A-level
PHYSICS
7408/3A

Paper 3 Section A

Mark scheme

June 2023

Version: 1.0 Final

236A7408/3A/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.

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	4.5×10^{-2} ✓	CAO	1	AO2-1h

Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	(short T_1) so images are not blurred (or wtte) OR to determine position of the ball (in each image or wtte) ✓	must refer to quality / property of images, eg 'images are sharp' / 'focused' / 'clear' / 'defined'; allow '(images of) ball are circular' / 'spherical' / 'not elongated' or wtte: accept sketch 'increasing distance between images' / 'image is accurate' are neutral allow 'to see (point) where ball is' / idea that (centre of) ball needs to be a 'single point' / 'ball does not move during each flash (T_1)' comments about the motion / trajectory of ball eg 'see a clear pattern' are neutral comments about the duty cycle / flash rate are neutral	1	AO2-1c

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>01.3</td><td>correct rearrangement to a three-term equation;
$\frac{H-h}{n}$ as the subject eg $\frac{H-h}{n}=\frac{u_0}{f}+\frac{gn}{2f^2}$ $_1$✓

valid suggestion for quantity plotted on x-axis;

allow use of $y=mx+c$ aligned with $\frac{H-h}{n}=\frac{u_0}{f}+\frac{gn}{2f^2}$

suitably annotated to identify x $_2$✓

explains how g found using the gradient for their x-axis;

insist on g as subject whether explanation is in words or expressed as an equation $_3$✓</td><td>for $_1$✓ condone $\frac{H-h}{n}=\frac{u_0}{f}+\frac{g}{2n}\left(\frac{n}{f}\right)^2$

$_3$✓ is contingent on $_2$✓;

for a correct equation or if no equation is seen mark $_2$✓ and $_3$✓ as below:
<table><tr><th>for $_2$✓</th><th>for $_3$✓</th></tr><tr><td>n</td><td>g = gradient × $2f^2$</td></tr><tr><td>$\frac{n}{2}$</td><td>g = gradient × f^2</td></tr><tr><td>$\frac{n}{f}$</td><td>g = gradient × $2f$</td></tr><tr><td>$\frac{n}{2f}$</td><td>g = gradient × f</td></tr><tr><td>$\frac{n}{f^2}$</td><td>g = gradient × 2</td></tr><tr><td>$\frac{n}{2f^2}$</td><td>g = gradient</td></tr></table>for an incorrect equation with n in the 'mx' term allow ECF for $_2$✓ and $_3$✓</td><td>1

2</td><td>AO1-1b

AO2-1g</td></tr>
</table>

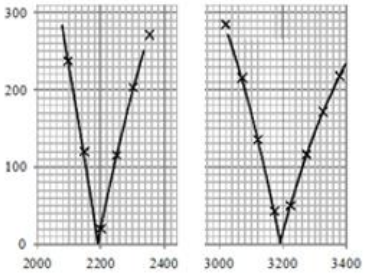
Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	$n = 17 \pm 1$ $_1$✓	$_1$✓ expect integer $n = 17 \pm 1$ but see valid unusual approach below left	1	AO1-1b
	use of $H = \frac{u_0 n}{f} + \frac{g}{2}\left(\frac{n}{f}\right)^2$ OR use of $H = u_0 t + \frac{1}{2} g t^2$ (eg with t from $\frac{n}{31}$) $_2$✓	for $_2$✓ either approach 'use of' means full substitution without error (with $h = 0$ shown or implied by omission) so that u_0 is the only unknown; condone $g = \pm 9.79$ OR $\pm 9.8(1)$; condone POT error / mixed units for H and g	1	AO2-1h
	u_0 correctly evaluated to (minimum) 2 sf $_3$✓	for $_3$✓ see table for u_0 with n = 16 OR 18 AND/OR for the (intermediate) rounding of t; accept > 3 sf that rounds to values in table:		
	valid alternative method: use of **Figure 1** to determine non-zero h for integer $n > 0$ for $_1$✓ a valid h for their integer n (≤ 16) eg when $n = 5$, $h = \frac{89\ (\text{mm})}{99\ (\text{mm})} \times 1550\ (\text{mm}) = 1393\ (\text{mm})$ for $_2$✓ full sub including a valid h for their n for $_3$✓ u_0 correct for their n and h eg for $n = 5$ and $h = 1393$, $u_0 = 0.18(4)$ (m s^{-1}) $_3$✓		1	AO3-1b

	subs n, f	truncates t	
expected	$t = 17/31$	3 sf	2 sf
t / s	(0.548387)	0.548	0.55
u_0 / m s^{-1}	0.14	0.15	0.13

