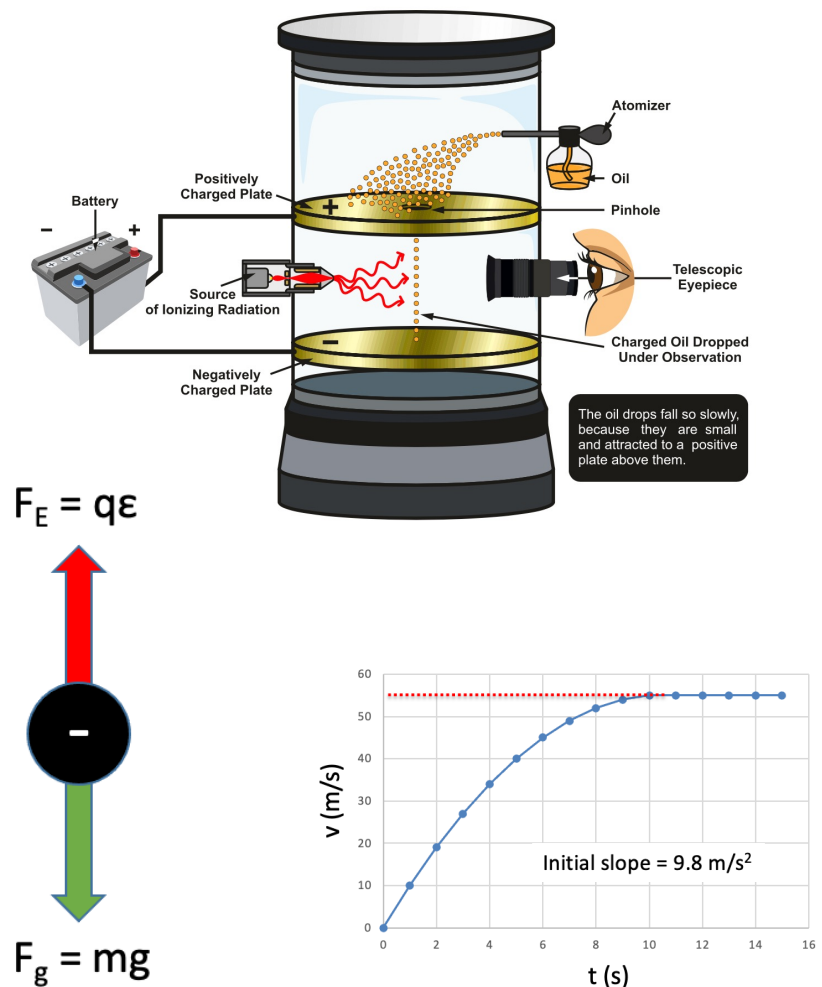


Millikan's Experiment

Determining the Elementary Charge

- Robert Millikan
- Millikan's Experiment
- Voltage and the Electric Field
- Solving for Charge (q)
- The Charge on the Electron
- The Mass of an Electron
- Calculating the Number of Electrons
- Check Your Understanding



