A-level
PHYSICS
7408/3BD

Paper 3 Section B Turning points in physics

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

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	Idea that filament/metal is heated (by an electric current), giving (some) electrons in the metal (sufficient) energy to leave the surface ✓	Allow references to the work function (but not just ϕ) Thermionic emission is not enough by itself. Do not allow heating of electrons. Reject 'accelerated' (unless it is clearly after they leave the metal) / 'ionise' Ignore references to processes that take place after electron leaves the metal Ignore references to free electrons inside the metal	1	1 × AO1

Question	Answers	Additional comments /Guidance	Mark	AO
01.2	Use of $\frac{1}{2}mv^2 = eV$ To give $v = 1.33 \times 10^7$ (m s^{-1}) ✓	Must see 500V for the potential difference (not 506.3V or 493.7V) ≥ 3 SF required. 1.325×10^7 (do not allow 1.32×10^7)	1	1 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	Suggestion that, for diffraction to be demonstrated, hole diameter should be of same order of size as wavelength ✓ Evidence of $\lambda = \frac{h}{p}$ **OR** $\lambda = \frac{h}{\sqrt{2meV}}$ to give 5.5×10^{-11} (m) OR 5.6×10^{-11} (m) ✓ Idea that this diameter is smaller than an atom / too small for hole to be made **and** therefore this apparatus cannot be used (for this speed/wavelength) / the student is **incorrect** ✓	Do not allow $\lambda <$ gap or gap $< \lambda$ for MP1 (Must refer to gap not just anode) Discussions in terms of crystalline diffraction can score MP1 and MP2. Must calculate λ for MP2. Condone use of 506.3V or 492.7V as penalised in 1.2 Allow 1 SF or order of magnitude calculation. Do not ignore PoT for calculation. Ignore incorrect conversion to nm if m value given. Condone the idea that the student is correct in principle but this particular setup will not work. Do not allow ecf to MP3 unless their calculated hole diameter is of the order of 10^{-10} m or smaller in MP2.	3	3 × AO3

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>01.4</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><td>Mark</td><td>Criteria</td></tr>
<tr><td>6</td><td>All three areas covered with at least two aspects 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>A fair attempt to analyse all three areas. If there are several errors or missing parts then 5 marks should be awarded.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be 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>
<tr><td>0</td><td>No relevant analysis.</td></tr>
</table>
</td>
<td>
For each area (bullet point), consider whether the response is fully addressed, partially addressed or not addressed. Typically, any missing points mean that the area is partially addressed.

Significance
Very large e/m (compared to value for hydrogen ion).
(Hydrogen ion had largest known specific charge at the time.)
Therefore particles have very small mass / very large charge (condone light for small mass)

Experimental procedures and measurements
For a full answer everything should be directly measurable (not Electric Field, Kinetic Energy, velocity)
Except no details are required for measurement of B

Determination of e/m
Answers should end in e/m =
Expected to be in steps but can carry the algebra through
Allow use of measured Electric Field here.
A full answer should not include e or m as part of the calculation (likely to be found in working out v)

If methods are mixed up this can be treated as full credit for one of procedures or determination or as a partial for both.

The minimum response required to address an area fully is given below
<hr>
Fine Beam Tube

Experimental procedure and measurements
fine beam tube described / diagram including low pressure gas,
(Perpendicular) magnetic field to cause electrons to move in a circle

Radius of curved path r, Accelerating voltage V, Magnetic flux density B

Determination of e/m
($\frac{1}{2}mv^2 = eV$ and $r = \frac{mv}{Be}$)
$\frac{e}{m} = \frac{2V}{r^2B^2}$
</td>
<td>6</td>
<td>4 × AO1
1 × AO2
1 × AO3</td>
</tr>
<tr><td>Total</td><td></td><td></td><td>11</td><td></td></tr>
</table>

