br><br>**OR**<br><br>The volume equation assumes that the nucleus is a perfect sphere (which is not true) OWTTE<br><br>**OR**<br><br>The density equation that uses the nuclear radius formula implies that the density is uniform within a nucleus which is not true. OWTTE<br><br>**OR**<br><br>Protons have a slightly different mass to a neutron | Do not accept "density of individual nucleons can be different from each other". It is not allowed as it does not occur in the working equation. | 1 | AO3 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| 06.5 | $R_0 = \left( \frac{R}{A^{\frac{1}{3}}} = \frac{4.02\times10^{-15}}{(35)^{\frac{1}{3}}} \right) = 1.2(3)\times10^{-15}\,(\text{m})$ ✓1<br><br>Substitutes values into density equation ✓2<br><br>Density = $2.1 \times 10^{17}\,(\text{kg m}^{-3})$ ✓3 | ✓2 e.g. Density=$\left( \frac{\text{mass}}{\text{volume}} = \frac{Am}{\frac{4}{3}\pi R^3} \right) = \frac{35 \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi\left(4.02 \times 10^{-15}\right)^3}$<br><br>✓3 Evidence of a calculation must be given to gain this mark<br><br>Accept 2.15 but not 2.2 | 3 | AO2 ×3 |
| **Total** | | | **10** | |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **07.1** | Heavy water<br>**OR**<br>Beryllium / Be<br>**OR**<br>(normal) Water ✓ | Accept $D_2O$ and $H_2O$ | 1 | AO1 |

| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **07.2** | Any **two** points from: ✓✓<br>• U-235/Uranium fuel will (be more likely to) absorb the neutron<br>• slow neutrons are less damaging **OR** cause less fatigue to the structure of the reactor/shielding/etc<br>• slow neutrons (spend longer within the fissionable material and) increase the chance of causing fission<br>• slowing neutrons transfers heat energy to the moderator (which can make heat easier to extract)<br>all points OWTTE | Condone the answer:<br>As an alternative to the first point<br>Fission of U-236 is much more likely.<br><br>Condone the answer:<br>Absorption by U-238 is less likely. | 2 | AO1<br>AO2 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| 07.3 | $\frac{\text{final kinetic energy}}{\text{initial kinetic energy}} = \left(\frac{\frac{1}{2}m_N v^2}{\frac{1}{2}m_N u^2}\right) = \left(\frac{v}{u}\right)^2 = 0.85^2 = 72\%$ ✓1<br><br>(Hence) proportion of kinetic energy lost = 28% ✓2 | ✓1 can be for any of the terms shown equating to the kinetic energy ratio.<br><br>✓2 can be an ecf but only for an arithmetic error. | 2 | AO2<br>AO3 |

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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **07.4** | final kinetic energy = $(\frac{3}{2}kT =) 7.2 \times 10^{-21}$ (J) ✓1<br>initial kinetic energy = $(W = QV) = 1.6 \times 10^{-13}$ (J) ✓2<br>**OR**<br>final kinetic energy = $0.045$ (eV) ✓1<br>initial kinetic energy = $1.0 \times 10^{6}$ (eV) ✓2<br>(Rearranging equation $y = \frac{\ln\left(\frac{E_0}{E_f}\right)}{b}$)<br>$y = 23.(2)$ ✓3 | ✓1+2 Both marks must come from the same alternative route and have consistent units (which may not be seen).<br>✓1 Initial kinetic energy =<br>$\frac{3}{2} \times 1.38 \times 10^{-23} \times 350 = 7.245 \times 10^{-21}$ J<br>$= \frac{7.245 \times 10^{-21}}{1.60 \times 10^{-13}} = 0.045$ eV<br>✓2 Using the eV unit alternative the second mark cannot be given without an attempt at the first mark.<br>The $1.0 \times 10^{6}$ eV can be seen in a later substitution provided eV is used throughout.<br>✓3 $y = \frac{\ln\left(\frac{1.0 \times 10^{6}}{0.045}\right)}{0.73} = 23.2$<br>Condone answer 24 provided it is given as an integer. | 3 | AO2 ×3 |



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| Question | Answers | Additional comments/Guidelines | Mark | AO |
|---|---|---|---|---|
| **07.5** | Idea that the model/**Figure 15** shows that low nucleon number (and so low mass) gives a greater change/reduction in speed/KE (in a collision) ✓<br><br>Idea that fewer collisions needed (with a low mass number so moderator can be thinner) ✓ | Condone the use of nuclear mass instead of mass number. | 2 | AO2 ×2 |
| **Total** | | | **10** | |

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| Question | Key | Answer |
|---|---|---|
| **8** | C | $60\ \text{kg}$ |
| **9** | C | Charles's Law |
| **10** | C | $10^{36}$ |
| **11** | B | $\left(\frac{M}{R}\right)^{\frac{1}{2}}$ |
| **12** | B | $\sqrt{\frac{GM}{(R+h)}}$ |
| **13** | D | Signals from the satellite can be sent to at any point on the Earth's surface during one orbit. |
| **14** | C | $\frac{2Q}{\pi\varepsilon_0 d^2}$ |
| **15** | A | $20\ \mu\text{N}$ |
| **16** | A | vertically down the plane. |
| **17** | C | the electric potential of the sphere. |

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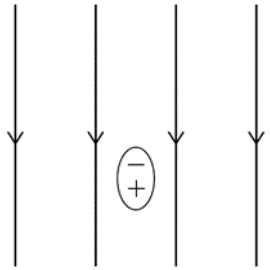
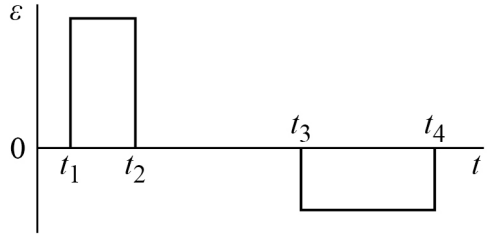
| | | |
|---|---|---|
| **18** | A |  |
| **19** | C | $4.0 \times 10^{-14}$ m |
| **20** | B | $6.0 \times 10^{-3}$ T |
| **21** | B | The radius of the path followed by an ion is different for each isotope. |
| **22** | A |  |
| **23** | D | 600 μV |
| **24** | D | 395 V |
| **25** | D | gamma radiation from nuclides with a small decay constant. |
| **26** | C | The number of alpha particles deflected backwards is greater than the number that pass straight through the foil. |
| **27** | C | 0.174 A |

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| | | |
|---|---|---|
| **28** | A | when a particular nucleus will decay. |
| **29** | B | $\beta^-$ |
| **30** | C | 16 MBq |
| **31** | B | $1.0 \times 10^8$ W |
| **32** | D | $6.1 \times 10^8$ |

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