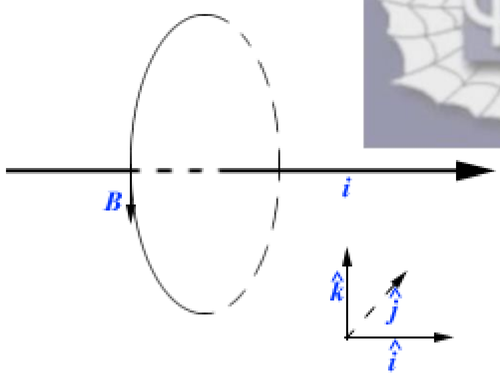
457.

Problem 35.5 (RHK)

A long straight wire carries a current of 48.8 A. *An electron, travelling at* 1.08×10^{7} m s^{-1}, *is* 5.20 cm *from the wire. We have to calculate the force that acts on the electron if the electron velocity is directed* (a) *toward the wire,* (b) *parallel to the current, and* (c) *at right angles to the direction defined by* (a) *and* (b).

Solution:



We fix a coordinate system as shown in the figure. Flow of current in the long straight wire is in $\hat{i}$ direction. Magnitude of the magnetic field at a distance of 5.20 cm from the wire will be

$$B=\frac{\mu_0 i}{2\pi r}=\frac{4\pi\times10^{-7}\times48.8}{2\pi\times5.20\times10^{-2}}\ \text{T}=1.876\times10^{-4}\ \text{T}.$$

Direction of the vector is along the tangent to the circumference of the circle and therefore for answering the problem we fix it as

$$\vec{B}=-1.876\times10^{-4}\hat{k}\ \text{T}.$$

We now consider the three parts of the problem one-by-one.

(a)

Electron moving with speed 1.08×10^{7} m s^{-1} is travelling toward the wire. Its velocity will be

$$\vec{v} = 1.08\times10^{7}\,\hat{j} \text{ m s}^{-1}.$$

Its charge is

$$e = -1.6\times10^{-19} \text{ C}.$$

Force on a charge, *e*, moving with velocity $\vec{v}$ in magnetic field $\vec{B}$ is given by

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

Therefore,

$$\vec{F} = -1.6\times10^{-19}\left(1.08\times10^{7}\,\hat{j}\right)\times\left(-1.876\times10^{-4}\,\hat{k}\right) \text{ N}$$

$$= 3.24\times10^{-16}\,\hat{i} \text{ N} = 0.324\hat{i} \text{ fN}.$$

Force on the electron is in the same direction as that of the current in the wire.

(b)

Electron is moving parallel to the current. Its velocity will be

$$\vec{v} = 1.08\times10^{7}\,\hat{i} \text{ m s}^{-1}.$$

Therefore,

$$\vec{F} = -1.6\times10^{-19}\left(1.08\times10^{7}\hat{i}\right)\times\left(-1.876\times10^{-4}\hat{k}\right)\ \text{N}$$

$$= -3.24\times10^{-16}\,\hat{j}\ \text{N} = -0.324\,\hat{j}\ \text{fN}.$$

The direction of the force is radially outward.

(c)

Direction at right angles to $\hat{j}$ and $\hat{i}$ is $\hat{k}$. Therefore, the force on the electron will be zero as the velocity and the magnetic field are in the same direction.