Magnetic Force
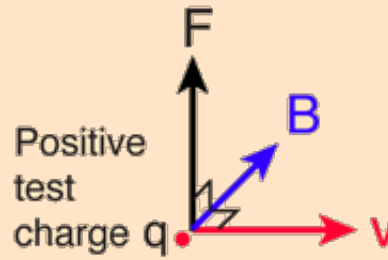
The magnetic field B is defined from the <u>Lorentz Force Law</u>, and specifically from the magnetic force on a moving charge:

$$\vec{F} = q\vec{v} \ x \ \vec{B}$$

The implications of this expression include:

1. The force is perpendicular to both the velocity v of the charge q and the magnetic field B.

2. The magnitude of the force is F = qvB sinθ where θ is the angle < 180 degrees between the velocity and the magnetic field. This implies that the magnetic force on a stationary charge or a charge moving parallel to the magnetic field is zero.

3. The direction of the force is given by the <u>right hand rule</u>. The force relationship above is in the form of a <u>vector product</u>.

$$\vec{F} = \ \vec{I}L \ x \ \vec{B}$$

Force on straight wire of length L
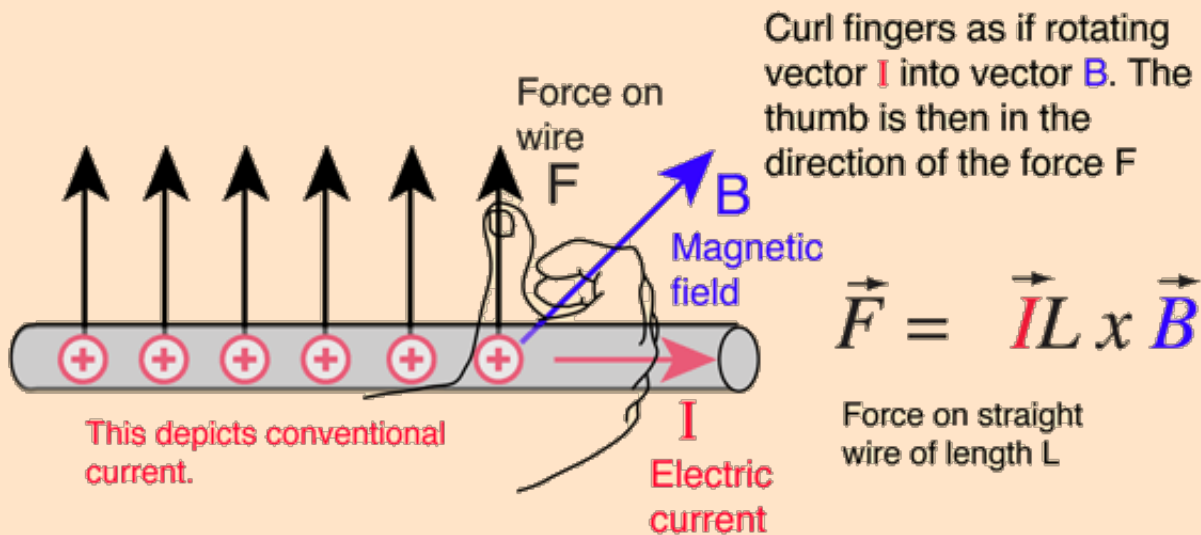
When the magnetic force relationship is applied to a <u>current-carrying wire</u>, the right-hand rule may be used to determine the direction of force on the wire.

From the force relationship above it can be deduced that the units of magnetic field are Newton seconds /(Coulomb meter) or Newtons per Ampere meter. This unit is named the Tesla. It is a large unit, and the smaller unit Gauss is used for small fields like the Earth's magnetic field. A Tesla is 10,000 Gauss. The <u>Earth's magnetic field</u> at the surface is on the order of half a Gauss.

