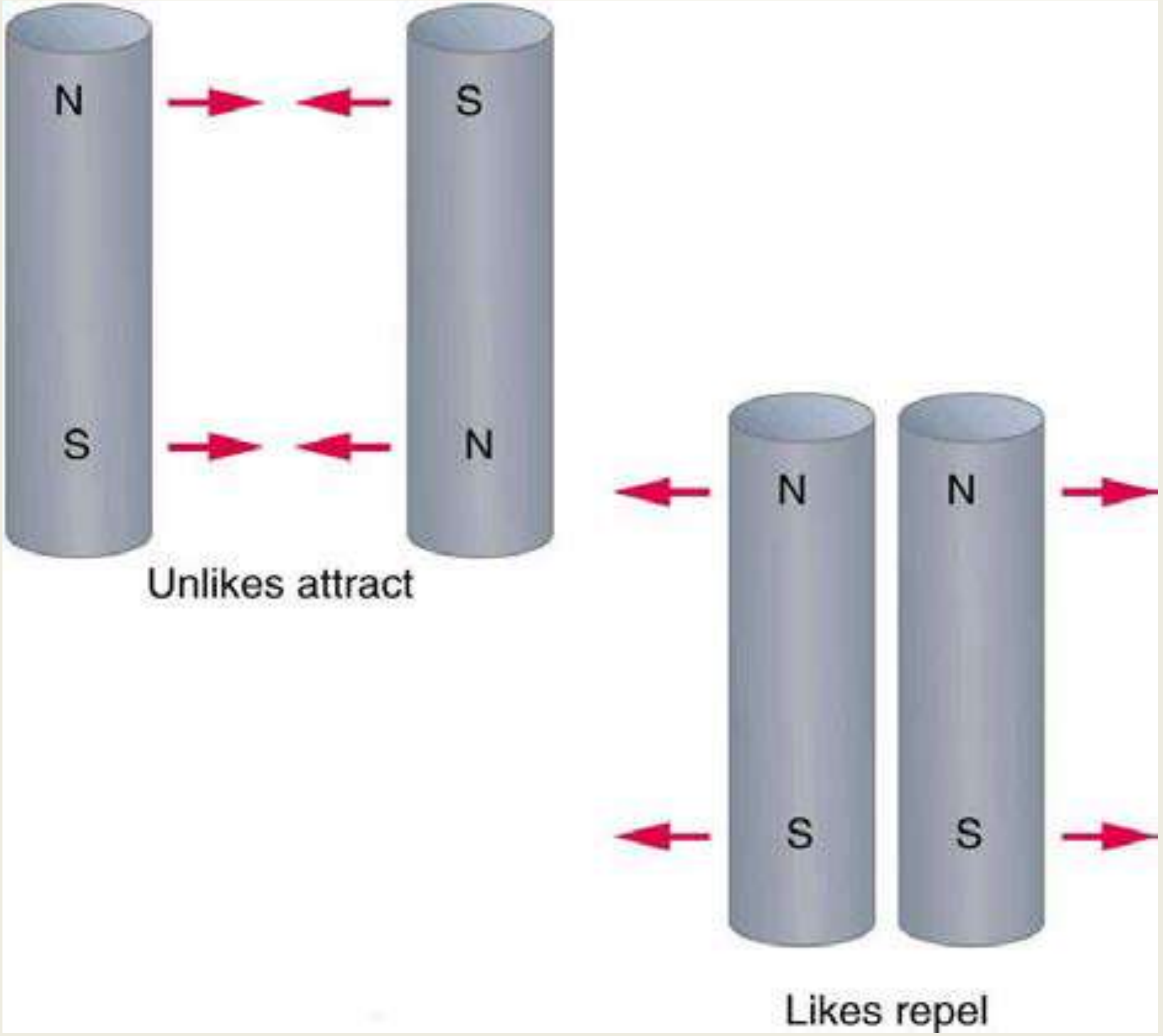
MAGNETISM

Engr Ghulam Raza


MAGNETS AND B-FIELDS

Magnets and B-Fields

- Magnets have two ends called poles
  - North and South poles
  - There are no single poles
- Like poles repel, Opposite poles attract

