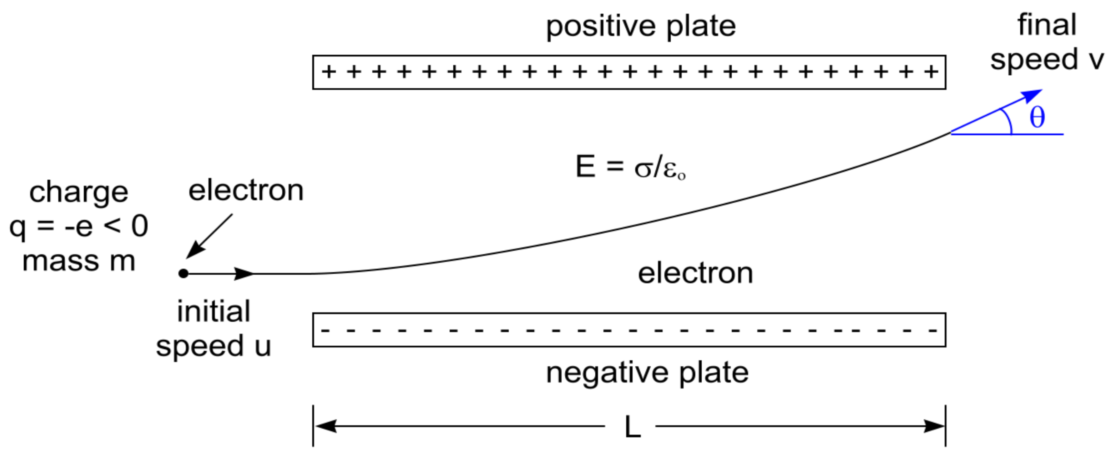
Theoretical Physics
Prof. Ruiz, UNC Asheville
Chapter D Homework. "Derivation of the Maxwell Equations"

HW-D1. Electric Field. An electron is traveling East at constant speed u. It enters a region between 2 large plates. See the figure below. Show that

$$\tan\theta = \frac{e\sigma L}{\varepsilon_o m u^2}.$$



SOLUTION

Inside the plates, $F_y = eE = ma$ in the vertical direction and $F_x = 0$ in the horizontal direction. Therefore, the speed in the x direction is constant: $v_x = u$. For the y directon we use $v_y = at$ with $a = \frac{eE}{m}$. Note that $v_x = u = \frac{L}{t}$ and $E = \frac{\sigma}{\varepsilon_o}$.

Then,

$$v_y = at = \frac{eE}{m}\frac{L}{u} = \frac{e}{m}\frac{\sigma}{\varepsilon_o}\frac{L}{u}$$

$$\tan\theta = \frac{v_y}{v_x} = \frac{e\sigma L}{\varepsilon_o m u}\cdot\frac{1}{u}$$

$$\boxed{\tan\theta = \frac{e\sigma L}{\varepsilon_o m u^2}}$$

HW-D2. Magnetic Field. A particle with mass m and charge q is traveling East at a constant speed v. It then enters a magnetic field region where the magnetic field is perpendicular to the traveling charge as shown in the figure. The particle then begins a circular path since $\vec{F} = q\vec{v}\times\vec{B}$.

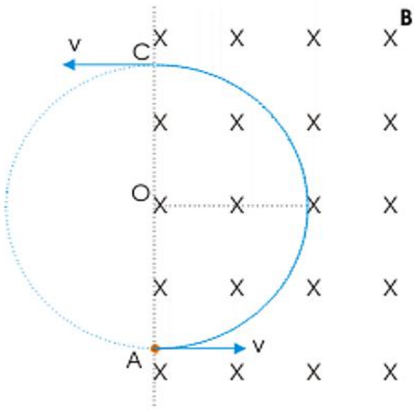


Figure Courtesy OpenStax CNX, Rice University.

Show that the radius of the circular path is given by

$$r = \frac{mv}{qB}.$$

Since the velocity vector $\vec{v}$ and the magnetic field $\vec{B}$ are at right angles $\vec{F} = q\vec{v}\times\vec{B}$ leads to $F = qvB$ with the direction being towards the center of the circle shown in the figure.

Newton's 2[nd] Law then gives

$$F = ma = m\frac{v^2}{r}.$$

Combining with $F = qvB$, we get

$$m\frac{v^2}{r} = qvB$$

$$m\frac{v}{r} = qB$$

$$mv = rqB$$

$$\boxed{r = \frac{mv}{qB}}$$