AQA

A- LEVEL

Physics

PHA5/2D – Turning Points in Physics
Mark scheme

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Version/Stage: v1 Final

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 Assessment Writer.

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

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 Or mentions a centripetal force✓ Force is at right angles to the magnetic field <u>and</u> the electron motion Or <u>direction</u> given by left hand rule✓	First mark is for condition for circular motion Not speed Second mark is for a statement relating to the origin of the force 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 or Quotes $r = \frac{mv}{Be}$ from formula sheet and change of subject to $v = Ber/m$ seen	Accept delete marks or rewrite as $Be = \frac{mv}{r}$ or rearrangement as $\frac{v^2}{v} = \frac{Ber}{m}$	1	
1(a)(iii)	States $Bev = \frac{eV}{d}$ or $F = Bev$ $F = \frac{eV}{d}$ (or $F=Ee$ and $E = \frac{V}{d}$ in any form) <u>and</u> states $v = \frac{V}{Bd}$✓	Allow use of e or Q No mark for just quoting final equation. There must be evidence of useful starting equations	1	

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 =' Note there is no ecf. Candidates who use an incorrect equation in 1a(iii) will lose this mark unless they restart from first principles. Condone *Q/m*	1	

1(c)	Using band marking 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. **Level 1 (1-2 marks)** Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency **Level 2 (3—4 marks)** Answer has some omissions but is generally supported by some of the relevant points below: - the argument shows some attempt at structure - the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar **Level 3 (5—6 marks)** Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:		6	

	- argument is well structured with minimum repetition or irrelevant points - accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar **A** Measure the terminal speed of the falling droplet At the terminal speed weight = viscous force (+ upthrust) $mg = 6\pi\eta rv$ and $m = 4\pi r^3\rho/3$ so $r^2 = \frac{9\eta v}{2\rho g}$ r could be determined as density of drop, viscosity of air and g are known(r is the only unknown) **B** m can be determined if r is known Apply pd between the plates so electric field = V/d and adjust until droplet is stationary $QV/d = mg$ so Q can be found **C** Make a number of measurements to find Q Results for Q are in multiples of 1.6×10^{-19}C so Q can be found	e.g. 1-2 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. 3-4 Should cover most of the point in two of A, B & C coherently A & B may be well done in an answer that is easy to follow or B and C may be well explained but there may be significant errors or omissions in the determination of *r.* or a bit of all A B and C with significant errors or omissions 5-6 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		

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

Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)(i)	Appreciation that one component changes speed while the other component at right angles does not✓ When entering a denser medium a corpuscle /light accelerates or its velocity/momentum increases perpendicular to the interface ✓ There is a (short range) attractive force between light corpuscle and the (denser) material✓	Not allowed: Attraction due to opposite charges Force making them move faster is not enough Accelerate in medium Not gains energy	3	
2(a)(ii)	Light (was shown by experiment to) travel slower in (optically)denser medium OWTTE✓ Newton's theory required light to travel faster, wave theory suggested slower speed✓ or Newton's theory could not explain the slower speed or Huygens theory could explain the slower speed	Condone 'waves..' instead of 'light' OWTTE e.g. speed in vacuum higher than speed in other medium Not allowed: 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✓ Corpuscles can only travel in straight lines or 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	

2(b)	Substitutes data in photon wavelength = *hc/E* ; Allow for substitution with no conversion to J✓ 2.48 x 10^{-10} m✓ For electron: Substitution in $\lambda = \frac{h}{\sqrt{2mE}}$ 2.48 x 10^{-10}(or their λ) = 6.6 x 10^{-34}/(2 x 9.11 x 10^{-}31x 1.6 x 10^{-19} *V*)$^{1/2}$ ✓ *V* = 24(.4) V✓ =1.49 x 10^{-18}/(their λ)^2✓ 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) 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✓ or Expected light to travel at different speeds in the two directions 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) Not longer/different paths or path difference	2	

3(b)(i)	speed through aether = <u>circumference of Earth orbit around the Sun</u> time for one orbit (1 year) or $v = (GM/r)^{1/2}$ with M and r defined	Need to be clear about the distance and time. 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 Speed of light in direction of motion is same as in perpendicular direction or speed of light does not depend on speed of source or observer Speed of light being invariant or Aether theory incorrect/no aether/no absolute motion It was a postulate/assumption of the theory of special relativity Or this supports the theory✓	Allow is always 3×10^8 m s^{-1} in air or vacuum instead of invariant Second mark is for e<u>xplicitly</u> 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 $= 10700(1-0.996^2)^{1/2} = 956$ m✓ Time taken in muons' frame of reference = 3.2 μs✓ This is 2 half-lives so number reaching Earth = 250✓ **OR** Time in Earth frame of reference $= 10700/(0.996 \times 3 \times 10^8) = 3.581 \times 10^{-5}$ s✓ Time taken in muons' frame of reference = 3.2 μs✓ This is 2 half-lives so number reaching Earth = 250✓ **OR** Half-life in Earth frame of reference $=1.6 \times 10^{-6}/(1-0.996^2)^{1/2} = 17.9 \times 10^{-6}$ s✓ Time taken = 35.8×10^{-6} s✓ This is 2 half lives so number reaching Earth = 250✓ **OR** Distance travelled in muons' frame of reference $= 10700(1-0.996^2)^{1/2} = 956$ m✓ Distance the muon travels in one half-life in muons reference frame $= 0.996 \times 3 \times 10^8 \times 1.6 \times 10^{-6} = 478$ m✓ Therefore 2 half-lives elapse to travel 956 m so number = 250✓ **OR** decay constant in muon frame of reference or decay constant in the Earth frame of reference✓ Uses the corresponding elapsed time and decay constant in $N = N_o e^{-\lambda t}$✓ Arrives at 250✓	All steps in the working must be seen Award marks according to which route they appear to be taking. The number left must be deduced from the correct time that has elapsed in the frame of reference they are using.	3	

4(a)(ii)	<table><tr><td></td><td>✓ if correct</td></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 = $9.11 \times 10^{-31} \times (3 \times 10^{8})^{2}/(1-0.98^{2})^{1/2}$ ✓ 4.12×10^{-13} J seen to 2 or more sf ✓	Show that so working must be seen	2	
4(b)(ii)	Change = 7.5×10^{-14} J *V* = 469 (470) kV allow ecf using their answer to (b)(i) ✓	ecf is their ((b)(i) $-3.37) \times 10^{-13}/1.6 \times 10^{-19}$ Using 4×10^{-13} gives 394 (390)kV Using 3.9×10^{-13} gives 331(330) kV Do not allow 1 sf answer	1	
Total			7	