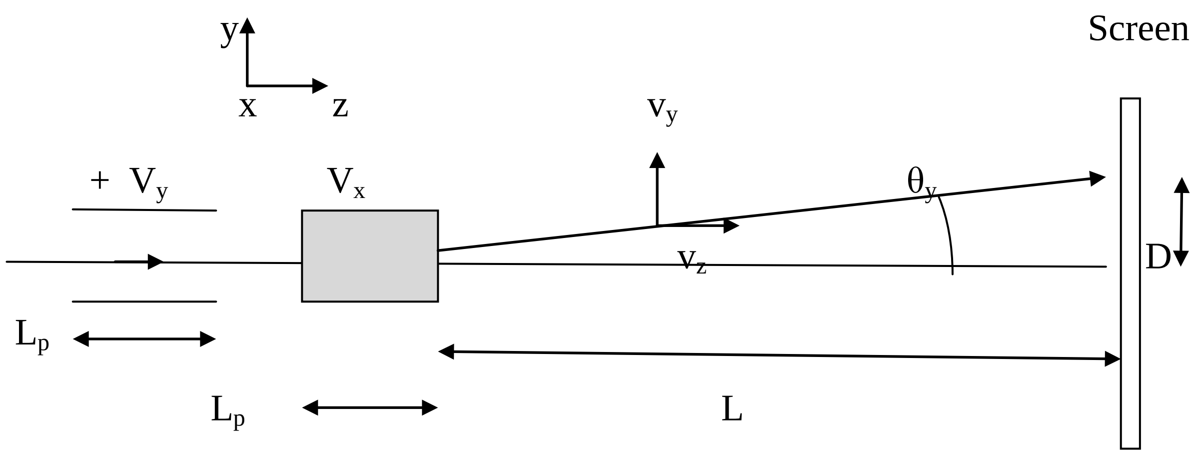
Experiment 2

Controlling the motion of electrons in a vacuum

Applying electric fields in two orthogonal directions gives the possibility of rastering an electron beam in a plane perpendicular to the direction of beam propagation.



The electron enters with (V_A is the accelerating potential)

$$v_z = (2\ e\ V_A / m)^{1/2}$$

It is accelerated by the field $E_y = V_y / d$, where d is the distance between plates, and leaves with velocity v_y

Then

$$\tan \theta_y = v_y / v_z$$

and

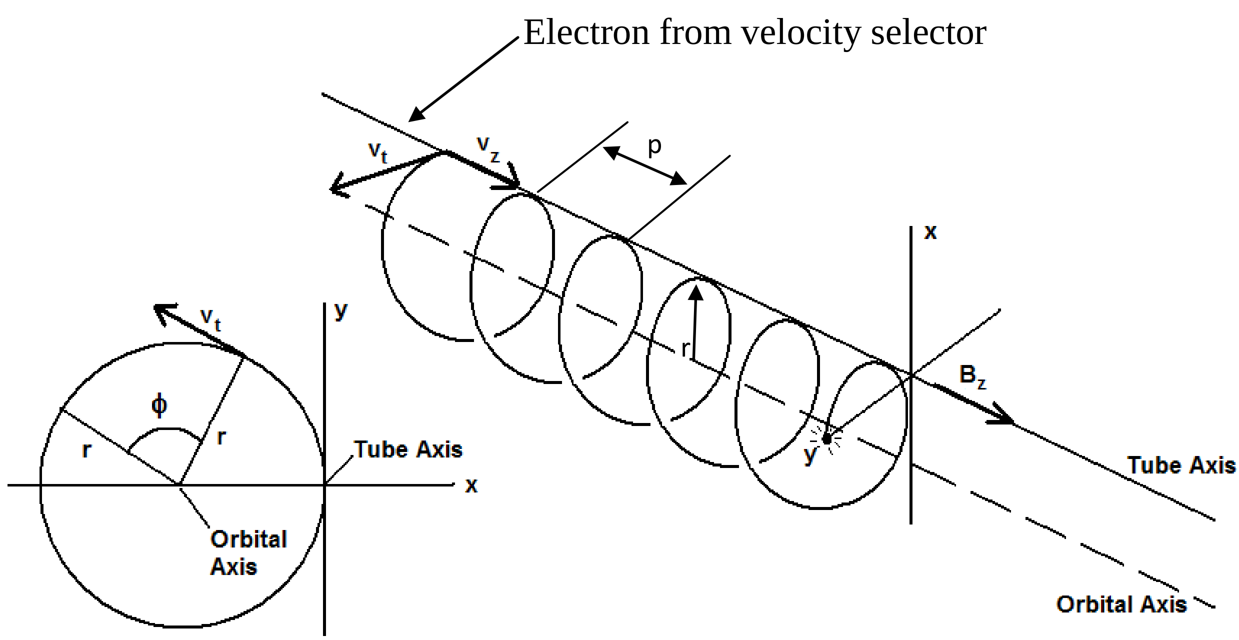
$$D_y = L \tan \theta_y = L\ (v_y / v_z) = (L\ L_p\ V_y / 2\ d\ V_A)$$

similarly

$$D_x = L \tan \theta_x = L\ (v_x / v_z) = (L\ L_p\ V_x / 2d\ V_A)$$

The velocities are determined by V_y and V_x as well as the separation, d, between the plates and their length, L_p. controlling these voltages then allows the electron beam to be rastered in an (x, y) motion on the screen.

Helical motion in an applied B field



The v_z motion of the electron is unaffected by the B field, while the tangential velocity v_t causes the electron to undergo cyclotron motion in a plane perpendicular to the B axis. The radius of this circle is

$$r = mv_t / e\,B$$

and

$$\omega = e\,B / m \qquad\qquad T = 2\,\pi / \omega$$

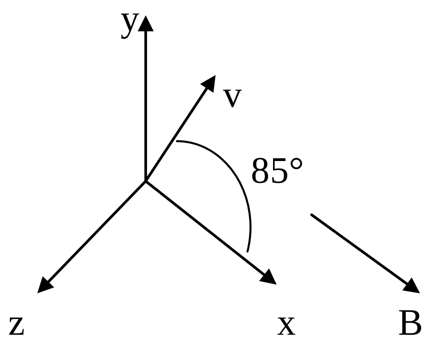
Then

$p = v_z T$

The overall path is then a helix. Electrons are imaged on the z axis at points z = Np.

Example

A positron ($q = 1.6\text{x}10^{-19}$ coul, $m = 9.1\text{x}10^{-31}$ kg) has a velocity $v = 5\text{x}10^6$ m/sec in the xy plane. At t = 0 it enters a region with B = 0.15 tesla as shown. Find the coordinates of the positron at t = 1.072 nsec.



$v_x = v \cos 85 = 4.36\text{x}10^6$ m/sec

$v_y = v \sin 85 = 4.98\text{x}10^6$ m/sec

v_x is the drift velocity

v_y gives cyclotron motion about B with radius r

$r = m\, v_y / q\, B = 1.89\text{x}10^{-4}$ m

$\omega = q\, B / m = 2.64\text{x}10^{10}$ rad/sec

$T = 2\pi / \omega = 2.38\text{x}10^{-10}$ sec

The periodicity

$p = v_x / T = 1.04\text{x}10^{-4}$ m

At T = 1.072 nsec = 4.5T the positron is at

$(x, y, z) = (1.072\, v_x, 0, -2r)$

The cyclotron motion is about the axis $z = -r$

Prof. W. Duley, May 2013