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Problem 34.10 (RHK)

An electron has initial velocity $(12.0\hat{j} + 15.0\hat{k}) \text{ km s}^{-1}$ and a constant acceleration of $(2.00 \times 10^{12} \text{ m s}^{-2})\hat{i}$ in a region in which uniform electric and magnetic fields are present. If $\vec{B} = 400\hat{i} \text{ } \mu\text{T}$, we have to find the electric field \vec{E} .

Solution:

Lorentz force on an electron moving with velocity \vec{v} in electric field \vec{E} and magnetic field \vec{B} is

$$\vec{F} = e\vec{E} + e\vec{v} \times \vec{B},$$

where,

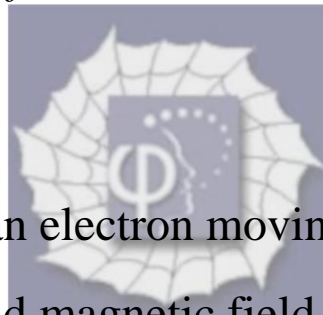
charge of electron, $e = -1.6 \times 10^{-19} \text{ C}$,

mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$,

velocity of electron, $\vec{v} = (12.0\hat{j} + 15.0\hat{k}) \text{ km s}^{-1}$,

and magnetic field, $\vec{B} = 400\hat{i} \text{ } \mu\text{T}$.

Electron in the uniform electric and magnetic fields is moving with acceleration



$$\vec{a} = (2.00 \times 10^{12} \text{ m s}^{-2}) \hat{i}.$$

Therefore, force on the electron will be

$$\begin{aligned} \vec{F} &= m_e \vec{a} = 9.11 \times 10^{-31} \times (2.00 \times 10^{12} \text{ m s}^{-2}) \hat{i} \text{ N} \\ &= 1.822 \times 10^{-18} \hat{i} \text{ N}. \end{aligned}$$

From the Lorentz force equation, we write

$$\begin{aligned} 1.822 \times 10^{-18} \hat{i} \text{ N} &= -1.6 \times 10^{-19} \left(\vec{E} + \left((12.0 \hat{j} + 15.0 \hat{k}) \times 4 \times 10^{-1} \hat{i} \text{ m s}^{-1} \text{ T} \right) \right) \text{ C} \\ &= -1.6 \times 10^{-19} \left(\vec{E} + (-4.8 \hat{k} + 6.0 \hat{j}) \text{ m s}^{-1} \text{ T} \right) \text{ C}. \end{aligned}$$

Or

$$\begin{aligned} \vec{E} &= \left(-\frac{1.822 \times 10^{-18}}{1.6 \times 10^{-19}} \hat{i} + 4.8 \hat{k} - 6.0 \hat{j} \right) \text{ V m}^{-1} \\ &= (-11.38 \hat{i} - 6.0 \hat{j} + 4.8 \hat{k}) \text{ V m}^{-1}. \end{aligned}$$