A-level
PHYSICS
7408/3A

Paper 3 Section A

Mark scheme

June 2024

Version: 1.0 Final

246A7408/3A/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

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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.

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 <u>not</u> 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. i.e. 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/Guidelines	Mark	AO
01.1	(±) 0.5(0) mm CAO ✓		1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	6.72 mm ✓	tick in second box	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	use of ratchet with valid justification OR use of thimble **and then** the ratchet with valid justification ✓	allowable ideas should focus on the possible consequences of **not** using the ratchet: can cause the object being measured to be distorted / squeezed / crushed / subject to excessive force or WTTE; can change the diameter / shape of the object; may lead to the reading shown being **smaller** than true value; damage might occur (to the mechanism); the frame (of the micrometer) might become warped; condone 'will over-tighten (micrometer)'; condone 'thimble used to close gap / clamp wire' then use ratchet to tighten or WTTE + justification treat following as neutral: 'use the thimble then the ratchet to save time' / 'to get accurate reading' 'use ratchet to make sure wire is secure' 'using thimble (or **not** using ratchet) might change the reading' / 'affect results' / 'might cause a zero error' / 'cause a reading below zero' / 'could lead to systematic error'	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	use of $I = \frac{(0.)931}{1.2}$ OR $R = \frac{(0.)397}{\text{their } I}$ $_1$✓	for $_1$✓ allow I > 2 sf rounding to 0.78 (A) OR $\frac{(0.)397}{(0.)776}$ OR $\frac{(0.)397}{(0.)78}$ in working OR $R = \frac{(0.)397 \times 1.2}{(0.)931}$ with any subject OR use of a valid potential divider approach eg $\frac{1.2}{1.2+R} = \frac{0.931}{0.397+0.931}$	2	AO2
	$R = 0.51$ (Ω) $_2$✓	for $_2$✓ condone 0.512 OR 0.5117 (Ω)		

Question	Answers	Additional comments/Guidelines	Mark	AO
01.5	continuous <u>ruled</u> best-fit line drawn $_1$✓	for $_1$✓ line **must not** pass above centre of 2nd point AND below centre of 4th point; reject hairy, thick or dashed lines if withholding mark examiner must add comment to clip	2	AO2
	gradient evaluated from ΔR divided by ΔL; with correct $\Delta R \geq 0.2\ (\Omega)$ OR correct $\Delta L \geq 150\ (\text{mm})$ $_2$✓	$_2$✓ is for the process if using points these must lie on their line; do not penalise for AE / POT in result; expect gradient about $1.66\ (\Omega\ \text{m}^{-1})$ withhold both marks for no line on **Figure 5**		

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>01.6</td>
<td>attempts to find ρ_X using $\frac{\pi d^2}{4} \times \frac{\Delta R}{\Delta L}$ $_1$✓

ρ_X in range below for their metal on the answer line $_2$✓
<table>
<tr><th>metal</th><th>resistivity / Ω m</th></tr>
<tr><td>copper</td><td>1.6 to 1.8 ($\times 10^{-8}$)</td></tr>
<tr><td>tungsten</td><td>5.4 to 5.9 ($\times 10^{-8}$)</td></tr>
<tr><td>alumel</td><td>3.3 to 3.8 ($\times 10^{-7}$)</td></tr>
<tr><td>nichrome</td><td>1.0 to 1.2 ($\times 10^{-6}$)</td></tr>
</table>
POT correct and unit = Ω m for their metal on the answer line $_3$✓

nichrome CAO $_4$✓</td>
<td>for $_1$✓ expect use of their $\frac{\Delta R}{\Delta L}$ OR the closest value in Table 1;
allow use of concordant $\frac{\Delta R}{\Delta L}$ and d values for the metal that is the valid choice for their $\frac{\Delta R}{\Delta L}$;
d must be correct for their $\frac{\Delta R}{\Delta L}$;
if value not seen in working, judge d from their ρ_X;
for no 01.5 result condone the substitution of concordant R and L values for a point on Figure 5
don't penalise for AE or POT

for $_2$✓ ignore POT and use the most significant digits in their ρ_X to judge result, eg for alumel $\rho_X = 0.351$ scores $_2$✓$_3$× because this is equivalent to 3.51×10^{-1}
allow >2 sf values that round to 2 sf in range

for $_3$✓ allow alternative valid answer eg (for nichrome) 1.1×10^{-3} Ω mm

for $_4$✓ must be consistent with their 01.5 $\frac{\Delta R}{\Delta L}$</td>
<td>4</td>
<td>1 × AO3

