ELEMENTS OF MODERN PHYSICS LABORATORY

Course Code- PHY259
Practical-5

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List of Practicals

- To study The Photo Electric Effect using Planck's Constant Set.
- Determine the Planck's constant using LEDs of at least 4 different colors.
- Determine work function of material of filament of directly heated vacuum diode.
- Determine the wavelength of H-alpha emission line of Hydrogen atom.
- Determine the charge of an electron with the help of Millikan oil drop Set.
- Show the tunneling effect in tunnel diode using I-V characteristics.
- Determine the wavelength of laser source using diffraction of single slit.
- Determine the wavelength of laser source using diffraction of double slits.
- Determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
- Determine the absorption lines in the rotational spectrum of Iodine vapor

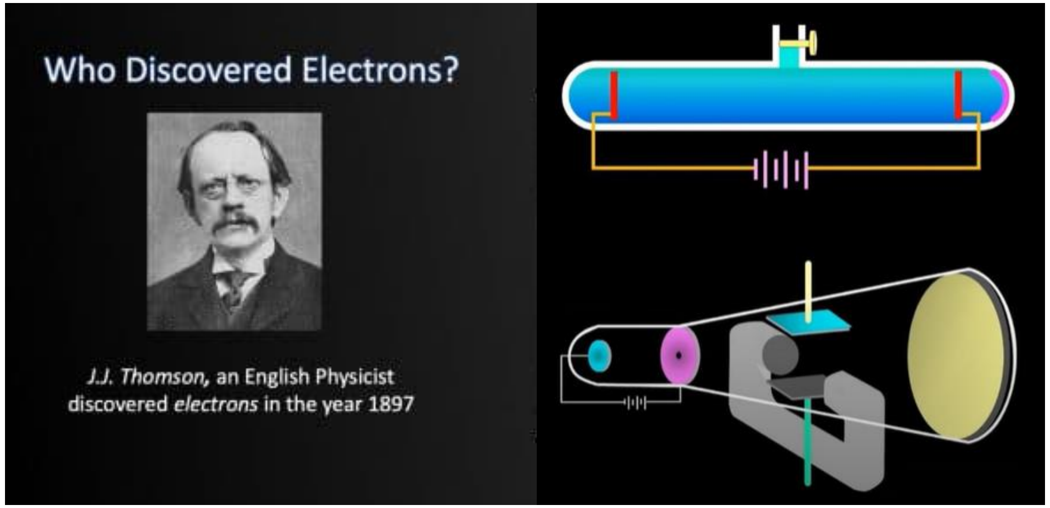
Objective: **Determine the charge of an electron with the help of Millikan oil drop Set.**

Learning Objectives

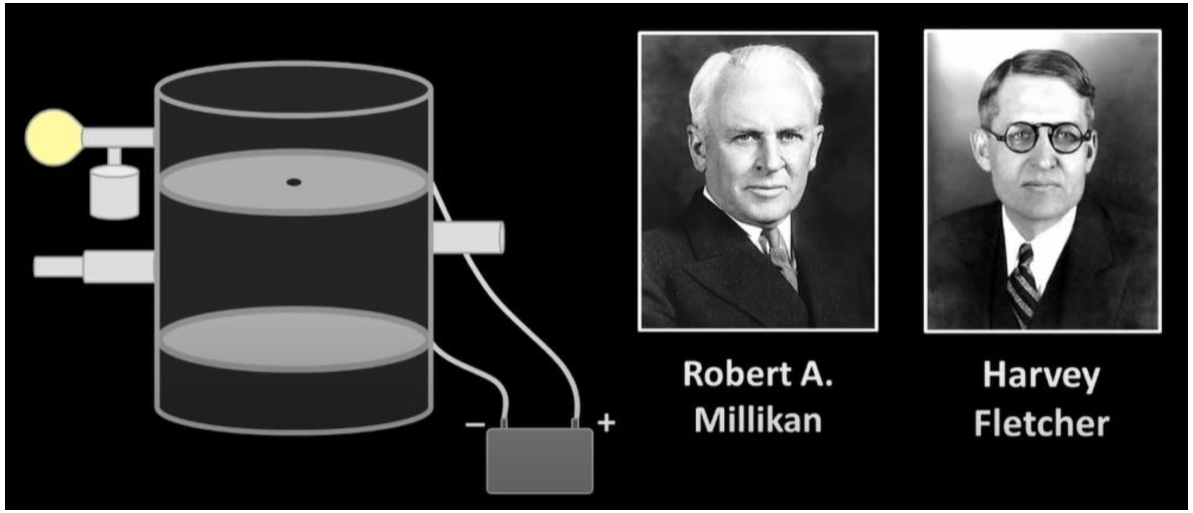
1. **To understand Hydrogen spectra w.r.t. absorption and emission.**
2. **Knowing solution of calculation of wavelegnth of emitted photon**
3. **Dealing with spectrometer and able to see different wavelengths.**
4. **Determine the wavelength of H-alpha emission line of Hydrogen atom.**

