AQA

# A- LEVEL

# Physics

## PHA5/2D – Turning Points in Physics
## Mark scheme

2450
June 2015

Version/Stage: v1 Final

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| Question | Answers | Additional Comments/Guidance | Mark | ID details |
|---|---|---|---|---|
| 1(a)(i) | There is a (constant) force acting which is (always) at right angles/perpendicular to the path/motion/velocity/direction of travel/to the beam<br>Or mentions a centripetal force✓<br><br>Force is at right angles to the magnetic field and the electron motion<br>Or<br>direction given by left hand rule✓ | First mark is for condition for circular motion<br>Not speed<br><br>Second mark is for a statement relating to the origin of the force<br>Any mention of attraction to the plates is talk out (TO) | 2 | |
| 1(a)(ii) | States $Bev = \frac{mv^2}{r}$ and evidence of correct intermediate stage showing manipulation of the formula<br><br>or<br><br>Quotes $r = \frac{mv}{Be}$ from formula sheet and change of subject to *v =Ber/m* seen | Accept delete marks<br>or rewrite as $Be = \frac{mv}{r}$<br>or rearrangement as $\frac{v^2}{v} = \frac{Ber}{m}$ | 1 | |
| 1(a)(iii) | States $Bev = \frac{eV}{d}$<br>or $F = Bev$ $F = \frac{eV}{d}$ (or $F=Ee$ and $E = \frac{V}{d}$ in any form)<br><br>and<br>states $v = \frac{V}{Bd}$✓ | Allow use of $e$ *or* $Q$<br><br>No mark for just quoting final equation. There must be evidence of useful starting equations | 1 | |

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| 1(b) | Equates the formulae for $v$ and shows $\frac{e}{m}$ equated to $\frac{V}{B^2rd}$ | Must include 'e/m = 'not just 'specific charge ='<br><br>Note there is no ecf. Candidates who use an incorrect equation in 1a(iii) will lose this mark unless they restart from first principles.<br>Condone *Q/m* | 1 | |

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| 1(c) | Using band marking<br>Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking.<br>**Level 1 (1-2 marks)**<br>Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure.<br>Unstructured answer<br>Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency<br>**Level 2 (3—4 marks)**<br>Answer has some omissions but is generally supported by some of the relevant points below:<br>- the argument shows some attempt at structure<br>- the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar<br>**Level 3 (5—6 marks)**<br>Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below: | | 6 | |

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| | - argument is well structured with minimum repetition or irrelevant points<br>- accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar<br><br>**A**<br>Measure the terminal speed of the falling droplet<br>At the terminal speed weight = viscous force (+ upthrust)<br><br>$mg = 6\pi\eta rv$ and $m = 4\pi r^3\rho/3$ so $r^2 = \frac{9\eta v}{2\rho g}$<br><br>$r$ could be determined as density of drop, viscosity of air and $g$ are known($r$ is the only unknown)<br><br>**B**<br>$m$ can be determined if $r$ is known<br><br>Apply pd between the plates so electric field = $V/d$ and adjust until droplet is stationary<br><br>$QV/d = mg$ so $Q$ can be found<br><br>**C**<br>Make a number of measurements to find $Q$<br><br>Results for $Q$ are in multiples of $1.6 \times 10^{-19}$C so $Q$ can be found | e.g.<br>1-2<br>Superficial with some sensible comments about the procedure with significant errors in attempts at use of equations. May do one part of A B or C reasonably well. Relevant Equations without little explanation may be worth 1.<br><br>3-4<br>Should cover most of the point in two of A, B & C coherently<br>A & B may be well done in an answer that is easy to follow<br>or B and C may be well explained but there may be significant errors or omissions in the determination of *r.*<br>or a bit of all A B and C with significant errors or omissions<br><br>5-6<br>Will cover the points made in A B & C with few omissions in an answer that is easy to follow. The candidate will define some terms used in | | |

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| | | equations.<br><br>1-2<br>Attempt to explain how to determine radius with detail of how to use data<br>or<br>Makes a relevant point about some part of the procedure about the determination<br><br>3-4<br>radius determination explained with sensible equations<br>explanation of how to use data to find mass of the drop<br>Idea of holding the drop stationary<br><br>5-6<br>Answer includes all steps to determine the charge of a droplet with correct equations showing how to use the measurements<br><br>For highest mark the answer should include idea of interpreting results of many measurements | | |
| **Total** | | | 11 | |

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| 2(a)(i) | Appreciation that one component changes speed while the other component at right angles does not✓<br><br>When entering a denser medium a corpuscle /light accelerates or its velocity/momentum increases perpendicular to the interface ✓<br><br>There is a (short range) attractive force between light corpuscle and the (denser) material✓ | Not allowed:<br>Attraction due to opposite charges<br>Force making them move faster is not enough<br>Accelerate in medium<br>Not gains energy | 3 | |
| 2(a)(ii) | Light (was shown by experiment to) travel slower in (optically)denser medium OWTTE✓<br><br>Newton's theory required light to travel faster, wave theory suggested slower speed✓<br>or<br>Newton's theory could not explain the slower speed<br>or<br>Huygens theory could explain the slower speed | Condone 'waves..' instead of 'light'<br>OWTTE e.g. speed in vacuum higher than speed in other medium<br><br>Not allowed:<br>Reference to Young's two slit- question asks them about refraction. | 2 | |
| 2(a)(iii) | A corpuscular theory predicts only two (bright) lines/high intensity patches of light whereas a wave theory predicts many fringes✓<br><br>Corpuscles can only travel in straight lines<br>or<br>waves can produce fringes because (diffract and) interfere/superpose/ arrive in and out of phase/have different path differences ✓ | Need to describe the patterns ie not just interference fringes are seen for the first mark | 2 | |