3 × AO2</td>
</tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark	AO
01.7	the **error bars** for L / the horizontal error bars are the same length or WTTE $_1$✓	for $_1$✓ allow' they are $10\ \text{mm}$' / the width is same'; any quantitative detail eg limiting values / percentage uncertainty about the horizontal error bars is neutral condone 'bars are same' / 'have same range' 'bars are constant' is neutral	2	AO3
	quantitative comment about the **error bars** for R / the vertical error bars $_2$✓	for $_2$✓ expect (about) $\pm\ 0.02$ / (height) 0.04 (Ω) AND fifth (about) $\pm\ 0.04$ / (height) 0.08 (Ω); allow suitable limiting values of the error bars eg $(0.)329 - (0.)371$ AND $(0.)614 - (0.)692$; allow 'fifth is (about) twice the length of first' detail in an annotated sketch can earn $_1$✓ and $_2$✓ 'bars aligned with respective axes' / 'bars are equidistant above / below data point' are neutral		

Question	Answers	Additional comments/Guidelines	Mark	AO
01.8	idea that **any two** of maximum gradient, minimum gradient or mean gradient are determined using **lines** that pass through (all) the error bars $_1$✓	for $_1$✓ allow 'measure / find gradient' / 'gradient can be found'; insist on idea of a line but don't insist on 'draw / construct'; allow mean = 'best', maximum = 'steepest' etc, maximum OR minimum = 'worst'; 'using the error bars' / 'draw line from top of first bar to bottom of last bar' etc are neutral	2	AO1
	explains how to determine uncertainty in gradient $_2$✓	for $_2$✓ allow word equation or any of the following $(m - m_2)$ OR $(m_1 - m)$ OR $\frac{(m_1 - m_2)}{2}$ where m = mean gradient m_1 = maximum gradient, m_2 = minimum gradient allow 'G' for gradient allow 'best gradient – worst gradient' or vice-versa etc condone valid expressions for fractional uncertainty or for percentage uncertainty		

Total			15

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	(**C** because the ohm-meter) reading is 2 dp OR explains where the decimal point is ✓	must refer to the decimal places displayed or the position of the decimal point: allow 'displays 2 figures before decimal point' / 'displays 2 figures after decimal point' / decimal point between 2nd and 3rd digit / 'in format XX.XX' or WTTE; condone 'resolution (shown) **is** 0.01' / 'decimal point is after the second digit' / 'decimal point is in the middle' / reject 'because of where the decimal point is' / / 'decimal point is in the same place' / 'decimal places are the same' / 'reading is between maximum and minimum for the range on C setting' / 'readings have same resolution' / 'reading is 3 sf'	1	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	valid attempt to determine E_V using $R = 2840$ $_1$✓ $E_V = 132$ (lx) $_2$✓	> 3 sf that rounds to 132 get both marks for $_1$✓ expect $3.45(3)$ in a calculation; allow $_{12}$✓ = 1 MAX for use of 2.84 leading to 1.01×10^6 (lx) OR allow use of $\ln(2840)$ leading to 2.46×10^{-2} (lx)	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	reads off from at least **three** different points on the line / graph $_1$✓	for $_1$✓ allow 'get' / 'obtain'; must specify 3 or more; condone 'several' / 'many' / 'numerous' / 'quite a lot' / 'quite a few'; 'multiple' is neutral	2	AO1
	suggests a valid test of **Figure 7** that confirms the inverse square law $_2$✓	for $_2$✓ eg calculates $E_V \times x^2$ for each point; shows that '(percentage) differences (between results) are 'small' / 'insignificant' OR shows that values are 'close' / 'same' / 'similar' / 'consistent' condone values should be 'close' / 'see if values are / should be constant' / 'agree' etc allow a reverse-working approach		
	OR proposes a valid graph (using data from **Figure 7**) $_1$✓ a valid test to confirm the inverse square law based on their graph $_2$✓	OR **plot** of log E_V against log x $_1$✓ gradient is ≈ -2 $_2$✓ OR **plot** of E_V against $\frac{1}{x^2}$ $_1$✓ linear graph through (0, 0) $_2$✓		

