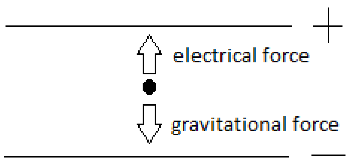
TURNING POINTS

1-4 The determination of the charge of the electron, e, by Millikan's method

1. $m = 2.60 \times 10^{-15}$ kg, $d = 6.00$ mm $= 6.00 \times 10^{-3}$ m, $\Delta V = 320$ V

   (a) Droplet in between plates:



   As the droplet is stationary is must be being attracted to the upper place and is thus negatively charged.

$$F_{gravitational} = F_{electrical}$$

$$mg = QE \qquad \text{but } E = V/d \text{ so}$$

$$mg = \frac{QV}{d}$$

giving $$Q = \frac{mgd}{V}$$

$$= \frac{2.60 \times 10^{-15} \times 9.81 \times 6.00 \times 10^{-3}}{320}$$

$$= 4.782.....\times 10^{-19} \text{ C}$$
$$= 4.78 \times 10^{-19} \text{ C}$$

   (b) $\frac{4.78 \times 10^{-19}}{1.60 \times 10^{-19}} = 3$

   Therefore 3 electrons are responsible for its charge.

2. $r = 1.10 \times 10^{-6}$ m, $E = 8.20 \times 10^{4}$ Vm^{-1} , $\rho = 960$ kgm^{-3}

   (a) $\rho = m/V$ so $m = \rho V$, and $V = \frac{4}{3}\pi r^3$ so

   $m = \rho\frac{4}{3}\pi r^3 = 960 \times \frac{4}{3} \times \pi \times (1.10 \times 10^{-6})^3 = 5.352... \times 10^{-15}$ kg
   $= 5.35 \times 10^{-15}$ kg to 3 sf

   (b) (i) $QE = mg$ as the drop is stationary so

$$Q = \frac{mg}{E}$$
$$= \frac{5.35 \times 10^{-15} \times 9.81}{8.20 \times 10^{4}}$$
$$= 6.40 \times 10^{-19} \text{ C}$$

   The field acts upwards so the top plate is negative.
   As the drop is attracted upwards it must have a positive charge

(ii) $\frac{6.40 \times 10^{-19}}{1.60 \times 10^{-19}} = 4$

Therefore the loss of 4 electrons is responsible for its charge.

3. d = 5.00 mm = 5.00×10^{-3} m, ΔV = 610 V, v = 1.15×10^{-4} ms^{-1} , ρ_{oil} = 960 kgm^{-3}, $\eta_{air} = 1.80 \times 10^{-5}$ Nsm^{-2}

(a) Stoke's law states $F_{drag} = 6\pi\eta rv$
and weight = mg = $\rho\frac{4}{3}\pi r^3 g$

At the terminal velocity the drag force and the weight are equal so

$$\rho\frac{4}{3}\pi r^3 g = 6\pi\eta rv$$

$$r^2 = \frac{9\eta v}{2\rho g}$$

$$= \frac{9 \times 1.80 \times 10^{-5} \times 1.15 \times 10^{-4}}{2 \times 960 \times 9.81}$$

$$= 9.89... \times 10^{-13}\ m^2$$

$$r = 9.945 \times 10^{-7}\ m$$
$$= 9.95 \times 10^{-7}\ m \text{ to 3 sf}$$

$$m = \rho\frac{4}{3}\pi r^3 = 960 \times \frac{4}{3} \times \pi \times (9.95 \times 10^{-7})^3 = 3.9557... \times 10^{-15}\ kg$$
$$= 3.96 \times 10^{-15}\ kg \text{ to 3 sf}$$

(b) $F_{gravitational} = F_{electrical}$

$mg = QE$ but E = V/d so

$$mg = \frac{QV}{d}$$

giving $Q = \frac{mgd}{V}$

$$= \frac{3.96 \times 10^{-15} \times 9.81 \times 5.00 \times 10^{-3}}{610}$$

$$= 3.18 \times 10^{-19}\ C \text{ to 3 sf}$$

4. (a) Charges calculated were always a multiple of 1.60×10^{-19} C and thus quantised. Furthermore in a charge of n x 1.60×10^{-19} C, n was the number of electrons lost/gained. The charge on an electron was thus the natural unit of charge.
(b) When stationary the gravitational force equalled the electrical force, i.e. $F_{gravitational} = F_{electrical}$. With the field switched off an unbalanced resultant force acts on the droplet. At first it accelerates with a = g = 9.81 ms^{-2}. However it soon reaches terminal velocity as the drag force increases with increasing speed until the drag force counterbalances the gravitational force.