8 Read the following article on the Millikan Oil Drop experiment then answer the questions that follow.

In 1909, Millikan and Fletcher performed the oil drop experiment to measure the elementary electric charge – the charge of the electron. Millikan received the Nobel prize in Physics due to the results of this experiment.

Fig. 8.1 shows the important features of the apparatus used by Millikan to measure the electron charge by observations on charged oil droplets.

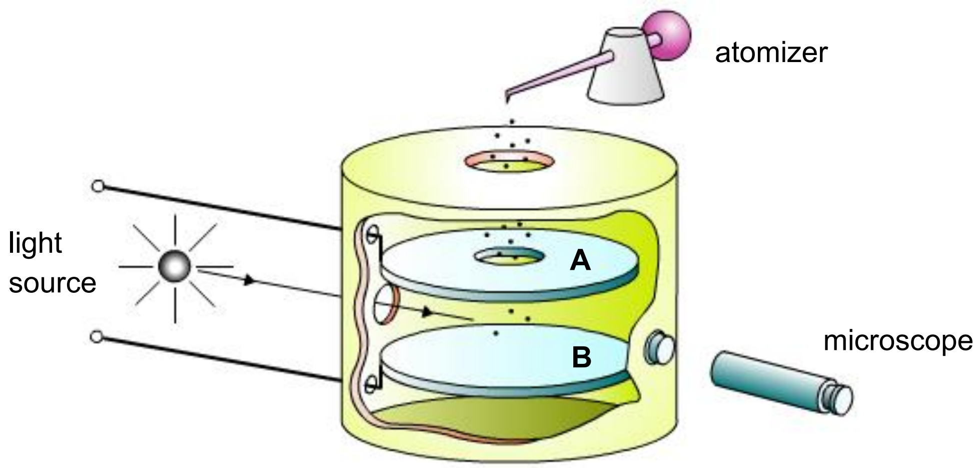


Fig. 8.1

The apparatus consists of a pair of horizontal metal plates A and B separated by a distance *d*.

The microscope is focused on the illuminated space under the hole through which oil droplets can enter.

The atomizer introduces a mist of oil droplets through the hole in the top plate that is ionized by X-rays, making them negatively charged.

When electric field is applied across plates A and B, the potential difference between the plates can be adjusted until a particular oil droplet is suspended. The value *V* that suspends that specific oil droplet can then be measured.

By repeating the experiment multiple times with differently sized oil droplets and recording the potential difference used, the charge of each oil droplet can be determined as small integer multiples of a certain base value of electronic charge. It is proposed that this base value is the elementary electric charge *q*.

$$\text{Charge of oil droplet, } Q = N\,q$$

where N is an integer
and q is the base value of electronic charge

(a) **(i)** A particular oil droplet suspended at rest with potential difference V, has a weight W and carries a charge Q. Assuming the upthrust of the air is negligible, show that

$$Q = W\left(\frac{d}{V}\right)$$

[1]

(ii) State and explain which plate, A or B, is at higher potential.

....

....

.... [2]

(iii) Explain why it is reasonable to neglect the upthrust.

....

.... [1]

(b) When the electric field is removed, the suspended oil droplet will start to fall. The oil droplets quickly reaches terminal velocity. The terminal velocity of the falling droplet can be measured.

The weight of an oil droplet is found by timing its fall at terminal speed over a standard distance, when the potential difference across the plates is zero.

Fig. 8.2 shows the relationship between the weight *W* of oil droplets and the time *T* taken by the oil droplets to fall 1.00 mm in air.

Fig. 8.2

The results shown in Fig. 8.3 were obtained with a Millikan apparatus.

For each oil droplet, the experimenter measured V across the plates at which the droplet was observed to be stationary. The distance between the plates was 4.42 mm.

The experimenter also measured the time T for the droplet to fall 1.00 mm in air at terminal speed after switching off the potential difference across the plates.

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6		
820	6.9	5.9	3.18
395	6.2	7.0	7.83

Fig. 8.3

Complete Fig. 8.3. [2]

(c) It is suggested that the drag force F_D on a small sphere of radius r moving with speed v through a viscous fluid is given by

$$F_D = 6\pi\eta rv$$

where η is the coefficient of viscosity of the fluid.

If the coefficient of viscosity of air at room temperature is 1.8×10^{-5} kg m^{-1} s^{-1}, estimate the radius of the oil droplet for the first row of Fig. 8.3.

