Background:

Millikan Oil-Drop Experiment

As is common in the progress of science, Millikan's oil-drop experiment developed from the ideas and work of scientists who preceded him. There are many creative aspects to doing science; Millikan's creativity is in the realm of experimental design—creating the new plan and equipment to reliably measure what others had failed to do. Millikan was an experimentalist and hence his work was entirely empirical (see summary of the nature of scientific knowledge).

Creation of the Concept of an Electron

Michael Faraday, the famous English chemist and physicist, made many significant contributions in the fields of electromagnetism and electrochemistry. His study of electrolysis, reported in 1834, showed that the mass of a substance reacted at an electrode depends, among other factors, on an integer or the valency number of the ions of the substance. The Irish physicist George Stoney proposed the following explanation:

> "And, finally, Nature presents us, in the phenomenon of electrolysis, with a single definite quantity of electricity which is independent of the particular bodies acted on. To make this clear I shall express `Faraday's Law' in the following terms, which, as I shall show, will give it precision, viz.:—*For each chemical bond which is ruptured within an electrolyte a certain quantity of electricity traverses the electrolyte which is the same in all cases.* This definite quantity of electricity I shall call E_r. If we make this our unit quantity of electricity, we shall probably have made a very important step in our study of molecular phenomena." (*Journal of the Chemical Society, August, 1874*)

In the same paper, Stoney coined the term, electron, and estimated its charge as 1×10^{-20} C (translated into SI units) based on studies of the number of molecules present in a gas. This is an amazing hypothesis considering that most physicists at the time believed that the atom was indivisible. Faraday believed this and disagreed completely with Stoney's hypothesis. Further complicating the situation, James Clerk Maxwell argued that electric charge was infinitely divisible and represented a "strain in the electromagnetic ether".

Early Measurements of the Charge on an Electron

- John Sealy Townsend, a former student of J. J. Thomson, did the first measurement of the charge on an electron in 1898, just a year after Thomson reported the results of his charge-to-mass experiments for cathode rays. Townsend obtained clouds of charged water droplets from an electrolysis experiment and estimated their mass by measuring the speed of descent of a water droplet. The total mass of the cloud was determined by weighing the water and the total charge by using an electrometer. Townsend obtained a value of about 1×10^{-19} C (in modern SI units), assuming every droplet carried one charge.
- After his famous charge-to-mass experiment on cathode rays that established the existence of the electron as a component of all atoms, J. J. Thomson turned his attention to the measurement of the charge on an electron. C.T.R Wilson had already discovered that a charged particle acts as a nucleus around which water

vapour condenses and thus invented the first primitive cloud chamber. Using a combination of Townsend's method, C.T.R. Wilson's cloud chamber, and a very indirect means of measuring mass and charge of the cloud, Thomson obtained a value of 1.1×10^{-19} C for the charge on an electron.

- Harold Wilson was a colleague of J.J. Thomson in Cambridge in 1896. Wilson improved Thomson's method by using the influence of an external electric field to more directly determine the charge on a water droplet. In 1903, Wilson reported the charge as 1.03×10^{-19} C.

All of the above methods determined the average electric charge for water droplets but were inconclusive with respect to the smallest unit of charge. However, these studies provided important experimental details for Millikan's conclusive experiment that started in 1909.