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	result in range $627(.0)$ to $646(.0)$ mm $_1$✓ result in range $634(.0)$ to $639(.0)$ mm $_2$✓	use result on answer line for $_1$✓ accept 630 and 640 but not 6.3×10^2 OR 6.4×10^2	2	AO2

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>02.5</td><td>1645 AND 1.73 correctly added to Table 3 $_1$✓

valid reasoned judgement to support use of range;
allow ECF for incorrect values in Table 3 $_2$✓</td><td>for $_1$✓ do not insist on units;
condone extra sf that round to these values
<table><tr><th>Setting</th><th>Min R</th><th>Max R</th></tr><tr><td>range B</td><td>1645 (Ω)</td><td>1717 Ω</td></tr><tr><td>range C</td><td>1.63 kΩ</td><td>1.73 (kΩ)</td></tr></table>for $_2$✓ states that B should be used because
(half) range is smaller / (percentage) difference between max and min R is smaller
OR
any valid and correct quantitative comparison between both settings, eg
<table><tr><th></th><th>Range (/ Ω)</th><th>Uncert. (/ Ω)</th><th>% Diff.</th><th>% Uncert.</th></tr><tr><td>B</td><td>72</td><td>(±)36</td><td>≈ 4%</td><td>≈ 2%</td></tr><tr><td>C</td><td>100</td><td>(±)50</td><td>≈ 6%</td><td>≈ 3%</td></tr></table>allow ‘resolution is smaller’ not ‘better’;
‘more precise’ / ‘more accurate’ / ‘(percentage) uncertainty is smaller’ are neutral</td><td>2</td><td>AO3</td></tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark	AO
02.6	ANY 2 OF $_1$✓ to $_3$✓ below:		2	1 × AO1
	light level / brightness / intensity in the room OR WTTE $_1$✓	for $_1$✓ allow 'background lighting' / 'external light sources' / 'maintain blackout'; 'temperature' is neutral		1 × AO3
	voltage (across) / current in / power of / brightness of the lamp $_2$✓	for $_2$✓ allow 'intensity of (light from) the lamp' / 'luminosity of lamp' / 'pd of power supply'; allow $_{12}$✓ for light incident on slides $= 400$ (lx) do not allow unqualified 'light intensity'		
	thickness of the **glass** / slides $_3$✓	for $_3$✓ allow 'transparency / opacity / colour of the glass / slides'; condone 'surface of slides must be clean'		
		the following are neutral: μ / refractive index / density / 'type' of glass 'type' / 'size' / 'width' / 'area' / 'shape of slide' (vertical) distance between the lamp and the LDR' / 'ohm-meter setting' type of power supply / lamp / LDR / ohm-meter / connecting wires / shape of bulb positions of equipment		