ECF	$t = 16/31$	3 sf	2 sf
t / s	(0.516129)	0.516	0.52
u_0 / m s^{-1}	0.48	0.48	0.44

ECF	$t = 18/31$	3 sf	2 sf
t / s	(0.580645)	0.581	0.58
u_0 / m s^{-1}	–0.17	–0.18	–0.17

Question	Answers	Additional comments/Guidelines	Mark	AO
01.5	calculates the horizontal velocity; divides a valid horizontal displacement $s_2 - s_1$ by a time $_1$✓ horizontal velocity in range 1550 and 1650 (mm s^{-1}) $_2$✓	for $_1$✓ $s_2 - s_1$ in range 490 to 1000 (mm); expect time to be found from counting intervals between flashes but allow use of **their 01.6** result; condone use of distance between contacts with time of $\frac{19}{31}$ and $\frac{20}{31}$; $_2$✓ is not contingent on $_1$✓ allow 2 sf 1.6×10^3 (mm s^{-1})	2	AO2-1h

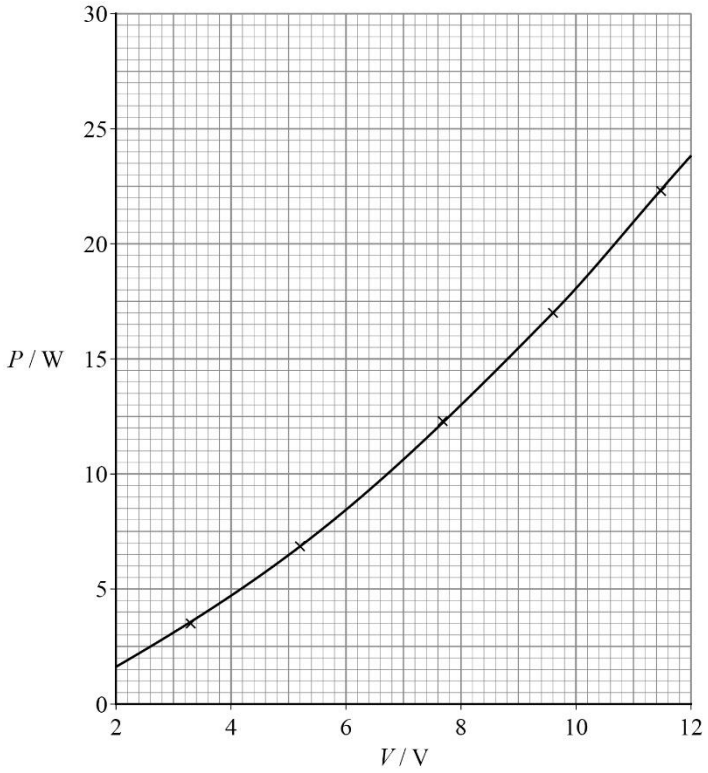
Question	Answers	Additional comments/Guidelines	Mark	AO
01.6	determines h_{max} (at top of bounce) using an annotation to **Figure 3** $_1$✓ eg  valid attempt to find time t between contacts by using $suvat$ with $u = 0$, eg time $= (2\times)\sqrt{\frac{2 \times \text{their } h_{max}}{9.81 \text{ OR } 9.79}}$ $_2$✓ OR determines s for <u>both</u> contacts OR determines $s_2 - s_1$ using annotations to **Figure 3** $_1$✓ eg  valid attempt to find t by $= \frac{\text{their } s_2 - s_1}{\text{their horizontal velocity in 01.5}}$ $_2$✓ time in range $0.61(0)$ to $0.65(0)$ (s) $_3$✓	for $_1$✓ annotation should be a smooth curve through (at least) top 4 points, $n = 51$ to 54; don't insist on seeing a horizontal line to the h axis for $_2$✓ accept mixed units / POT in substitution / time to maximum height calculated / valid working in **01.5** OR for $_1$✓ annotation should be at least one smooth (allow straight) line to define each contact; eg (at least) through $n = 41/42$ OR $43/44$ to $h = 0$ AND through $n = 61/62$ OR $63/64$ to $h = 0$ for $_1$✓or $_2$✓ accept valid working in **01.5**; accept use of horizontal distance $= 1000$ (mm) for $_2$✓do not condone use of integer number of intervals, eg $t = \frac{19}{31} = 0.61(3)$ OR $t = \frac{20}{31} = 0.645$ $_3$✓ is contingent on $_2$✓; exception: award $_3$✓ for t in range if obtained by estimating a **non-**integer number of intervals, eg $t = \frac{19.5}{31}$	3	AO2-1h
Total			**13**	

