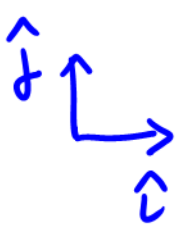
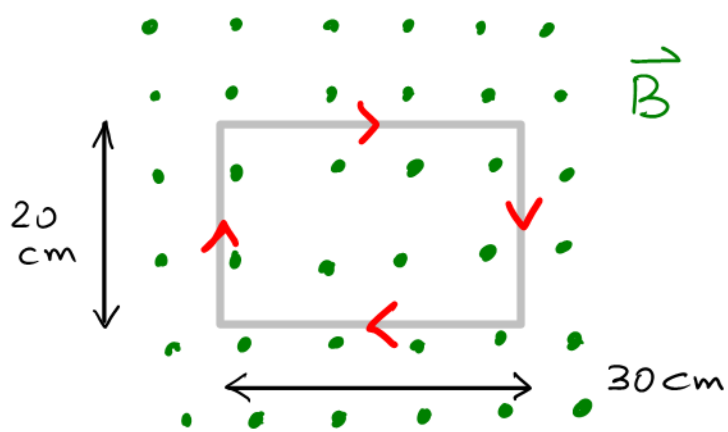
PhysicsTutor

Magnetic force on a rectangular loop

Problem:

- A 20 cm by 30 cm rectangular loop of wire carries 1.0 A of current clockwise around the loop and sits in a magnetic field **B**.
- A) Find the magnetic force on each side of the loop if **B** is out of the page and B=2.5 T.
- B) What is the net force on the loop?





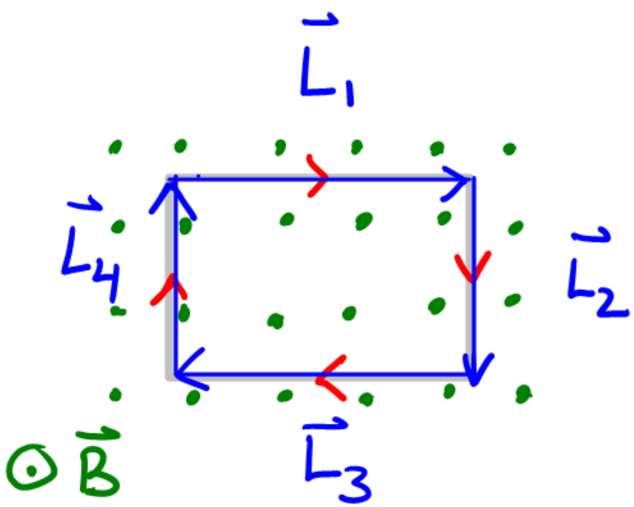
$\vec{B}$ uniform, (homogeneous) out of page $B = 2.5\,T$

CW current 1.0 A

Relevant ideas:

Relevant ideas:

- An electric current corresponds to charged particles moving with some velocity. Thus, the magnetic force from a **B** field acts on it.



charge q $\vec{v}$

$$\vec{F}_M = q\,\vec{v} \times \vec{B}$$

current I

$$\vec{F}_M = I\,\vec{L} \times \vec{B}$$

Since $I = nq\,A\,v_D$

number of charges per unit volume

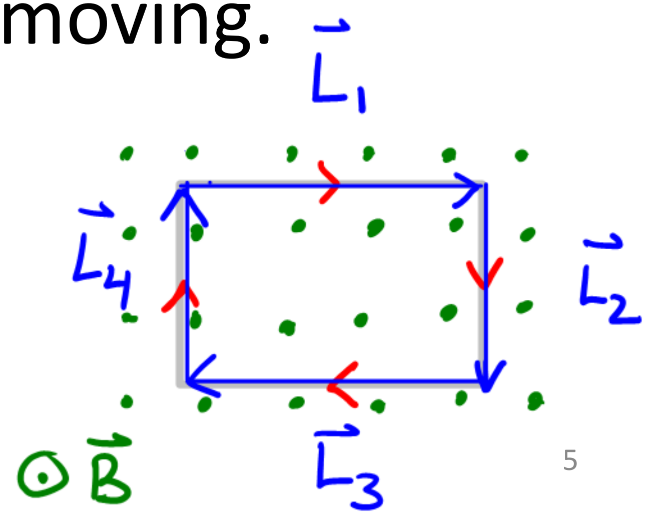
cross-sectional area of wire

drift velocity

Relevant ideas:

- An electric current corresponds to charged particles moving with some velocity. Thus, the magnetic force from a **B** field acts on it.
- The cross-product right-hand rule determines the direction of the force. Use the current convention of positive charge moving.

