

- M1.(a)** (i) There is a (constant) force acting which is (always) at right angles / perpendicular to the path / motion / velocity / direction of travel / to the beam
Or mentions a centripetal force ✓

First mark is for condition for circular motion

Not speed

Second mark is for a statement relating to the origin of the force

Force is at right angles to the magnetic field and the electron motion

Or

direction given by left hand rule ✓

Any mention of attraction to the plates is talk out (TO)

2

- (ii) States $Bev = \frac{mv^2}{r}$ and evidence of correct intermediate stage showing

manipulation of the formula

or

Quotes $r = \frac{mv}{Be}$ from formula sheet and change of subject to $v = \frac{Ber}{m}$ seen

Accept delete marks

or rewrite as $Be = \frac{mv}{r}$

or rearrangement as $\frac{v^2}{v} = \frac{Ber}{m}$

1

- (iii) States $Bev = \frac{eV}{d}$

or $F = Bev$ $F = \frac{eV}{d}$ (or $F = Ee$ and $E = \frac{V}{d}$ in any form)

Allow use of e or Q

and

states $v = \frac{V}{Bd}$ ✓

No mark for just quoting final equation. There must be evidence of useful starting equations

1

- (b) Equates the formulae for v and shows $\frac{e}{m}$ equated to $\frac{V}{B^2rd}$

Must include 'e / m =' not just 'specific charge ='

Note there is no ecf. Candidates who use an incorrect equation in (a) (iii) will lose this mark unless they restart from first principles

Condone Q / m

1

- (c) Using band marking

Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response.
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.

A

Measure the terminal speed of the falling droplet
At the terminal speed weight = viscous force (+ upthrust)

$mg = 6\pi\eta rv$ and $m = \frac{4\pi r^3 \rho}{3}$ so $r^2 = \frac{9\eta v}{2\rho g}$
 r could be determined as density of drop, viscosity of air and g are known (r is the only unknown)

B

m can be determined if r is known
Apply pd between the plates so electric field = V/d and adjust until droplet is stationary
 $QV/d = mg$ so Q can be found

C

Make a number of measurements to find Q
Results for Q are in multiples of $1.6 \times 10^{-19}C$ so Q can be found

e.g.

1-2

Superficial with some sensible comments about the procedure with significant errors in attempts at use of equations. May do one part of A B or C reasonably well. Relevant Equations without little explanation may be worth 1

3-4

*Should cover most of the point in two of A, B & C coherently
A & B may be well done in an answer that is easy to follow
OR B and C may be well explained but there may be significant errors or omissions in the determination of r
OR a bit of all A B and C with significant errors or omissions*

5-6

Will cover the points made in A B & C with few omissions in an answer that is easy to follow

The candidate will define some terms used in equations

1-2

Attempt to explain how to determine radius with detail of how to use data

OR

Makes a relevant point about some part of the procedure about the determination

3-4

*Radius determination explained with sensible equations
Explanation of how to use data to find mass of the drop
Idea of holding the drop stationary*

5-6

Answer includes all steps to determine the charge of a droplet with correct equations showing how to use the measurements

For highest mark the answer should include idea of interpreting results of many measurements

6
[11]

- M2.(a)** At terminal speed (v), the viscous force on the droplet = its weight
For weight: allow mg or the force of gravity on it
For viscous force: allow 'drag' or 'resistance' or 'friction'
Not upthrust.

$$6\pi\eta r v = 4\pi r^2 \rho g / 3 \quad \checkmark$$

1

Manipulation leading to $r = (9 \eta v / 2\rho g)^{1/2} \quad \checkmark$

1

- (b) r (can be calculated as above then) used in the formula $m = 4\pi r^2 \rho / 3$ to find the droplet mass, $m \quad \checkmark$ (WTTE)
Alternative ; (from $6\pi\eta r v = mg$: as all values are known use) $m = 6\pi\eta r v / g \quad \checkmark$

1

- (c) electric force (or QV/d) = the droplet weight (or mg) \checkmark
Do not give 1st mark if eV/d given instead of QV/d

1

$Q =$

$$\frac{mgd}{V} = \frac{3.4 \times 10^{-15} \times 9.8(1) \times 15.0 \times 10^{-3}}{1560} = 3.2 \times 10^{-19} \text{ C} \quad \checkmark$$

1

- (d) Millikan's conclusion: Electron charge is $(-)\mathbf{1.6 \times 10^{-19} \text{ C}}$ (WTTE) \checkmark

The charge on each droplet is a whole number $\times 1.6 \times 10^{-19}$ C which agrees with Millikan ✓

Student's results suggest -3.2×10^{-19} C as smallest quantum of charge ✓
allow multiple or n , where n is an integer

3

[8]