Millikan's Experiment

Millikan devised and performed a series of experiments to answer the following questions:

1. Does there exist, in nature, a smallest unit of electric charge of which all other charges are a multiple?

2. If so, what is this elementary charge, and what is its magnitude, in coulombs?

He reasoned that the elementary charge would be the charge on a single electron. In order to determine the magnitude of this charge, he made use of the uniform electric field in the region between two oppositely charged parallel plates. He used this apparatus to isolate and suspend charged oil drops, and to measure the charge on each.

Millikan further reasoned that the charges of these oil drops would be integer multiples of the elementary charge. Through thorough analysis of his data, Millikan was able to determine the charge on an electron, or the elementary charge, with great precision.

$$e = 1.6 \times 10^{-19}\ C$$

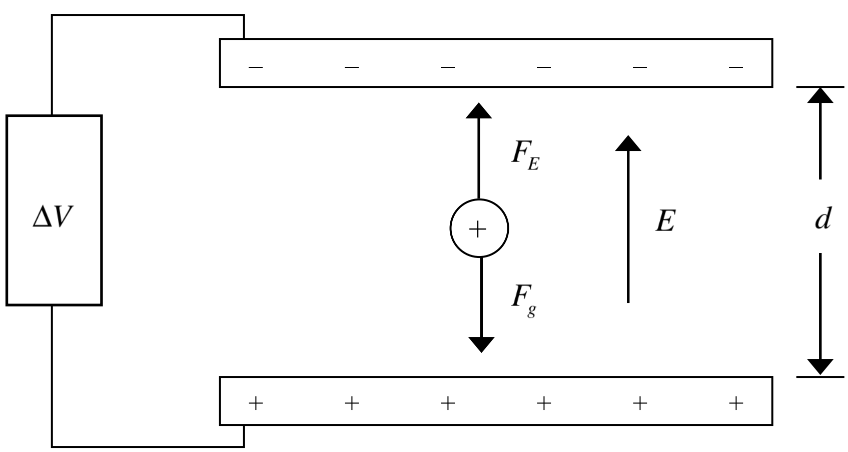
Knowing this value allows us to calculate the number of excess or deficit electrons that constitute any electric charge.

An object with an excess (or deficit) of N electrons has a charge q that is given by

$$q = N \cdot e$$

The Physics of Millikan's Experiment

Millikan used his apparatus to "balance" a charged oil drop between the parallel plates. When the drop is balanced, the gravitational force exerted downward upon it is equal to the electrical force acting upward. Below is a representation of Millikan's apparatus



For a positively charged drop of mass m and charge q, the electric force acts upward.

$$F_E = qE$$

When the charged drop is balanced in the field

$$F_E = F_g$$
$$qE = mg$$

However, the electric field intensity between parallel plates is constant, and is given by

$$E = \frac{\Delta V}{d}$$

So, for an oil drop of mass m and charge q, balanced by a potential difference ΔV,

$$q = \frac{mg}{E}$$

$$\boxed{q = \frac{mgd}{\Delta V}}$$

Examples

1. Calculate the charge on a small sphere with an excess of 5×10^{14} electrons.

2. In a Millikan type experiment, two horizontal plates are 2.5 cm apart. A latex sphere of mass 1.5×10^{-15} kg remains stationary when the potential difference between the plates is 460 V, with the upper plate positive.
   a) Is the sphere charged negatively or positively?

   b) What is the magnitude of the electric field intensity between the plates?

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

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

Homework
Millikan's Experiment Worksheet

Millikan's Experiment Worksheet

1. How many electrons must be removed from a neutral, isolated conducting sphere to give it a positive charge of 8.0×10^{-8} C? (5.0×10^{11} electrons)

2. What will be the force of electric repulsion between two small spheres placed 1.0 *m* apart, if each has a deficit of 10^{8} electrons? (2.3×10^{-12} N)

3. A drop is falling in a Millikan oil-drop apparatus when the electric field is off.
   a) What are the forces acting on the oil drop, regardless of its acceleration?
   b) If the drop is falling at constant velocity, what can be said about the forces acting on it?

4. An oil drop weighs 1.9×10^{-15} N. It is suspended in an electric field of 6.0×10^{3} N/C.
   a) What is the charge on the drop? (3.2×10^{-19} C)
   b) How many excess electrons does it carry? (2)

5. A positively charged oil drop weighs 6.4×10^{-13} N. An electric field of 4.0×10^{6} N/C suspends the drop.
   a) What is the charge on the drop? (1.6×10^{-19} C)
   b) How many electrons is the drop missing? (1)

6. If three more electrons were removed from the drop in problem 5, what field would be needed to balance the drop? (1.0×10^{6} N/C)

7. A small object has an excess of 5.0×10^{9} electrons. Calculate the magnitude of the electric field intensity and the electric potential at a distance of 0.500 *m* from the object. (-28.8 N/C, -14.4 V)

8. Two large, horizontal metal plates are separated by 0.050 *m*. A small plastic sphere is suspended halfway between them, and experiences an electric force of 4.5×10^{-15} N that just balances the force of gravity on it.
   a) What is the potential difference between the plates, if the charge on the plastic sphere is 6.4×10^{-19} C? (3.5×10^{2} V)
   b) Calculate the mass of the plastic sphere. (4.6×10^{-16} kg)

9. An oil drop, whose mass is found to be 4.95×10^{-15} kg, is balanced between two large, horizontal plates 1.0 *cm* apart, by a potential difference of 510 *V*, with the upper plate positive. What is the charge on the drop, both in coulombs and in elementary charges, and is it excess or deficit electrons? (9.5×10^{-19} C, $6e$, excess)

10. Delicate measurements indicate that the earth has an electric field surrounding it, similar to that around a positively charged sphere. Its magnitude at the surface of the earth is about $100\ N/C$. What charge would an oil drop of mass $2.0 \times 10^{-15}\ kg$ need to have, in order to remain suspended by the earth's electric field? Give your answer in both coulombs and elementary charges. ($1.96 \times 10^{-16}\ C$, $1.2 \times 10^{3} e$)