

Name of the Student: _____

Max. Marks : 25 Marks

Time : 25 Minutes

Mark Schemes

Q1.

- (a) Idea that filament/metal is heated (by an electric current), giving (some) electrons in the metal (sufficient) energy to leave the surface ✓

Allow references to the work function (but not just ϕ)

Thermionic emission is not enough by itself.

Do not allow heating of electrons.

Reject 'accelerated' (unless it is clearly after they leave the metal) / 'ionise'

Ignore references to processes that take place after electron leaves the metal

Ignore references to free electrons inside the metal

1

- (b) Use of $\frac{1}{2}mv^2 = eV$

To give $v = 1.33 \times 10^7 \text{ (m s}^{-1}\text{)} \checkmark$

Must see 500V for the potential difference (not 506.3V or 493.7V)

≥ 3 SF required.

1.325×10^7 (do not allow 1.32×10^7)

1

- (c) Suggestion that, for diffraction to be demonstrated, hole diameter should be of same order of size as wavelength ✓

Do not allow $\lambda < \text{gap}$ or $\text{gap} < \lambda$ for MP1

(Must refer to gap not just anode)

Discussions in terms of crystalline diffraction can score MP1 and MP2.

Evidence of $\lambda = \frac{h}{p}$ OR $\lambda = \frac{h}{\sqrt{2meV}}$

to give $5.5 \times 10^{-11} \text{ (m)}$ OR $5.6 \times 10^{-11} \text{ (m)} \checkmark$

Must calculate λ for MP2.

Condone use of 506.3V or 492.7V as penalised in 1.2

Allow 1 SF or order of magnitude calculation.

Do not ignore PoT for calculation.

Ignore incorrect conversion to nm if m value given.

Idea that this diameter is smaller than an atom / too small for hole to be made **and** therefore

this apparatus cannot be used (for this speed/wavelength) / the student is **incorrect** ✓

Condone the idea that the student is correct in principle but this particular setup will not work.

Do not allow ecf to MP3 unless their calculated hole diameter is of the order of 10^{-10} m or smaller in MP2.

3

- (d) **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. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

Mark	Criteria
6	All three areas covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all three areas. If there are several errors or missing parts then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed, or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

For each area (bullet point), consider whether the response is fully addressed, partially addressed or not addressed. Typically, any missing points mean that the area is partially addressed.

Significance

Very large e/m (compared to value for hydrogen ion).

(Hydrogen ion had largest known specific charge at the time.)

Therefore particles have very small mass / very large charge (condone light for small mass)

Experimental procedures and measurements

For a full answer everything should be directly measurable (not Electric Field, Kinetic Energy, velocity)

Except no details are required for measurement of B

Determination of e/m

Answers should end in $e/m =$

Expected to be in steps but can carry the algebra through

Allow use of measured Electric Field here.

A full answer should not include e or m as part of the calculation (likely to be found in working out v)

If methods are mixed up this can be treated as full credit for one of procedures or determination or as a partial for both.

The minimum response required to address an area fully is given below

Fine Beam Tube

Experimental procedure and measurements

fine beam tube described / diagram including low pressure gas, (Perpendicular) magnetic field to cause electrons to move in a circle

Radius of curved path r , Accelerating voltage V , Magnetic flux density B

Determination of e/m

$$\left(\frac{1}{2}mv^2 = eV \text{ and } r = \frac{mv}{Be}\right)$$

$$\frac{e}{m} = \frac{2V}{r^2 B^2}$$

Correct Alternative Methods

Crossed Fields

Experimental procedure and measurements

Parallel plates with voltage applied.

Magnetic field applied to produce balanced forces Accelerating voltage V_A

When beam is horizontal: plate voltage V_p , separation d , magnetic flux density B

Determination of e/m

$$\left(\frac{eV_p}{d} = Bev \Rightarrow\right) v = \frac{V_p}{dB} \text{ (allow } \frac{E}{B} \text{ from measured } E)$$

$$\left(\frac{1}{2}mv^2 = eV_A \Rightarrow\right) \frac{e}{m} = \frac{v^2}{2V_A} \text{ Or } \frac{e}{m} = \frac{V_p^2}{2d^2B^2V_A} \text{ Or } \frac{e}{m} =$$

$$\frac{E^2}{2B^2V_A}$$

Measure deflected distance

Experimental procedure and measurements

Initial balanced magnetic and electrical forces to produce horizontal beam

Measure magnetic flux density B , plate p.d. V , distance between plates d and length of plates x

With no magnetic field, measure vertical deflection y

Determination of e/m

$$\left(\frac{eV}{d} = Bev \Rightarrow\right) v = \frac{V}{dB} \text{ (allow } \frac{E}{B} \text{ from measured } E)$$

$$\text{Horizontal motion: } t = \frac{x}{v}$$

$$\text{Vertical motion: } (y = 0t + \frac{1}{2}at^2 = \frac{1}{2}at^2 \Rightarrow) a = 2y/t^2$$

$$\text{or any of } \frac{e}{m} = \frac{2dy}{Vt^2} = \frac{2dyv^2}{Vx^2} = \frac{2yV}{dx^2B^2}$$