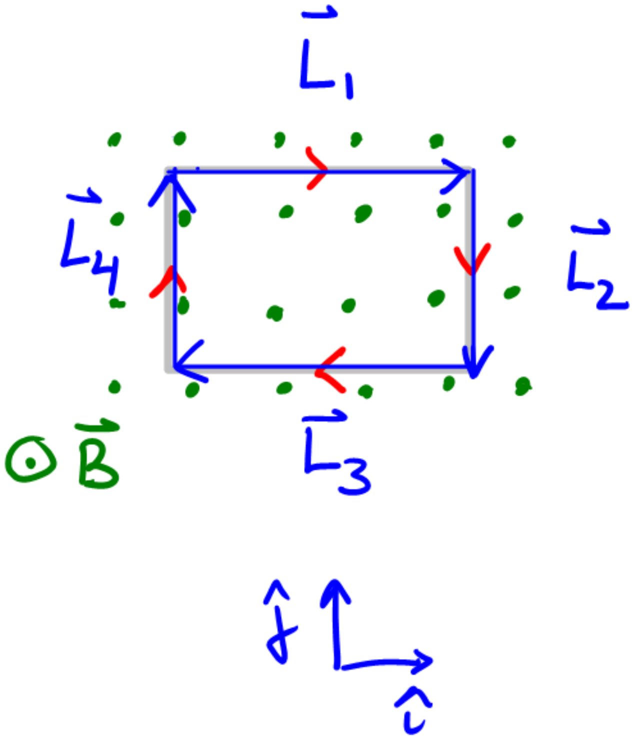
$$\vec{F}_M^{(i)} = I \vec{L}_i \times \vec{B}$$



Relevant ideas:

- An electric current corresponds to charged particles moving with some velocity. Thus, the magnetic force from a **B** field acts on it.
- The cross-product right-hand rule determines the direction of the force. Use the current convention of positive charge moving.
- The loop is rigid. Opposite forces acting on it will cancel. Watch out for the net force.

Equations associated with ideas:



$$\vec{F}_M^{(i)} = I \, \vec{L}_i \times \vec{B}$$

$$\vec{L}_1 = 0.3 \text{ m } \hat{i}$$

$$\vec{B} = B \hat{k}$$

$$\hat{i} \times \hat{k} = -\hat{j}$$ by RH rule

$$\vec{F}_{net} = \sum \vec{F}_M^{(i)}$$

Strategy

Strategy

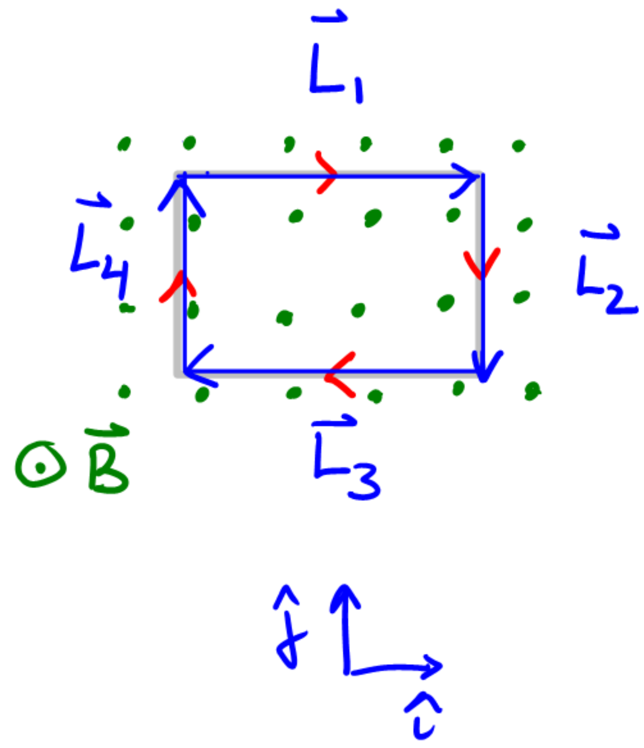
- Use the RH rule for each of the four straight segments to find the direction of the magnetic force on them.