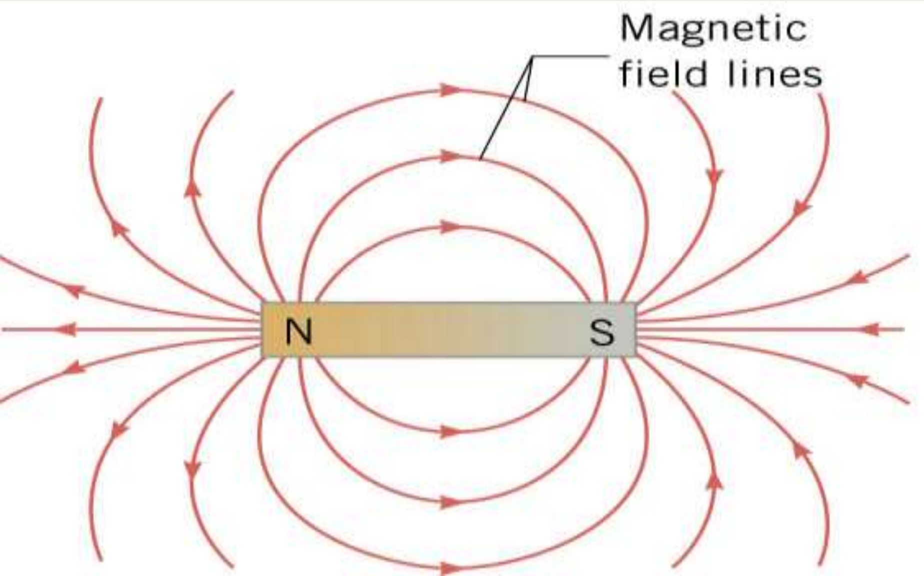


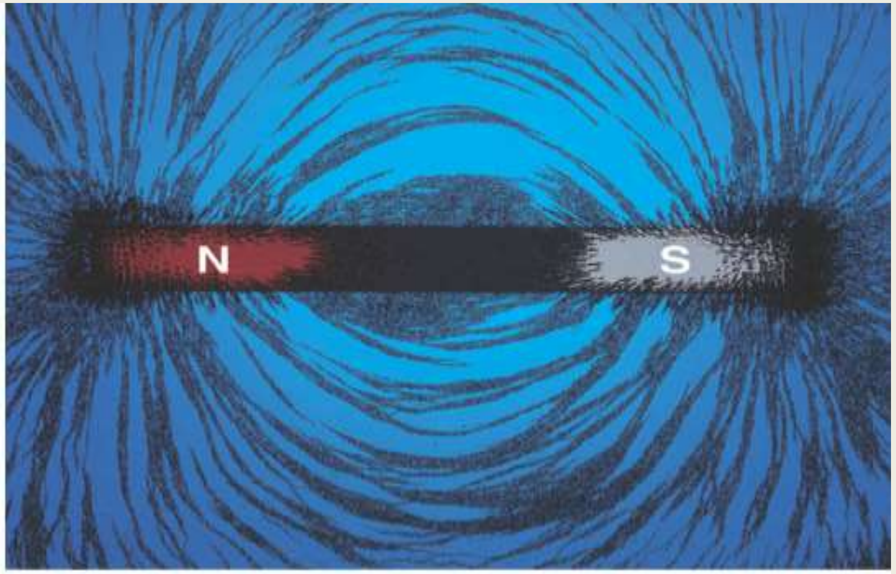
Magnets and B-Fields

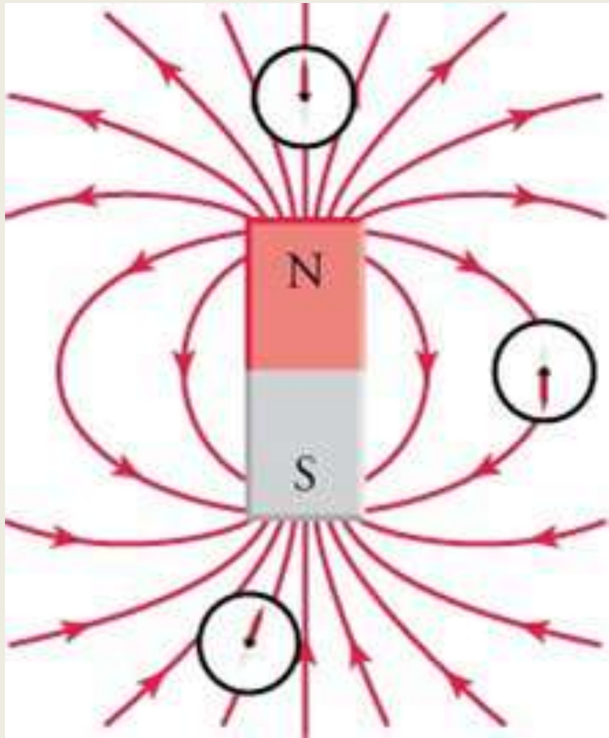
- Electromagnetism
  - It was discovered that running current through a wire produced a magnet
  - The magnetism around permanent magnets and currents are very similar, so both must have common cause.
  - Current is the cause of all magnetism

Magnets and B-Fields

- Around a magnet is a magnetic field (**B**-field)
  - At every point in space there is a magnetic force
  - Unit is Tesla (T)
- Magnetic fields can be visualized with field lines.
  - Start at N pole and end at S pole
  - The more lines in one area means stronger field