Question	Answers	Additional comments/Guidelines	Mark	AO
02.7	**plot** $\ln E_V$ against N OR plot **implied** by comparison between **correct algebra** $\ln E_V = -\mu N + \ln 400$ and $y = mx + c$ 1✓	for 1✓ allow plot $\ln\left(\frac{E_V}{400}\right)$ against N; must clearly imply that N is the abscissa; allow aligned expressions eg $\ln E_V = \ln 400 \text{ OR } 5.99 - \mu N$ $y \ (=) \ c \ (+) \ mx$	2	AO1
	μ is –gradient 2✓	allow 2✓ for '$-\mu$ is gradient' / 'μ is absolute value of gradient' / 'μ is modulus of gradient value' where $\ln E_V = -\mu N + \ln 400$ without comparison with $y = mx + c$ seen;		
	plot $\ln E_V$ against N with incorrect algebra is talk out for 1✓ allow ECF if linking μ to **gradient** based on their incorrect algebra for 2✓	use of 'log-linear graph paper' is only acceptable with further explanation use of 'logarithmic graph paper' is neutral		
		OR allow **plot** $\log E_V$ against N OR plot **implied** by $\log E_V = -\mu \log(e) N + \log 400$ compared with $y = mx + c$ 1✓ μ is $\frac{-\text{gradient}}{\log(e)}$ 2✓		

Question	Answers	Additional comments/Guidelines	Mark	AO
02.8	evidence for any workable method that would lead to EITHER $N_{½} \approx 7.7$ OR a final integer answer that is appropriate to their calculated value $_1$✓ $N_{½}$ **=** 8 slides CAO $_2$✓	for $_1$✓ expect use of $\ln 0.5 = -9.0 \times 10^{-2} N_{½}$ or similar (including trial and improvement)	2	AO3
Total			**15**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	(use of a ruler to) **measure** height **from bench to rod** at (minimum of two) different points $_1$✓ explains how the **ruler** is made vertical $_2$✓ checks heights are the same $_3$✓ (contingent on $_1$✓) OR use of a metre ruler placed on the rod with a spirit level placed on the ruler; check no gap between ruler and rod $_{12}$✓ check bubble is at centre $_3$✓ (contingent on $_{12}$✓) OR use of metre ruler placed with no gap on top of nested set-squares so the metre ruler can be compared with rod $_{12}$✓ lower set-square in contact with the bench (no gaps) $_3$✓ (contingent on $_{12}$✓)	for $_1$✓ points may be **anywhere** along rod; allow 'measure height of rod at each end' / 'at both clamps'/ 'measure height from ground' do not allow 'find height' / 'measure on both sides of the rod / wire' for $_2$✓ expect to see a set-square in **contact with** the bench AND in **contact with** the upright ruler; allow use of a spirit level / T-square / plumb line / **large** protractor to make ruler vertical; use of set-square between the ruler and the rod OR between stand and rod is neutral; for $_1$✓ and $_2$✓ allow annotation to **Figure 10** allow $_{12}$✓ for use of a set-square in contact with the bench that reaches the rod (ie no ruler mentioned) as long as **measuring** is being done with it for $_3$✓ allow 'compare heights to check rod is parallel to bench / level' allow 'measurements match' / 'contingent' etc 'straight' for horizontal or for vertical / 'heights are constant' is neutral	3	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	force on **rod** is down(wards) $_1$✓	‘force down’ & ‘current to right’ & ‘field out of page by left-hand rule’ earns ✓✓✓ = 3/3; for $_1$✓ allow use of $F \downarrow$ for force on rod down; may be indicated on **Figure 11** allow unqualified ‘force’; condone force = ‘motion’ / rod = ‘wire’ ‘force **on balance / yoke** is up’ is neutral	3	1 × AO1 2 × AO3
	the current (in rod) is from left / to right / rightwards $_2$✓	for $_2$✓ allow $I \rightarrow$ for current from left / to right; may be indicated on **Figure 11** condone ‘current clockwise’; ‘from positive to negative’ is neutral		
	predicts direction of field based on their force and their current using valid (left-hand) rule or WTTE $_3$✓	$_3$✓ is contingent on seeing $_1$✓ force up or down and on seeing $_2$✓current left or right etc; for $_3$✓ allow use of B for field and LHR for left-hand rule; allow B ⊙ by LHR; for reversed F OR for reversed I allow ⊗ by LHR, eg ‘force upwards’ / ‘current to right’ / ‘field into page’ etc earns ✗✓✓ = 2/3		

