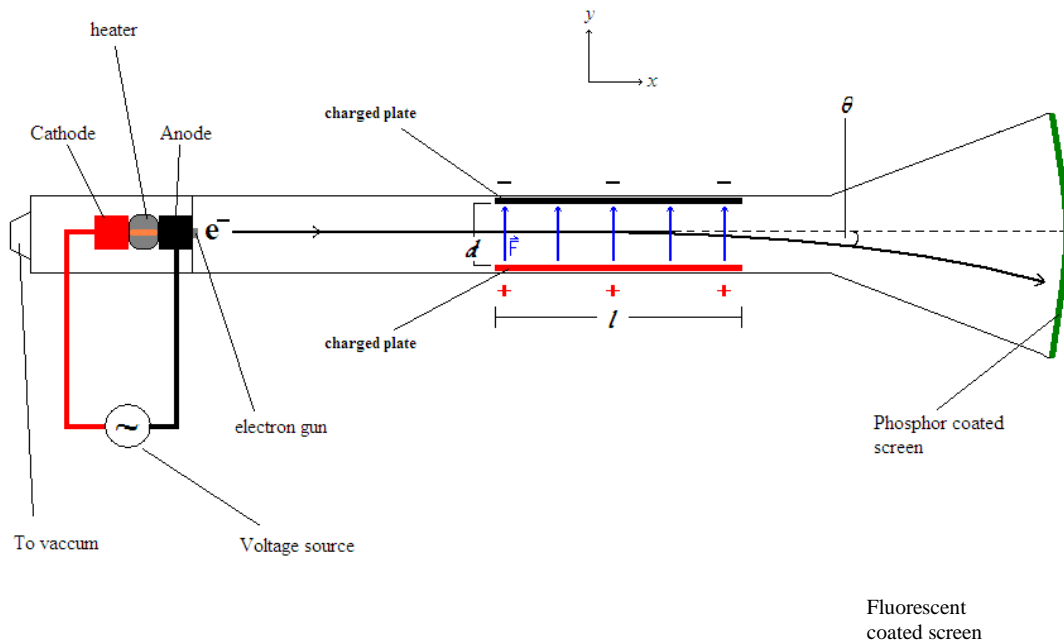


Experiment 3:

Thomson wanted to find the mass and charge of the new particles by measuring the degree to which they had been bent. He did this by subjecting the particles to electrical currents of varying strengths. The charge to mass ratio that he found suggested that the particle was thousands of times smaller than a hydrogen atom.

Diagram of the cathode ray tube:



Derivation of the charge to mass ratio for the electron:

$\mathbf{v}_x = \mathbf{v}_{0x} + \mathbf{a}_x t$ and $\mathbf{v}_y = \mathbf{v}_{0y} + \mathbf{a}_y t$, where \mathbf{v}_x and \mathbf{v}_y are respectively the final x-direction and y-direction velocities of the electron; \mathbf{v}_{0x} and \mathbf{v}_{0y} are the initial velocities of the electron in each direction, respectively; \mathbf{a}_x and \mathbf{a}_y are the accelerations of electron in each direction, respectively; and t is the time that it takes the electron to pass through the electric field created by the two charged plates.

*The velocity (in the x direction) of the electron prior to entering the electric field is independent of the force (in the y direction) applied by the electric field on the electron, and since it is assumed that there are no forces acting upon the electron in the y-direction before entering the electric field, we can set $\mathbf{v}_{0x} = \mathbf{0}$ and $\mathbf{v}_{0y} = \mathbf{0}$.

Therefore,

$$\mathbf{a}_x = \frac{v_x}{t} \quad \text{and} \quad \mathbf{a}_y = \frac{v_y}{t}$$

$$\mathbf{F}_x = m \mathbf{a}_x \quad ; \quad \text{substituting } \frac{v_x}{t} \text{ for } \mathbf{a}_x \text{ in the force expression, } \mathbf{F}_x = m \left(\frac{v_x}{t} \right)$$

$$\mathbf{F}_y = m \mathbf{a}_y \quad ; \quad \text{substituting } \frac{v_y}{t} \text{ for } \mathbf{a}_y \text{ in the force expression, } \mathbf{F}_y = m \left(\frac{v_y}{t} \right)$$

The force (in the y-direction) on the electron applied by the electric field can be expressed as: $\mathbf{F}_y = e\mathbf{E}$, where e is the charge of the electron, \mathbf{E} is the electric field created between charged plates, and that $\mathbf{E} = \frac{V}{d}$, where V is the potential difference between the two plates, and d is the distance between the plates.

Setting the two equations for \mathbf{F}_y equal to one another, $e\mathbf{E} = m \left(\frac{v_y}{t} \right)$ or

$$\frac{eV}{d} = m \left(\frac{v_y}{t} \right)$$

The angle of deflection, θ , can be defined trigonometrically by the expression $\tan(\theta) = \frac{v_y}{v_x}$

Solving for v_y , $v_y = \tan(\theta) v_x$

Substituting $\tan(\theta) v_x$ for v_y in the equation $\frac{eV}{d} = m \left(\frac{v_y}{t} \right)$,

$$\frac{eV}{d} = m \left(\frac{\tan(\theta) v_x}{t} \right)$$

Solving for the charge to mass ratio of the electron, $\frac{e}{m}$, $\frac{e}{m} = \frac{\tan(\theta) v_x d}{t V}$

The displacement of the electron (in the x-direction) from the time that it enters the E-field to the time that it exits, can be represented by the following expression:

$v_x = \frac{l}{t}$ where l is the length of the plates (in the x-direction) and the displacement of the electron (in the x-direction) from the time that it enters the E-field to the time that it exits, and t is the time it takes to do so.

Solving for t , $t = \frac{l}{v_x}$ and substituting into the $\frac{e}{m}$ equation, $\frac{e}{m} = \frac{\tan(\theta) v_x d}{\left(\frac{l}{v_x}\right)^2 V}$ or

the charge to mass ratio of the electron, $\frac{e}{m} = \tan(\theta) \frac{v_x^2 d}{V l}$

Experiment 3 results:

In the third experiment, the cathode rays bent differently to different electrical field strengths which surrounded the cathode ray tube.