MAGNETIC FORCE ON A MOVING CHARGE

Magnetic Force on a Moving Charge

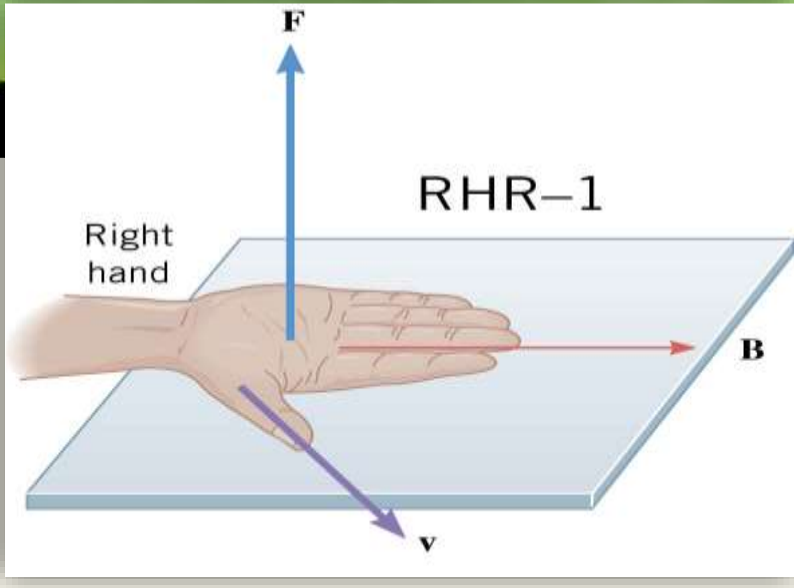
- Since currents (moving charges) make B-fields, then other B-fields apply a force to moving charges.
- For a moving charge to experience a force
  - Charge must be moving
  - The velocity vector of the charge must have a component perpendicular to the B-field

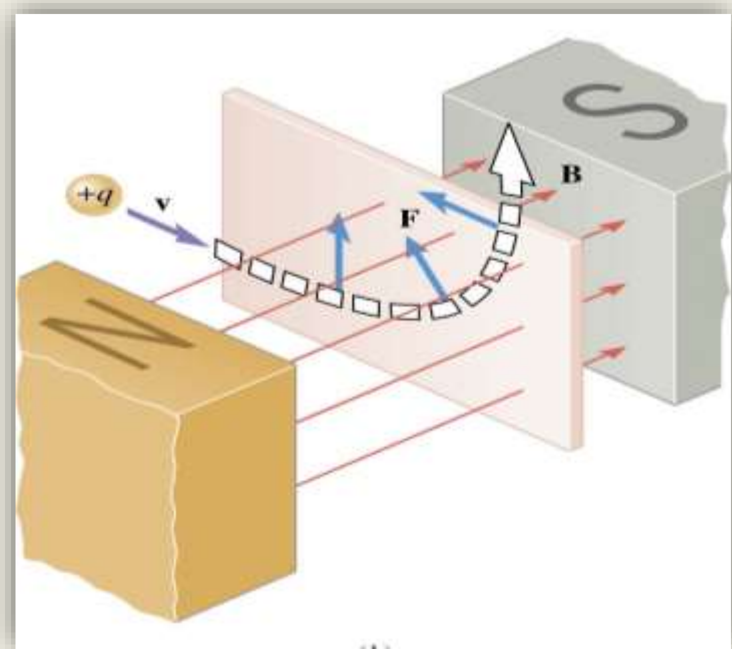
- $\vec{F} = q\vec{v} \times \vec{B}$
- $\vec{F} = qvB \sin\theta$
  - Where
  - F = force
  - q = charge
  - v = speed of charge
  - B = magnetic field
  - θ = angle between v and B

Magnetic Force on a Moving Charge

- Direction of force on positive moving charge
  - Right Hand Rule
    - Fingers point in direction of B-field
    - Thumb in direction of *v*
    - Palm faces direction of *F* on positive charge

