Section 8.3: Magnetic Force on a Current-Carrying Conductor

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1. Given: L = 155 mm = 0.155 m; I = 3.2 A; B = 1.8 T; θ = 90°

Required: $F_{\text{on wire}}$

Analysis: $F_{\text{on wire}} = ILB \sin \theta$

Solution:
$$F_{\text{on wire}} = ILB\sin\theta$$
$$= \left(3.2\ \frac{\cancel{\text{C}}}{\text{s}}\right)(0.155\ \text{m})\left(1.8\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 90°$$
$$F_{\text{on wire}} = 0.89\ \text{N}$$

Statement: The magnitude of the force on the wire is 0.89 N.

(b) By the right-hand rule, the magnetic force is in the $-x$ direction.

2. Given: $F_{\text{on wire}}$ = 0.75 N; I = 15 A; θ = 90°; B = 0.20 T

Required: L

Analysis: $F_{\text{on wire}} = ILB\sin\theta$
$$L = \frac{F_{\text{on wire}}}{IB\sin\theta}$$

Solution:
$$L = \frac{F_{\text{on wire}}}{IB\sin\theta}$$
$$= \frac{\left(0.75\ \cancel{\text{kg}}\cdot\frac{\text{m}}{\cancel{\text{s}^2}}\right)}{\left(15\ \frac{\cancel{\text{C}}}{\cancel{\text{s}}}\right)\left(0.20\ \frac{\cancel{\text{kg}}}{\cancel{\text{C}}\cdot\cancel{\text{s}}}\right)\sin 90°}$$
$$= 0.25\ \text{m}$$
$$L = 25\ \text{cm}$$

Statement: The length of the wire is 25 cm.

3. Given: $F_{\text{on wire}}$ = 1.4 × 10^{-5} N; L = 0.045 m; θ = 18°; B = 5.3 × 10^{-5} T

Required: I

Analysis: $F_{\text{on wire}} = ILB\sin\theta$
$$I = \frac{F_{\text{on wire}}}{LB\sin\theta}$$

Solution:
$$I = \frac{F_{\text{on wire}}}{LB\sin\theta}$$
$$= \frac{\left(1.4\times10^{-5}\ \cancel{\text{kg}}\cdot\frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\right)}{(0.045\ \cancel{\text{m}})\left(5.3\times10^{-5}\ \frac{\cancel{\text{kg}}}{\text{C}\cdot\cancel{\text{s}}}\right)\sin 18°}$$
$$I = 19\ \text{A}$$

Statement: The current in the wire is 19 A.

4. Given: I = 1.5 A; L = 5.7 cm = 0.057 m; $\theta = 90°$; $F_{\text{on wire}} = 5.7 \times 10^{-6}$ N
Required: B
Analysis: $F_{\text{on wire}} = ILB\sin\theta$

$$B = \frac{F_{\text{on wire}}}{IL\sin\theta}$$

Solution: $B = \frac{F_{\text{on wire}}}{IL\sin\theta}$

$$= \frac{\left(5.7\times10^{-6}\ \text{kg}\cdot\frac{\cancel{\text{m}}}{\text{s}^2}\right)}{\left(3.2\ \frac{\text{C}}{\cancel{\text{s}}}\right)(0.057\ \cancel{\text{m}})\sin 90°}$$

$$B = 6.7\times10^{-5}\ \text{T}$$

Statement: The magnitude of Earth's magnetic field around the lamp is 6.7×10^{-5} T.

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1. (a) Given: B = 1.4 T; L = 2.3 m; $F_{\text{on wire}}$ = 1.8 N; $\theta = 90°$
Required: I
Analysis: $F_{\text{on wire}} = ILB\sin\theta$

$$I = \frac{F_{\text{on wire}}}{LB\sin\theta}$$

Solution: $I = \frac{F_{\text{on wire}}}{LB\sin\theta}$

$$= \frac{\left(1.8\ \cancel{\text{kg}}\cdot\frac{\cancel{\text{m}}}{\text{s}^2}\right)}{(2.3\ \cancel{\text{m}})\left(1.4\ \frac{\cancel{\text{kg}}}{\text{C}\cdot\cancel{\text{s}}}\right)\sin 90°}$$

