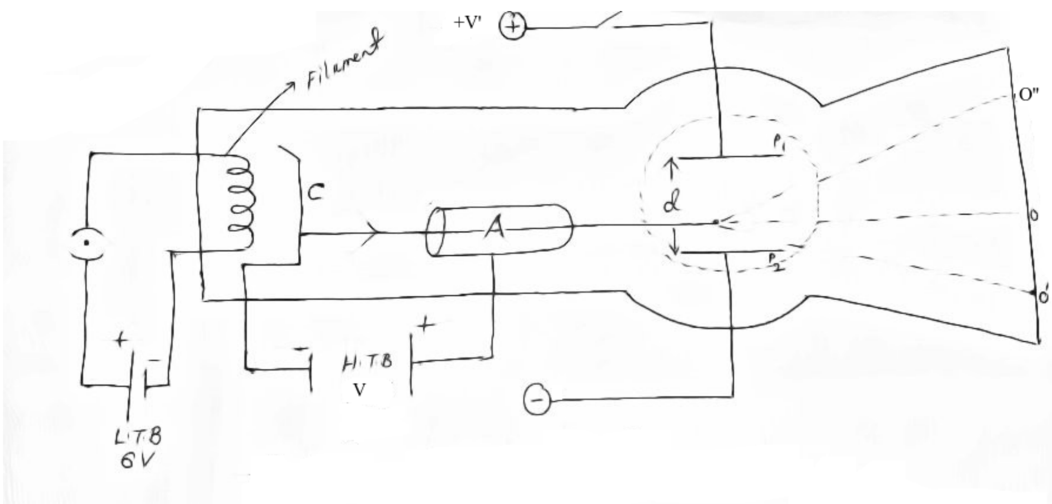
Determination of Specific charge (e/m) of an Electron by J.J. Thomson's Experiment

Roshan Shrestha

The ratio of charge and mass of a charged particle is called its specific charge. J.J. Thompson devised an experiment for measuring the ratio of charge(e) and mass(m) for an electron. The experiment set up consists of an evacuated glass tube containing cathode C and a cylindrical anode A maintained at a high positive potential with respect to the cathode by means of a high tension battery of about 10kV. The cathode is heated by a filament connected to a low tension battery of about 6V which emits electrons on heating. These electrons accelerate towards to the anode travelling the horizontal axis of the tube and strikes at the middle of the fluorescent screen at the other end of the tube at point O (say).



Thomson's apparatus for determination of e/m for electron

A uniform magnetic field with flux density **B** is applied to the beam of electrons by using Helmholtz coil as shown in figure (shown by dotted lines). The magnetic field is into the plane of paper and is perpendicular to the motion of beam of electrons where **v** is the velocity of electron with which it enters the field. Then, the electron experiences the magnetic force (F_m) in upward direction so that the electron deflects downward and strikes the fluorescent screen at point (O') which is given by,

$$\mathbf{F_m} = \mathbf{Bev} \tag{1}$$

Now, the magnetic field is switched off and a uniform electric field with electric field intensity **E** is applied between the two horizontal parallel plates P_1 and P_2 maintained at a potential difference V' and separated by a distance d. Then, the electron experiences the electric force (F_e) in downward direction so that the electron deflects upward and strikes the fluorescent screen at point (O'') which is given by,

$$\mathbf{F_e} = \mathbf{eE} = \frac{\mathbf{eV'}}{\mathbf{d}} \tag{2}$$

When the electron is accelerated through high potential difference (V) between cathode C and cylindrical anode A, it gains the kinetic energy given by,

$$\mathbf{K.E. = eV}$$

$$\mathbf{or, \frac{1}{2}mv^2 = eV}$$

$$\mathbf{\frac{e}{m} = \frac{v^2}{2V}} \tag{3}$$

Now, when both the electric field and magnetic field are applied perpendicular to each other and are adjusted so that the electron beam is neither deflected upward nor downward and hence passes straight along the axis of tube and strikes the point O, then the magnetic force and electric force are equal,

$$\mathbf{F_m = F_e}$$

$$\mathbf{or, Bev = \frac{eV'}{d}}$$

$$\mathbf{v = \frac{V'}{Bd}} \tag{4}$$

Substituting (4) into (3) we have,

$$\mathbf{\frac{e}{m} = \frac{V'^2}{2B^2d^2V}}$$

Thus, by knowing the value of V',B,V and d, we can calculate the value of $\frac{e}{m}$. The value of $\frac{e}{m}$ for electron calculated by J.J. Thompson was $1.76 \times 10^{11} C/kg$.