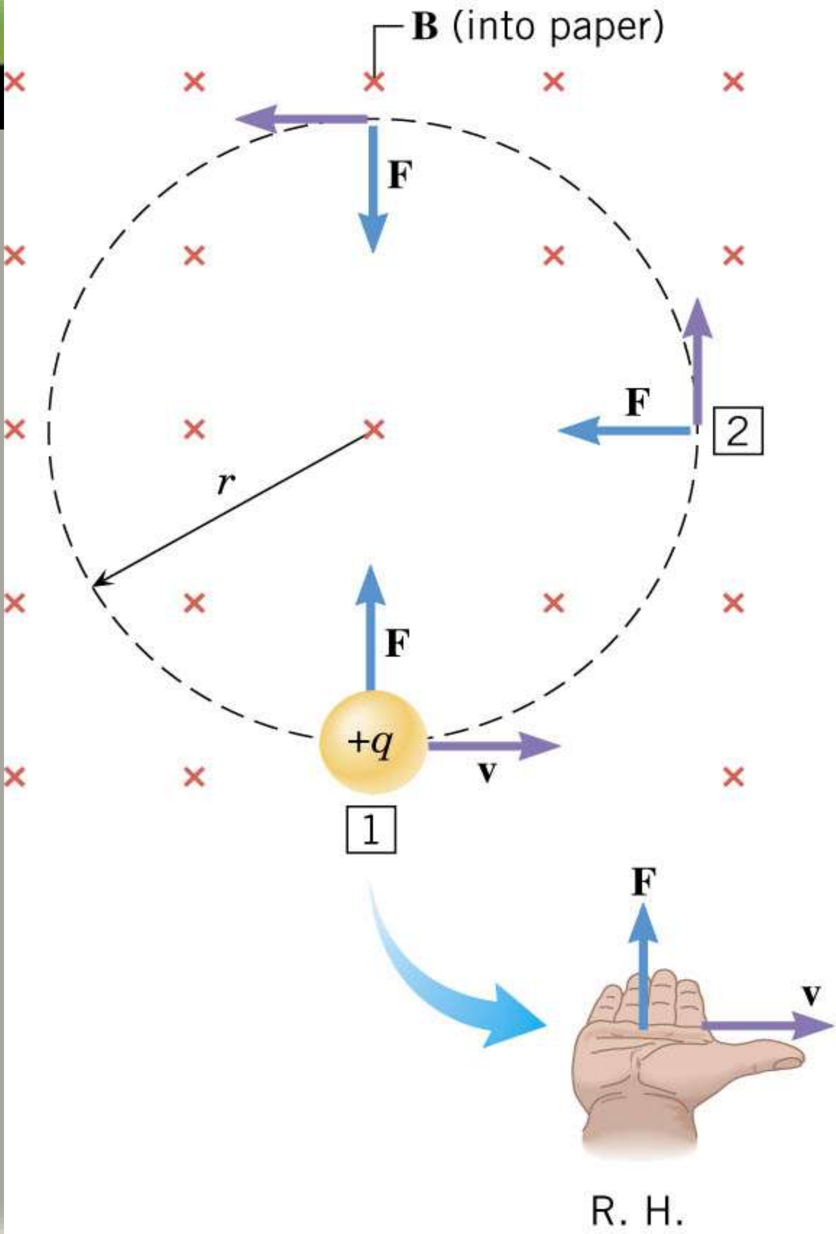
- Force will be zero if *v* and *B* are parallel, so a moving charge will be unaffected





Magnetic Force on a Moving Charge

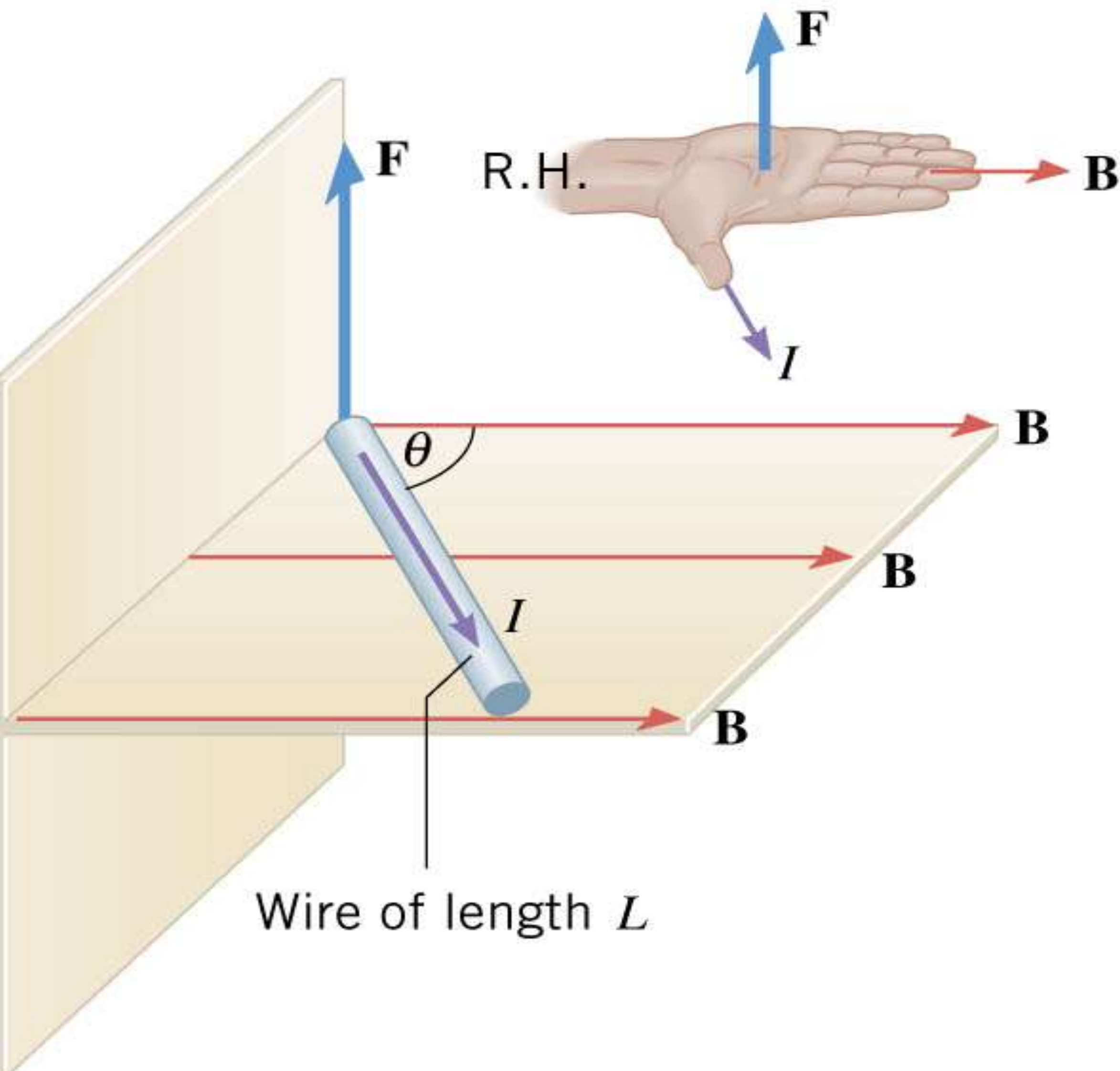
- Motion of moving charged particle in uniform B-field
  - Circular
  - $F = qvB \sin\theta$
  - $F_C = \frac{mv^2}{r}$
  - $qvB \sin\theta = \frac{mv^2}{r}$
  - $r = \frac{mv}{qB}$