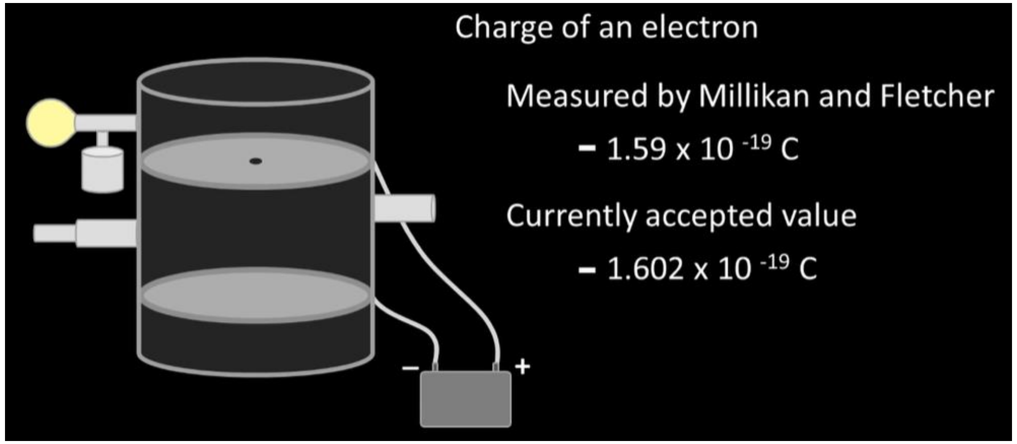
Basic Understandings

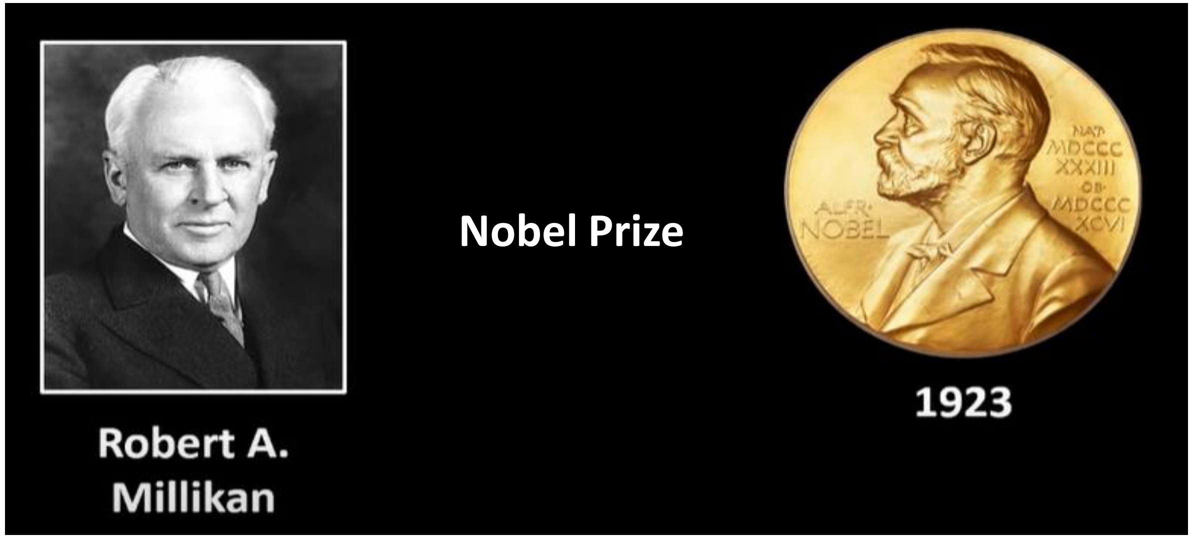
1897


Who Discovered Electrons?
J.J. Thomson, an English Physicist
discovered *electrons* in the year 1897

