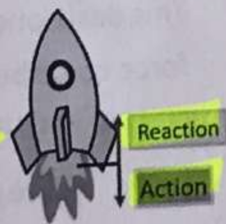
answer Key

U3:L8 Electromagnetism #2

In the previous lesson we saw that an **electric current exerts a force on magnet** such as a compass needle. Thanks Oersted!

In our study of dynamics, we learned by Newton's Third Law that if one object exerts a force on a second object, then the second object must exert an equal and opposite force on the first.

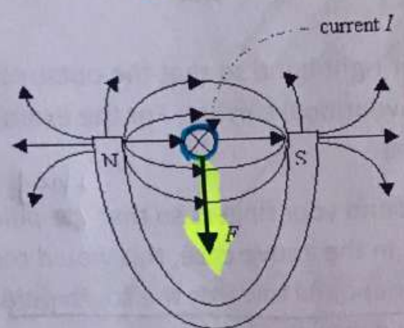


So if a current exerts a force on a magnet, then a **magnet exerts a force on a current carrying wire.**

The diagram below shows a horseshoe magnet and its magnetic field.

A current carrying wire is placed between the poles of the magnet so that the current is perpendicular to the field.

The symbol on the left indicates that the electric current is perpendicular to this plane and pointing into the plane. ⊗



When the current flows through this wire, a force is exerted on the wire.

But this force is not toward one or the other poles of the magnet. Instead, the force is directed at right angles to the magnetic field direction.

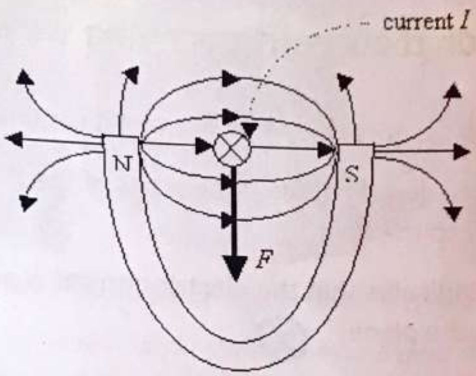
In this case the wire will be forced downwards. If the current is reversed in direction, the force will be in the opposite direction.

So in the above situation, if the current was coming out of the plane instead of into the plane, the force on the wire would be up.

The direction of the **force** (F) is perpendicular to the direction of the **current** (I) and also perpendicular to the direction of the **magnetic field** (B).

This description however does not completely describe the direction since the force could be either **up or down** and still be perpendicular to both the current and the magnetic field.

The direction of the force is given by a different right hand rule:

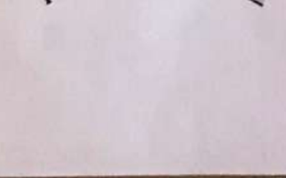


wow, ugly drawing ↓ MS. BURNS

INTO The page

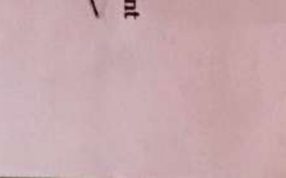
1. First you orient your right hand so that the outstretched fingers point in the direction of the conventional current. For the example above, point your fingers into the plane.
2. From this position, bend your fingers so that they point in the direction of the magnetic field lines. In the above case, this would require you to rotate your hand so that the palm points towards the south pole. Extend your middle finger to point in the direction of your palm.
3. When you hand is oriented in this way, the extended thumb points in the direction of the force on the wire.

TRY IT!



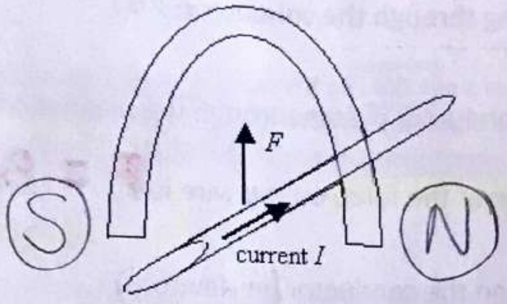
OR...