MAGNETIC FORCE ON CURRENT-CARRYING WIRE

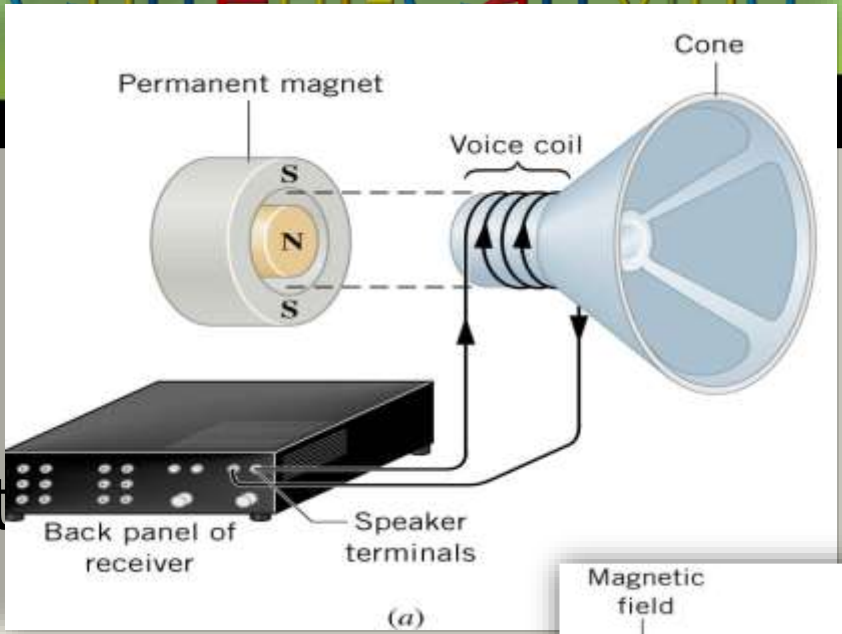
Magnetic Force on Current-Carrying Wire

- Force on a current-carrying wire in B-field
  - Direction Follows RHR
  - $F = qvB\sin\theta$
  - $F = \frac{q}{t}vtB\sin\theta$
  - $I = \frac{q}{t}\ L = vt$
  - $F = ILB\sin\theta$

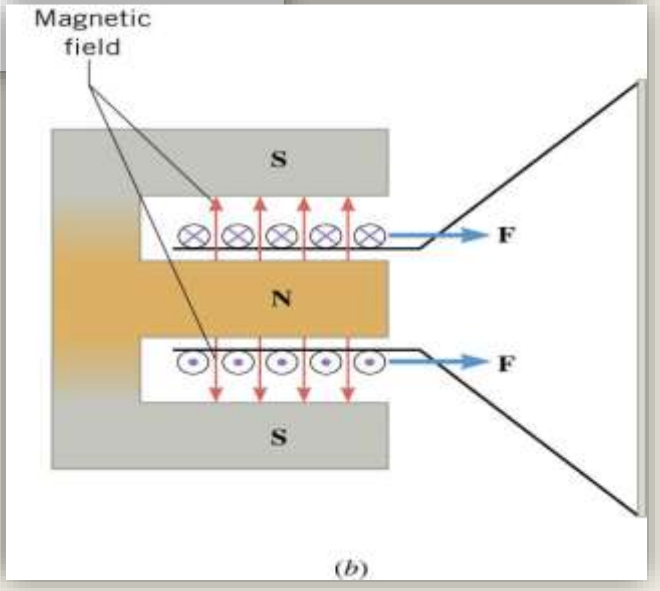


Magnetic Force on Current-Carrying Wire

- Speakers
  - Coil of wire attached to cone
  - That is enclose by a magnet
  - A varying current is run through the wire
  - The current in the B-field makes the speaker cone move back and forth