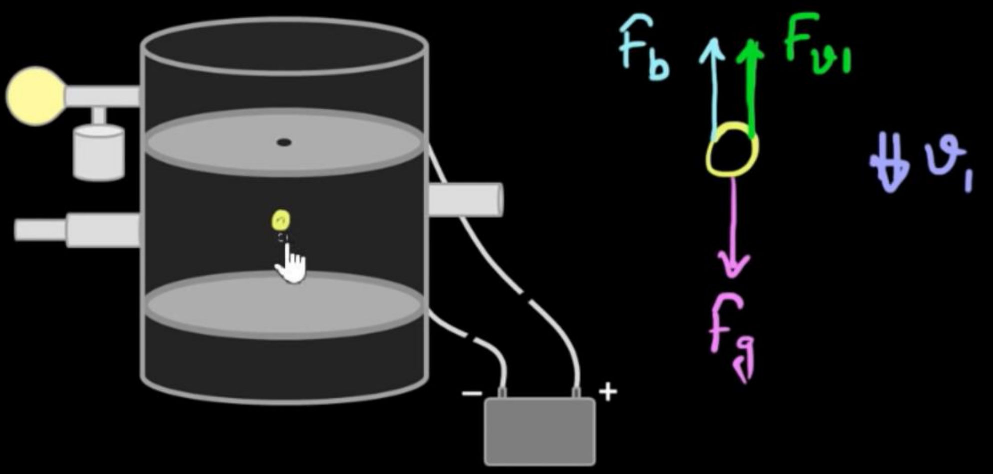
1909


Robert A.
Millikan
Harvey
Fletcher


Charge of an electron
Measured by Millikan and Fletcher
-1.59×10^{-19} C
Currently accepted value
-1.602×10^{-19} C


