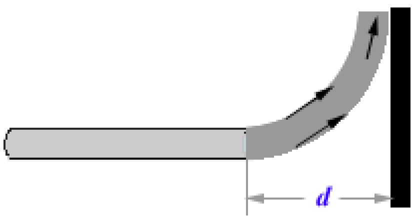
432.

<u>Problem 34.16 (RHK)</u>

A beam of electrons whose kinetic energy is K emerges from a thin-foil "window" at the end of an accelerator tube. There is a metal plate a distance d from this window and at right angles to the direction of the emerging beam. (a) *We have to show that we can prevent the beam from hitting the plate if we apply a magnetic field B such that*

$$B \geq \sqrt{\frac{2mK}{e^2 d^2}},$$

In which m and e are the electron mass and charge. (b) *We have to identify the orientation of* $\vec{B}$.



<u>Solution:</u>

Let the kinetic energy of the electron beam as it emerges out of the accelerator tube be *K*. Let the speed of the electrons having kinetic energy *K* be *v*. We have

$$\frac{1}{2}mv^2 = K,$$

or

$$v = \sqrt{\frac{2K}{m}}.$$

Let the magnetic field $\vec{B}$ be uniform and be perpendicular to the direction of the velocity $\vec{v}$ of the electron beam. As the electrons are negatively charged and force on the electrons in magnetic field $\vec{B}$ is given by

$$\vec{F} = e\vec{v} \times \vec{B}.$$

If we want the electron beam to move in counter-clockwise direction, as shown in the figure, direction of the magnetic field vector has to be perpendicular to the plane of the figure emerging out of it.

In a uniform magnetic field the magnitude of the velocity of electrons remains constant and only the direction of their velocity changes. Electrons will move in a circular orbit. If we have to adjust the magnitude of the magnetic field such that the electron beam just grazes along the metal sheet, which is at a distance *d* from the exit of the accelerator tube, the radius of their circular orbit has to be just equal to *d*. We have

$$\frac{mv^2}{d} = evB,$$

or

$$B = \frac{mv}{ed}.$$

If we want to prevent the electron beam to touch the metal plate,

$$B \geq \frac{mv}{ed},$$

or

$$B \geq \frac{m}{ed}\sqrt{\frac{2K}{m}},$$

or

$$B \geq \sqrt{\frac{2Km}{e^2 d^2}}.$$