(a)



(b)

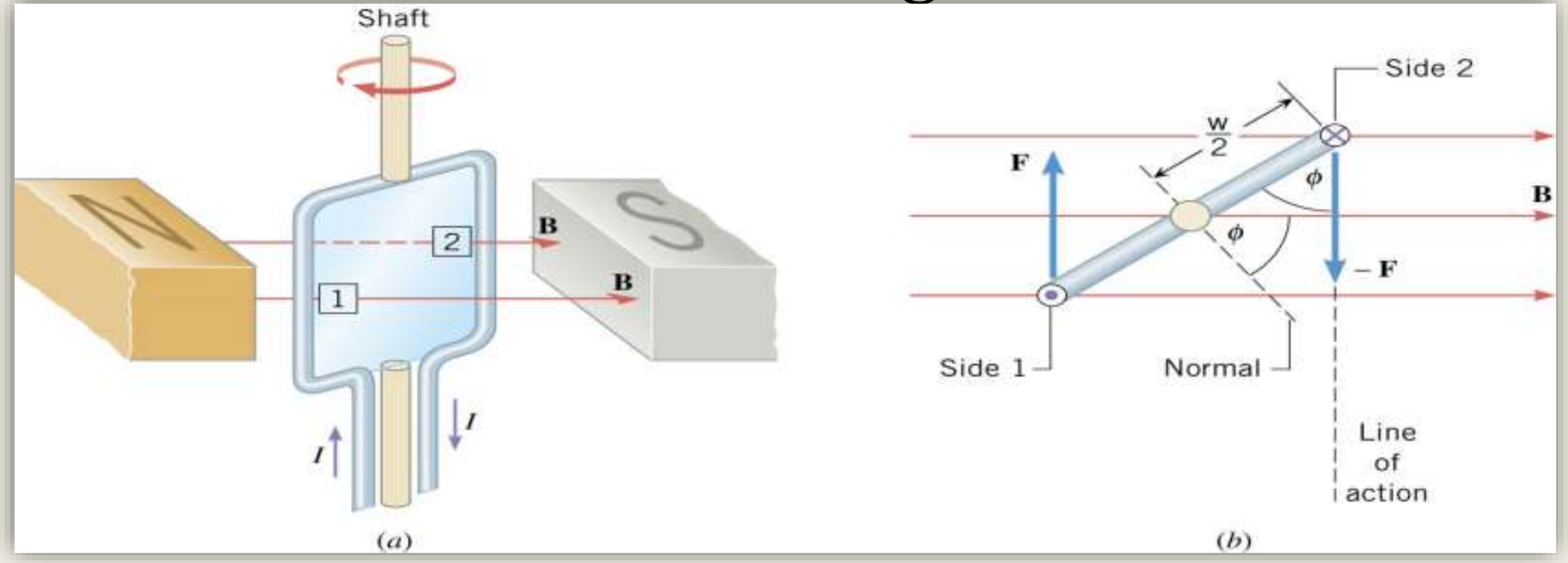
Magnetic Force on Current-Carrying Wire

- A 2 m wire is in a 2×10^{-6} T magnetic field pointing into the page. It carries 2 A of current flowing up. What is the force on the wire?

- $F = 8 \times 10^{-6}$ T Left

Magnetic Force on Current-Carrying Wire

- What happens when you put a loop of wire in a magnetic field?
- Side 1 is forced up and side 2 is forced down (RHR)
- This produces a torque
- The loop turns until its normal is aligned with the B-field



Magnetic Force on Current-Carrying Wire

- Torque on Loop of Wire
  - $\tau = NIAB \sin\phi$
- where
  - N = Number of loops
  - I = Current
  - A = Area of loop
  - B = Magnetic Field
  - ϕ = Angle between normal and B-field
- NIA = Magnetic Moment
  - Magnetic moment ↑, torque ↑