Robert A.
Millikan
Nobel Prize
1923

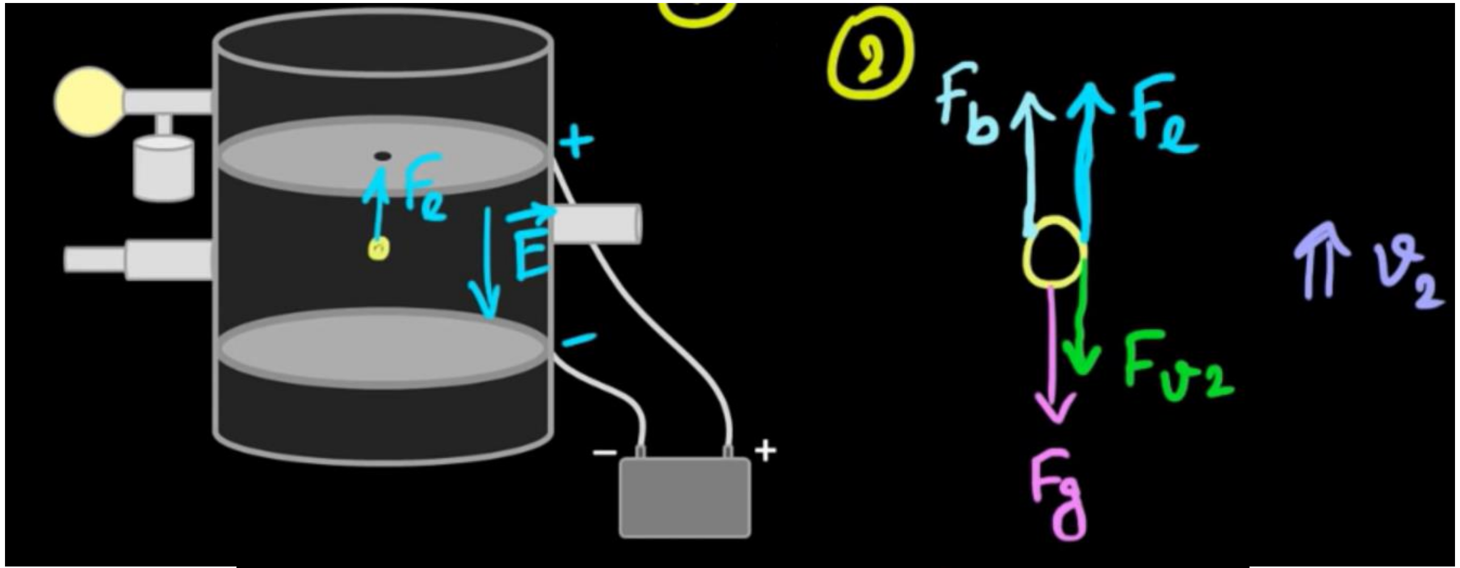
Millikan's *Oil Drop* Experiment



$$F_g = mg = \frac{4}{3}\pi r^3 \rho_o g$$

$$F_b = \frac{4}{3}\pi r^3 \rho_a g$$

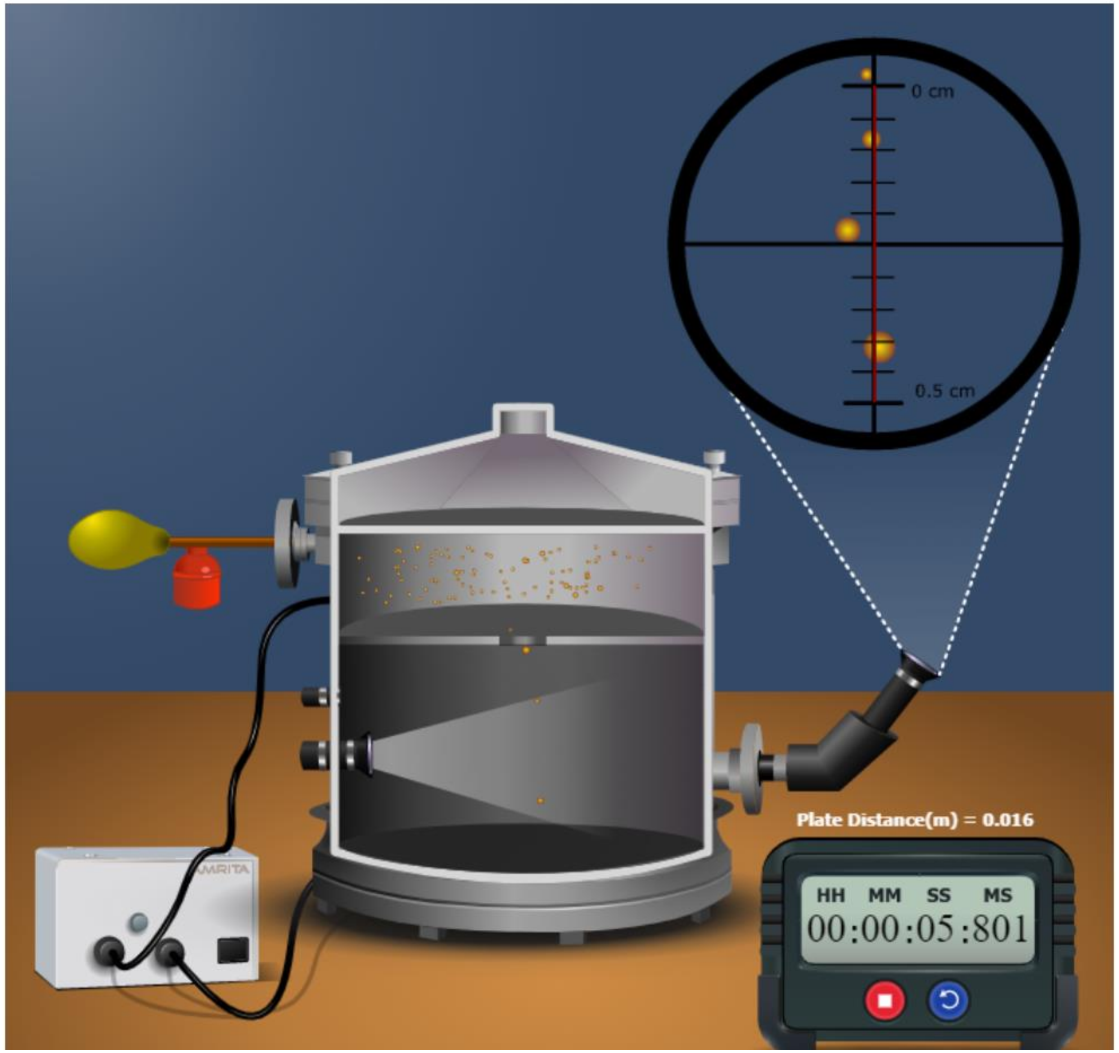
$$F_{v1} = 6\pi r \eta v_1$$



$$① \quad F_g = F_b + F_{v1}$$

$$② \quad F_g + F_{v2} = F_e + F_b$$

Millikan’s Oil Drop Set-up



About Apparatus

- Apparatus consist of an atomizer, which helps to spray tiny droplets.
- By means of a short focal distance telescope, the droplets can be viewed.
- There are two plates, one positive and the other negative above and below the bottom chamber.
- dc supply is attached to the plates. Some of the oil drops fall through the hole in the upper plate.
- Using X-rays the bottom chamber is illuminated causing the air to ionize. As the droplets traverses through the air, electrons accumulate over the droplets and negative charge is acquired.
- With the help of dc supply a voltage is applied. Speed of its motion can be controlled by altering the voltage applied on the plates. By adjusting the voltage applied, drop can be suspended in air.
- Millikan observed one drop after another, varying the voltage and noting the effect. After many repetitions he concluded that charge could assume only certain fixed values.

