A-level
PHYSICS
7408/3BD

Paper 3 Section B Turning points in physics

Mark scheme

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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.

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

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

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

Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

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

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

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

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

2. Emboldening

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

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

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

3. Marking points

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

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

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

3.2 Marking procedure for calculations

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

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

3.3 Interpretation of 'it'

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

3.4 Errors carried forward, consequential marking and arithmetic errors

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

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

3.5 Phonetic spelling

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

3.6 Brackets

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

3.7 Ignore / Insufficient / Do <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.

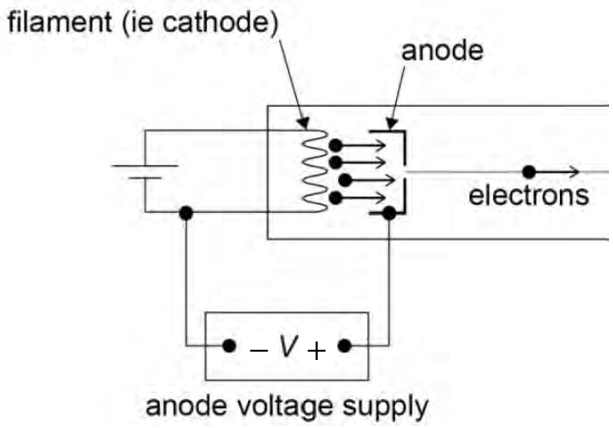
When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use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

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

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

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

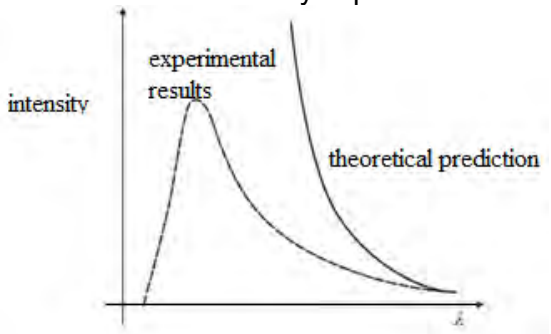
An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional comments/Guidance	Mark	AO
01.1	Max 2 from: ✓✓ • Vacuum / low pressure gas (in a glass tube) • Heater/filament/(thin) wire (correctly) connected to (ac or dc) power supply / has a current passing through it. • An accelerating potential difference (must not be ac) connected to an electrode with a **hole** referred to as anode or connected to the positive terminal of power supply. heater power supply ≤ 20 V **and** accelerating pd > 200 V (less than 1000 kV) ✓	Answers may come from the written answer or a labelled diagram. Allow battery or cell symbol for dc power supply. A voltmeter is not sufficient for bullet 2 or bullet 3 but may be used to award MP3 if values are given. Condone resistor drawn for filament. BP3 do **not** allow horizontal plates (as shown in Figure 1).  	3	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	$\frac{eV}{d} = Bev$ **AND** (therefore) $v = \frac{V}{dB}$ or $\frac{V}{d} = Bv$ ✓ $v = \frac{V}{dB} = \frac{750}{0.05\times0.64\times10^{-3}} = 2.34 \times 10^{7}$ ✓ (m s^{-1})	Do **not** allow use of 1.6×10^{-19} (unless cancelled) or 9.11×10^{-31} ≥ 3 SF required. Allow use of E for $\frac{V}{d}$ and Q for e.	2	AO2
01.3	v_v = their ans to **01.2** × tan 25° = 1.09×10^{7} (m s^{-1}) **OR** $v = \frac{\text{(their) ans to 01.2}}{\cos 25°}$ **and** $v_v = v \sin 25°$ $(= 1.09 \times 10^{7}$ m s$^{-1})$ ✓	Do **not** allow use of 1.6×10^{-19} or 9.11×10^{-31} ≥ 3 sf required. 2.3×10^{7} m s^{-1} gives 1.07×10^{7} m s^{-1} Allow ecf from their **01.2**	1	AO2
01.4	$t = \frac{0.10}{\text{(their) ans to 01.2}}$ ✓$_1$ $(= 4.27 \times 10^{-9}$ s)	Condone for **1 mark only** $a = \frac{\text{their ans to 01.3}^2}{2\times0.025}$ ✓$_{12}$ Do **not** allow use of 1.6×10^{-19} or 9.11×10^{-31} but ✓$_1$ can be awarded if this is only used in ✓$_2$ ≥ 3 sf required Allow ecf from their **01.3** and **01.2**	2	AO2
	$a = \frac{\text{(their) ans to 01.3 (– 0)}}{\text{(their) } t}$ $(= 2.56 \times 10^{15}$ m s$^{-2})$✓$_2$			
01.5	$ma = \frac{QV}{d}$ or or $ma = QE$ ✓$_1$	Do **not** allow use of 1.6×10^{-19} or 9.11×10^{-31} in ✓$_2$ and ✓$_3$ but ✓$_1$ can be awarded. Do **not** allow answer with no working. Answer must follow from correct working. Allow $\frac{e}{m} = \frac{V\tan 25°}{0.10dB^2}$ **OR** $\frac{v_v}{0.10B}$ **OR** $\frac{v_h \tan 25°}{0.10B}$ **OR** $\frac{a}{Bv_h}$ ✓$_1$ substitution ✓$_2$ Other approaches based on $\frac{1}{2}mv^2 = eV$ or B are likely to be incorrect.	3	AO2
	$(\frac{e}{m} = \frac{ad}{V} =) \frac{\text{(their) ans to 01.4}\times0.050}{750}$ ✓$_2$			
	$\frac{e}{m} = 1.7 \times 10^{11}$ ✓$_3$ (C kg^{-1}) (cao)			

