A Level AQA Physics

27 Discovery of the electron – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	Anode is positive; cathode is negative	Both needed for mark	1	1	3.12.1.1
01.2	When a magnet was brought near the tube, the positive column was distorted/deflected		1	1	3.12.1.1
01.3	The applied potential difference is sufficient to produce an electric field that pulls electrons out of atoms and ionises them When the positive ions and electrons recombine, photons are emitted		1 1	1	3.12.1.1
01.4	Some electrons that were pulled out of the gas do not recombine, but are pulled away from the cathode, so appear to come from the cathode, (not the anode)		1	2	3.12.1.1
01.5	Using magnetic fields The direction of deflection would show the charge Using electric fields The deflection would give an indication of mass		1 1 1 1	1	3.12.1.1
02.1	The electrons emitted from the filament would collide with air molecules and not reach the screen.		1	1	3.12.1.2
02.2	V_1 is the p.d. in a circuit that is used to heat the cathode / cause thermionic emission To give the free/conduction electrons enough energy to escape V_2 is the pd in a circuit that is used to accelerate the electrons		1 1 1	2	3.12.1.2
02.3	$eV = \frac{1}{2}mv^2$ $V = \sqrt{\frac{2eV}{m}}$ $= \sqrt{\frac{2 \times 1.61 \times 10^{-19} \times 4500}{9.11 \times 10^{-31}}}$ $= 3.98 \times 10^7\ \text{m s}^{-1}$	Substitution Answer	1 1	2	3.12.1.2

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02.4	If the p.d. is decreased, the energy of the electrons is less When the electron hits the screen, it transfers less energy to the atoms in the phosphor/fluorescent screen Fewer electrons in the atoms of the screen are excited to a higher level and subsequently return to their original level Fewer photons are emitted from the screen, so the dot appears dimmer		1 1 1 1	3	3.12.1.2
03.1	The largest specific charge known at the time was that of the hydrogen ion/proton The specific charge of the electron was larger So the electrons had a much bigger charge or a much smaller mass		1 1 1	1	3.12.1.3
03.2	The magnetic force is downwards, and the current is from right to left By Fleming's left hand rule, the magnetic field is into the page		1 1	2	3.12.1.3
03.3	Increasing the accelerating pd increases the speed, and hence the magnetic force on the beam The accelerating pd needs to be increased to prevent the beam from being deflected.		1 1	3	3.12.1.3
03.4	Magnetic force = electric force so $Bev = Ee$, so $Bv = E$ $E = \frac{V_p}{d} = Bv$, $V_p = Bvd$ $eV = \frac{1}{2}mv^2$, $v = \sqrt{\frac{2eV_{acc}}{m}}$ $V_p = B \times \sqrt{\frac{2eV_{acc}}{m}} \times d$ $V_p^2 = B^2 \times \frac{2eV_{acc}}{m} \times d$ $V_{acc} = \frac{m}{ed^2B^2} \times V_p^2$ A graph of V_{acc} against V_p^2 has a gradient of $\frac{m}{ed^2B^2}$	Use of magnetic force and electric force Use of $eV = \frac{1}{2}mv^2$ Equation of line	1 1 1	2	3.12.1.3

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Question	Answers	Extra information	Mark	AO	Spec reference
03.5	$\frac{e}{m} = \frac{d^2B^2}{\text{gradient}}$			2	3.12.1.3
	$= \frac{0.150^2 \times 0.250^2}{8.30 \times 10^{-15}}$	Substitution	1		
	$= 1.69 \times 10^{11}\ \text{C kg}^{-1}$	Answer	1		
	Uncertainty = $0.35 \times 10^{-15}\ \text{kg C}^{-1}\ \text{m}^{-2}\ \text{T}^{-2}$	Alternate method:			
	$\frac{e}{m} = \frac{d^2B^2}{\text{gradient}}$	% uncertainty = $\left(0.35 \times \frac{100}{8.3}\right)$ = 4.2%			
	$= \frac{0.15^2 \times 0.25^2}{8.65 \times 10^{-15}}$	4.2% of 1.69 = 0.07			
	$= 1.63 \times 10^{11}$		1		
	Value = $(1.69 \pm 0.06) \times 10^{11}\ \text{C kg}^{-1}$	Answer with uncertainty			
04.1	The drag force acting vertically upwards is equal to the weight		1	1	3.12.1.4
	There is no net force, so no change of velocity/it moves at terminal velocity		1		
04.2	Weight = $mg = \frac{4}{3}\pi\rho r^3 g$	Use of drag force = weight	1	2	3.12.1.4
	Drag force = $6\pi\eta r v$				
	$\frac{4}{3}\pi\rho r^3 g = 6\pi\eta r v$	Expression for r	1		
	$\frac{4}{3}\rho r^2 g = 6\eta v$				
	$r = \sqrt{\frac{9\eta v}{2\rho g}}$	Expression for mass	1		
	Mass = $\frac{4}{3}\pi\rho g\left(\sqrt{\frac{9\eta v}{2\rho g}}\right)^3$				

