AQA

A-level
PHYSICS
7408/3BD

Paper 3 Section B Turning points in physics

Mark scheme

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2 4 6 A 7 4 0 8 / 3 B D / M S

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	Electrostatic force and magnetic force are equal in magnitude OR opposite in direction / magnetic force down and electrostatic force up OR equal and opposite ✓ Electrostatic force and magnetic force are equal in magnitude AND opposite in direction / magnetic force down and electrostatic force up AND Balanced **forces** / resultant force = 0 (so travels in a straight line according to Newton 1 / no (vertical) acceleration according to Newton 2) ✓	Allow electric force / force from electric field / force due to potential difference / force due to plates for electrostatic force. Ignore references to gravity. Electric and magnetic forces being equal without reference to magnitude or opposite is not enough for MP1. Ignore references to a vacuum so no collisions between particles. Ignore references to the directions of fields. Do not allow answers which suggest that the magnitude of magnetic field is equal to the magnitude of the electric field. Condone cancel for balanced forces in mp2 Ignore counteract in mp2. Do not allow **horizontal** force for mp2.	2	2 AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	$Bev = \frac{eV_{(P)}}{d}$ **OR** $v = \frac{V_{(P)}}{dB}$ ✓ $\frac{1}{2}mv^2 = eV_{(A)}$ **OR** $\frac{e}{m} = \frac{v^2}{2V_{(A)}}$ ✓ At least one correct from ✓ • $v = \frac{1.51\times10^3}{5\times10^{-2}\times1.59\times10^{-3}} (= 1.9\times10^7 \text{ m s}^{-1})$ • $\frac{e}{m} = \frac{(\text{their v})^2}{2\times1\times10^3}$ • $\frac{e}{m} = \frac{(1.51\times10^3)^2}{2\times1\times10^3\times(5\times10^{-2})^2\times(1.59\times10^{-3})^2}$ • $\frac{e}{m} = \frac{V_{(P)}^2}{2V_{(A)}d^2B^2}$ $1.8(0380523)\times10^{11}$ C kg^{-1} without using 1.60×10^{-19} or 9.11×10^{-31} ✓	Allow Q for e Condone mixed up V_A and V_P or no subscripts in first 2 marking points. $\frac{e}{m} = \frac{V_{(P)}^2}{2V_{(A)}d^2B^2}$ or any valid rearrangement gains mp1, mp2, mp3 Substituted data can gain MP1 and MP2 (in addition to MP3) Condone PoT errors in mp3 Do not credit values using 1.60×10^{-19} or 9.11×10^{-31} in mp3 or mp4 Do not allow 1.76×10^{11} for mp4 as this is from the data booklet not the data in the question. If no other marks are awarded, condone max 1 for $\frac{e}{m} = \frac{V}{2d^2B^2}$ with any or no V subscript	4	1 AO1 3 AO2
Total			**6**	

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>2.1</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 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>Method
Field is off or with the switch open
Measure time and distance (for falling drop)
(Measure distance using lines on microscope)
calculate velocity using $v = \frac{s}{t}$
Calculation (Just quoting formulae from the formulae and data booklet is not enough to partially address this area.)
$m = \frac{4}{3}\pi\rho r^3$
$mg = 6\pi\eta rv$
leading to $r = \sqrt{\frac{9\eta v}{2\rho g}}$
or $r = \sqrt{\frac{9\eta v}{2\rho g}}$ quoted
ρ is identified as the density of the oil
η is identified as the viscosity of the air

Principles/Assumptions (This area is normally fully addressed by 2 statements.)
Falls at terminal velocity since weight = viscous drag force / Stokes’ law
Air acts like a viscous fluid so Stokes’ law applies.
Balanced forces according to Newton 1 or 2
Oil droplet is spherical (hence $V = \frac{4}{3}\pi r^3$)
Upthrust is negligible / can be ignored.
Any mention that air resistance is negligible or not present when field is off would not allow this area to be fully addressed.
Ignore reference to free fall.</td><td>6</td><td>6 AO1</td></tr>
</table>

		Ignore details of Millikan's experiment that are not about determining r.		