Question	Answers	Additional comments/Guidance	Mark	AO
01.6	Specific charge was **much** larger / approx. 2000 times than the largest so far discovered / hydrogen ion / hydrogen nucleus / proton ✓1 Electron has a **much** smaller mass than the hydrogen ion (proton) ✓2	Do **not** allow references to hydrogen atom or just hydrogen in ✓1 but condone in ✓2. Ignore references to size. Ignore "**or** greater charge" larger in mp1 and smaller in mp2 is not sufficient without much/very/… Allow << and/or >> but not < or > A comparison is required in ✓1 and ✓2	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.7	(Method 2 is preferred) Any **three** from: ✓✓✓ • Idea that in method 1 the spot is unlikely to be on a scale line when the magnetic field is off • Idea that (percentage) uncertainty/resolution is (likely to be) smaller for magnetic field reading than for angle. • Idea that using method 2 the pd can be adjusted to place (the centre of) the spot on a scale line • Using method 2 allows you to select the angle and therefore use a large value to minimise the % uncertainty in θ	Ignore any suggestion that there is a different number of measurements in the two methods. Ignore references to parallax error. Max 2 if method 2 is not preferred. Allow current reading for magnetic field reading Condone the idea that the angle can be set to an easily read value for bullet 3. Allow increase the accuracy instead of reduce the uncertainty in bullet 4. If no other marks awarded condone for max 1: method 2 because of the idea that θ does not have to be measured / is chosen / is set.	3	AO3
Total			**16**	

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	Any **three** from: ✓✓✓ • Experiment agreed with theory at high wavelengths / theory was correct at high wavelengths • The existence of a peak was shown by experiment but was not predicted by theory / can be shown by labelled curves. • The existence of a cut-off at low λ was shown by experiment but was not predicted by theory / can be shown by labelled curves if experimental line touches λ axis at low but non-zero λ with a correct theoretical line • Theory predicted intensity tends to infinity when wavelength tends to 0 which is not matched by experiment / the experimental graph not tending to infinity can be shown from the graph (but the theoretical intensity tending to infinity requires a written comment).	Any reference to non-EM radiation MAX 2. Condone a positive y-intercept except for bullet 4. Do **not** allow any bullet which is contradicted by the graph but reward comments that refer to behaviour beyond the range shown on the graph. To gain marks for labelled curves it must be clear which line is theoretical and which is experimental. Bullet 4: Condone intensity tends to infinity at UV (even with non-zero asymptote drawn) which is not matched by experiment. 	3	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Light (waves) / (EM) radiation (is emitted) in **quanta** and idea that energy is proportional to frequency ✓	Do **NOT** accept photons / particles. Allow small packets of energy/waves for quanta. Condone energy for EM radiation.	1	AO1
Total			**4**	

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>03</td><td>The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>All three areas covered in some detail.
6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr>
<tr><td>5</td><td>All three areas covered, at least two in detail.
Whilst there will be gaps, there should only be an occasional error.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr>
<tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr>
<tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>None of the three areas covered without significant error.</td></tr>
</table></td><td>Models before 1800
1 bullet partially covers this area, all 3 are required to fully cover this area.
• (Newton proposed) particle / corpuscular model and (Huygens proposed) wave model.
• Newton / particle / corpuscular model predicted that the speed of light in glass/water was faster than in air.
• Huygen / wave model predicted that the speed of light in glass/water was slower than in air.
[Allow a comparison based on (optical) density.]