Preview File

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Robert Millikan



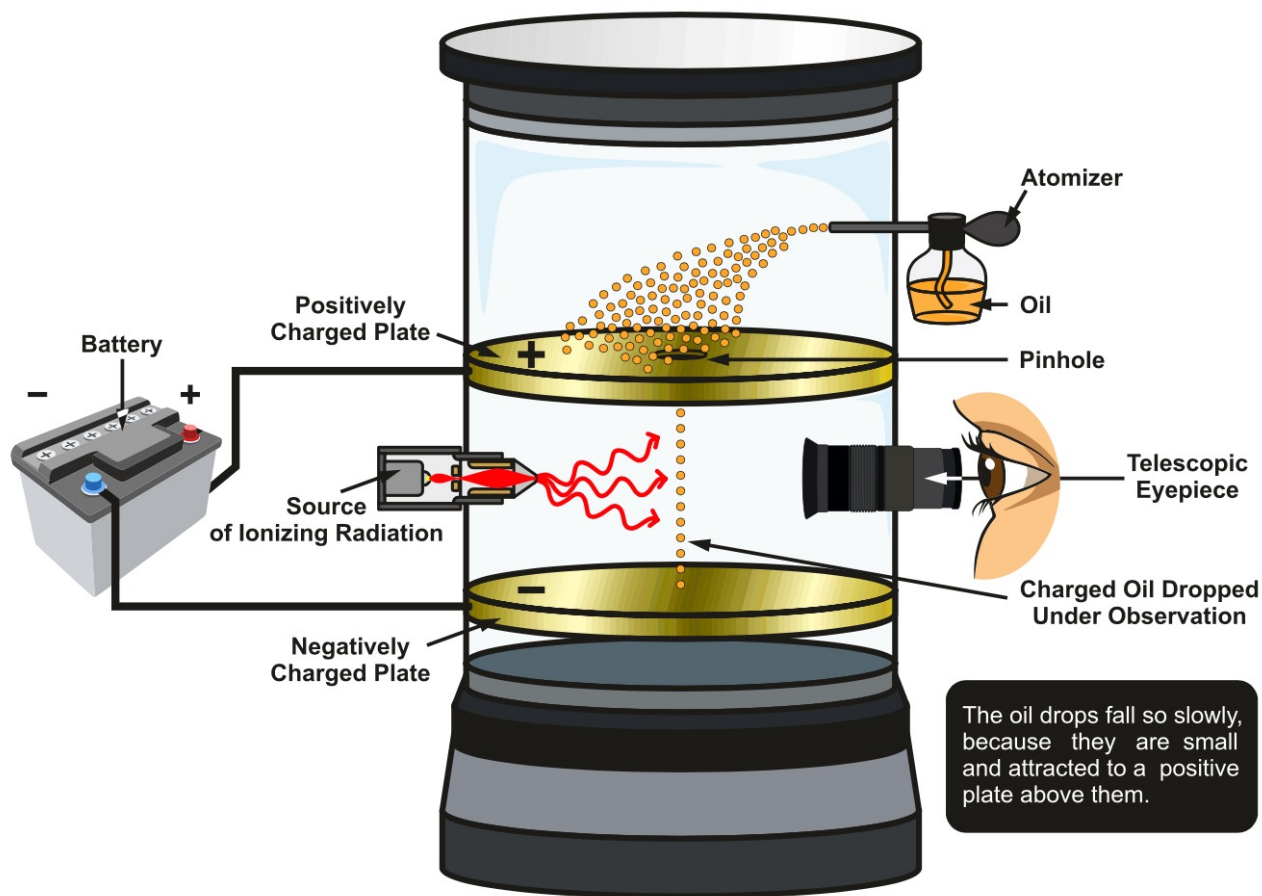
- 1868-1953
- Determined the amount of charge on single electron in 1909

Millikan Asked...

Does there exist a smallest unit of electric charge?

If so, what is the magnitude of the “elementary charge”?

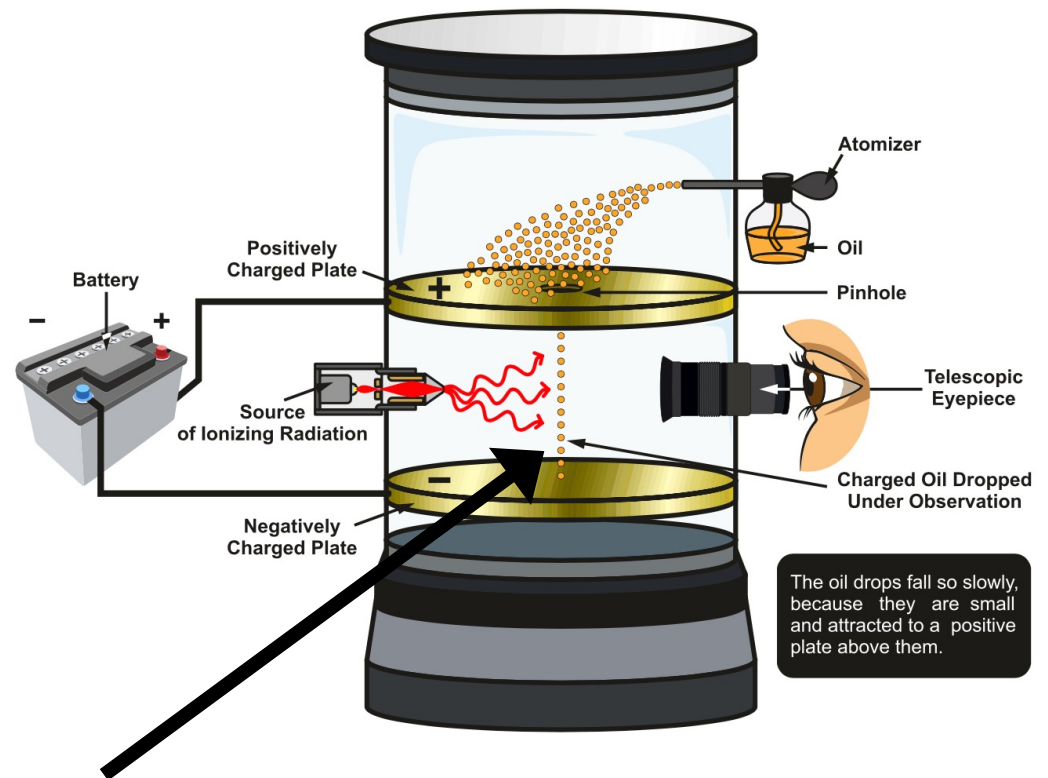
Millikan's Experiment



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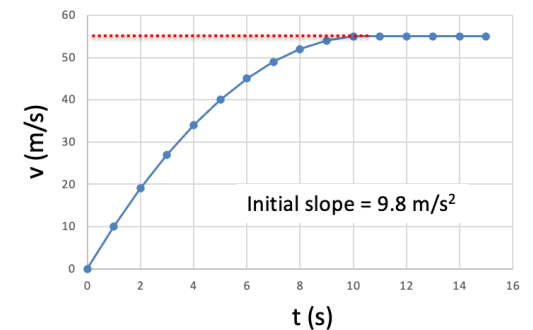
The Experiment – Step 2

