AQA

A-level
Physics

PHYA5/2D – Turning Points in Physics
Mark scheme

2450
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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 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.

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Question	Answers	Additional Comments/Guidance	Mark
1(a)	Experiments suggested cathode rays were negatively charged particles✓ Particle has mass much smaller than mass of an atom/hydrogen ion **OR** Compares Specific charge with that of hydrogen ion/atom✓ Particles were part of the substructure of matter/atoms✓ Particles emitted in each case were the same **OR** Particles emitted were the same for different gases/for photoelectrons and particles from thermionic emission✓	MAX 2 Specific charge defined =0 Millikan/Rutherford deductions=0 Do not allow small mass alone Allow proton *Allow two correct deductions in 1 or 2 provided that the other comment is not relevant but does not contradict*,	2
1(b)(i)	electrons collide with atoms of gas✓ (condone molecules) *Reference to collisions with nucleus = 0 for the question* atoms/electrons are excited or atoms /electrons change to higher energy states✓ light/photon emitted when relaxation/de-excitation occurs or as electrons move/fall back to lower energy level✓	Do not allow • collide with gas unless atoms mentioned later • particles • electrons absorbed by atoms Allow move from ground state Allow return to ground state	3

1(b)(ii)	$eV = ½\ mv^2$ **and** $\frac{mv^2}{r} = Bev$ or $\frac{e}{m} = \frac{v}{Br}$ in any form ✓ or $\frac{e}{m} = \frac{2V}{B^2r^2}$ Correct substitution of data in the question allowing errors in powers of 10✓ 1.9 x10^{11} ✓ C kg^{-1} ✓	Must be seen Substitution of values of *e* and m_e can gain 1st and last marks only	4
Total			9

Question	Answers	Additional Comments/Guidance	Mark
2(a)	**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 0 Nothing of relevance** **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:** **- 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**		6

	examples of possible points in the response **Observations** • Initially ammeter record current • as pd increases the current decreases • eventually current becomes 0 **Emission** • Photons/light cause emission of electrons • Emitted electrons have KE (if photon energy > work function • pd tends to stop emitted electrons reaching the electrode/anode (**not** stop electrons being emitted) • Recognises that the electrode is negative w.r.t. the cathode or vice versa • Recognises that there are a range of electron KEs • Explains why there is a range of KEs • Electrons with low energy stopped (first) so current decreases **Stopping potential** • The potential between the electrodes when the current =0 • The potential that prevents electrons reaching the anode/electrode • Stopping potential depends on maximum electron KE **Application of Einstein equation** • Use of $E_{k(max)} = hf - \phi$ • Defines terms • Explain/identifies that stopping potential x electron charge = atoms/molecules/electrons $V_s\ e = E_{k(max)}$		**extra information** **5-6** will address 3 aspects well or all 4 with minor omissions in coherent response **3-4** will address three of the points with significant omissions or e,g, give good response to 2 parts **1-2** may give brief but relevant comments on • the emission • what is meant by stopping potential • Some attempt to apply Equation **0** makes no relevant comment	

2(b)(i)	Kinetic energy of emitted electrons = 0.24 X 1.6 x 10^{-19} **or** 0.38 x 10^{-19}(J) seen✓ energy of photon incident = 6.63 x 10^{-34} x 3 x 10^{8} /490 x 10^{-9} **or** 4.06 x 10^{-19}(J) seen✓ Work function = 3.68 x 10^{-19} (J)✓ Or energy of photon incident = 6.63 x 10^{-34} x 3 x 10^{8} /490 x 10^{-9}= 4.06 x 10^{-19}(J)✓ (energy of photon incident=2.54 eV so) work function =2.30 eV✓ Work function = 3.7 (3.68) x 10^{-19} (J) ✓	Must see all values substituted to get the mark by substitution	3
2(b)(ii)	No of electrons emitted = 6.1 x 10^{-6}/ their photon energy(1.5(1.48) x 10^{13} if correct) ✓ Current = Their electron number x 1.6 x 10^{-19} (2.4(2.37) μA if correct) ✓	Allow for first mark only 6.16 x $10^{—6}$/work function (1.65x 10^{13}) Allow ecf for incorrect calculation of photon energy from (b))(i) or first step	2
Total			11

Question	Answers	Additional Comments/Guidance	Mark
3(a)	electric field strength **and** magnetic flux density/magnetic field strength✓ They are in phase with each other ✓ **OR** Phase difference = 0 (not 2π)	Allow *E* and *B* (not E field and B field) Not electric field and magnetic field Not allowed if quantities are mentioned are not related to electric and magnetic fields(e.g. frequency & wavelength) or no quantities given	2
3(b)(i)	Direct and reflected waves superpose/ Waves arriving directly interfere with reflected waves. Or Direct and reflected wave produce a stationary wave✓ When a maximum constructive interference or explanation of condition and minimum destructive interference or explanation of condition Or maximum/constructive interference at antinode and minimum /destructive interference at a node✓ Explains maximums/antinodes and minimums/nodes in terms of wavelengths, relative phase or path difference✓ i.e. there is constructive interference/antinode • reflected wave travels whole number of wavelengths further • path difference is whole number of wavelengths • waves are in phase destructive interference minimum/node when • the direct and reflected waves interfere destructively • the waves become antiphase/180° out of phase • path difference is $\lambda/2$ or $(n+1/2)\ \lambda$	Do not allow superimpose Do not allow out of phase	3

3(b)(ii)	Wavelength = $\frac{3\times10^{8}}{2.2\times10^{9}}$ **or** 0.136 m (0.14) seen or appreciates that the reflector has to move $\lambda/4$✓ 0.034 or 0.035 (m) ✓	Penalise 1 sf answer	2

3(c)	<table><tr><td>Light is diffracted when it falls on a slit</td><td></td></tr><tr><td>Light travels as 3×10^{8} m s^{-1} in free space</td><td>✓</td></tr><tr><td>Light changes speed when it enters a medium of different optical density</td><td></td></tr><tr><td>Light can be polarised when it is passes through polaroid</td><td></td></tr></table>		1
Total			11

Question	Answers	Additional Comments/Guidance	Mark
4(a)	The laws of physics are the <u>same</u> in <u>all inertial</u> frames of reference OWTTE	Allow specified laws e,g, Newton's laws applies in all inertial frames of reference Do not allow laws of physics are **obeyed or apply** Allow any/every inertial frame of reference	1

4(b)(i)	Converts 24 GeV to J $24 \times 10^{9} \times 1.6 \times 10^{-19}$ or 3.84×10^{-9} (J) seen✓ 3.84×10^{-9} or $24 \times 10^{9} = \frac{9.11\times10^{-31}\times(3\times10^{8})^{2}}{(-9.11 \times 10^{-31} \times (3 \times 10^{8})^{2})}$ ✓ 2.14 or 2.13×10^{-5}✓ from correct working at least 3 sf needed	Many convert to equivalent mass 4.27×10^{-26} and then work in masses throughout May include the bracketed term. Depending on whether they assume 24 GeV to be the total energy or the kinetic energy Allow incorrect powers of 10 May use given and find energy and compare with 24 GeV	3
4(b)(ii)	$3000 \times 2.1 \times 10^{-5} = 0.063$ or 0.064 m✓		1
4(c)	Starts at m_0✓ Shallow increase to • no more than $2m_o$ at $0.7c$ • curves (sharply) upwards becoming greater than $0.9c$ at $6m_o$ • never greater than $1.0\ c$ • within ½ square of $1.0c$ at $12m_0$ ✓	Never greater than $1.0c$ Allow statement of asymptote	2
Total			7