Maxwell's theory
1 bullet partially covers this area, all 3 are required to fully cover this area.
• Idea that Maxwell predicted the existence of / the speed of electromagnetic waves.
• Maxwell's waves consisted of (oscillating) electric fields and magnetic fields.
• At least one extra detail: e,g. Maxwell wrote equations that related magnetic fields to electric fields / $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ where μ_0 is related to magnetic field strength and ε_0 is related to electric field strength / electric field and magnetic field oscillates perpendicular to each other and the direction of energy transfer / electric and magnetic field oscillate in phase …</td><td>6</td><td>4 × AO1
2 × AO2</td></tr>
</table>

	0 No relevant comments	*[Ignore the idea that Maxwell predicted the speed of light.]* **Significance** 1 bullet partially covers this area, 2 is enough to fully cover this area. • Foucault's experiment suggested wave/Huygen model was correct / particle/Newton/corpuscular model was incorrect. • Fizeau's measurement matched the prediction of the speed of electromagnetic waves suggesting that light was an electromagnetic wave. • Hertz's measurement equalling predicted speed of electromagnetic waves confirmed Maxwell's theory. *[Ignore idea that Hertz's measurement matching Maxwell's prediction showed radio waves were electromagnetic.]* *[Experiments given in question, so answer must link these experiments to their significance not just speeds matching.]*		
Total			**6**	

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	t_0 or t or l_0 or l identified and substituted into $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ or $l = l_0\sqrt{1-\frac{v^2}{c^2}}$ ✓ Substitution using $v = \frac{s}{t}$ with their substituted values in the same reference frame✓ All correct shaded value(s) from any row seen ✓	$l_0 = 1.4 \times 10^{14}$, $t_0 = 10$ (days) or 864000 (s), l or t from the result of $v = \frac{s}{t}$ for their v (allow t in days) Identification can be explicit or inferred from substitution. Condone missing squares on v and c in MP1. v: either $s = 1.4 \times 10^{14}$ or $t = 8.64 \times 10^5$ s with their answer from a relativistic calculation (but **not** with each other). Do **not** allow $v = \frac{1.4\times10^{14}}{10(\times24\times60\times60)}$ or use of $v = c$ for MP2 and MP4. s or t: $v = 0.5c$ and **one** of $s = 1.4 \times 10^{14}$, $t = 8.64 \times 10^5$ s or their answer from a relativistic calculation	4	AO3

	Comparison for their value(s) from using $v = \frac{s}{t}$ **and** a relativity equation **and** a consistent conclusion ✓ Consistent reference frame must be used for comparison but does not have to be identified.	MP3 implies MP1 and MP2. If multiple values are seen, mark values used in conclusion. If there is no conclusion, all values must be correct. **Either reference frame** minimum v | | actual v 1.4×10^8 m s^{-1} | < | 1.5×10^8 m s^{-1} **Spaceship reference frame** time taken | | maximum time 9.4 or 9.3 d | < | 10 d 8.1 or 8.0×10^5 s | < | 8.6×10^5 s distance travelled | | maximum distance 1.2×10^{14} m | < | 1.3×10^{14} m **Planet's reference frame** time taken | | maximum time 10.8 d | < | 11.5 d 9.3×10^5 s | < | 9.9×10^5 s distance travelled | | maximum distance 1.4×10^{14} m | < | 1.5×10^{14} m Do not award MP4 unless MP1 and MP2 are awarded.		

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	Use of $\sqrt{1-0.5^2}$ or $\sqrt{1-\frac{0.5^2c^2}{c^2}}$ or $\sqrt{1-\frac{(1.5\times10^8)^2}{(3\times10^8)^2}}$ or $\sqrt{1-0.25}$ $\sqrt{0.75}$ or 0.866 or $\frac{\sqrt{3}}{2}$ with lengths ✓ l = 200 (m) or l_0 = 210 (m) identified ✓ (l_0 for ship) = 231 (m) or (l for cargo) = 182 (m) ✓ Yes **AND** either $231 > 210$ **OR** $182 < 200$ ✓	Condone MP1 if L and L_0 are mixed up. Squares must be seen in substitution for MP1 but allow MP2 if missing. Correct substitution into $l = l_0\sqrt{1-\frac{v^2}{c^2}}$ gains first 2 marks e.g. $l = 210\sqrt{1-0.5^2}$ or $200 = l_0\sqrt{1-0.5^2}$ or equivalent MP3 implies MP2 but not MP1 MP3 is cao and can be awarded if MP1 is withheld for missing squares in working but answer is correct. Allow ecf for MP4 for missing squares or calculation error provided a cargo length is compared to a ship length based on an attempted relativistic calculation.	4	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	c	Speed of light is the same regardless of the speed of the observer or source	1	AO2
Total			**9**	