Correct Alternative Methods		
Crossed Fields **Experimental procedure and measurements** Parallel plates with voltage applied. Magnetic field applied to produce balanced forces Accelerating voltage V_A When beam is horizontal: plate voltage V_p, plate separation d, magnetic flux density B **Determination of e/m** $\left(\frac{eV_p}{d} = Bev \Rightarrow\right) v = \frac{V_p}{dB}$ (allow $\frac{E}{B}$ from measured E) $\left(\frac{1}{2}mv^2 = eV_A \Rightarrow\right) \frac{e}{m} = \frac{v^2}{2V_A}$ or $\frac{e}{m} = \frac{V_p^2}{2d^2B^2V_A}$ or $\frac{e}{m} = \frac{E^2}{2B^2V_A}$	**Measure deflected distance** **Experimental procedure and measurements** Initial balanced magnetic and electrical forces to produce horizontal beam Measure magnetic flux density B, plate p.d. V, distance between plates d and length of plates x With no magnetic field, measure vertical deflection y **Determination of e/m** $\left(\frac{eV}{d} = Bev \Rightarrow\right) v = \frac{V}{dB}$ (allow $\frac{E}{B}$ from measured E) Horizontal motion: $t = \frac{x}{v}$ Vertical motion: $\left(y = 0t + \frac{1}{2}at^2 = \frac{1}{2}at^2 \Rightarrow\right) a = 2y/t^2$ $\left(a = \frac{F}{m} = \frac{eV}{dm} \Rightarrow\right) \frac{e}{m} = \frac{da}{V}$ Or any of $\frac{e}{m} = \frac{2dy}{Vt^2} = \frac{2dyv^2}{Vx^2} = \frac{2yV}{dx^2B^2}$	**Measure deflected angle** **Experimental procedure and measurements** Initial balanced magnetic and electrical forces to produce horizontal beam Measure magnetic flux density B, plate p.d. V, distance between plates d and length of plates x With no magnetic field, measure angle θ beam is deflected through **Determination of e/m** $\left(\frac{eV}{d} = Bev \Rightarrow\right) v = \frac{V}{dB}$ (allow $\frac{E}{B}$ from measured E) Horizontal motion: $t = \frac{x}{v}$ $v_y = v \tan\theta$ Vertical motion $\left(v_y = 0 + at = at \Rightarrow\right) a = \frac{v_y}{t}$ $\left(a = \frac{F}{m} = \frac{eV}{dm} \Rightarrow\right) \frac{e}{m} = \frac{da}{V}$

Incorrect Methods	
Milikan's Oil drop / use of measured weight / Gas tube / Crooke's tube / Discharge tube Partial credit for one area ONLY can be awarded for a good treatment that includes all of the following • At least one experimental detail • Some measurements • Some calculation	**Quantum Jumping or anything else** These cannot address areas 1 and 2 Ignore use of undescribed velocity selector, mass spectrometer, … No credit for measure Q and m and divide them.

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	(Reads off terminal speed from graph) to give 0.053 ± 0.005 mm s^{-1} ✓ Evidence of $mg = 6\pi\eta rv$ ✓ Substitutions seen to give 1.8×10^{-5} (N s m^{-2}) ✓	Allow PoT error in MP1 If MP1 not given, allow ecf if read off misread Do not accept work from a gradient. W or mg or $1.2 \times 10^{-14} = 6\pi\eta rv$ is enough for MP2 Condone $\frac{4}{3}\pi r^3 \rho g = 6\pi\eta rv$ for MP2. Calculator value = $1.766425562 \times 10^{-5}$	3	2 × AO2 1 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Evidence of $EQ = mg$ ✓ $Q = 6.4 \times 10^{-19}$ (C) ✓ Divides their Q by e to get number of electrons **and** makes sensible comment consistent with their value ✓	By substitution – allow PoT error for E in MP1 Allow $EQ = mg$ without substitution for MP1 Expect to see 4.0 or 3.99 ≈ 4 and therefore yes Condone for MP3 only (max 1) Use of $E = Q/4\pi\varepsilon_0 r$ which gives $Q = 6.04 \approx 6$ so yes.	3	2 × AO2 1 × AO3
Total			**6**	

Question	Answers	Additional comments/Guidance	Mark	AO
03.1	Sinusoidal electric field in vertical plane, in phase with magnetic field **AND** Indication of direction perpendicular to both fields ✓	Expect to see arrow at either end of long axis line Condone only one of E or ‘direction of propagation’ not labelled. Accept ‘direction’ for ‘direction of propagation’. Accept lower case e for E	1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
03.2	Maxwell ✓ CAO		1	1 × AO1

