Millikan's Oil Drop Experiment

Millikan attempted to answer two very important questions:

1. Does there exist in nature a smallest unit of electric charge of which all other units are multiples?

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

Despite the fact that a single proton or electron is far too small to be seen directly, Millikan was able to develop an ingenious method to measure the charge.

Millikan's Experiment (summary)
The apparatus that Millikan used is pictured on the handout included with this lesson. You will find a brief explanation of his method below:

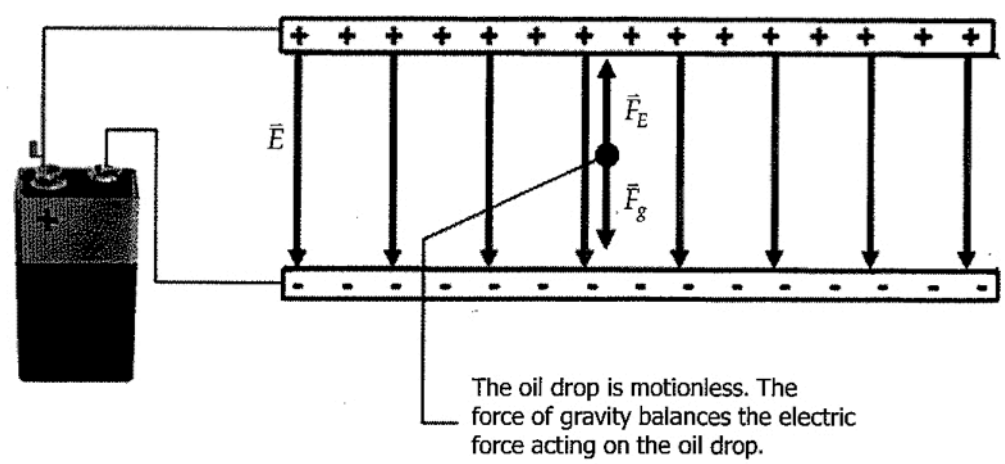
1. Oil drops are sprayed from the atomizer. As they are sprayed, they become negatively charged by friction.

2. Gravity causes the drops to fall. A few pass through the hole in the top plate of the apparatus.

3. An electric field exists between the charged plates. This field is directed down and, therefore, exerts an upward force on the negatively charged oil drops.

4. By adjusting the voltage of the plates, the field strength can be changed. Millikan adjusted the field until the oil drop was **suspended** between the plates.

The diagram below shows the electric field lines and the forces acting on the oil drop:



With the charged oil drop suspended motionless, it should be clear that the net force is zero. This means that the upward electric force must exactly match the size of the downward gravitational force.

$$F_E = F_g$$
$$qE = mg$$
$$q = \frac{mg}{E}$$

Since he knew the electric field strength and the mass of the oil drop, Millikan was able to calculate the charge on the drop. He did this for a large number of oil drops (hundreds) and compiled a list of charges. He then analyzed those charges, looking for a lowest common denominator. He determined that every charge he had measured could be expressed as a multiple of $1.6 \times 10^{-19}\ C$. He concluded that this number was the so called **elementary charge**.

Example

An oil drop of mass $1.22 \times 10^{-14}\ kg$ is held motionless between the plates of the parallel plate apparatus. The electric field between the plates is $1.50 \times 10^{5}\ N/C$. The top plate is negatively charged.

a) Draw a free-body diagram of this situation.

b) Determine the charge on the oil drop in coulombs.

c) Determine the number and type of excess elementary charges on the oil drop.

Electric Fields Worksheet #4

1. How many electrons must be removed from an electrically neutral silver dollar to give it a charge of +2.4 μC ? (1.5×10^{13})

2. What is the charge on an electroscope that has a deficit of 4.0×10^{11} electrons? ($+6.4\times10^{-8}\ C$)

3. An oil drop weighs 1.9×10^{-15} N. It is suspended in an electric field of 6.0×10^{3} N/C [down].
   a) What is the charge on the drop? (-3.2×10^{-19} C)
   b) How many excess electrons does it carry? (2)
   c) If the electric field were increased to 9×10^{3} N/C [down], what would be the acceleration of the oil drop? ($5.1\ \text{m/s}^2$ [up])

4. 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? ($+1.6\times10^{-19}$ C)
   b) How many electrons is the drop missing? (1)
   c) What is the direction of the electric field?

5. What field would be needed to cause the oil drop in Question 2 to accelerate downward at $0.75\ \text{m/s}^2$? (3.69×10^{6} N/C [up])

6. If three more electrons were removed from the drop in Question 2, what field would be needed to suspend the drop? (1.0×10^{6} N/C [up])

7. The Earth's electric field has been determined to be 100 N/C [up]. What charge would an oil drop of mass 2.0×10^{-15} kg need to have in order to remain suspended by the Earth's magnetic field? ($+1.96\times10^{-16}$ C)

8. An oil drop carries a charge of 8.0×10^{-19} C. It accelerates upward at $1.0\ \text{m/s}^2$ in an electric field of intensity 4.25×10^{5} N/C . What is the mass of the oil drop? (3.15×10^{-14} kg)