Initially the oil drops are allowed to fall between the plates in the absence of electric field. Due to gravity they accelerate first, but gradually slowdown because of air resistance.

The terminal velocity v_1 in the absence of an electric field is calculated as

$$v_1 = \frac{l_1}{t_1}$$

where 'l_1' is the distance travelled by the oil drop and 't_1' is the time taken.

The drag force acting upon the drop is calculated from stokes's law and is given as

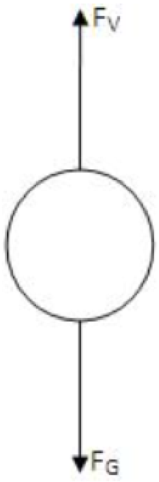
$$F_v = 6\pi\eta r v_1$$

The apparent weight (true weight minus up thrust) for a perfectly spherical body is given by,

$$F_G = \frac{4}{3}\pi r^3 g(\rho - \rho_{air})$$

At terminal velocity the oil drop is not accelerating, so the total force acting on it must be zero

$$F_V - F_G = 0.$$



i.e.,

$$F_V = F_G$$

$$r^2 = \frac{9\eta v_1}{2g(\rho - \rho_{air})}$$

r-radius of oil drop
η-viscosity of air
V_1-terminal velocity
g-acceleration due to gravity
ρ-density of liquid
ρ_{air}-density of air

Now a field is produced in the bottom chamber with the supply voltage. A likely looking drop is selected and kept in the middle of the field of view by adjusting the voltage.

If the electric forces F_e, balances the gravitational force F_G, the drop suspends in the air.

Then,

$$F_e = F_G$$

$$qE = mg$$

$$\frac{qV}{d} = mg$$

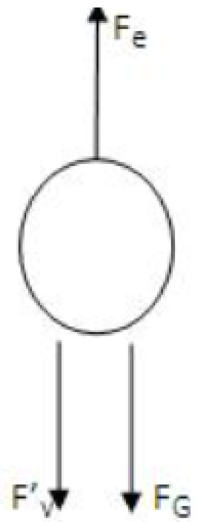
where V is the balancing potential and d is the distance between the plates.

If the applied electric force F_e is greater than the downward forces, some of the drops (the charged ones) will start to rise. Now the electric force will act upwards,gravity and viscous forces acts downwards.

Corresponding terminal velocity v_2 is calculated as,

$$v_2 = \frac{l_2}{t_2}$$

Now the total force acting on drop is $F_e - F'_V - F_G = 0$.



$$F_e = F'_V + F_G$$

F'_V is the new viscous force under the action of electric field.

$$qE = 6\pi\eta r v_2 + 6\pi\eta r v_1$$

$$\frac{qV}{d} = 6\pi\eta r(v_1 + v_2)$$

$$q = 6\pi\eta r(v_1 + v_2)\frac{d}{V}$$

Millikan repeated the experiment no. of times, each time varying the strength of X-rays ionizing the air. As a result no. of electrons attaching to the oil drop varied. Then he obtained various values for q, and is found to be a multiple of 1.6×10^{-19}C.

Procedure for Simulation:

1. Click on 'START' button.
2. Click on Combo box to choose the oil.
3. Double click 'START' button of stop watch and notice the time taken t_1 by a drop, to travel distance l_1 between any two points .
4. Click 'Voltage On' to suspend the same oil drop in air, which is the balancing voltage V.
5. Click the 'X Ray ON' button and notice the time taken t_2 by same drop to travel distance l_2 between any two points.
6. Charge of drop is calculated using the equation, $q = \dfrac{6\pi\eta r(v_1 + v_2)d}{V}$
7. Repeat the experiment for another oil.

Observations

Distance travelled l1 (cm)	Time taken t1 (s)	Distance travelled l2 (cm)	Time taken t2 (s)	Terminal velocity		Balancing potential V	charge of the drop q
				v_1 (m/s)	v_2 (m/s)		