The mass of the oil drops that made it through could be determined (see next slide).



Finding the Mass using Terminal Velocity

- As an object free falls, it encounters more and more air resistance
- Acceleration will occur until the air resistance negates the gravitational force downwards
- At this point, they will fall at a constant speed – this is their terminal velocity



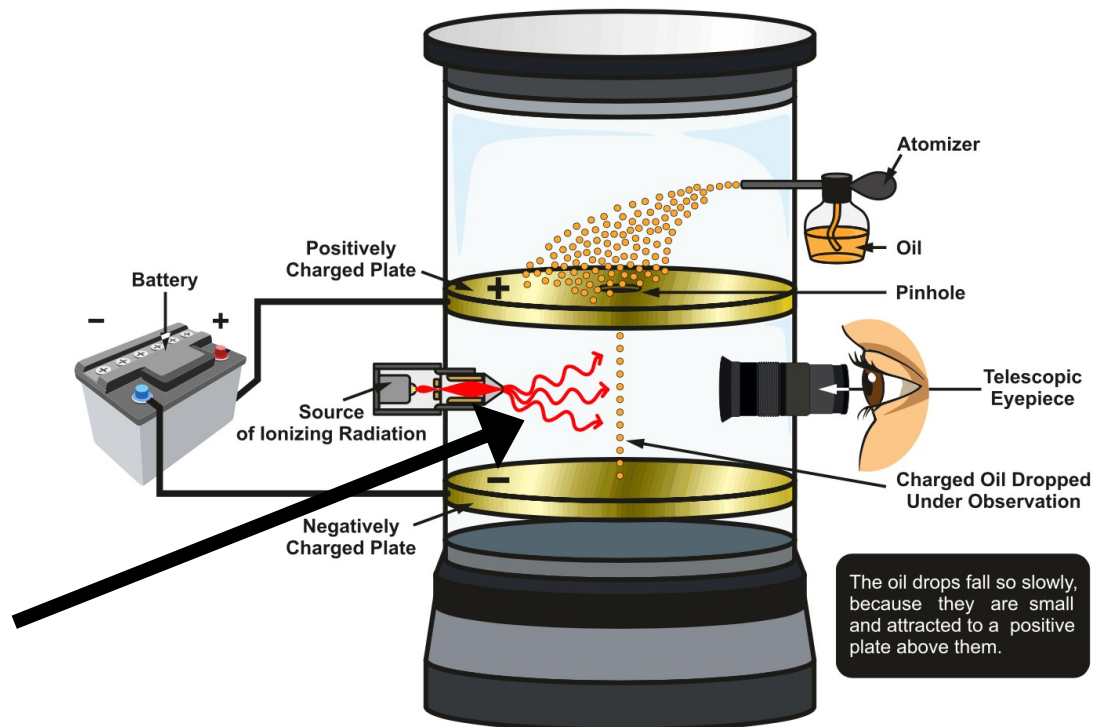
- _____
- $F_g = mg$ & $F_w = \frac{1}{2} C_D \rho A F v^2$
- Therefore, $mg = \frac{1}{2} C_D \rho A F v^2$ --> Since all the variables are known, the mass of the falling oil droplets can be determined



The Experiment – Step 3

- X-rays were used to separate electrons away from the air molecules in the chamber

