Details of Thomson's *e/m* Calculations

To calculate e/m it was first necessary to determine the velocity of the electrons in the cathode rays. This was done by deflecting the beam with a magnetic field, H, and then applying an opposing electrical field, E, just strong enough to restore a straight-line path. (Note: Vector direction of H is N→S.) The forces exerted on the traveling electrons are given by

$$F_{\text{mag}} = Hev \quad \text{and} \quad F_{\text{elec}} = Ee$$

where e is the charge on the electron and v is its velocity. With both fields adjusted to give straight-line motion, $F_{\text{mag}} = F_{\text{elec}}$, so

$$Hev = Ee$$

$$\Rightarrow v = E/H \tag{1}$$

By determining the necessary applied E and H fields to achieve a straight-line beam, the velocity v could be determined from equation (1). Thomson observed that the velocity only depended on the voltage across the cathode and anode.

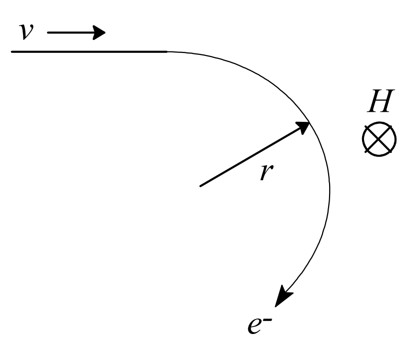
With v known as a function of applied tube voltage, Thomson was able to determine the ratio e/m by two methods. We will only consider the more direct of these. With the magnetic field applied alone, the beam is bent by a force $F_{\text{mag}} = Hev$. But any force is mass times acceleration, $F = ma$, so

$$F_{\text{mag}} = Hev = ma$$

$$\Rightarrow e/m = a/Hv \tag{2}$$

At this point both H and v were known, so a means of getting the acceleration, a, was required to solve equation (2).

When the beam of negatively charged electrons is deflected by the applied magnetic field, H, it begins to assume a circular trajectory with a radius of curvature, r.



This radius can be determined by observing the point at which the curved beam strikes the fluorescent screen at the end of the tube.

With r now known, the acceleration can be calculated by using the fundamental equation for the acceleration of a body moving in a circular trajectory:

$$a = v^2/r \tag{3}$$

Substituting this value of a from equation (3) into the e/m equation (2) gives

$$e/m = \frac{v^2/r}{Hv} = v/Hr \tag{4}$$

With v, H, and r known, e/m could be calculated by equation (4).