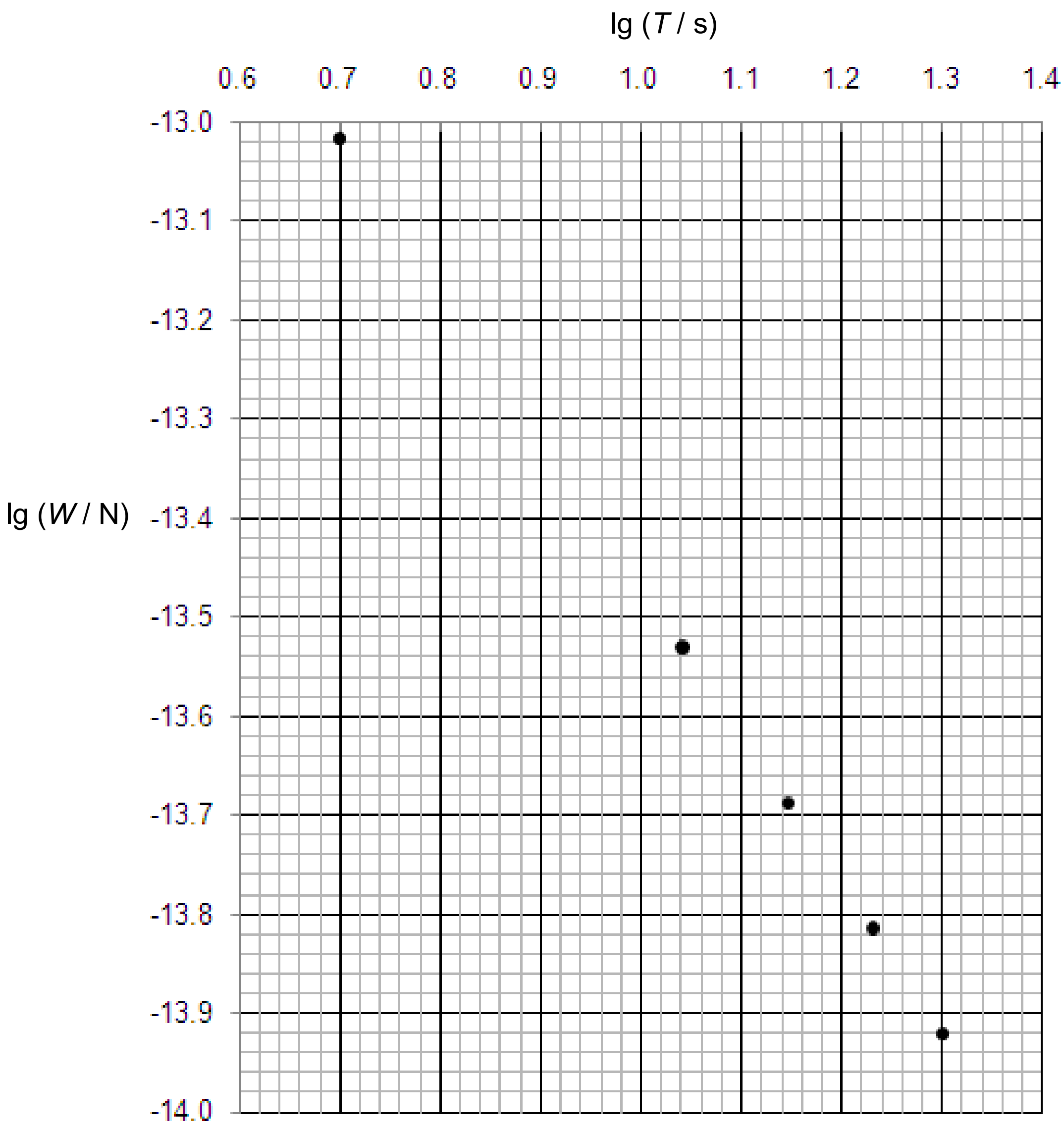
radius = ... m [3]

(d) It is thought that, when the potential difference between the plates is zero, the weight W of an oil droplet varies with time T of its fall (at terminal speed over a standard distance) according to the equation

$$W = aT^b \quad \text{------} \quad (1)$$

where a and b are constants.

Some data from Fig. 8.2 are used to plot the graph of Fig. 8.4



(i) Use Fig. 8.2 to determine lg (W / N) for a time T of 8.0 s.

lg (W / N) = ... m [1]

(ii) On Fig. 8.4,

1. plot the point corresponding to T = 8.0 s [1]

2. draw the line of best fit for the points. [1]

(iii) Use the line drawn in **(d)(ii)** to determine the constant b in equation (1).

b = ... [2]

(iv) Deduce, from your value of b in **(d)(iii)**, how the weight W of oil drop would depend on its terminal speed v.

[2]

(e) The Millikan experiment is said to provide experimental evidence for the *quantisation of charge*. Suggest what is meant by *quantisation of charge.*

....

.... [1]

(f) An early experimenter, working in non S.I. units, obtained the following six values for the magnitudes of the charges on small oil drops.

$Q/10^{-9}$ units	6.86	4.44	8.37	5.39	1.97	2.96

Use these results to find the magnitude of the largest possible basic electronic charge as measured in these units.

basic electronic charge = ………………………….units [3]

[Total: 20]

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