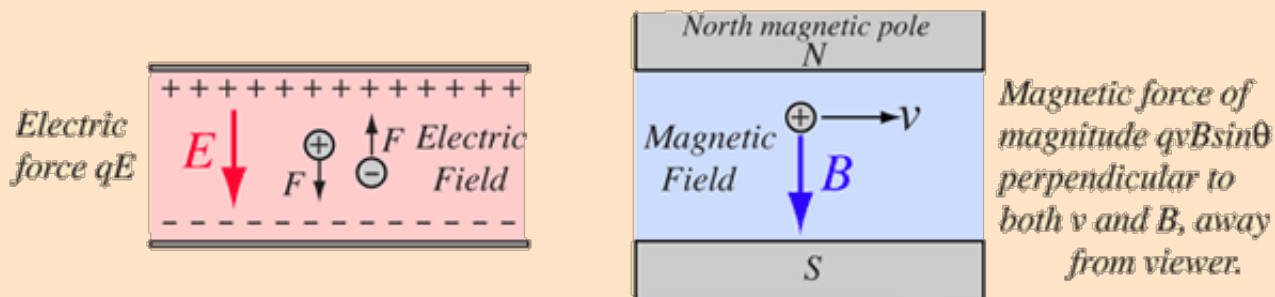<u>Magnetic interactions with charge</u> | <u>Magnetic force applications</u>

Lorentz Force Law

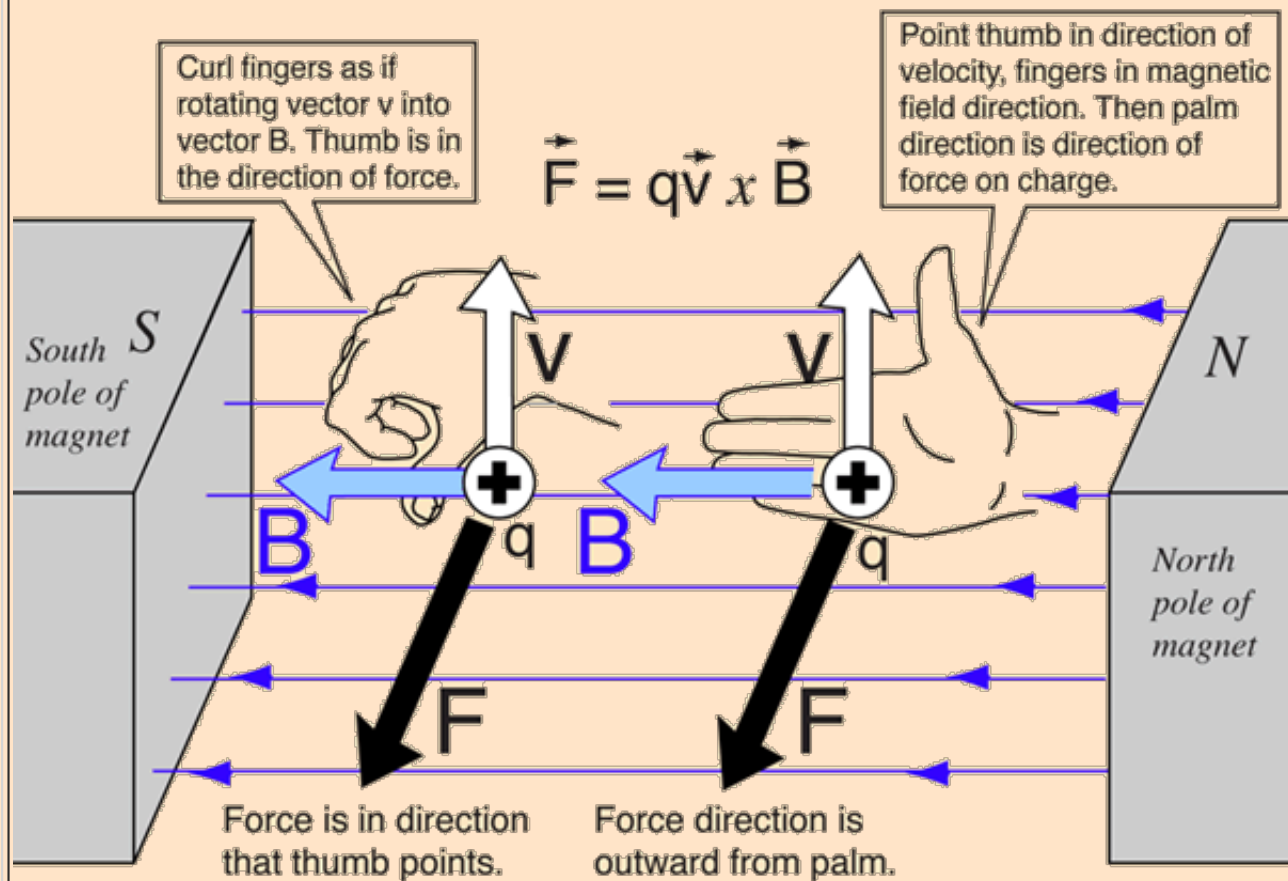Both the electric field and magnetic field can be defined from the Lorentz force law:

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

Electric force   Magnetic force

The electric force is straightforward, being in the direction of the electric field if the charge q is positive, but the direction of the magnetic part of the force is given by the right hand rule.

