

Name of the Student: _____

Max. Marks : 19 Marks

Time : 19 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

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

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

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

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.

$$(a) \text{ Use of } f = \frac{1}{T} \text{ or } (T =) 2.63 \times 10^{-15} \text{ (s) seen}$$

or

$$\text{number of waves} = \frac{6 \times 10^{-9}}{\text{their } T}$$

or

$$6 \times 10^{-9} \times 3.8 \times 10^{14} \checkmark$$

Condone POT error in MP1

Use of $f = \frac{1}{T}$ is f substituted and formula rearranged to make T the subject.

$$\frac{1}{6 \times 10^{-9}} \text{ is not sufficient for use of } f = \frac{1}{T}$$

Alternative for MP1:

calculates the length of a pulse ($6 \times 10^{-9} \times 3 \times 10^8 = 1.8 \text{ m}$) **and**

$$\text{calculates the wavelength} = \frac{3 \times 10^8}{3.8 \times 10^{14}} = 7.9 \times 10^{-7}$$

OR

Determines maximum number of pulses per second $\frac{1}{6 \times 10^{-9}}$ **and** divides number of cycles per second by the number of pulses per second. That is:

$$\frac{3.8 \times 10^{14}}{\frac{1}{6 \times 10^{-9}}} \text{ Or } \frac{3.8 \times 10^{14}}{1.67 \times 10^8}$$

$$2.3 \times 10^6 \checkmark$$

Calculator display 2280000

Unsupported answers with POT error 1 mark

2

(b) Use of speed = $\frac{\text{distance}}{\text{time}}$

by substituting for speed ($3 \times 10^8 \text{ ms}^{-1}$) and time ($10.7 \times 10^{-6} \text{ s}$) **and** making distance the subject

OR

Use of speed = $\frac{\text{distance}}{\text{time}}$ **and** divides their distance by 2

OR

$$(\text{time} =) \frac{10.7 \times 10^{-6}}{2} / (\text{time} =) 5.35 \times 10^{-6} \text{ s } \checkmark$$

Condone POT error on MP1

An answer = $3.2(1) \times 10^3 \text{ (m)}$ obtains 1 mark with working (allow POT on this compensatory mark)

Alternative calculation for total distance: Multiplies the wavelength (7.9

$$\times 10^{-7} \text{ m}) \text{ by the number of waves in } 10.7 \mu\text{s} \left(\frac{10.7 \times 10^{-6}}{2.63 \times 10^{-15}} \right):$$

$$\text{That is } \frac{3 \times 10^8}{3.8 \times 10^{14}} \times \frac{10.7 \times 10^{-6}}{2.63 \times 10^{-15}} /$$

$$\frac{3 \times 10^8}{3.8 \times 10^{14}} \times \frac{10.7 \times 10^{-6}}{\frac{1}{3.8 \times 10^{14}}} / 7.9 \times 10^{-7} \times \frac{10.7 \times 10^{-6}}{2.63 \times 10^{-15}}$$

$/ 7.9 \times 10^{-7} \times 4.066 \times 10^9$ seen

OR

Multiples the wavelength ($7.9 \times 10^{-7} \text{ m}$) by the number of waves in $10.7 \mu\text{s}$. ($10.7 \times 10^{-6} \times f$) where $f = 3.8 \times 10^{14}$

That is:

$$7.9 \times 10^{-7} \times 10.7 \times 10^{-6} \times 3.8 \times 10^{14} /$$

$$\frac{3 \times 10^8}{3.8 \times 10^{14}} \times 10.7 \times 10^{-6} \times 3.8 \times 10^{14} \text{ seen}$$

$$1.6 \times 10^3 \text{ (m)} \checkmark$$

(Calculator displays 1605)

2

- (c) Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $\checkmark$ by substitution

Condone use of $\theta_1 = 38^\circ$ provided $n_{\text{air}} = 1$: need to see an explicit statement $1 \times \sin \theta_1$ **and** answer = 1.0(2).

Allow their θ_1 from an attempt to find $90 - 38$ in use of

Allow 62 or 42 for θ_1 without supporting evidence in use of

Do not allow $\theta_1 = 90^\circ$ in use of

$$\text{Allow use of } 1n_2 = \frac{\sin i}{\sin r} \text{ or } \frac{n_2}{n_1} = \frac{\sin i}{\sin r}$$

$$\text{or } n = \frac{\sin i}{\sin r}$$

must see $i =$ their θ_1 **and** $r = 37^\circ$ for use of any of these

Do not allow this method for $i = \theta_1 = 38^\circ$ unless answer = 1.0(2) **and either**

$$\frac{1n_2}{\frac{n_2}{n_1}} \text{ is seen as subject}$$

or

n is subject and there is an explicit statement that $n_{\text{air}} = 1$

$$(n_2 =) 1.3(1) \checkmark$$

2

- (d) Attempted use of $n = \frac{c}{c_s}$

Expect to see $c_s = 2.3 \times 10^8 \text{ (m s}^{-1}\text{)}$

$$\text{Ecf from part (c) in use of } n = \frac{c}{c_s}$$

Or

$$\text{use of their } c_s = f\lambda \checkmark$$

Condone their c_s in use of $c = f\lambda$

6.0×10^{-7} (m) or 6.1×10^{-7} (m) ✓

Ecf from part (c)

Answer = $7.7(4) \times 10^{-7}$ (m) for $n = 1.02$

Or $7.7(2) \times 10^{-7}$ (m) for $n = 1.02$ where no rounding on ecf

Alternative

Divides wavelength in air by the refractive index ✓

Answer = 7.89×10^{-7} (m) for $n = 1.0$ (only condone this answer where $n = 1$ or $n = 1.0$ seen as ecf from part (c))

6.0×10^{-7} (m) or 6.1×10^{-7} (m) ✓

Expect to see 6.03×10^{-7} or 6.07×10^{-7}

Maximum of 1 mark where speed in ice sheet is more than speed of light in a vacuum is seen.

Penalise 1 significant figure

2

[8]