Millikan's Determination of Planck's Constant.

In 1916 Robert Millikan devised an experiment based on photo-electric emissions to determine the value of Planck's constant.
In 1905 Einstein had incorporated Planck's Law into his photoelectric theory with the equation:

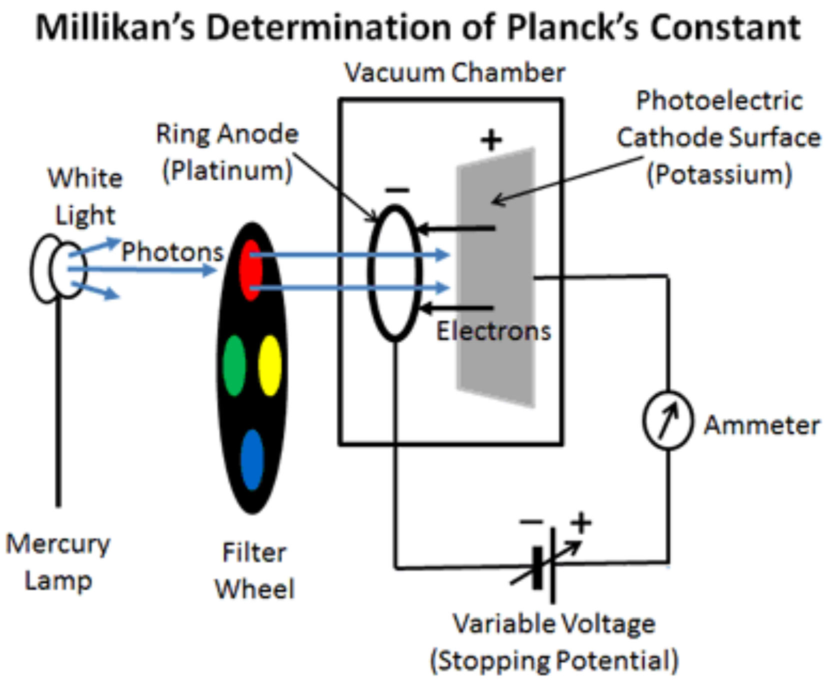
$$E = 1/2mv^2 = hf - W$$

where **E** is the energy of the electrons emitted from a metal due to photoelectric emission, **h** is Planck's constant, **f** is the frequency of the incident light, and **W** is the work function, in Millikan's words, "the work necessary to get the electron out of the metal". Einstein expressed the energy in terms of the kinetic energy of the emitted electrons, but since this was difficult to measure, no accurate value of Planck's constant had yet been determined.

Millikan used instead the electrical equivalent of the energy namely:

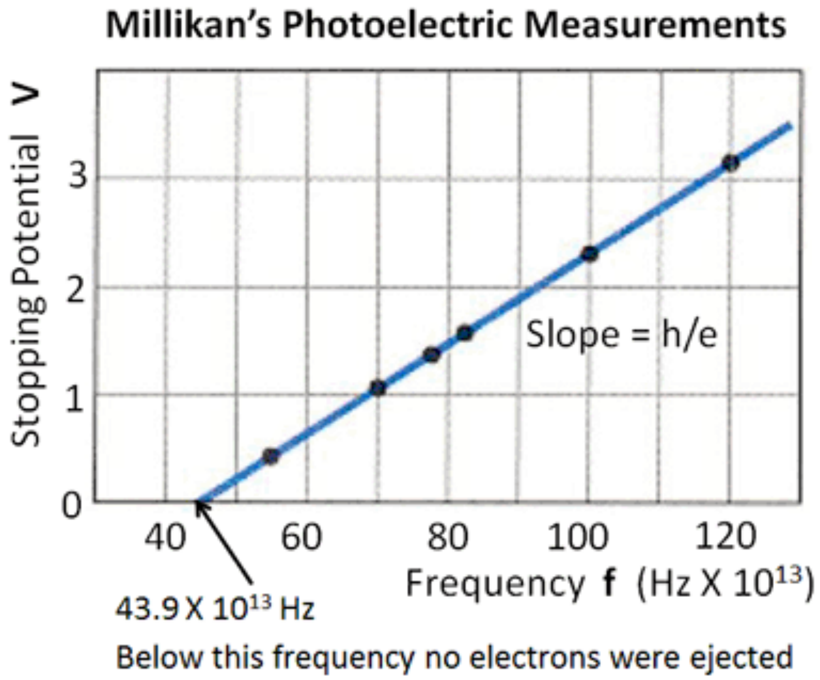
$$eV = hf - W$$

where **e** is the electric charge on an electron and **V** is the voltage of the corresponding electrical field, so that **eV** is the electrical energy of the emitted electrons. This enabled him to devise a simpler, more accurate experiment for determining Planck's constant based on photo-electric emissions.



Light from a white light source was directed through a coloured filter and a ring shaped electrode in a vacuum chamber to illuminate a photoelectric target which in response emitted a stream of electrons. By means of an external circuit, a variable voltage **V** was applied between the metal target and the anode ring which drove any free electrons back towards the target. This "stoppng" voltage was noted when the ammeter indicating the current from the battery was zero indicating that the applied voltage was just sufficient to balance the current due to the photoelectric emission. The procedure was repeated using different coloured filters which provided incident light over a range of frequencies.

Millikan's 1912 graph of the "stopping voltage" versus the incident light frequency, shown below, indicates a linear relationship between the frequency of the incident light and the potential needed to suppress the emission of electrons and that V is proportional to the emitted energy.



Rearranging the energy equation, the graph represents the following relationship:

V = f h/e - W/e

It shows that the slope of the graph is equal to **h/e** and since Millikan had recently detrmined the value of **e**, then **h** could be calculated. He thus determined the value Planck's constant to be 6.57 x 0^{-34} joule-seconds which was about 0.8 % of its currently accepted value today.

By extrapolating the graph down to the intercept $\mathbf{V^i}$ on the "voltage" axis which passes through the "frequency" origin, (not shown), the value of the work function **W** can also be calculated. (**W = $\mathbf{V^i}$e**).