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<table>
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr><td>04.3</td><td>$mg = Eq = \frac{Vq}{d}$
$q = \frac{mgd}{V}$
$= \frac{3.2\times10^{-14}\,\text{kg} \times 9.8 \times 12\times10^{-3}}{4700}$
$= 8.0\times10^{-19}\,\text{C}$
Number of excess electrons $= \frac{8.0\times10^{-19}\,\text{C}}{1.6\times10^{-19}\,\text{C}} = 5$</td><td>Expression for e
Answer
Number</td><td>1
1
1</td><td>2</td><td>3.12.1.4</td></tr>
<tr><td>04.4</td><td>The value of $\frac{e}{m}$ is lower than it should be, so the mass is larger than it should be
The value of the viscosity of air used was larger than it should be</td><td></td><td>1
1</td><td>3</td><td>3.12.1.4</td></tr>
<tr><td>05.1</td><td>The negatively charged particles were not named electrons until later/until J.J. Thomson’s experiments</td><td></td><td>1</td><td>2</td><td>3.12.1.3</td></tr>
<tr><td>05.2</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
<table>
<tr><th>Mark</th><th>Criteria</th><th>QoWC</th></tr>
<tr><td>6</td><td><u>A thorough and well-communicated</u> discussion using most of the statements in bullets 1 and 2</td><td rowspan="2">The student presents relevant information coherently, employing structure, style, and SP&G to render meaning clear. The text is legible</td></tr>
<tr><td>5</td><td><u>An explanation that includes</u> discussion using most of the statements in bullets 1 and 2, but may contain minor errors or omissions</td></tr>
</table></td><td>The following statements are likely to be present:
Bullet point 1 in question
(Description of cathode rays in Crookes tube)
1. A tube is filled with low pressure gas
2. Gases at sufficiently low pressure in sealed glass tubes conduct electricity
3. The glowing gas near the anode, the positive column, was easily distorted when a magnet was brought near to the tube
4. This observation showed charged particles move through the gas when it conducts electricity</td><td>6</td><td>1</td><td>3.12.1.1
3.12.1.2</td></tr>
</table>

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<table>
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr>
<td></td>
<td>
<table>
<tr><th>Mark</th><th>Criteria</th><th>QoWC</th></tr>
<tr><td>4</td><td><u>The response includes a well-presented</u> discussion of two from bullet 1 and two from bullet 2</td><td rowspan="2">The student presents relevant information and in a way which assists the communication of meaning.
The text is legible.
SP&G are sufficiently accurate not to obscure meaning</td></tr>
<tr><td>3</td><td><u>The response includes a</u> discussion of either two from bullet 1 and one from bullet 2 or vice versa; must not all be from the same bullet</td></tr>
<tr><td>2</td><td><u>The response</u> makes one comment from each bullet point</td><td rowspan="2">The student presents some relevant information in a simple form. The text is usually legible.
SP&G allow meaning to be derived although errors are sometimes obstructive</td></tr>
<tr><td>1</td><td>Makes relevant comment from the list</td></tr>
<tr><td>0</td><td>No relevant coverage of the likely statements</td><td>The student's presentation, SP&G seriously obstruct understanding</td></tr>
</table>
</td>
<td>
5. Radiation from the direction of the cathode forced 'a paddle wheel' placed in the tube to rotate. This radiation was referred to as 'cathode rays'
6. Neither the cathode nor the anode were heated
Bullet point 2 in question
(Description of cathode rays from thermionic emission)
7. When a cathode is heated, some of the electrons that move about freely inside the metal gain sufficient kinetic energy to leave the metal at its surface
8. The cathode is a wire filament, which is heated by passing an electric current through it
9. The filament or 'cathode' is at one end of an evacuated glass tube with a metal plate or 'anode' nearby
10. The electrons emitted from the filament are attracted to the anode by connecting a high voltage power supply between the anode and the cathode, with the anode positive relative to the filament
11. Because there are no gas molecules in the tube to stop the electrons, the electrons are accelerated to the anode where some of them pass through a small hole to form a narrow beam
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<td></td><td></td><td></td>
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Question	Answers	Extra information	Mark	AO	Spec reference
05.3	Crookes added a paddle wheel to the centre of the tube When the tube was working, the wheel moved because electrons/ cathode rays were colliding with it		1 1	1	3.12.1.1
05.4	Yes, the p.d. increases the energy according to $eV = \frac{1}{2}mv^2$		1	3	3.12.1.2
06.1	Quarks have fractional charge		1	1	3.2.1.6
06.2	$mg = Ee = \frac{Ve}{d}$ $V = \frac{mgd}{e}$, p.d. is proportional to V if the charge is the same $V = \frac{7\times10^{-5}\,\text{g} \times 3000}{3\times10^{-11}\,\text{g}}$ $= 7\times10^{9}\,\text{V}$	Expression for V Assumption Answer	 1 1 1	3	3.12.1.4
06.3	For a force to be exerted, a charged object/particle needs to be moving		1	2	3.7.5.2
06.4	The positrons are anti-electrons When they interact with electrons, they annihilate (producing two gamma rays), which reduces the charge on the sphere		1 1	3	3.2.1.3
06.5	The resolution of his measuring instruments was not sufficient to distinguish between whole and fractional charge/there were no quarks produced on the oil drops		1	3	3.12.1.4
07.1	Similarities: Both use electron beams In both methods, a force is exerted on the beam Differences: The force on the beam due to the magnetic field is perpendicular to the velocity The force on the beam due to the electric field is perpendicular to the plates	Two similarities Two differences 	2 2	1	3.12.1.3