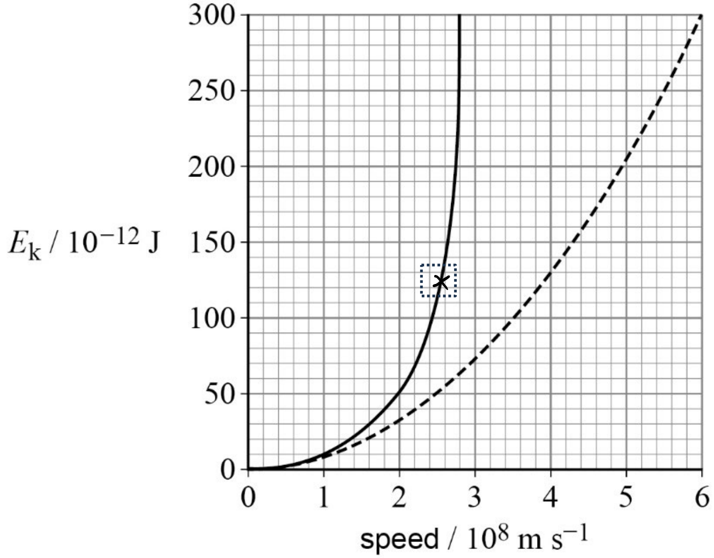
Question	Answers	Additional comments/Guidance	Mark	AO
03.3	Light is made of <u>corpuscles</u> ✓ When corpuscles meet boundary [any 2 from] ✓ • component of velocity/momentum parallel to surface unchanged • Component perpendicular to surface increases • (short range) force of attraction (to surface) • light travels faster in glass When corpuscles meet boundary [all 4] ✓ • component of velocity/momentum parallel to surface unchanged • Component perpendicular to surface increases • (short range) force of attraction (to surface) • bends towards the normal / angle of refraction < angle of incidence	Marks can be awarded for suitable labelled diagram Allow particles for corpuscles in MP2 and MP3 but not MP1. Condone references to horizontal/vertical components in MP2 but not MP3 unless clarified in diagram or text. Condone attracted / attraction for force of attraction Do not accept force of gravity but can still gain MP2 if 2 other points are made. Condone light bending wrong way for MP2 but not for MP3. Ignore short-range force of attraction to <u>normal</u> for MP2 but do **not** allow for MP3 If no other marks condone light is made of particles and one bullet from MP2 for 1 mark.	3	2 × AO1 1 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.4	Diffraction/interference experiment described ✓ describe / show in labelled diagram a feature that is only explained by waves e.g. series of maxima and minima, bright and dark, series of fringes, spectra (from diffraction grating not prism), bright spot in centre of double slit, intensity graph … ✓ diffraction/interference/superposition is a wave phenomenon **AND** describe how the feature would look with particles e.g. two bright spots, no bright spot in the centre, etc ✓	MP1 is for the set up. MP2 is for what is seen. MP3 is for showing why Newton's theory is not correct. Marks can be awarded for suitable labelled diagram Expect description of Young's double slits experiment but allow any suitable diffraction experiment, eg single slit or grating. Stating 'Young's Double Slits' is insufficient. For MP1 experiment must be consistent with description given in MP2 and MP3. Ignore experiment to measure speed of light in glass or any reference to refraction including producing a spectra from a prism. Ignore references to polarisation. Interference pattern is not enough for MP2. If no other marks allow 1 mark for 2 from • Young's double slits • Interference/diffraction • Interference/diffraction is a wave phenomenon	3	2 × AO1 1 × AO3
Total			**8**	

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	Either • Equation (for speed of light) only contains (universal) constants **OR** • Speed of light is invariant / constant / same in all reference frames / does not depend of speed of source or observer. ✓ Both bullet points above and **one** from • Constants don't depend on reference frame or speed of source / observer **OR** • (refers to the) speed of light as being in free space / vacuum ✓	Speed of light is constant in equation is not enough for MP1. Do NOT allow speed of light is invariant in all <u>inertial</u> reference frames for MP2 but condone for MP1. Ignore calculations of speed of light	2	1 × AO1 1 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	Use by manipulation or substitution of $l = l_0\sqrt{1-\frac{v^2}{c^2}}$ ✓ to give $69\ \mathrm{m}$ ✓	Condone substitution and working leading to 21 m e.g. $38\sqrt{1-\frac{2.5^2}{3^2}} = 21$ for 1 mark only. (mixes up l_0 and l) $l_0 = \frac{l}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{38}{\sqrt{1-\frac{2.5^2(\times 10^8)^2}{3.0^2(\times 10^8)^2}}}$ Allow use of $v = \frac{s}{t}$ and $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ for either route. 93 m comes from $\frac{38}{\sqrt{1-\frac{2.5}{3.0}}}$ and gains 1 mark.	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	Evidence of idea that kinetic energy = total energy – rest energy ✓ $E_k = \dfrac{m_0 c^2}{\sqrt{1 - \dfrac{v^2}{c^2}}} - m_0 c^2$ with substitutions correct ✓ 1.21 or 1.22×10^{-10} (J) ✓	If no other mark awarded, give one mark for calculation of total energy (2.72×10^{-10} J) or rest energy (1.5×10^{-10} J) Use of $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ with $E_k = \frac{1}{2}mv^2$ is 0 marks In MP2 allow use of γ from earlier 04.2 but value must be seen here. Allow rest energy = $931.5 \times 10^6 \times 1.60 \times 10^{-19}$ as part of calculation. At least 3 sf Allow 1.23×10^{-10} (J) A substitution missing the squares and showing 2.2×10^{-10} J is eligible for MP2.	3	3 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
04.4	Follows dashed line up to $v = 1$; condone divergence starting anywhere from $v = 0.3$ to $v = 1.1$ ✓ Increasing gradient passing within one grid square of $(2.5, 122)$ ✓ Increasing gradient and does not go beyond $v = 3$ ✓ 	For MP3, if line reaches $v = 3$ must be asymptoti'c MP3 should not be awarded if continuing the line would clearly cross $v = 3$	3	3 × AO3.1a
Total			**10**	