8.3 Magnetic Force on a Conductor

Physics Tool box

- The magnitude of the force on the conductor F is in the direction perpendicular to both the magnitude of the magnetic field B and in the direction of the current I.
- $F = IlB\sin(\phi)$
- SI of magnetic field strength is the telsa (T)
- $1T = 1\frac{N}{A\cdot m}$
- The force on the conductor $\vec{F}$ is in a direction perpendicular to both the magnetic field $\vec{B}$ and the direction of the current I.
- Reversing either the current direction or the magnetic field reverses the direction of the force.

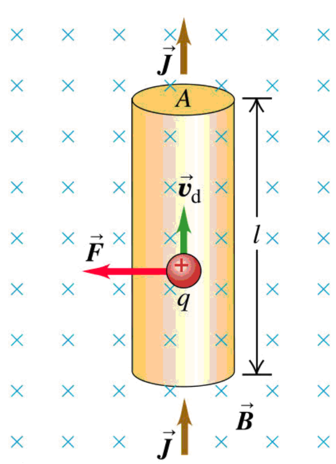
What makes an electric motor work? The forces that turn an electric motor are simply the forces that a magnetic field exerts on a conductor carrying a current. The magnetic forces on the moving charges within the conductor are transmitted to the material of the conductor and thus the conductor as a whole experiences a force distributed along its length.

We can calculate the force on a current carrying conductor by starting with:

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

We want to drive an expression for the total force on all the moving charges in a length l of a conductor with a cross-sectional area A. The number of charges per unit volume is n, a segment of the conductor with length l has volume $A\cdot l$ and thus contains a number of charges equal to nAl, thus the total force $\vec{F}$ on all moving charges in this segment has magnitude

$$F = (nAl)(qvB)$$
$$= (nqvA)(lB)$$



The current density $J = nqv$. On the left we have a diagram of the forces on a moving positive charge in a current-carrying conductor.

Now current is defined by $I = nqvA$

$$\text{Thus } F = IlB$$

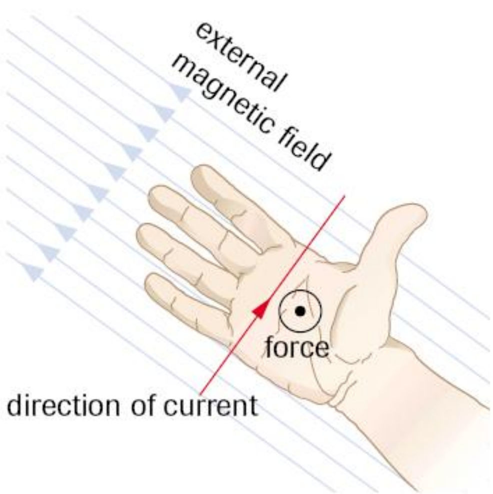
If the field is not perpendicular to the wire but makes an angle ϕ with it, we then apply the normal vector rules, thus

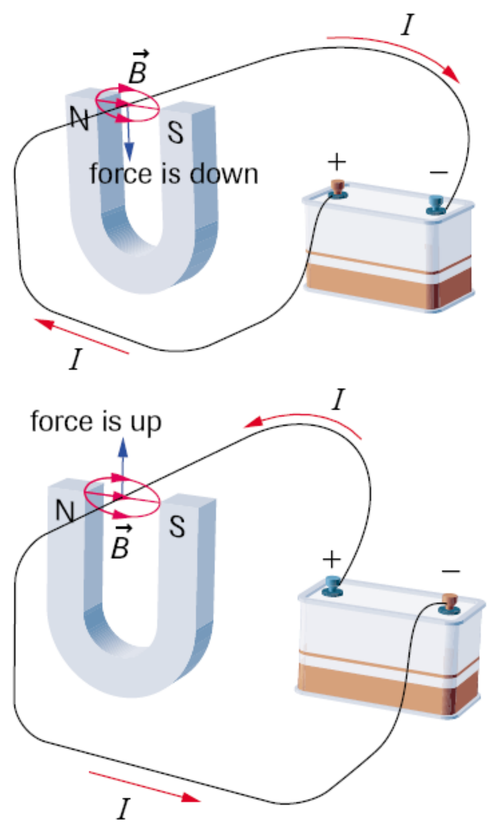
$$F = IlB\sin(\phi)$$

Note: current , I, is not a vector.

The direction of the force, can be determined with another simple right hand rule.

If the right thumb points in the direction of the current (flow of positive charge), and the extended fingers point in the direction of the magnetic field, the force is in the direction in which the right palm pushes.





1T is the magnetic field strength present in a conductor with a current of 1A and a length of 1 m at an angle of $90°$ to the magnetic field experiences a force of 1N.

$$T = \frac{N}{A \cdot m}$$

Example

A straight conductor 5.0 cm long with a current of 21 A moves through a uniform 0.40T magnetic field . Calculate the magnitude of the force when the angle between the current and the magnetic field is 30°

Solution:

$$F = I \cdot l \cdot B \cdot \sin(\phi)$$
$$= (21A)(0.05m)(0.4T)\sin(30^\circ)$$
$$= 0.21N$$