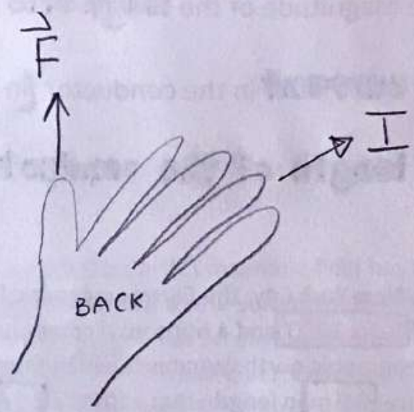
ROTATED



EXAMPLE:

The drawing shows a current carrying wire that passes through the gap in a horseshoe magnet. The magnetic force *F* exerted on the wire is directed upward. Which end of the magnet is the north pole and which is the south pole?





Rounded fingers / palm point in the direction of magnetic Field (B) which is ⟸

- magnetic Field lines point towards <u>South</u>

The magnitude of this force is directly proportional to

- the strength of the magnetic field: $F \alpha B$
- the length of the conductor in the magnetic field: $F \alpha L$
- the current flowing through the conductor: $F \alpha I$

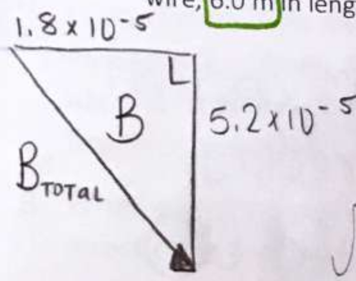
If we assume that the conductor passes through the magnetic field at right angles to it, then the magnitude of the force on the wire is **F = BIL**

- **F** is the **force** on the conductor (in Newtons)
- **B** is the magnitude of the **magnetic field** strength (in Teslas)
- **I** is the **current** in the conductor (in Amperes)
- **L** is the **length of the conductor** in the magnetic field (in meters)

EXAMPLES:

1) In New York City, the Earth's magnetic field has a vertical (downward) component of 5.2×10^{-5} T and a horizontal component of 1.8×10^{-5} T that is directed toward geographic north. What is the magnitude of the magnetic force on a long, straight wire, 6.0 m in length, that carries a 28 A current due east?

Pythagoras for TOTAL



$$(B_{TOTAL})^2 = (1.8\times10^{-5})^2 + (5.2\times10^{-5})^2$$

$$(B_{TOTAL})^2 = (3.24\times10^{-5}) + (27.04\times10^{-5})$$

$$\sqrt{(B_{TOTAL})^2 = 30.28\times10^{-5}}$$

$$B_{TOTAL} = 5.5\times10^{-5}\ T$$

$$F = BIL$$

$$F = (5.5\times10^{-5}\ T)(28A)(6.0m)$$

$$F = 9.2\times10^{-3}\ N$$

If the current carrying wire crosses the magnetic field at some angle θ, then the force on the current carrying wire can be written as **F = BIL sinθ.**

If the current is **parallel** to the magnetic field, then there will be **no force** on the wire at all.

EXAMPLES:

2) An electric power line caries a current of 1400 A in a location where the Earth's magnetic field is 5.0×10^{-5} T. The line makes an angle of 75° with respect to the field. Determine the magnitude of the magnetic force on a 120 m length of wire.

$$F = BIL\sin\theta$$

$$F = (5.0 \times 10^{-5}\,T)(1400\,A)(120\,m)\sin 75^\circ$$

$$F = 8.4 \sin 75^\circ$$

$$\boxed{F = 8.1\,N}$$

3) Near the equator in South America the Earth's magnetic field has a strength of 3.2×10^{-5} T. The field at this location is parallel to the surface of the Earth and points due north. A straight wire, 46 m in length, has an east-west orientation and experiences a magnetic force of 0.058 N, directed vertically down (toward the Earth). What is the magnitude and direction of the current in the wire?

$$F = BIL \text{ so... } I = \frac{F}{BL}$$

$$I = \frac{0.058\,N}{(3.2 \times 10^{-5}\,T)(46\,m)}$$

$$I = \frac{5.8 \times 10^{-2}\,N}{1.47 \times 10^{-3}\,T \cdot m}$$

$$I = 3.95 \times 10^{1}\,A$$

$$\boxed{I \approx 40\,A}$$