EM06 The Motor Principle and Its Applications

Section Summary
- The motor principle states that a current-carrying conductor will experience a magnetic force as long as the conductor is not parallel to the magnetic field.
- The factors that affect the strength of the magnetic force are the current, the magnetic field, and the length and orientation of the conducting wire.

Section Summary
- The electric motor, loudspeaker, and particle accelerator all operate according to the motor principle.

The Motor Principle

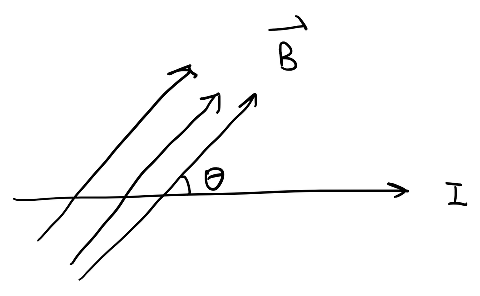
Recall: a current-carrying wire produces a magnetic field
When two magnetic fields interact, there is a force generated between them.

Therefore, when a current-carrying wire is placed in an external magnetic field it experiences a magnetic force given by:

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

$\vec{F}_B = BIL\sin\theta$

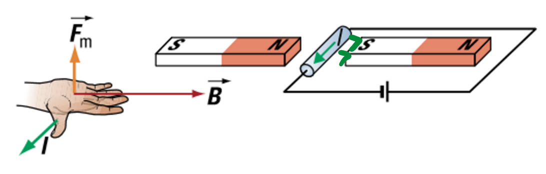
magnetic field current length



- Force is maximum when
  $\theta = 90°$ field & wire are perpindicular
- Force is zero when
  $\theta = 0°$
  $\theta = 180°$ field and wire are parallel

Assuming there is a component of current perpendicular to the field, the direction of the force is given by **Right hand rule #3**:

- Point your thumb along the current
- Point your fingers along magnetic feld
- Your palm gives direction of force



Example: A 0.80 m wire carrying 0.640 A East is placed in a 0.22 T magnetic field oriented south. What is the force on the wire?

N W E S

into page = down

$I = 0.640$

$\vec{B} = 0.22$

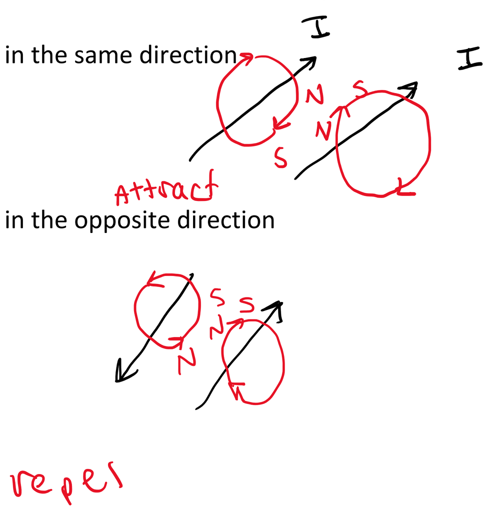
$\vec{F}_B = BIL\sin\theta$
$= 0.22(0.64)0.8\sin(90)$
$= 0.11$ N [Down]

Example: A 0.80 m wire carrying 0.640 A South is placed in a 0.22 T magnetic field oriented up. What is the direction of force on the wire?

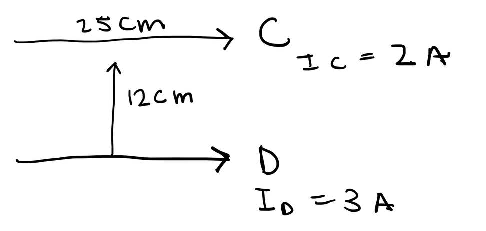
Magnetic force between current carrying wires

Ampere's Law gives the direction of force between parallel current-carrying wires:

- When current is in the same direction
- When current is in the opposite direction



Example: What is the magnitude and direction of force on wire C which is 25 cm long, carrying 2.0 A East, when it is placed 12 cm north of wire D which carries 3.0 A East? Recall $B = \mu_0 I / 2\pi r$.



$B = \frac{4\pi \times 10^{-7}}{2\pi \times 0.12} \times 3$

$B = 5 \times 10^{-6}$ T

$F_B = BIL\sin\theta$

$F_B = 5 \times 10^{-6} \times 2 \times 0.25$

$F_B = 2.5 \times 10^{-6}$ N [south]

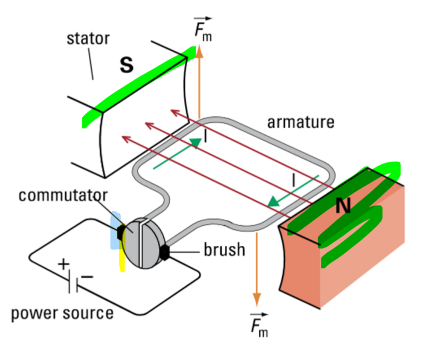
Applications of Electromagnetism

The DC Electric motor

The electric motor is a device which transforms electrical energy into kinetic energy using electromagnetism.

- The stator is a frame with a permanent magnet which provides the magnetic field.
- The armature is a rotating loop of conducting wire which will experience a force and rotate when current is run through the wire.
- The commutator is a split metal ring which conducts electricity into the armature. The two sides of the ring have NO contact
- The brushes are metal contacts which conduct electricity from the DC power source into the commutator and armature.

The armature is attached to a wheel or gear which makes use of its motion.

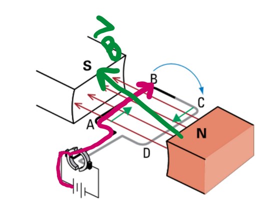


Let's use Right Hand Rule #3 to see how rotation occurs.

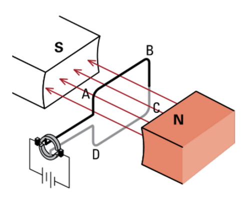
Position 1
Wire segment AB experiences a force up

Wire segment CD experiences a force down

The armature will spin clockwise until AB has rotated 90^0.



Position 2
The commutator doesn't make contact with the brushes, so there is no current and therefore no force. The armature needs sufficient momentum to rotate more than 90^0 and fall to 180^0.

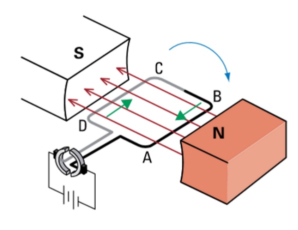


Position 3
The brushes are now in contact with the opposite side of the commutator, so the current switches direction.

Wire segment AB experiences a force down.

Wire segment CD experiences a force up.

The armature will spin clockwise 180^0 and AB will be back in its original position, with the brushes having switched back to contacting the original sides of the commutator.



Brushless DC motors

Pros and Cons of the DC motor

• Inexpensive to build • Can run for a long time • High speed • Powered by batteries, so it's portable	• Brushes wear out • Sparks occur between contact, wasting energy • Force on armature is not uniform.

The Loudspeaker

How Speakers Make Sound

A solenoid called a voice coil is connected to the speaker cone and surrounded by a permanent magnet.

The voice coil and cone are held by a piece of folded paper called the spider which allows them to vibrate back and forth.

The amplifier sends current into the voice coil creating a magnetic field which interacts with the field of the permanent magnet. It either attracts or repels the permanent magnet, moving the speaker cone in and out rapidly.

This oscillation pushes the air, creating sound waves.