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Question	Answers	Extra information	Mark	AO	Spec reference
07.2	The vertical acceleration of the ball is 9.8 m s^{-2}			3	3.4.1.3
	The distance the ball falls is $s = \frac{1}{2}at^2 = \frac{1}{2} \times 9.8 \times t^2$	Expression for time (explicit or implied)	1		
	$t = 0.319\ldots$ s				
	The time it takes the ball to travel 10 m is $v = \frac{d}{t} = \frac{10}{0.319} = 31.3\ldots$	Use of equation of motion	1		
	= 31 m s^{-1}	Answer	1		
07.3	The mass of the electron is extremely small, so the force of the Earth is negligible compared to the force of the magnetic or electric fields		1	1	3.12.1.3
07.4	The force is perpendicular to the motion of the particles		1	2	3.7.5.2
07.5	Force on an object moving in a circle	Use of equation for circular motion and Lorentz force	1	3	3.6.1.1 3.7.5.2
	$F = \frac{mv^2}{r} = Bqv$				
	So $\frac{mv}{r} = Bq$	Substituting for v and T	1		
	And $v = \frac{2\pi r}{T} = 2\pi rf$	Answer			
	$\frac{m2\pi rf}{r} = Bq$		1		
	So $f = \frac{qB}{2\pi m}$				
08.1	Electrons in an atom in the screen move to a higher energy level when the accelerated electron transfers energy to the atom		1	2	3.2.2.2
	When the electron in the atom returns to its origin level, an X-ray is emitted		1		
	The difference in energy between the levels must be sufficiently large to produce a photon with the wavelength/frequency of an X-ray		1		

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Question	Answers	Extra information	Mark	AO	Spec reference
08.2	Wavelength = 10^{-10} m Energy = $\frac{hc}{\lambda}$ $= \frac{6.63\times10^{-34} \times 3.00\times10^{8}}{10^{-10}}$ $= 1.99\times10^{-15}$ J allow 2×10^{-15} or 10^{-15} J	Estimate Substitution Answer	1 1 1	1 2	3.2.1.3
08.3	Energy = eV $V = \frac{\text{energy}}{e}$ $= \frac{1.99\times10^{-15}}{1.60\times10^{-19}}$ = 12 400 V	 Substitution Answer	 1 1	2	3.12.1.2
08.4	A spark requires a very large potential difference, which can be produced by a transformer if there are very many more coils on the secondary than on the primary A sudden change in the pd across the primary produces rapidly changing flux in the core Which produces a very large pd/induces a large emf as induced pd depends on the rate of change of flux and the number of turns		1 1 1	3	3.7.5.4
08.5	Electric field = $\frac{V}{d}$ $= \frac{10\,000}{0.01}$ = 10^{6} V m^{-1}	 Answer	 1	2	3.7.3.2

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Skills box answers

Question	Answer
1	$eV = \frac{1}{2}mv^2$ is rearranged to obtain $v^2 = \frac{2eV}{m}$ $v = \sqrt{\left(\frac{(2 \times 1.6 \times 10^{-19}\,\text{C} \times 30\,\text{V})}{(9.11 \times 10^{-31}\,\text{kg})}\right)}$ $v = 3.2 \times 10^{6}\,\text{m s}^{-1}$ (Check units: $\text{C V kg}^{-1} = \text{A s V kg}^{-1} = \text{W V}^{-1}\,\text{s V kg}^{-1} = \text{J kg}^{-1} = \text{N m kg}^{-1} = \text{kg m s}^{-2}\,\text{m kg}^{-1} = \text{m}^2\,\text{s}^{-2}$)
2	work done $= \frac{1}{2}mv^2 = \frac{1}{2} \times 9.11 \times 10^{-31}\,\text{kg} \times (3.0 \times 10^{7}\,\text{m s}^{-1})^2 = 4.1 \times 10^{-16}\,\text{J}$
3	work done $= eV$ $V = \frac{\text{work done}}{e} = \frac{1.2 \times 10^{-17}\,\text{J}}{1.6 \times 10^{-19}\,\text{C}} = 75\,\text{V}$