Experimental Science: Millikan Oil Drop*

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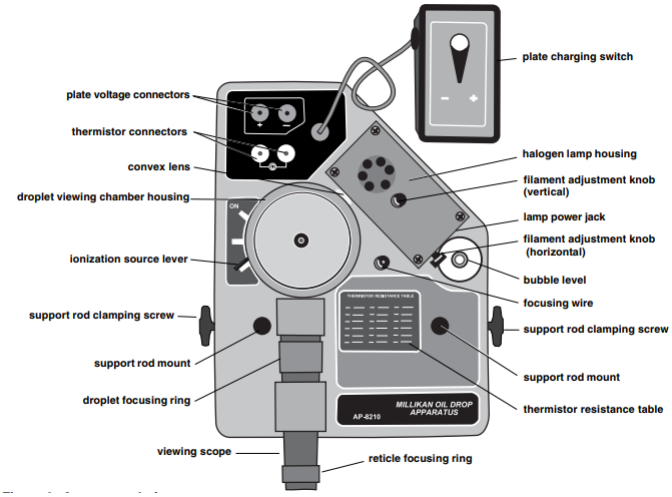
Abstract: The determination of the charge of an electron had been meticulously devised through experimental data science in which Robert Millikan was able to create an experiment that manipulated mathematical techniques using mists of oil drops sprayed into a chamber that used capacitor plates to measure the rising and falling speed of the oil drops in the condition of an electric field being present. Through this he was able to determine the electric force on a charge in addition to finding magnitude of the field which further allowed to determine the charge of the suspended isolated drops in the process. The purpose that Millikan set out to do this experiment was to experimentally find the charge of an electron and to either prove or disprove the atomic theory of electricity at that time.

Usage: Informational Purpose

I. APPARATUS OF THE MILLIKAN OIL DROP

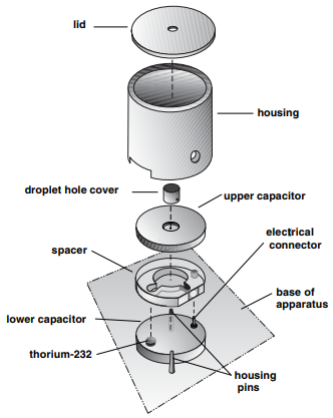
The design of the apparatus for the experiment as of now is a cylindrical chamber with a small opening that only allows for a small spray of droplets. The chamber is constructed with 2 capacitor plates separated by a spacer that will be responsible for a negative and positive charge across the plates.

The top plate has a small hole for when the oil drops are sprayed in a mist into the top cover opening of the chamber to allow for the drops to enter into the viewing chamber where the drops will be observed. To manipulate the oil drops the apparatus is designed with a lever that allows for the user to ionize the drops with the ionization source that is the thorium 232 alpha source.



A.

The apparatus also has a thermistor that will provide the user with the temperature within the chamber. In order to view the drops the apparatus is also built with a halogen lamp that is directed towards a convex lens to focus the light into the chamber. There are two voltage plate connectors that will allow us to supply the plates with a voltage of 500V through an external power supply.



B.

With that being said the remaining important parts is the plate charging switch which will allow the user to manipulate the field within the chamber that will affect the positively or negatively ionized oil drop. The last piece would be the viewing scope that can adjust the amount of light coming into the scope and additionally a tuner for viewing the reticle lines. Other equipment that

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would be necessary to do the experiment today would also be a multi meter to measure the voltage being input to the voltage conductors and to measure the resistance when finding the temperature with the thermistor.

C. Experimental Procedure

The process that Millikan set out was as follows, first, introduce a spray of drops. Ideally, the spray should be quite modest as the best procedure is to avoid with clumps of drops in which a drop cannot be isolated in view. Next, a drop will be chosen in which initially the user will measure the falling velocity of the oil drop within the reticle lines. The reticle lines are approximately 0.5 mm major divisions and 0.1 mm minor divisions within the field of view. In this step, the capacitor plates will not be used. The drop will naturally fall without any ionization sources being present. Afterwards, the ionization source will be turned on and the plate charge switch will be used to manipulate the observed drop upward and downward depending on the charge of the drop. After, tabulating and keeping track of the charge events of the drops, the measurements will be averaged.

By using Stoke's theorem and analyzing the forces on the drop as buoyant forces Millikan was able to determine the mass of the drop and through mathematical manipulations of equations was able to find a way to establish a relationship with the data that he had collected. The other part that is significant to this process is that Millikan took numerous samples of these events so that he could accurately determine the charge of e. The reason this is important is that it is employing the idea of the law of large numbers. By doing an event a large N number of times the resultant data will begin to converge to a value that is within a range of what the expected value should be.

$$Eq = mg + kv$$

the density of air can be neglected when analyzing the forces on the drop since it is significantly smaller than the drop

$$q = mg(vf + vr)$$

$$m = 4/3pa^3$$

In this case the mass of the drop is unknown but through some manipulation and based on assumption that the oil drop is spherical employing Stokes's theorem when it is falling we can eliminate the usage of m when trying to determine q.

$$a = \sqrt{(9vf/2gp)}$$

Other things that need to be taken into account is that Stokes's theorem tends to fail under certain conditions when velocity of the drop is too slow. By taking into account those conditions the viscosity will have to be multiplied by a factor of resulting in a more effective value to be used

$$1/(1 + b/pa)$$

With some mathematical techniques Millikan arrived at the equation for the charge of the oil drop.

$$q = \left[400\pi d\left(\frac{1}{g\rho}\left[\frac{9\eta}{2}\right]^3\right)^{1/2}\right] x \left[\left(\frac{1}{1+\frac{b}{pa}}\right)^{3/2}\right] x \left[\frac{v_f + v_r\sqrt{v_f}}{V}\right] \text{e.s.u.}$$

As mentioned previously, taking the average charges of the events lead to being able to observe the various changes between each new drops manipulation and then taking the average difference between all of the varying charge sizes. By dividing the average charge by the average difference the value of e was able to be determined.

D. Conclusion

By using Stokes's theorem and modifying the conditions that it began to fail under Millikan was able to determine the charge of the electron which would later on be used to be able to determine the mass of the electron as well. This experiment is very critical to our understanding of modern physics as we're able to incorporate Millikan's work into the majority of physics whether it be classical physics or quantum physics. He wasn't immediately recognized for his work but Millikan eventually did receive credit for his discovery after other researchers found that his experiment provided profound information.

1. References/Sources

Editor - Sunny Bishop
Date Accessed - 12/10/2020
Author - Pasco.com
Source - https://hepweb.ucsd.edu/2dl/pasco/Millikans