A-LEVEL
PHYSICS A

PHYSICA5/2D – Turning points in Physics
Mark scheme

2450
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Version 1.0 Final

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Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a)	(i)	Electrons pulled out of (gas) atoms so(gas) atoms become (+) ions OR ionisation by collision (also) occurs OR (+) ions (that) hit cathode causing it to release electrons ✓ conduction due to electrons and <u>positive </u>ions ✓	2	; Allow 'electrons ionise atoms' as compensation mark (if no marks elsewhere)
1	a)	(ii)	ions and electrons (moving in opposite directions)collide (with each other) and recombine and emit photons ✓ electrons excite gas atoms (by collision) and photons are emitted when de-excitation occurs ✓ gas needs to be at sufficiently low pressure in order that the particles (or uncharged gas atoms/ions/electrons) in the gas are widely spaced ✓ otherwise (+) ions and/or electrons/particles would be stopped by gas atoms OR so that ions/electrons are accelerated (or gain enough ke) to cause excitation ✓	3max	Owtte If light not photons given in 1st 2 mark points, 1 max for 1st two mark points Owtte

1	b)		Specific charge = charge / mass (and charge(s) of ion does not depend on the type of gas) ✓ Mass of ion depends on the type of gas ✓	2	Accept Q/m in symbols Q/m but not e/m if e/m is specifically stated as specific charge

2	a)		emitted electrons have a range of speeds✓ (electrostatic) force acting on electrons emitted from surface increases OR pull/attraction on electrons from surface increases✓ microammeter reading due to electrons reaching T (moving round circuit)✓ (microammeter reading decreases because) electrons unable to reach T due to increasing force(or insufficient ke or too much work needed) ✓	3max	Alternative for last point ; (microammeter reading decreases because) fewer electrons can reach T as pd increases,

2	b)	(i)	Graph ; straight line with a positive gradient ✓ intercept on + x-axis (or on – y-axis if drawn) ✓	2	Need to see 1st point to get the 2nd point

2	b)	(ii)	$E_{K(max)} = eV_S$ (or $E_{K(max)}$ proportional to V_S) ✓ gives $eV_S = hf - \varphi$ where hf = photon energy and φ = work function of metal ✓ Graph of V_S against f is a straight line with gradient h/e✓ and x-intercept = φ / h (or y-intercept = $-\varphi / e$) ✓	3 max	Alt for 2nd mark; recognition that $V_S = \frac{hf}{e} - \frac{\varphi}{e}$ where φ = work function of metal so this is equation for st line (or $y = mx + c$) Accept either of last 2 marks if shown on the graph clearly

2	c)		$hf = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{418\times10^{-9}} = 4.76\times10^{-19}$ J ✓ $E_{K(max} = eV_S = 1.6\times10^{-19}\times1.92 = 3.07\times10^{-19}$J ✓ $\varphi = hf - E_{K(max)}$ (or $4.76\times10^{-19} - 3.07\times10^{-19}$) $= 1.69\times10^{-19}$ ✓ J ✓ (or 1.06 eV)	**4**	Accept sub or ans for marks1 and 2 (Ans in J ; allow 1.7 or 1.66* or 1.70 in place of 1.69) (Ans in eV ; allow 1.1 or 1.04*) *arises from rounding 3.07 to 3.1)

3	a)	(i)	(kinetic energy is constant because) The (magnetic) force on a moving electron is always perpendicular to its velocity/direction of motion ✓ (so) no work is done on the electron (by the field) OR no acceleration in the direction of motion ✓	2	
3	a)	(ii)	$\lambda\ (=\frac{h}{\sqrt{2meV}}) = \frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times1.60\times10^{-19}\times21000}}$ ✓ $= 8.5\times10^{-12}$ m ✓ correct to 2sf only ✓ (Alternative ; use of $\frac{1}{2}mv^2 = eV$ gives $v = 8.59\times10^{7}$ m s^{-1} ✓ , and use of $\lambda = h / mv$ gives answer above ✓correct to 2sf ✓)	3	Correct ans <u>only</u> gets 1st 2 marks (+ SF mark if SF correct) SF mark can only be given if some valid working is provided. For value of v , accept ans in range 8.5 to 8.6 to any number of sfs