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	rate = 1.40 to 1.75 (V s^{-1}) $_1$✓ rate = 1.50 to 1.65 (V s^{-1}) $_2$✓	for $_1$✓ accept 2 sf 1.5, 1.6 and 1.7 (V s^{-1}) for $_2$✓ accept >3 sf rounding to value in range; accept 2 sf 1.6; expected answer is 1.57(2) (V s^{-1})	2	AO3-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	maximum 1 mark per marking point (see $_1$✓ to $_4$✓ below) reduces impact of statistical error (involved in reading and recording data manually) $_1$✓ data can be collected at a high(er) rate or wtte $_2$✓ idea that data (in digital form) may be easily processed $_3$✓ two (or more) sets of data (I and V) can be made simultaneously or wtte $_4$✓ treat suggestions that data logging improves 'precision' / 'resolution' / reduces 'uncertainty' / eliminates 'systematic' / 'parallax errors' / 'anomalous readings' as neutral	for > 2 ideas mark as a list for $_1$✓ allow reducing 'human error' / 'random error' / 'improving accuracy' as same idea; idea that random error / uncertainty can be eliminated is talk out; condone 'no human error / reaction'; for $_2$✓ condone 'quickly' / 'works faster' 'collect data at a steady rate'/ 'saves time' / comments about 'reaction time' are neutral for $_3$✓ eg can be transferred to / graphed with / analysed using a digital device or application eg computer / spreadsheet allow 'can be processed automatically' treat the following as neutral since they are not specifically applicable to this experiment: can carry out experiment 'remotely' / 'in inaccessible or dangerous environments' / 'automatically' / 'without any human (being present)' or wtte; can 'start / stop data collection at some suitable (future) time' / 'collect large amount of data' or wtte; 'a wide variety of sensors are available' / 'data logging is (increasingly) cheap'	Max 2	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	identifies that **circuit 2** can produce the data because the pd can be varied between 0 V and 12 V $_1$✓	for $_1$✓ allow 'can achieve $12\ \text{V}$ range' or wtte; reject 'can produce 0 V and 12 V'	2	AO1-1b
	identifies that **circuit 1** cannot produce (all of) the data shown on **Figure 4** $_2$✓	for $_2$✓ allow '**circuit 1** is not suitable' / 'not **circuit 1**'; award $_1$✗$_2$✓ for 'neither can produce the data'		
	for **circuit 1** with **X** set to maximum resistance calculates (minimum) I OR calculates (minimum) V $_3$✓	for $_3$✓ (at least one) result should be evaluated to min 2 sf but condone '≈ 0.7' if decimal intermediate result is ok; do not accept rounding to 0.69; allow use of 17.2 without justification; minimum $I\left(=\frac{12}{17.2}\right)=0.70\ \text{A}$ OR minimum $V\left(=12\times\frac{2.3}{17.2}\right)=1.6\ \text{V}$	2	AO3-2a
	their minimum I or minimum V for **circuit 1** compared with value of first (or second) point in **Figure 4** $_4$✓	for $_4$✓ could say their minimum $I > 0.36$ / I for first data point $< 0.7(0)$ / $0.70 > 0.36$ etc allow 'cannot produce $I < 0.7(0)$ in Fig 4'; 'cannot produce all the values' is not enough		

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	$P = 6.82$ in row 2 $_1$✓ $I = 1.77$ in row 4 $_2$✓ $P = 17.0$ in row 4 $_3$✓	$_1$✓ / $_2$✓$_3$✓ V / V | I / A | P / W 3.30 | 1.07 | 3.53 5.17 | 1.32 | **6.82** 7.69 | 1.59 | 12.2 9.58 | **1.77** | **17.0** 11.47 | 1.94 | 22.3 for $_1$✓ CAO for $_2$✓ allow 1.77 ± 0.01 for $_3$✓ ECF for their (incorrect) $I \times 9.58$; deduct MAX 1 mark if any are **not** to 3 sf	3	AO2-1h

Question	Answers	Additional comments/Guidelines	Mark	AO
02.5	vertical axis labelled P / W $_1$✓ suitable vertical scale for their data $_2$✓ 5 points plotted AND smooth curve of increasing gradient $_3$✓  	for $_1$✓allow P (W), P in W; reject comma separator, eg P, W; allow words, eg power for P / watt(s) for W for $_2$✓ expect 1 cm interval = 2 W OR 2 cm intervals = 5 W vertical scale must • be linear • be marked in integer values • be marked with a frequency of not less than 4 cm intervals • cover the range of plotted points assume $P = 0$ at unmarked origin for $_3$✓ check the plotting of any obviously suspect point; points must **not** be thick / faint / dots / blobs; line must • be a continuous **curve** • be neither thick or faint • (at least) extend from the first to the fifth point • be a reasonable best-fit for their data; withhold mark if line deviates by ≥ 2 minor squares from examiner's best line (by eye) if I / A is plotted award $_2$✓ if the effective range of vertical scale is ≥ half height of grid	2 1	AO1-1b AO2-1h