Magnetic Force on Current-Carrying Wire

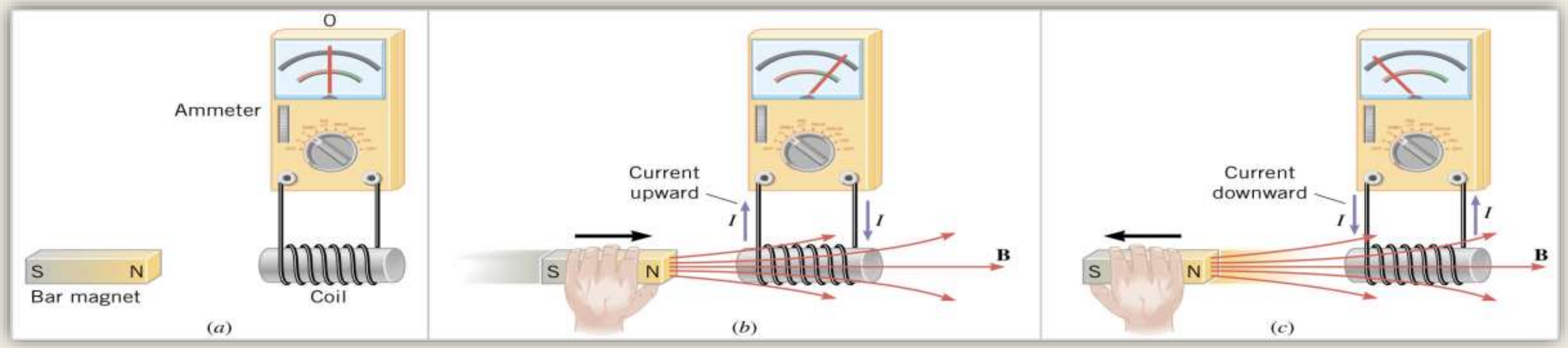
- A simple electric motor needs to supply a maximum torque of 10 Nm. It uses 0.1 A of current. The magnetic field in the motor is 0.02 T. If the coil is a circle with radius of 2 cm, how many turns should be in the coil?

- $N = 3.98 \times 10^6$ turns

FARADAY'S LAW OF INDUCTION AND LENZ'S LAW

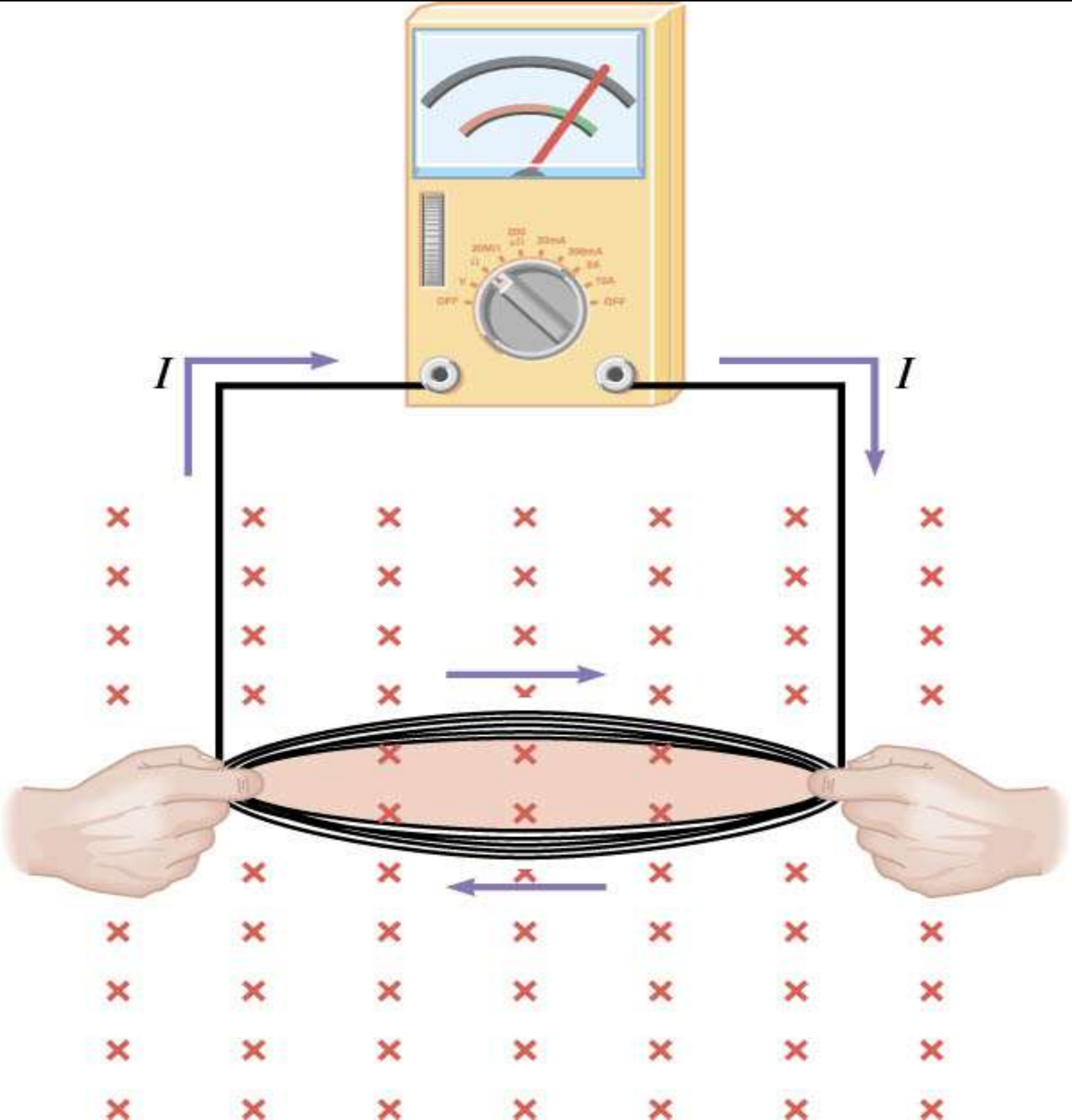
Faraday's Law of Induction and Lenz's Law