3	b) **QWC**	**Descriptor**	**Mark**	
	Good - Excellent	The candidate provides a comprehensive and logical description of most of the physical processes that occur and recognises at least two relevant properties, including a relevant wave property and a relevant particle property. The candidate also appreciates why and where in the instrument each of these properties is relevant to the formation and quality of the image. Their answer should be well-presented in terms of spelling, punctuation and grammar.	5 or 6	

Modest – adequate	The candidate provides a logical and coherent description of some of the physical processes that occur and includes a relevant wave property or a relevant particle property. The candidate also appreciates why and where in the instrument each of these properties is relevant to the formation and quality of the image although their explanation of why each property is relevant may be sketchy. Their answer should be adequately or well-presented in terms of spelling, punctuation and grammar.	3 or 4
Poor to limited	The candidate recognises a wave property and/or a particle property that are relevant in the context of the instrument although they may not be able to identify where in the instrument each property is relevant . They may confuse their account with incorrect terms such as interference and refraction. Their answer may lack coherence and may contain a signifcant number of errors in terms of spelling and punctuation.	1 or 2

The explanations expected in a good answer should include most of the following physics ideas

A At the sample ;-

1. electrons passing through the sample are scattered/diffracted by structures in the object which is a wave property .

B At the magnetic lenses

1. magnetic lenses deflect the electrons which is a particle property
2. 1st lens (condenser lens) forms electrons into a parallel beam directed at the sample
3. 2nd lens (objective) deflects and focuses the electrons to form an (intermediate) image
4. 3rd lens (magnifier) deflects and focuses the electrons to form a magnified image on the screen

C At the screen

1.electrons collide with atoms of the screen and excite atoms by collision which is a particle property

2. excited atoms emit photons (so image is visible)

D Image quality affected by

1. loss of ke/speed (or increase of de Broglie wavelength) in passing through image affecting deflection / focusing by magnetic lenses
2. repeat scattering/diffraction of electrons passing through the object if the object is too thick.
3. diffraction of electrons occurs as they pass through each lens
4. diffraction affects resolution of nearby image points (on the screen)
5. point objects that are too close overlap / can't be resolved

4	a)		(A frame of reference) that has a constant velocity ✓	1	accept no acceleration

4	b)	(i)	Distance = 4.3 c light years (or 4.1×10^{16} m) Speed $\left(= \dfrac{4.3\,c}{5.0}\right) = 2.6 \times 10^{8}$ m s^{-1} (or 0.86 c)	**1**	Correct answer only gets the mark Accept 2.58

4	(b)	(ii)	$t = \left(\dfrac{t_o}{(1 - v^2/c^2)^{1/2}}\right)$ where t = 5.0 years (or 1.58×10^{8} s) and v = 0.86 c (or 2.58×10^{8} m s^{-1}) 1st mark for correct substitution of either t or v into the above eqn ✓ t_o = 5.0 x $(1 - (0.86c)^2/c^2)^{1/2}$ ✓ = 2.6 years ✓ **Alt scheme** $l = l_o\,(1 - v^2/c^2)^{1/2}$ where t = 5.0 years (or 1.58×10^{8} s) and v = 0.86 c(or 2.58×10^{8} m s^{-1}) 1st mark for correct substitution of either t or v into the above eqn ✓ (l_o = 4.3 x 365 x 24 x 3600 x 3.0 x 10^{8} = 4.07×10^{16} m) l = $4.07 \times 10^{16}\,(1 - (0.86c)^2/c^2)^{1/2}$ or 2.08×10^{16} m✓ $t_o = \dfrac{l}{v}\left(= \dfrac{2.08 \times 10^{16}\ \text{m}}{2.6 \times 10^{8}\ \text{m/s}} = 8.05 \times 10^{7}\text{s}\right)$ = 2.6 years ✓	**3**	CF from bi to bii provided answer to bi < c Accept t or v in alternative units Accept 1.58 (or 1.6) x 10^{8} s in place of 5.0 yr in 3rd mark point Accept 2.5 to 2.6 to any number of sfs Alternative for last 2 marks in Alt scheme (l_o = 4.3 l yr) l = 4.3 $(1 - (0.86c)^2/c^2)^{1/2}$ = 2.2 l yr✓ $t_o = \dfrac{l}{v}\left(= \dfrac{2.2}{0.86}\right)$ = 2.6 years ✓

Total = 35