Electric force qE

+ + + + + + + + + + + +
E ⊕   ↑F Electric
      F↓ ⊖   Field
- - - - - - - - - - - -

North magnetic pole
N

Magnetic Field

⊕ ──→v
    B↓

S

Magnetic force of magnitude qvBsinθ perpendicular to both v and B, away from viewer.

Index

Electromagnetic force

Magnetic force

Magnetic field concepts

Right Hand Rule

Curl fingers as if rotating vector v into vector B. Thumb is in the direction of force.

Point thumb in direction of velocity, fingers in magnetic field direction. Then palm direction is direction of force on charge.

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

South S pole of magnet

V

V

N

B q B q

North pole of magnet

F F

Force is in direction that thumb points.

Force direction is outward from palm.

The right hand rule is a useful mnemonic for visualizing the direction of a magnetic force as given by the Lorentz force law. The diagrams above are two of the forms used to visualize the force on a moving positive charge. The force is in the opposite direction for a negative charge moving in the direction shown. One fact to keep in mind is that the magnetic force is perpendicular to both the magnetic field and the charge velocity, but that leaves two possibilities. The right hand rule just helps you pin down which of the two directions applies.

For applications to current-carrying wires, the conventional electric current direction can be substituted for the charge velocity v in the above digram.

Curl fingers as if rotating vector I into vector B. The thumb is then in the direction of the force F

Force on wire F

B

Magnetic field

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

I

Electric current

Force on straight wire of length L

This depicts conventional current.
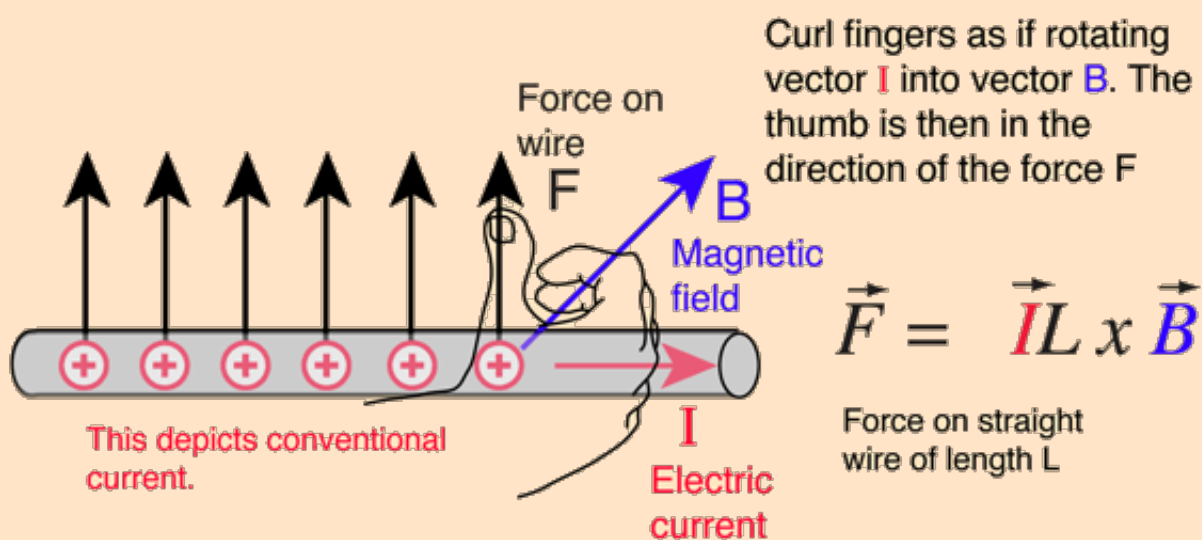
Magnetic force as a vector product

Magnetic force on a moving charge