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Max ✓✓ • Substitution into $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times (1.2 \times 10^{-6})^3$ • Substitution of $m = \rho V = 880 \times \text{their volume}$ • Substitution of $Q = \frac{dmg}{V} = \frac{6.0\times10^{-3}\times \text{their mass } \times 9.81}{467}$ $Q = 8.0(3) \times 10^{-19}$ (C) ✓	Max 2 if no equations are seen but only substitution (one for a correct substitution and one for correct answer) MP1 and MP2 require substitutions. Need ≥ 2 sf (no ecf in mp3)	3	3 AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	% uncertainty in $Q = 3 \times 4 + 1 + 0.1 + 0.2 + 2 = ((\pm)15(.3)\%)$ ✓1a uncertainty in $Q = \frac{15}{100} \times 8.02 \times 10^{-19} = (\pm)1.2 \times 10^{-19}$ (C) ✓2a **Alternative method for ✓1 and ✓2** max value of $Q = \frac{4\pi\times(1.2\times10^{-6}\times1.04)^3\times880\times1.01\times6\times10^{-3}\times1.02\times9.81\times1.001}{3\times467\times0.998}$ $(= 9.3(3) \times 10^{-19}$ C) **OR** min value of $Q = \frac{4\pi\times(1.2\times10^{-6}\times0.96)^3\times880\times0.99\times6\times10^{-3}\times0.98\times9.81\times0.999}{3\times467\times1.002}$ $(= 6.8(7) \times 10^{-19}$ C)✓1b Correct use of max or min value with $8(.02) \times 10^{-19}$ or half the range using max and min if their max and/or min comes from a correct method with up to one error in each✓2b $1.2 \times 10^{-19} > \frac{1.60 \times 10^{-19}}{2}$ therefore it is not possible to confirm charge quantisation (as any value is possible) ✓3	Allow fractional uncertainties in ✓1a Allow ecf for Q and % uncertainty ✓3 is independent if 1×10^{-19} is used or an answer that rounds to 1×10^{-19}. **Alternatives for ✓3** the possible range overlaps 4, 5, 6 electrons (allow 4, 5 or 5, 6 or 4, 6) Allow a calculated max and/or min value of Q $(8 \pm 1) \times 10^{-19}$ (expect 7 or 9) is not an (integer) multiple of 1.6×10^{-19} Condone because the uncertainty (not % uncertainty) is too close to 1.6×10^{-19}. Range or uncertainty or % uncertainty is too large is not enough without explicit comparison of absolute uncertainty with 1.60×10^{-19} in some form.	3	2 AO2 1 AO3
Total			**12**	

Question	Answers	Additional comments/Guidance	Mark	AO
03	Max 2 ✓✓ • Identified transmitter and detector as used by Hertz e.g. spark gap or dipole transmitter and dipole or loop receiver. • Correct placement of a (metal) reflector • Creation of a stationary (radio) wave with a reflector • Use a **movable** detector $\lambda = 2 \times$ max to **adjacent** max OR $2 \times$ min to **adjacent** min OR $4 \times$ max to **adjacent** min (divided by any multiples used in MP4) ✓ Use of a reflector (condone mirror) **AND** measure distance from (multiples of) max to max or min to min or max to min ✓ Use of a reflector (condone mirror) **AND** an attempt at a realistic measurement of λ **AND** $c = f\lambda$ ✓	**Award 0 marks for answers which do not use radio waves.** Ignore references to other experiments e.g. Fizeau. Ignore reference to use of computers or oscilloscopes. Evidence for MP1 and MP2 may come from a **labelled** diagram Condone MP1 and MP2 from other experiments with radio waves. Do **not** allow mirror for metal reflector in MP1 or MP2 but only penalise once. In MP3 and MP4 allow node for min and anti-node for max. A labelled diagram with λ clearly marked with an arrow (or equivalent) can gain MP3 Do not allow MP4 if first harmonic is used. MP4 may come from the diagram but a reference to what is measurement not just λ is required. Do **not** allow any reference to $v = \frac{s}{t}$ for MP5	5	5 AO1
Total			**5**	

