A-Level Physics

Specific Charge of an Electron

Mark Scheme

Time available: 62 minutes
Marks available: 49 marks

Mark schemes

1. (a) Weight/gravitational force AND electric/electrostatic force ✓

Equal (magnitudes) and opposite directions,

AND one direction at least specified ✓

The second mark is conditional on the first.

First mark is for naming the two forces.

Condone 'electromagnetic' for 'electric'

Do not allow field or potential for force.

Allow "force due to electric field"; "force due to magnetic field"

Penalise additional forces in MP2.

The second mark is for the relationship between them. Must include idea of size and direction.

e.g. weight down equals E force up/towards positive plate/away from negative plate.

Do not allow 'balanced' or 'in equilibrium' for equals

The forces can be in the form of formulae for MP1 and MP2 (e.g. Eq, EV/d, mg)

2

(b) $m = 4\pi r^3\rho/3$ and $mg = 6\pi\eta rv$ seen ✓

$r^2 = 18\ \eta v / 4\ \rho g$ is seen in in some form, in symbols or through substituted data, ✓

Correct use of equations to obtain $r = 9.7 \times 10^{-7}$ m ✓

Do not allow backward calculation

Can be seen by substitution.

Can be seen in single equation:

$4\pi r^3\rho g/3 = 6\pi\eta rv$

Do not award if v and V confused

Do not condone 1sf answer.

Must be clear answer refers to r, not r^2 for example.

If no other mark given MP1 can be awarded if F used for mg, and/or volume AND density equations seen separately

3

(c) The number of excess electrons on the droplet is 3 ✓

In order for each half to remain stationary, the charge would have to split equally
OR
Due to the quantisation of charge, the charge cannot split equally ✓

It is not possible for both droplets to remain stationary / the student is wrong ✓

May be seen in terms of values of charge or e

Award for idea that charge would have to be 1.5e

Evidence for MP1 and MP2 may be seen together. E.g. charge on drops are e and 2e, OR 1.6×10^{-19} and 3.2×10^{-19}

Ignore reference to particles repelling each other

3

[8]

2. (a) Electrons collide with atoms.✓

Electron in an atom is excited into a higher energy level.✓

Emits a photon when the electron relaxes / moves to lower energy level.✓

3

(b) Substitutes in $eV = \frac{1}{2}mv^2$✓

Manipulates and gives answer to 2 or more sfs.✓

2

(c) Deduces *e/m* = *v/Br*.✓

Substitutes data (condone power of 10 errors).✓

$$\frac{e}{m} = \frac{3.0 \times 10^7}{3.1 \times 10^{-3} \times 5.7 \times 10^{-2}}$$

1.7×10^{11} (C kg^{-1}).✓

Substitution may come before manipulation.

3

(d) Electron velocity decreases when they collide.✓

v is proportional to *r*
OR *r* = *vm/Be* and *m*, *B* and *e* are constant.✓

r (gradually) decreases

or path with be an inwards spiral.✓

3

[11]

3. (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 $Bev = \frac{mv^2}{r}$ 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 $v = Ber / m$ 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

<u>and</u>

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 $\frac{V}{B^2 rd}$

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 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 $m = 4\pi r^3\rho / 3$ 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]

4. (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 $\frac{1}{2} m v^2 = e V_{(A)}$ ✓

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

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

3

[9]

5. (a) (i) emission of (conduction) electrons from a heated metal (surface) or filament/cathode **(1)**
work done on electron = eV **(1)**

(ii) gain of kinetic energy (or $\frac{1}{2} mv^2$) = eV; rearrange to give required equation **(1)** 3

(b) (i) work done = force × distance moved in direction of force **(1)**
force (due to magnetic field) is at right angles to the direction of motion/velocity
[or no movement in the direction of the magnetic force
∴ no work done] **(1)**
electrons do not collide with atoms **(1)**

any two **(1)(1)**

[alternative for 1st and 2nd marks
(magnetic) force has no component along direction of motion **(1)**
no acceleration along direction of motion **(1)**
or acceleration perpendicular to velocity]

$r = \frac{mv}{Be}\left(or Bev = \frac{mv^2}{r}\right)$ **(1)**

$v^2 = \frac{2eV}{m}$ **(1)**

$\therefore r^2\left(= \frac{m^2v^2}{B^2e^2}\right) = \frac{m^2}{B^2e^2} \times \frac{2eV}{m} = \frac{2mV}{B^2e}$ **(1)**

(iii) (rearranging the equation gives) $\frac{e}{m} = \frac{2V}{B^2r^2}$ **(1)**

$\frac{e}{m} = \frac{2 \times 530}{(3.1 \times 10^{-3})^2 \times (25 \times 10^{-3})^2} = 1.7(6) \times 10^{11}$ C kg^{-1} **(1)**

7

[10]