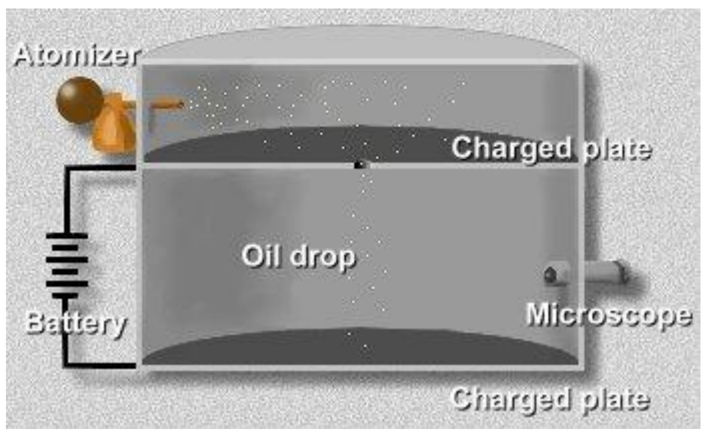
Notes

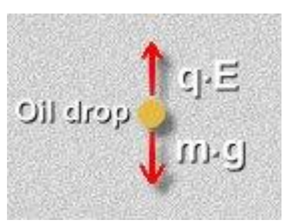
Physics Tool box

- **Elementary Charge, e** – the smallest unit of charge, called the elementary charge, e, of which other units are simple multiples; $e = 1.602 \times 10^{-19} C$.
- $q = Ne$

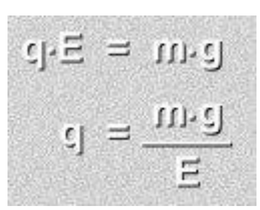
In 1911, American scientist R. A Millikan succeeded in measuring the charge on a single droplet of oil. The droplet of radius $10^{-6} m$ falls through the air at a constant speed and picks up a charge by contact with an ion. The droplet then falls between two brass plates. The upper plate, connected to a battery that gives the plate a charge opposite to that of the droplet. Now because the droplet is charged, it can be acted upon by an electric force. The force causes the droplet to move upward. When the batter is turned off, the droplet falls. If the distance and the time of the droplet's motions is known, its speed can be calculated. If we know the speed of the droplet, the voltage of the battery, and the properties of oil and air, we can determine the charge on the oil droplet.



When a drop is suspended, its weight **m · g** is exactly equal to the electric force applied $q \cdot \varepsilon$



The values of ε, the applied electric field, **m** the mass of a drop, and **g**, the acceleration due to gravity, are all known values. So you can solve for **q**, the charge on the drop:



Millikan determined the charge on a drop. Then he redid the experiment numerous times, each time varying the strength of the x-rays ionizing the air, so that differing numbers of electrons would jump onto the oil molecules each time. He obtained various values for ***q***.
The charge ***q*** on a drop was always a multiple of ***-1.602×10^{-19} C***, the charge on a single electron.

This number was the one Millikan was looking for, and it also showed that the value was quantized; the smallest unit of charge was this amount, and it was the charge on a single electron.

Millikan determined that an object with an excess (or deficit) of ***N*** electrons has a charge ***q*** that is given by:

$$q = Ne$$

Example

Calculate the charge on a small sphere with an excess of 7.0×10^{15} electrons

Solution:

$$\begin{aligned} q &= Ne \\ &= \left(7.0\times10^{15}\right)\left(1.6\times10^{-19}C\right) \\ &= 1.12\times10^{-3}C \end{aligned}$$

The charge on the sphere is $-1.1\times10^{-3}C$ (negative because of the excess of electrons)

Example

In a Millikan-type experiment, two horizontal plates are 3.5 cm apart. A latex sphere, of mass $1.2\times10^{-15}kg$, remains stationary when the potential difference between the plates is 520 V with the upper plate positive.

a) Is the sphere charged negatively or positively?

b) Calculate the magnitude of the charge on the latex sphere.

c) How many excess or deficit electrons does the sphere have?

Solution:

a) The electric force must be up, to balance the downward force of gravity. Since the upper plate is positive, the latex sphere must be negative. The electric field is downward, giving an upward force on a negative charge.

b)

$$F_E = F_g$$

$$q\varepsilon = mg$$

$$q\left(\frac{\Delta V}{r}\right) = mg$$

$$q = \frac{mgr}{\Delta V}$$

$$= \frac{\left(1.2\times10^{-15}kg\right)\left(9.8\frac{m}{s^2}\right)\left(3.5\times10^{-2}m\right)}{520}$$

$$= 7.915\times10^{-19}C$$

The magnitude of the charge is $7.9\times10^{-19}C$

c) $$N = \frac{q}{e}$$

$$= \frac{7.915\times10^{-19}C}{1.602\times10^{-19}C}$$

$$= 4.94$$

The sphere has 5 excess electrons (since the charge is negative)

Extra Notes and Comments