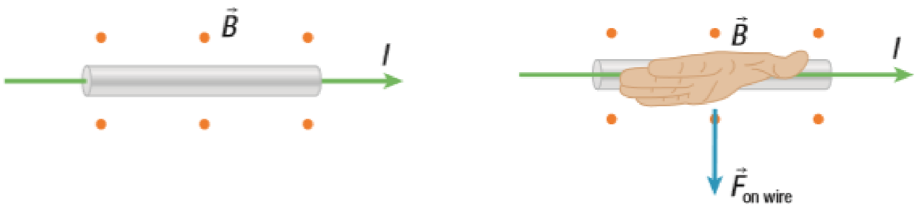
Sec. 8.3 - Magnetic Force on a Conductor (Wire usually)

Learning Goal: By the end of today, I will be able to determine the magnetic force on a conductor/wire of a certain length.

A wire with charge passing along it creates a magnetic field around it; no charge moving - no magnetic field.

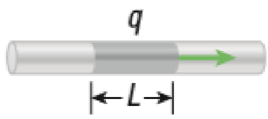
If a conducting wire is placed in an external magnetic field, then an unbalanced force is created on the wire.



A segment of the wire of length L is shown in **Figure 3**. The current, I, in this segment is

$$I = \frac{q}{\Delta t}$$ (recognize current relationship - "I" is intensity measured in Amperes)

where q is the electric charge that passes by one end of the wire segment in a time interval Δt.



Start with the force equation, and modify

$$F_M = qvB\sin\theta$$

The speed of the charge is just

$$v = \frac{L}{\Delta t}$$

Substituting the speed, v, in the magnetic force equation gives

$$F_M = qvB\sin\theta$$

$$= q\frac{L}{\Delta t}B\sin\theta$$

$$F_M = \frac{q}{\Delta t}LB\sin\theta$$

Using the relationship between current and charge, $I = \frac{q}{\Delta t}$, we get

$$F_M = ILB\sin\theta$$

Force on a Wire

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

I is current in Amps

L is length of wire in meters

B is the strength of the field in Tesla

theta is the angle of interaction

Example

A piece of wire 45.2 cm long has a current of 12 A (**Figure 5**). The wire moves through a uniform magnetic field with a strength of 0.30 T. Calculate the magnitude of the magnetic force on the wire when the angle between the magnetic field and the wire is (a) 0°, (b) 45°, and (c) 90°.

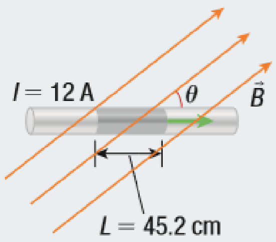


Figure 5

Given: $I = 12$ A; $L = 45.2$ cm $= 0.452$ m; $B = 0.30$ T

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

Two electrical poles support a current-carrying wire. The mass of a 2.5 m segment of the wire is 0.44 kg. A 15 A current travels through the wire. The conventional current is oriented due east, horizontal to Earth's surface. The strength of Earth's magnetic field at the location is 57 μT and is oriented due north, horizontal to Earth's surface (**Figure 6**).

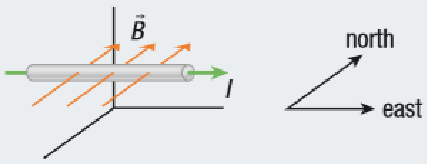


Figure 6

(a) Determine the magnitude and the direction of the magnetic force on the 2.5 m segment of wire.

(b) Calculate the gravitational force on the 2.5 m segment of wire.

Solution

(a) **Given:** $B = 57\ \mu T = 5.7 \times 10^{-5}$ T; $I = 15$ A; $L = 2.5$ m; $\theta = 90°$

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

(b) **Given:** $m = 0.44$ kg

Required: F_g

Analysis: $F_g = mg$

SUMMARY Magnetic Force on a Conductor

- The magnitude of the force on the conductor F is in a direction perpendicular to both the magnitude of the magnetic field B and the direction of the current I: in SI units, $F = IlB \sin \theta$.
- Reversing either the current direction or the magnetic field reverses the direction of the force.

Demo - Hanging Wire and Magnet

Homework

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