

- K<sub>1</sub>** ••26 In Fig. 28-38, an electron with an initial kinetic energy of 4.0 keV enters region 1 at time  $t = 0$ . That region contains a uniform magnetic field directed into the page, with magnitude 0.010 T. The electron goes through a half-circle and then exits region 1, headed toward region 2 across a gap of

**B<sub>1</sub>** 25.0 cm. There is an electric potential difference  $\Delta V = 2000$  V across the gap, with a polarity such that the electron's speed increases uniformly as it traverses the gap. Region 2 contains a uniform magnetic field directed out of the page, with magnitude 0.020 T. The electron goes through a half-circle and then leaves region 2. At what time  $t$  does it leave?

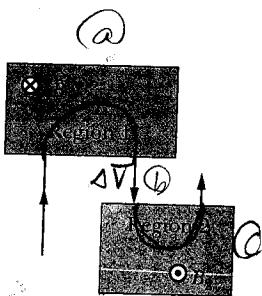


Fig. 28-38 Problem 26.

Recall cyclotron radius  
(e<sup>-</sup> path is bent by  
magnetic force)

$$F = ma$$

$$qV\sqrt{3} = mv^2/r$$

$$r =$$

We want to find the time it takes for electron to travel (a) through  $B_1$ ) + (b) through  $\Delta V$ ) + (c) through  $B_2$ )

- (a) Electron's Speed  $v$ , entering  $B_1$ , does not change because the magnetic force  $\vec{F} = q\vec{v} \times \vec{B}$  is PERPENDICULAR to its motion  $\vec{v} = \frac{ds}{dt}$ . So no work is done:  $\vec{W} = \int \vec{F} \cdot d\vec{s} = 0$

$$K_1 = \frac{1}{2}mv_1^2 = 4 \times 10^3 \text{ eV} \left| \frac{1.6 \times 10^{-19} \text{ eV}}{1.6 \times 10^{-19} \text{ eV}} \right| =$$

$$v_1 = \sqrt{\frac{2K_1}{m}} = \sqrt{\frac{2(4 \times 10^3 \text{ eV})}{9.1 \times 10^{-31} \text{ kg}}} = \frac{\text{kg m}^2/\text{s}^2}{\text{kg}} = \frac{\text{m}}{\text{s}}$$

Total distance traveled in  $B_1$  is half a circumference:

$$x_1 = \frac{1}{2}(2\pi r_1) = \pi r_1$$

$$\text{where } r_1 = mv_1 = 9.1 \times 10^{-31} \text{ kg} \left( \frac{\text{m}}{\text{s}} \right) = \text{m}$$

$$qB_1 = 1.6 \times 10^{-19} \text{ C} \cdot 10^{-2} \text{ T}$$

Since  $v_1 = x_1/t_1$ , the time spent in this region is

$$t_1 =$$

(b) The potential difference does accelerate the electron.

Work done = increase in kinetic energy

$$W = q\Delta V = \Delta K = e \cdot 2000V = 2000 \text{ eV}$$

$$K_2 = K_1 + \Delta K = 4 \text{ keV} + 2 \text{ keV} = 6 \cdot 10^3 \text{ eV} \quad \left| \frac{\text{Joul}}{1.6 \cdot 10^{-19} \text{ eV}} \right. = \quad \text{J}$$

$$\text{So the velocity increases to } v_2 = \sqrt{\frac{2K_2}{m}} =$$

To find the time it takes to travel through  $\Delta V$ ,

$$\text{use } VAV = \frac{\Delta X}{t_b} = \frac{1}{2}(v_2 + v_1) \rightarrow t_b =$$

$$t_b =$$

(c) In  $B_2$  the electron's speed does not change, since the magnetic force does no work. The distance travelled is half a circumference again:

$$x_2 = \frac{1}{2} 2\pi r_2 = \pi r_2$$

$$\text{where } r_2 =$$

Since  $v_2 = \frac{x_2}{t_2}$  the time spent in this region is

$$t_2 =$$

Electron leaves the system at time  $t = t_1 + t_b + t_2$

$$t =$$