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| 2(b) | Substitutes data in photon wavelength = *hc/E* ; Allow for substitution with no conversion to J✓<br><br>2.48 x $10^{-10}$ m✓<br><br>For electron: Substitution in $\lambda = \frac{h}{\sqrt{2mE}}$<br><br>2.48 x $10^{-10}$(or their λ)<br>= 6.6 x $10^{-34}$/(2 x 9.11 x $10^{-}$31x 1.6 x $10^{-19}$ *V*)$^{1/2}$ ✓<br><br>*V* = 24(.4) V✓ =1.49 x $10^{-18}$/(their λ)$^2$✓<br><br>May calculate *v* using *v* = *h/mλ* then substitution in *V* = ½ *mv*$^2$/*e* ✓(for third mark) | No conversion to J gives λ ≈4 x $10^{-29}$ and *V* ≈ 9 x $10^{38}$ V)<br><br>Allow small rounding errors in dp | 4 | |
| **Total** | | | 11 | |

| Question | Answers | Additional Comments/Guidance | Mark | ID details |
|---|---|---|---|---|
| 3(a) | They expected the time taken for the light to travel in one direction to be different from the other✓<br>or<br>Expected light to travel at different speeds in the two directions<br><br>There would be a phase shift /change in the phase relationship | However expressed e.g. in terms of the different times taken parallel and at right angles to the Earth's motion(through the Aether)<br><br>Not<br>longer/different paths<br>or<br>path difference | 2 | |

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| 3(b)(i) | speed through aether<br>= circumference of Earth orbit around the Sun<br>time for one orbit (1 year)<br><br>or $v = (GM/r)^{1/2}$ with $M$ and $r$ defined | Need to be clear about the distance and time.<br><br>Watch out for confusion between Earth's orbit around the Sun and Earth's rotation on its axis | 1 | |
| 3(b)(ii) | 11 m | | 1 | |
| 3(c) | Experiment showed speed of light from moving object is same as that from stationary object or<br>Speed of light in direction of motion is same as in perpendicular direction or<br>speed of light does not depend on speed of source or observer<br>Speed of light being invariant<br>or<br>Aether theory incorrect/no aether/no absolute motion<br><br>It was a postulate/assumption of the theory of special relativity<br>Or this supports the theory✓ | Allow is always $3 \times 10^8$ m $s^{-1}$ in air or vacuum instead of invariant<br><br>Second mark is for explicitly linking the observation to Einstein's theory | 2 | |
| **Total** | | | 6 | |

| Question | Answers | Additional Comments/Guidance | Mark | ID details |
|---|---|---|---|---|
| 4(a)(i) | Distance travelled in muons' frame of reference<br>= $10700(1-0.996^2)^{1/2}$ =956 m✓<br>Time taken in muons' frame of reference = 3.2 μs✓<br>This is 2 half-lives so number reaching Earth = 250✓<br>**OR**<br>Time in Earth frame of reference<br>= $10700/(0.996 \times 3 \times 10^8) = 3.581 \times 10^{-5}$ s✓<br>Time taken in muons' frame of reference = 3.2 μs✓<br>This is 2 half-lives so number reaching Earth = 250✓<br>**OR**<br>Half-life in Earth frame of reference<br>$=1.6 \times 10^{-6}/(1-0.996^2)^{1/2} = 17.9 \times 10^{-6}$ s✓<br>Time taken = $35.8 \times 10^{-6}$ s✓<br>This is 2 half lives so number reaching Earth = 250✓<br>**OR**<br>Distance travelled in muons' frame of reference<br>= $10700(1-0.996^2)^{1/2}$ =956 m✓<br>Distance the muon travels in one half-life in muons reference frame<br>= $0.996 \times 3 \times 10^8 \times 1.6 \times 10^{-6}$ = 478 m✓<br>Therefore 2 half-lives elapse to travel 956 m so number = 250✓<br>**OR**<br>decay constant in muon frame of reference<br>or decay constant in the Earth frame of reference✓<br><br>Uses the corresponding elapsed time and decay constant in<br>$N = N_o e^{-\lambda t}$✓<br>Arrives at 250✓ | All steps in the working must be seen<br>Award marks according to which route they appear to be taking.<br><br>The number left must be deduced from the correct time that has elapsed in the frame of reference they are using. | 3 | |

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| 4(a)(ii) | <table><tr><th></th><th>✓ if correct</th></tr><tr><td>For an observer in a laboratory on Earth the distance travelled by a muon is greater than the distance travelled by the muon in its frame of reference</td><td>✓</td></tr><tr><td>For an observer in a laboratory on Earth time passes more slowly than for a muon in its frame of reference</td><td></td></tr><tr><td>For an observer in a laboratory on Earth, the probability of a muon decaying each second in lower than it is for a muon in its frame of reference</td><td></td></tr></table> | | 1 | |
| 4(b)(i) | Total energy = $9.11 \times 10^{-31} \times (3 \times 10^{8})^{2}/(1-0.98^{2})^{1/2}$ ✓<br>$4.12 \times 10^{-13}$ J seen to 2 or more sf ✓ | Show that so working must be seen | 2 | |
| 4(b)(ii) | Change = $7.5 \times 10^{-14}$ J<br>*V* = 469 (470) kV allow ecf using their answer to (b)(i) ✓ | ecf is their ((b)(i) $-3.37) \times 10^{-13}/1.6 \times 10^{-19}$<br>Using $4 \times 10^{-13}$ gives 394 (390)kV<br>Using $3.9 \times 10^{-13}$ gives 331(330) kV<br>Do not allow 1 sf answer | 1 | |
| **Total** | | | 7 | |