Question	Answers	Additional comments/Guidelines	Mark	AO
02.6	evidence that P_r read-off to $\pm$ 1 minor grid square $_1$✓	for $_1$✓ best-fit line must be extrapolated to $V = 12$ V (at the right-hand margin of the grid); P_r correct to $\pm$ half a minor grid square; expect $P_r = 23.8$ W for a curve but accept a read-off obtained from a straight best-fit line	2	AO3-1a
	reads off P_2 corresponding to 6 V; evaluates $\frac{2 \times \text{their } P_2}{\text{their } P_r} \times 100$ $_2$✓	$_2$✓is not contingent on $_1$✓ for $_2$✓ expect $P_2 = 8.5$ W for a curve; expected % in range 70% to 73% if no read-off evidence is seen on **Figure 6** check for the possibility that **Figure 4** was used to obtain P_r and P_2 eg by drawing a curve through points to intersect at $V = 12$ V, then using $V\ (= 12) \times I\ (= 1.98)$ $P_r = 23.7$ using $V\ (= 6) \times I\ (= 1.42)$ $P_2 = 8.5(2)$ would lead to 72%		
Total			**16**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	search coil is not suitable or wtte:	$_1$✓and $_2$✓ can be earned independently but are contingent on a statement that the search coil is not suitable; insist on suitable use of the appropriate underlined term	1	AO1-1a
	no <u>emf</u> (would be induced in a search coil) $_1$✓	for $_1$✓condone 'potential difference' OR 'voltage' for emf		
	a search coil needs (to be cut by) changing <u>flux</u> OR search coil is not cut by changing <u>flux</u> OR <u>flux</u> (cutting coil) is constant or wtte $_2$✓	for $_2$✓ accept ϕ for flux; do not insist on 'flux linkage'; do not allow 'field' for 'flux'; 'current (in the coil on frame) must be ac' is neutral; the suggestion that a search coil cannot be connected to a data logger is neutral	1	AO3-1b
	alternative approach: search coil **is** suitable or wtte: suggests a valid method that changes the flux cutting the search coil eg rotate either coil / turn (dc) current off / move either coil relative to other coil $_1$✓	alternative approach: $_1$✓and $_2$✓ can be earned independently but are contingent on a statement that the search coil is suitable		
	states their method changes <u>flux</u> through search coil OR if search coil is cut by changing <u>flux</u> or wtte $_2$✓			

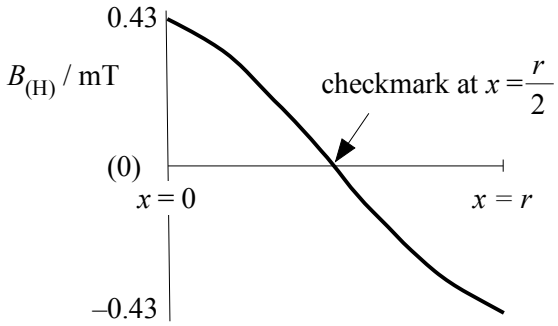
Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	use of $1 - \cos 25(°)$ or $1 - \sin 65(°)$ in a calculation of percentage change $_1$✓	for $_1$✓ expect either ≥ 3 sf rounding to $1 - 0.906$ OR $1 - 0.91$ seen in working OR $100 - 90.6$ or $100 - 91$ seen in working;	2	AO2-1h
	$(-)$ 9.4 (%) CAO $_2$✓	for $_2$✓ expect min 2 sf rounding to $(-)$ 9.4; allow $(-)$ 9.0 if $1 - 0.91$ seen in working; do not insist on minus sign or 'decrease' on answer line allow $_2$✓ for unsupported answer of $(-)$ 9.4; if no other mark is awarded allow $_{12}$✓ use of $1 - \sin 25(°)$ or $1 - \cos 65(°)$ in a % difference calculation leading to 58%		