Measure deflected angle

Experimental procedure and measurements

Initial balanced magnetic and electrical forces to produce horizontal beam

Measure magnetic flux density B, plate p.d. V, distance between plates d and length of plates x

With no magnetic field, measure angle θ beam is deflected through

Determination of e/m

$$\left(\frac{eV}{d} = Bev \Rightarrow\right) v = \frac{V}{dB} \text{ (allow } \frac{E}{B} \text{ from measured } E)$$

$$\text{Horizontal motion: } t = \frac{x}{v}$$

$$v_y = v \tan \theta$$

$$\text{Vertical motion } (v_y = 0 + at = at \Rightarrow) a = \frac{v_y}{t}$$

$$\left(a = \frac{F}{m} = \frac{eV}{dm} \Rightarrow\right) \frac{e}{m} = \frac{da}{V}$$

Incorrect Methods

Milikan's Oil drop / use of measured weight / Gas tube / Crooke's tube / Discharge tube

Partial credit for one area ONLY can be awarded for a good treatment that includes all of the following

- At least one experimental detail
- Some measurements
- Some calculation

Quantum Jumping or anything else

These cannot address areas 1 and 2

Ignore use of undescribed velocity selector, mass spectrometer, ...

No credit for measure Q and m and divide them.

6

[11]

Q2.

- (a) (Reads off terminal speed from graph) to give $0.053 \pm 0.0005 \text{ mm s}^{-1}$ ✓

$$\text{Evidence of } mg = 6\pi\eta rv \checkmark$$

$$\text{Substitutions seen to give } 1.8 \times 10^{-5} \text{ (N s m}^{-2}\text{)} \checkmark$$

Allow PoT error in MP1

If MP1 not given, allow ecf if read off misread

Do not accept work from a gradient.

W or $1.2 \times 10^{-14} = 6\pi\eta r v$ is enough for MP2.

Condone $\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v$ for MP2.

Calculator value = $1.766425562 \times 10^{-5}$

3

(b) Evidence of $EQ = mg$ ✓

$Q = 6.4 \times 10^{-19}$ (C) ✓

Divides their Q by e to get number of electrons **and** makes sensible comment consistent with their value ✓

By substitution - allow PoT error for E in MP1

Allow $EQ = mg$ without substitution for MP1

Expect to see 4.0 or $3.99 \approx 4$ and therefore yes

Condone for MP3 only (max 1)

Use of $E = Q/4\pi\epsilon_0 r^2$ which gives $Q = 6.04 \approx 6$ so yes.

3

[6]

Q3.

(a) Sinusoidal electric field in vertical plane, in phase with magnetic field

AND

Indication of direction perpendicular to both fields ✓

Expect to see arrow at either end of long axis line

Condone only one of E or 'direction of propagation' not labelled. Accept 'direction' for 'direction of propagation'.

Accept lower case e for E

1

(b) Maxwell ✓ CAO

1

(c) Light is made of corpuscles ✓

When corpuscles meet boundary

[any 2 from] ✓

- component of velocity/momentum parallel to surface unchanged
- Component perpendicular to surface increases
- (short range) force of attraction (to surface)
- light travels faster in glass

When corpuscles meet boundary

[all 4] ✓

- component of velocity/momentum parallel to surface unchanged
- Component perpendicular to surface increases
- (short range) force of attraction (to surface)
- bends towards the normal / angle of refraction $<$ angle of incidence

Marks can be awarded for suitable labelled diagram

Allow particles for corpuscles in MP2 and MP3 but not MP1.

Condone references to horizontal/vertical components in MP2 but not MP3 unless clarified in diagram or text.

Condone attracted / attraction for force of attraction

Do not accept force of gravity but can still gain MP2 if 2 other points are made.

Condone light bending wrong way for MP2 but not for MP3.

*Ignore short-range force of attraction to normal for MP2 but do **not** allow for MP3*

If no other marks condone light is made of particles and one bullet from MP2 for 1 mark.

3

(d) Diffraction/interference experiment described ✓

describe / show in labelled diagram a feature that is only explained by waves e.g. series of maxima and minima, bright and dark, series of fringes, spectra (from diffraction grating not prism), bright spot in centre of double slit, intensity graph ... ✓

diffraction/interference/superposition is a wave phenomenon **AND** describe how the feature would look with particles e.g. two bright spots, no bright spot in the centre, etc ✓

MP1 is for the set up.

MP2 is for what is seen.

MP3 is for showing why Newton's theory is not correct.

Marks can be awarded for suitable labelled diagram

Expect description of Young's double slits experiment but allow any suitable diffraction experiment, eg single slit or grating.

Stating 'Young's Double Slits' is insufficient.

For MP1 experiment must be consistent with description given in MP2 and MP3.

Ignore experiment to measure speed of light in glass or any reference to refraction including producing a spectra from a prism.

Ignore references to polarisation.

Interference pattern is not enough for MP2.

If no other marks allow 1 mark for 2 from

- *Young's double slits*
- *Interference/diffraction*
- *Interference/diffraction is a wave phenomenon*

3

[8]