$$\vec{F}_M^{(i)} = I\,\vec{L}_i \times \vec{B}$$

$$\vec{L}_2 = -0.2\text{ m}\ \hat{j}$$

$$\vec{B} = B\,\hat{k}$$

$$\hat{j} \times \hat{k} = \hat{i}$$ by RH rule



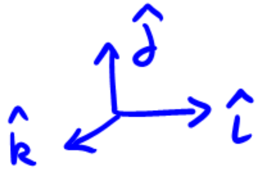
Strategy

- Use the RH rule for each of the four straight segments to find the direction of the magnetic force on them.
- Calculate the strength of the forces.

Strategy

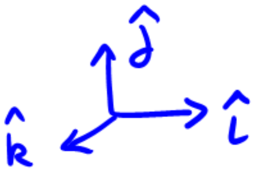
- Use the RH rule for each of the four straight segments to find the direction of the magnetic force on them.
- Calculate the strength of the forces.
- Add the forces vectorially to determine the net force on the loop.

Solution



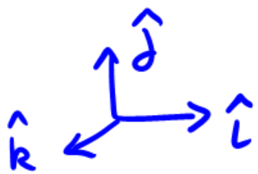
Solution

- $\vec{L}_1$: $\vec{F}_M^{(1)} = 1.0\,A \cdot 0.3\,m \; \hat{i} \times 2.5\,T \; \hat{k} = 0.75\,N \, (-\hat{j})$



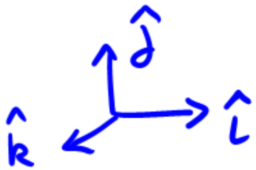
Solution

- $\vec{L}_1$: $\vec{F}_M^{(1)} = 1.0\,A \cdot 0.3\,m\ \hat{i} \times 2.5\,T\ \hat{k} = 0.75\,N\ (-\hat{j})$
- $\vec{L}_3$: $\vec{L}_3 = -\vec{L}_1 \quad \therefore \quad \vec{F}_M^{(3)} = -\vec{F}_M^{(1)} = 0.75\,N\ \hat{j}$



Solution

- $\vec{L}_1$: $\vec{F}_M^{(1)} = 1.0\,A \cdot 0.3\,m\,\hat{i} \times 2.5\,T\,\hat{k} = 0.75\,N\,(-\hat{j})$
- $\vec{L}_3$: $\vec{L}_3 = -\vec{L}_1 \quad \therefore \quad \vec{F}_M^{(3)} = -\vec{F}_M^{(1)} = 0.75\,N\,\hat{j}$
- $\vec{L}_2$: $\vec{F}_M^{(2)} = 1.0\,A \cdot 0.2\,m\,(-\hat{j}) \times 2.5\,T\,\hat{k} = 0.50\,N\,(-\hat{i})$



Solution

- $\vec{L}_1$: $\vec{F}_M^{(1)} = 1.0\,A \cdot 0.3\,m\ \hat{i} \times 2.5\,T\ \hat{k} = 0.75\,N\ (-\hat{j})$
- $\vec{L}_3$: $\vec{L}_3 = -\vec{L}_1 \quad \therefore \quad \vec{F}_M^{(3)} = -\vec{F}_M^{(1)} = 0.75\,N\ \hat{j}$
- $\vec{L}_2$: $\vec{F}_M^{(2)} = 1.0\,A \cdot 0.2\,m\ (-\hat{j}) \times 2.5\,T\ \hat{k} = 0.50\,N\ (-\hat{i})$
- $\vec{L}_4$: $\vec{L}_4 = -\vec{L}_2 \quad \therefore \quad \vec{F}_M^{(4)} = -\vec{F}_M^{(2)} = +0.50\,N\ \hat{i}$

$$\vec{F}_{net} = \sum \vec{F}_M^{(i)} = 0.$$

No net force.

Note: the current loop has a magnetic field $\vec{B}_{loop}$ into the page

$\vec{B}_{loop}$ is counteraligned with $\vec{B}$
anti-parallel

For the orientation shown it is torque-free, but unstable

The loop is not pushed $\sim \hat{k}$, since $\vec{B}$ is uniform.