Unit 20 · Electrons

HARDER PRACTICE QUESTIONS

Full marks 32

Write your answers on separate paper. Show your working. Take $e = 1.6 \times 10^{-19}$ C, the specific charge of an electron 1.76×10^{11} C/kg and $g = 9.8$ m/s^2.

1 Spot the error [3]

Find the mistake in the working and correct it.

In a Thomson-type experiment, the electrons are accelerated through 1500 V. The deflecting plates are 0.80 cm apart with 400 V across them, and the beam goes straight with B = 2.2 mT. Rojina wrote:

"$\frac{e}{m} = \frac{E^2}{2VB^2}$, E = 400 ÷ 0.008 = 5.0×10^4 V/m, so $\frac{e}{m} = \frac{(5.0 \times 10^4)^2}{2 \times 400 \times (2.2 \times 10^{-3})^2} = 6.5 \times 10^{11}$ C/kg."

2 Read the data [4]

Sabin measured the charges on five oil drops.

Drop	A	B	C	D	E
q (10^{-19} C)	3.21	4.79	8.02	6.41	11.18

i. Find the largest charge that each of them is (nearly) a whole number of times.
ii. How many electrons does each drop carry?
iii. Find the best value of e from all five readings together.
iv. Why can't the readings alone prove that e is not, say, 0.8×10^{-19} C?

3 Predict, then explain [3]

Write your prediction first, then explain it.

An electron beam is deflected by 2 mm as it passes between two charged plates. Predict the deflection if i. the p.d. across the plates is doubled, ii. the electrons enter twice as fast. Then explain from $y = \frac{eVD^2}{2mdv^2}$.

4 Show that [3]

In Thomson's experiment the electrons are accelerated through a p.d. V_a, then pass undeflected through crossed fields E and B. Show that $\frac{e}{m} = \frac{E^2}{2V_aB^2}$.

5 Estimate it [3]

Millikan used drops about a thousandth of a millimeter across. Estimate the weight of an oil drop of radius 1.0×10^{-6} m (density 900 kg/m^3), and the p.d. needed to hold it still with 2 extra electrons between plates 5.0 mm apart. What p.d. would a drop of radius 1 mm need? What does this tell you?

6 Which explanation fits? [2]

In the 1890s some scientists thought cathode rays were waves, like light; others thought they were charged particles. Thomson bent them with both an electric and a magnetic field. Which idea does this support? Why?

7 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

> Prerana wrote: “Millikan’s experiment measured the mass of the electron. In an electric field an electron beam moves in a circle. A velocity selector lets through only electrons, whatever their speed.”

8 Work backwards [3]

Electrons accelerated from rest through 500 V go round a circle of radius 5.0 cm in a uniform magnetic field at right angles to their motion. Find the field.

9 Design it [4]

Sujata wants a velocity selector that lets ions through at 4.0×10^6 m/s. Her magnet gives 0.050 T and her plates are 1.0 cm apart.

i. What field E, and what p.d. across the plates, does she need?
ii. Will it work for ions of a different charge or mass at that speed?
iii. Which way are ions moving a little faster bent?

10 What if? [2]

What if Thomson’s tube held protons instead of electrons, accelerated through the same p.d.? Say what changes in i. their speed, ii. the directions in which each field bends them.

11 Make your own [2]

Write a problem about an oil drop held still between two plates whose answer is “the drop carries 5 extra electrons”. Solve it to show it works.