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	uncertainty (in a single reading / judgement) is ½° $_1$✓	for $_1$ ✓accept 0.5 seen in numerator of % calculation OR absolute uncertainty is 2×0.5; allow a larger uncertainty up to $3°$ if justified with a comment about difficulty in judging the reading due to parallax, thickness of frame etc	1	AO1-1a
	(measurement of) θ is based on (difference between) <u>two</u> readings / judgements OR absolute uncertainty in θ (or $\Delta\theta$) $= 2\times$ uncertainty in each reading / judgement $_2$✓	for $_2$ ✓accept 2×0.5 OR $2\times$ their uncertainty in (a single) reading seen in numerator OR evidence for use of $2\times$ their uncertainty in result of % calculation; 'measured twice' is ambiguous	2	AO1-1b
	correct percentage uncertainty calculation based on $100\times$ their absolute uncertainty divided by 25 $_3$✓	for $_3$ ✓ allow 1 sf result; $\frac{2\times0.5}{25}\times100=4\%$ (use of $0.5°$) earns $_1$✓$_2$✓$_3$✓ $\frac{0.5}{25}\times100=2\%$ (missing $2\times$) earns $_1$✓$_2$✗$_3$✓ $\frac{2\times1}{25}\times100=8\%$ ($1°$ unexplained) earns $_1$✗$_2$✓$_3$✓ $\frac{1}{25}\times100=4\%$ ($1°$ unexplained) earns $_1$✗$_2$✗$_3$✓ $_{123}$✓✓✓ for two-judgement explanation leading to $1°$ used in a correct % uncertainty calculation		

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	r in range 67 to 69 mm OR $x_{0.5}$ in range 50 to 55 mm $_1$ ✓ $\frac{x_{0.5}}{r}$ in range 0.73 to 0.81 $_2$ ✓	$\frac{x_{0.5}}{r}$ in range gets both marks for $_1$ ✓ either value can be seen in working OR on (along horizontal axis in) **Figure 13** for $_2$ ✓ answer with no unit and minimum 2 sf	2	AO3-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	**use of Figure 11:** adds B_{H1} for experiment 1 to B_{H2} for experiment 2 at any point between $x = 17$ and $x = 51$ (mm); resultant B_H, minimum 2 sf, in range 0.91 to 0.99 (mT) $_1$✓ resultant B_H, minimum 2 sf, in range 0.93 to 0.97 (mT) $_2$✓	ignore any sign given with result	2	AO3-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
03.6	for more than 2 ideas mark as a list (field lines are) parallel or wtte $_1$✓ evenly-spaced or wtte $_2$✓	for $_1$✓ accept 'in the same direction' / 'uniform-direction'; 'horizontal' / 'directed to the right' / 'straight' / 'linear' / 'perpendicular to the coil' are neutral for $_2$✓ accept 'equally-spaced' / 'equidistant' / 'uniform-spacing' / 'equal distance between lines' or wtte; 'close together' / 'do not touch' are neutral; 'uniform field' / 'field lines are uniform' / 'they are uniform' are neutral	2	AO1-1a

Question	Answers	Additional comments/Guidelines	Mark	AO
03.7	a vertical axis drawn (at any point between $x = 0$ and $x = r$); continuous line (accept poorly-marked) between $x = 0$ and $x = r$ (by eye); intersecting or meeting horizontal axis / $B_{(H)} = 0$ at $x = \frac{r}{2}$ $_1$✓ vertical axis drawn, labelled with symbol B; negative gradient, line continuous between $x = 0$ and $x = r$; 2-quadrant graph $_2$✓ vertical axis drawn with symbol and unit eg $B_{(H)}$ / mT; continuous line between $x = 0$ and $x = r$; $B_{(H)} = 0.43 \pm 0.01$ at $x = 0$ OR $B_{(H)} = -0.43 \pm 0.01$ at $x = r$ $_3$✓ 2-quadrant graph, continuous line between $x = 0$ and $x = r$; approximately correct shape: see opposite; their y-value at $x = 0$ equal and **opposite** to their y-value at $x = r$ (by eye) $_4$✓	for $_1$✓ use checkmark on axis for guidance; for $_2$✓ allow 'magnetic flux density' in words; condone any flat section ≤ $r/4$ (judge by eye); allow (always) positive gradient for $_1$✓ and $_2$✓ allow a straight line; single quadrant can score $_1$✓ or $_3$✓ for $_3$✓apply usual symbol-separator-unit convention / allow $B_{(H)} = 4.3 \times 10^{-4}$ etc; adjust criteria for positive gradient graph for $_4$✓ if no values are marked on the axis, assume $B_{(H)} = 0$ is aligned horizontally with the *x*-axis (judge by eye); condone missing vertical axis  	MAX 3	AO3-2b
Total			**16**	