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 <u>and</u> the electron motion
Or
<u>direction</u> given by left hand rule ✓

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

2

(ii) States $Bev = \dfrac{mv^2}{r}$ and evidence of correct intermediate stage showing manipulation of the formula

or

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

Accept delete marks

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

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

1

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

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

Allow use of e or Q

<u>and</u>

Page 2

states $v = \dfrac{V}{Bd}$ ✓

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

1

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

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

A

Measure the terminal speed of the falling droplet

At the terminal speed weight = viscous force (+ upthrust)

$mg = 6\pi\eta rv$ and $m = 4\pi r^3 \rho / 3$ so $r^2 = \dfrac{9\eta v}{2\rho g}$

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 1.6×10^{-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)   (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 ✓

                                    ; Allow 'electrons ionise atoms' as compensation mark (if no marks elsewhere)

2

            (ii)   ions and electrons (moving in opposite directions) collide (with each other) and recombine and emit photons ✓
                           Owtte

                     electrons excite gas atoms (by collision) and photons are emitted when de-excitation occurs ✓
                           If light not photons given in 1ˢᵗ 2 mark points, 1 max for 1ˢᵗ two mark points

                     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 ✓
                           Owtte

                     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

        (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 ✓
                           Accept Q / m in symbols Q / m but not e / m if e / m is specifically stated as specific charge

2

[7]

Page 5

M3.   (a)   force due to electric field acts (vertically) downwards on electrons ✓

vertical (component) of velocity of each electron increases ✓

horizontal (component of) velocity unchanged (so angle to initial direction increases) ✓

3

    (b)   (i)   magnetic flux density should be reversed and adjusted in strength (gradually until the beam is undeflected) ✓

1

              (ii)   magnetic (field) force = Bev

and electric (field) force = eV/d ✓

(Accept Q or q as symbol for e (charge of electron)

$Bev = eV/d$ (for no deflection) gives $v = V/Bd$ ✓

2

    (c)   (gain of) kinetic energy of electron = work done by anode pd or $\frac{1}{2}\,m\,v^2 = e\,V_{(A)}$ ✓

$$\frac{e}{m}\left(=\frac{v^2}{2V_{(A)}}\right)=\frac{(3.9\times10^7)^2}{2\times4200} \checkmark$$

$= 1.8 \times 10^{11}$ C kg^{-1}.

3

[9]

M4.   (a)   (i)   **either**

(at terminal speed (v)) the viscous force on the droplet = its weight (or mg or the force of gravity on it)

or

Page 6

viscous force = $6\pi\eta rv$ (where r is the radius of the droplet and η is its viscosity) and weight (= mg) = $4\pi r^3 \rho g/3$ ✔

$4\pi r^3 \rho g/3 = 6\pi\eta rv$ ✔

(which gives $r = (9\eta v/2\rho g)^{\frac{1}{2}}$)

2

(ii) r (can be calculated as above then) used in the formula m = $4\pi r^3 \rho/3$ to find the droplet mess, m [owtte] ✔

alternatively; (from $6\pi\eta rv = mg$) (as all values are known use) $m = 6\pi\eta rv/g$ ✔

1

(b)   (i)   electric force (or QV/d) = the droplet weight (or mg) ✔

$Q = \dfrac{mgd}{v} = \dfrac{6.8\times10^{-15}\times9.8(1)\times5.0\times10^{-3}}{690} = 4.8\times10^{-19}$ C ✔

2 sf answer ✔

3

(ii)   **any two from**

the charge on each droplet is a whole number × 1.6×10^{-19} C (or × charge of the electron) ✔

the least amount of charge (or the quantum of charge) is the charge of the electron ✔

the quantum of charge is 1.6×10^{-19} C [owtte] ✔

max 2

[8]

M5.   (a)   (i)   The number of electrons (per second) in the beam will increase **(1)** because the filament will become hotter and will emit more electrons (per 2 second) **(1)**

2

(ii) the speed (or kinetic energy) of the electrons will increase **(1)**

because the electrons (from the filament) are attracted towards the anode with a greater acceleration (or force) **(1)**

(or gain more kinetic energy in crossing a greater pd)

2

(b) (i) (magnetic) force on each electron in the beam is perpendicular to velocity **(1)**

no work is done on each electron by (magnetic) force so ke (or speed) is constant **(1)**

magnitude of (magnetic) force is constant because speed is constant **(1)**

(magnetic) force is always perpendicular to velocity so is centripetal **(1)**

max 3

(ii) rearranging $r = \dfrac{mv}{Be}$ gives $\dfrac{e}{m} = \dfrac{v}{Br}$ **(1)**

$\dfrac{e}{m} = \dfrac{7.4 \times 10^{6}}{6.0 \times 10^{-4} \times 68 \times 10^{-3}} = 1.81 \times 10^{11}$ **(1)** C kg^{-1} **(1)**

for correct answer to 2 sf **(1)**

4

(iii) specific charge for the electron ≈ 2000 × specific charge of H$^+$ **(1)**
    (accept = and accept any value between 1800 and 2000)

which was the largest known specific charge before the specific charge of the electron was determined/measured **(1)**

(or which could be due to a much greater charge or a much smaller mass of the electron)

2

[13]