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	MAX 2 from: • **any** valid expression to demonstrate homogeneity of terms A✓ • $B = \frac{F}{IL}$ OR $BI = \frac{F}{L}$ B✓ • identifies the base units of F as kg m s^{-2} C✓ the units for k are s^2 3✓	correct units for k earns 3 marks unless evidence of incorrect working seen for A✓ and B✓ allow any valid expression or statement that contains both units AND quantities for A✓ idea that $k\ B\ I$ has units of **mass** any subject eg $k \equiv \text{kg T}^{-1}\ \text{A}^{-1}$ allow 'M OR mass OR g = $k\ B\ I$' condone words for **units**, eg 'amps' / 'tesla'; accept use of dimensional analysis, M (mass), L (length) and T (time) for B✓ allow T (OR B) $\equiv \frac{\text{N}}{\text{A m}} \equiv \frac{\text{N s}}{\text{C m}}$ for B✓ allow TA (OR $B\ I$) $\equiv \frac{\text{N}}{\text{m}}$ for AB✓✓ allow $k \equiv \text{kg} \frac{(\text{A})\text{m}}{\text{N}}(\text{A}^{-1})$ for BC✓✓ allow T (OR B) $\equiv \frac{\text{kg (m) s}^{-2}}{\text{A (m)}} \equiv \frac{\text{kg}}{\text{C s}}$ for BC✓✓ allow TA (OR $B\ I$) $\equiv \frac{\text{kg (m) s}^{-2}}{\text{(m)}}$	3	1 × AO1 2 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	records **two** vertical intercepts to 2 dp with at least one intercept correct to ± 0.05 (g) OR M_1 and M_2 read off to 2 dp for the same value of I with at least one read off correct to ± 0.05 (g)$_1$✓ derives **two** valid equations using their M_1 and M_2 that can be solved to determine Y OR their Y min 1 dp, consistent with their intercepts to $\pm 0.1(0)$ (g) $_2$✓ $Y = 87.85 \pm 0.1(0)$ (g) CAO $_3$✓	M_1 intercept $= 134.85 \pm 0.05$ (g) M_2 intercept $= 181.85 \pm 0.05$ (g) allow either value seen in working for $_2$✓ mark is for method OR for their Y equations **[A]** and **[B]** seen: $134.85 = (0+)\ 2Z + Y$ ……**[A]** $181.85 = (0+)\ 4Z + Y$ ……**[B]** OR $Y = 2 \times M_1$ intercept $- M_2$ intercept; $_2$✓ not contingent on $_1$✓ so allow their Y correctly deduced using two incorrect intercepts including intercepts rounded to 1 dp $_3$✓ is contingent on $_1$✓ for $_3$✓ min 1 dp; only allow 1 dp 87.8 OR 87.9	3	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	identifies that B is less $_1$✓	for $_1$✓ allow 'field' / '(magnetic) **flux density**' for B; allow 'B weaker' / 'less field lines through the rod' / '(rod) not affected by field as much'; 'B is not uniform' / '(rod) cuts less flux' / 'cutting less field lines' are neutral $_1$✓	3	1 × AO2 2 × AO3
	states and explains why the intercept is the same $_2$✓	for $_2$✓ allow intercept is the same **because** 'intercept is the mass of yoke **and** magnets' / 'intercept = $2Z$ AND Y' / 'Z AND Y don't change' / 'there is the same initial mass'		
	states and explains why the line is less steep $_3$✓	for $_3$✓ allow 'gradient is smaller' / 'gradient is **less** negative' / 'line is flatter' **because**		
	allow $_{23}$✓ for **stating** that the line is less steep **AND** that the intercept is the same without a valid explanation for either statement	'**change in** M_1 / balance reading / force is less for each (**change in**) I' OR 'force won't **change as much** with current' OR 'less force per unit current' OR gradient is kB / gradient $\propto B$		
	allow $_{13}$✓ for $B = 0$ or WTTE (reject 'rod not in field'); intercept same as in **Figure 13** AND gradient = 0 or WTTE; then mark $_2$✓ as above	'less force for same current' is neutral take account any sketch graph that correctly compares the new graph of M_1 against I with **Figure 13**		
Total			**15**	