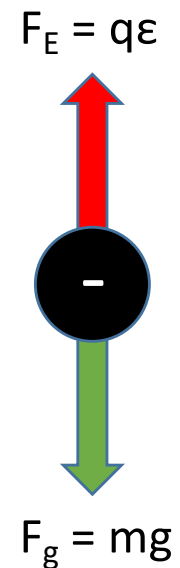
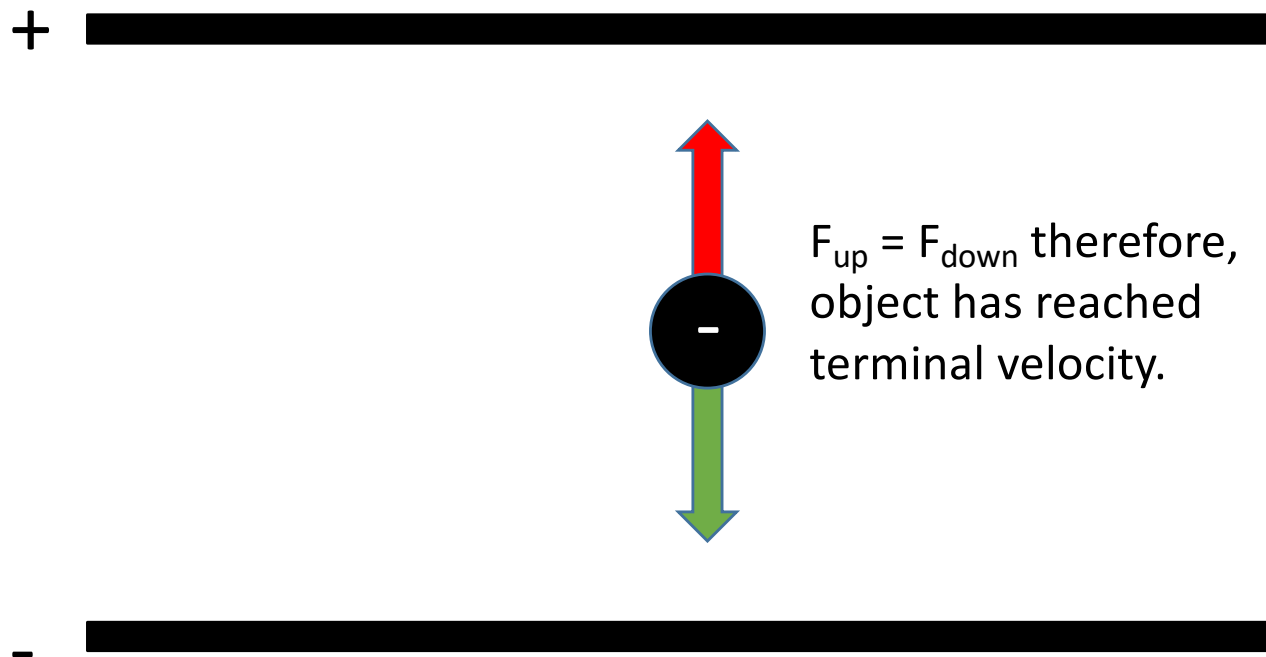
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The Experiment – Step 5

- If the voltage is increased enough, the electric force upwards ($F_E = q\varepsilon$) will exactly counter the force of gravity downwards ($F_g = mg$)
- At this point, the particles will be suspended between the two plates



Voltage and the Electric Field

$$\vec{\mathcal{E}} = \frac{\Delta V}{r}$$

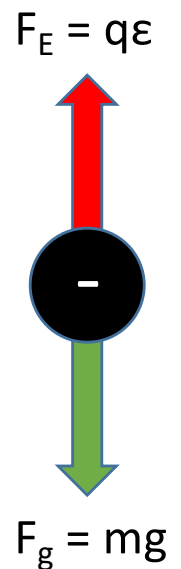
- r is the distance between the plates
- V is known and adjusted until the particles are properly suspended
- _____

The Experiment – Step 5

Force Up: $\vec{\mathcal{E}} = \frac{\vec{F}_E}{q} \rightarrow F_E = q\mathcal{E}$

Force Down: $F_g = mg$

Since $F_E = F_g$ when the particles are suspended in mid-air:



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The Charge on the Electron

- The list of values he determined for the total electric charge on each of the drops contained a significant pattern: all the values were simple multiples of the greatest common factor
- Many of the droplets had this smallest value of charge on them, but none had less
- _____

The Charge and Mass of the Electron

- _____

- Prior to Millikan, J.J. Thompson had determined the ratio of mass to charge of an electron using his cathode ray tubes:

$$\frac{1 \text{ g}}{-1.76 \times 10^8 \text{ C}}$$

- Using this ratio and the newly discovered charge of an electron, Millikan determined its mass

$$-1.60 \times 10^{-19} \cancel{\text{C}} \times \frac{1 \text{ g}}{-1.76 \times 10^8 \cancel{\text{C}}} = 9.10 \times 10^{-28} \text{ g}$$

Electron Mass vs. Proton Mass

Mass of an electron: 9.10×10^{-28} g

Mass of a proton: $1.67262178 \times 10^{-24}$ g

- protons and neutrons have approximately the same mass

- _____

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Check Your Understanding

Calculate the charge on a small sphere with an excess of 5.0×10^{14} electrons.

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

$$q = Ne$$

Check Your Understanding

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) Calculate the magnitude of the charge on the latex sphere.
- c) How many excess or deficit electrons does the sphere have?

$$q = Ne$$

$$\epsilon q = mg$$

$$\vec{\epsilon} = \frac{\Delta V}{r}$$