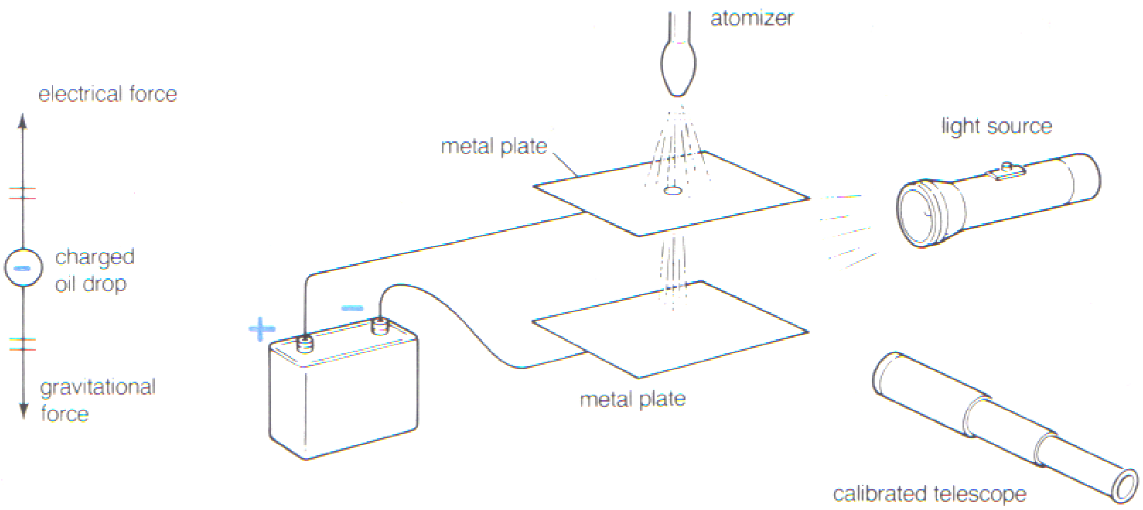
Section 12: A Unit of Charge Defined

For a quantitative study of electricity, we must be able to measure the electric charge on an object. Electric charge is measured in units called Coulombs (C), after the French scientist Charles de Coulomb (1736- 1806).

Early in the century, an American physicist, Robert Millikan (1868-1953), devised and performed a series of experiments (over a 7 year period) proving that there does exist a smallest unit of electric charge; all other electric charges are simple multiple multiples of this smallest charge. He reasoned that this elementary charge is the charge on a single electron.

A simplified diagram of Millikan's experiment can be seen below.



Millikan assumed that, when tiny oil drops are sprayed from an atomizer, they become charged by friction – some acquiring an excess of a few electrons while others have a deficit. Although there was no way of knowing how many extra electrons there were on an oil drop, or how many were missing, Millikan was able to devise a technique for measuring the total amount of charge on each individual drop.

Oil drops were sprayed into the space between two parallel plates. A light was shone on the oil drops, and they were observed through a telescope. A battery was connected to the plates creating a uniform electric field in the space between the plates. As a result, an upward electric force was exerted on those drops whose charge was the same sign as the lower plate's. By adjusting the amount of charge on the plates, it was possible to isolate a single oil drop and balance it so that the downward gravitational force and the upward electric force were equal.

Then using measurements of the "balancing field" and the speed at which the drop fell when the field was removed, Millikan was able to calculate the amount of electric charge on the oil drop in Coulombs.

By repeating this procedure many times, using the same oil drop with different amounts of charge on it and using different oil drops, Millikan was able to compile a long list of values for the amount of charge on an oil drop.

Millikan reasoned that the charge on each oil drop must be a whole number multiple of some smallest charge, the charge on a single electron. Using statistical analysis, Millikan was able to determine that the charge on one electron is $1.602\times10^{-19}C$. This is called the ***elementary charge*** (***e***) because the charge on an object must be some whole number multiple of "***e***".

A coulomb of charge can be negative or positive. If an object has an excess of electrons, the charge will be negative. If the object has a deficit of electrons the charge will be positive.

Formula: $q = Ne$ where N – the number of electrons removed or added
e – the elementary charge
q – the total charge on an object

Examples

1 What is the charge on an atomic particle that has an excess of 10 electrons?

2 When you rubbed a balloon on your hair you transferred 4.2 x 10^{17} electrons to the balloon. What is the charge on you hair?

3 How many protons are required to create a total charge of 8.0 C?

Do questions 41-45 on page 582 of your textbook.

Section 13: ***Coulomb's Law of Electric Force***

Coulomb's Law of Electric Force states:

The electric force between 2 charged objects is directly proportional to the product of the charges on the objects and inversely proportional to the square of the distance between them. The direction of the force extends along an imaginary line joining the centers of the two objects and is called **positive** for **repulsion** and **negative** for **attraction**.

Proportionality statement: $F_e \alpha \frac{q_1 q_2}{r^2}$

Equation: $F_e = k\frac{q_1 q_2}{r^2}$,

where q_1 and q_2 – are the charges on the objects in Coulombs (C)
r – is the distance between their centers in meters (m)
k – is the proportionality constant which is 9.0 x 10^9 Nm^2/C^2
F_e – is the electric force in Newtons (N)

Proportionality Exercises:

1 The electrostatic force between tow charged objects is 2.5×10^{-4} N. What will be the new force if the distance between them is tripled, one charge is doubled and the other charge is quartered?

2 The electrostatic force between two point charges is 6.0×10^{-5} N when the separation distance is 0.18 m. What will be the magnitude of the force if the distance changes to

A) 0.36 m B) 0.06 m C) 0.27 m

3 Two identical spheres have charges 3q and 11q respectively. They are a distance “r” apart. If the spheres are allowed to touch and are ten separated, what must be their new separation distance if the electrostatic force between them remains unchanged?

4 Ball 1 has a charge of 3q while an identical sphere (ball 2) has a charge of –5q. They are held a distance “r” apart and the force of attraction between them is 6.9×10^{-14} N. What will be the new force between them if they are allowed to touch and then are moved apart a distance of “r” again?