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	Either conversion of 1 MeV to J or $W = QV$ $1.60 \times 10^{-19} \times 1.30 \times 10^{6} = 2.08 \times 10^{-13}$ ✓ (J)	At least 2 sf required.	1	1 AO1

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	$Q = mc\Delta\theta = 1.5 \times 903 \times 68.0$ (= 92 106 J) **OR** E_K of one electron $= \frac{92\ 106}{4.50 \times 10^{17}}$ ✓ $(= 2.05 \times 10^{-13}\ \text{J})$ Both calculations and correct conclusion, eg Yes, this is consistent with an accelerating voltage of 1.30 MV. ✓	Alternative route Total E_K for all electrons = $2.08 \times 10^{-13} \times 4.50 \times 10^{17} = (93\ 600\ \text{J})$ **OR** $\Delta\theta = \frac{Q}{mc} = \frac{93600}{1.5 \times 903}$ ✓ $(= 69.1\ \text{K})$ which is consistent with the temperature rise observed. ✓ Can also compare total E_K with $mc\Delta\theta$ for MP2. Use of 2.0×10^{13} gives total E_K of 90 000 J and $\Delta\theta$ of 66 K which is consistent. Allow comparison of in eV or accelerating pd (1.28×10^{6}) with 1.3×10^{6} V or MeV with MV.	2	2 AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	Correct calculation of non-relativistic E_K ✓a Statement or attempted use of $E_K = mc^2 - m_0c^2$ ✓b Correct calculation of relativistic E_K ✓c Both calculations and comparison of with 2.1 × 10^{-13} or 2.0 × 10^{-13} J to conclusion consistent with idea that student B is correct ✓d **Alternative** Calculation of speed using $v = \sqrt{\frac{2E_k}{m}}$ ✓a Statement or attempted use of $E_K = mc^2 - m_0c^2$ ✓b Calculation of speed from relativistic equation ✓c Both calculations and comparison of results with 2.88×10^8 or 3×10^8 ✓d **Alternative** for Max 2 Correct calculation of non-relativistic E_K ✓a Calculation of relativistic mass, total energy or $\sqrt{1 - v^2/c^2}$ or $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ **AND** comment that **relativistic effects are significant (owtte)** so B is correct. ✓bcd	$E_K = \frac{1}{2}mv^2 = 3.78 \times 10^{-14}$ J $E = \frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_0c^2 = 2.11 \times 10^{-13}$ J For ✓d allow a comparison of $\Delta\theta$ from $m_{Al}c\Delta\theta = N(mc^2 - m_0c^2)$ with 68° Allow ecf for ✓d for minor calculation error, rounding error or transcription errors but there must be a relativistic KE and non-relativistic calculation to award ✓d. $v = 6.8 \times 10^8$ m s^{-1} if using 2.08×10^{-13} $v = 2.88 \times 10^8$ m s^{-1} if using 2.08×10^{-13} Allow calculations based on the total number of electrons and comparison with **04.2**. If no other marks awarded max 1 for student B is correct because speed is greater than 3.0×10^7 m s^{-1} or v is 96% of c (which is greater than 10%).	4	4 AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.4	< 29.8 ns ✓		1	1 AO2

Question	Answers	Additional comments/Guidance	Mark	AO
04.5	Max 4 • **Gain/change in** E_K is the same ✓a • due to the same loss of potential energy **OR** gain in $E_K = e(\Delta)V$ and same potential difference ✓b • **Increase/change** in speed is greater in stage 1 ✓c • Idea that mass increases with speed ✓d • Idea that energy is used to produce a large increase of mass and a small increase in speed in stage 13 (with a small increase in mass and a large increase in speed in stage 1) ✓e1 **OR** Idea that electron speed cannot increase much when close to the speed of light since electrons cannot travel faster than the speed of light ✓e2	Only allow use of $\frac{1}{2}mv^2$ or $E_K \propto v^2$ if it is clear that this refers only to stage 1 for ✓b or ✓e. ✓d Allow a correct sketch of relativistic mass and speed graph if c is labelled on speed axis. ✓d Condone with reference to $E_K = \frac{1}{2}mv^2$ ✓e must refer to relativity.	4	4 AO3
Total			**12**	