$$I = 0.56\ \text{A}$$

Statement: The current in the conductor is 0.56 A.
(b) When the magnetic force is a maximum, the angle is 90° because that is when sin θ is a maximum.
2. (a) Given: L = 120 mm = 0.120 m; $\theta = 56°$; B = 0.40 T; I = 2.3 A
Required: $F_{\text{on wire}}$
Analysis: $F_{\text{on wire}} = ILB \sin \theta$
Solution: $F_{\text{on wire}} = ILB\sin\theta$

$$= \left(2.3\ \frac{\cancel{\text{C}}}{\text{s}}\right)(0.120\ \text{m})\left(0.40\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 45°$$

$$F_{\text{on wire}} = 7.8\times10^{-2}\ \text{N}$$

Statement: The magnitude of the force on the wire is 7.8×10^{-2} N.
(b) By the right-hand rule, the direction of the magnetic force is upward.

3. (a) Given: $L = 2.6$ m; $I = 2.5$ A; $B = 5.0 \times 10^{-5}$ T; $\theta = 90°$

Required: $\vec{F}_{\text{on wire}}$

Analysis: $F_{\text{on wire}} = ILB \sin \theta$; by the right-hand rule, the magnetic force is downward.

Solution:
$$\begin{aligned} F_{\text{on wire}} &= ILB\sin\theta \\ &= \left(2.5\ \frac{\cancel{\text{C}}}{\text{s}}\right)(2.6\ \text{m})\left(5.0\times10^{-5}\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 90° \\ F_{\text{on wire}} &= 3.2\times10^{-4}\ \text{N} \end{aligned}$$

Statement: The force on the wire is 3.2×10^{-4} N [down].

(b) Given: $L = 2.6$ m; $I = 2.5$ A; $B = 5.0 \times 10^{-5}$ T; $\theta = 72°$

Required: $F_{\text{on wire}}$

Analysis: $F_{\text{on wire}} = ILB \sin \theta$

Solution:
$$\begin{aligned} F_{\text{on wire}} &= ILB\sin\theta \\ &= \left(2.5\ \frac{\cancel{\text{C}}}{\text{s}}\right)(2.6\ \text{m})\left(5.0\times10^{-5}\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 72° \\ F_{\text{on wire}} &= 3.1\times10^{-4}\ \text{N} \end{aligned}$$

Statement: The magnitude of the force on the wire is 3.1×10^{-4} N.

4. Given: $L = 1.4$ m; $I = 3.5$ A; $B = 1.5$ T; $\theta = 90°$

Required: $F_{\text{on wire}}$

Analysis: $F_{\text{on wire}} = ILB \sin \theta$

Solution:
$$\begin{aligned} F_{\text{on wire}} &= ILB\sin\theta \\ &= \left(3.5\ \frac{\cancel{\text{C}}}{\text{s}}\right)(1.4\ \text{m})\left(1.5\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 90° \\ F_{\text{on wire}} &= 7.4\ \text{N} \end{aligned}$$

Statement: The magnitude of the force on the wire is 7.4 N.

5. (a) The magnetic field is in the same direction as the wire, so the force is 0 N.

(b) Write the length of each segment in terms of L and θ:

$$\cos\theta = \frac{L}{L_{\text{hypotenuse}}}$$
$$L_{\text{hypotenuse}} = \frac{L}{\cos\theta}$$

$$\tan\theta = \frac{L_{\text{opposite}}}{L}$$
$$L_{\text{opposite}} = L\tan\theta$$

Write the magnetic force on each segment in terms of L and θ:

$$F_{\text{on wire}} = ILB\sin\theta$$

$$\begin{aligned}F_{\text{hypotenuse}} &= IL_{\text{hypotenuse}}B\sin\theta \\ &= I\left(\frac{L}{\cos\theta}\right)B\sin\theta \\ F_{\text{hypotenuse}} &= ILB\tan\theta\end{aligned}$$

$$F_{\text{on wire}} = ILB\sin\theta$$

$$\begin{aligned}F_{\text{opposite}} &= IL_{\text{opposite}}B\sin 90^\circ \\ &= I(L\tan\theta)B \\ F_{\text{opposite}} &= ILB\tan\theta\end{aligned}$$

The magnitudes of the two forces are equal. By the right-hand rule, the force on the hypotenuse is into the page and the force on the opposite side is out of the page. That means that the sum of the forces is 0 N.

(c) The magnetic force on a closed loop in a uniform magnetic field is zero.