Millikan's Experiment

At the end of the 1800's scientists asked two questions:

1. Does a simplest unit of electric charge exist in nature?
2. What is its value?

Millikan hypothesized that this should be the charge possessed by a single electron. He created the following experiment to measure the sign (positive or negative) and magnitude of this charge:

Millikan took two smooth parallel plates and drilled a hole through one of them. An atomizer sprayed oil above one of the charged plates. The oil particles picked up charge from the friction with the air particles in the chamber. Some oil would collect and drop through the hole in the top parallel plate. Because it was very small and charged, it obtained a terminal velocity when it dropped through the second chamber (which could be calculated). When the oil was dropping, it had a negative charge, so Millikan applied a positive charge to the upper plate. This caused the oil drop to change direction and move up at terminal velocity. He changed the charge of the plates several times to calculate the terminal velocity of the oil drop. Millikan then applied X-rays to the drop, which made it lose its charge. By comparing the new terminal velocity to the old one, he managed to calculate the amount of charge on the oil, thus finding a value for e.

Millikan had no way of knowing how many extra electrons were on each drop, but he knew that if he measured the charge on many drops (some big and some small) they would have a smallest common divisor. This must be the charge on one electron.

To do the math, Millikan knew that at terminal velocity the electric force ($F_e = q\varepsilon$) and the gravitational force ($F_g = mg$) must be balanced.

Free Body Diagram:

So at terminal velocity:

$$F_g = F_e$$

But between charged plates, we know (from yesterday) that the electric field is connected to the potential difference between the plates through the equation $\varepsilon = {}^{V}\!/_{r}$, therefore:

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

where:

q is the charge on the particle

m is the mass of each drop (in kg)
g is acceleration due to gravity ($9.81 m/s^2$)
r is the separation between the plates in metres
V is the potential difference in Volts (V)

Unit Analysis:

Millikan measured the mass of each drop by measuring its terminal velocity. He calculated the q values for many different oil drops and found the lowest common denominator:

$$e = -1.602 \times 10^{-19} \text{ C}$$

From this, he could use the equation (from grade 11) q = Ne to calculate the excess electrons on each oil drop.