- Magnetic field can produce current.
- The magnetic field must be moving to create current.
- The current created is called **induced current**.
- The emf that causes the current is called **induced emf**.



Faraday's Law of Induction and Lenz's Law

- Another way to induce emf is by changing the area of a coil of wire in a magnetic field.

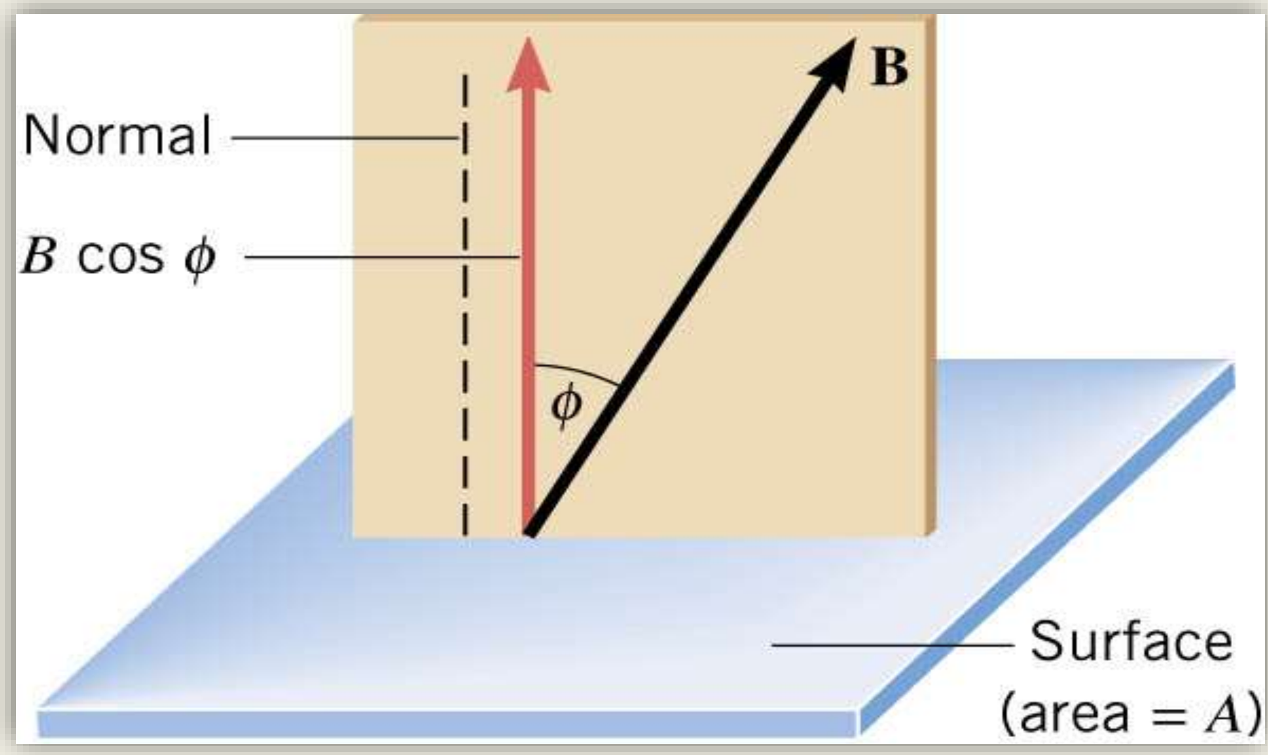


Faraday's Law of Induction and Lenz's Law

- Magnetic Flux through a surface
- $\Phi = \vec{B} \cdot \vec{A}$

$$\Phi = BA\cos\phi$$

- The angle is between the B-field and the normal to the surface.
- The magnetic flux is proportional to the number of field lines that pass through a surface.
- Any change in magnetic flux causes a current to flow



Faraday's Law of Induction and Lenz's Law

- emf is produced when there is a change in magnetic flux through a loop of wire.
- No change in flux; no emf.
- Experiments (and mathematics) show that $emf = -\frac{\Delta\Phi}{\Delta t}$ for a loop of wire
- If there are more than one loop, multiply by the number of loops.

Faraday's Law of Induction and Lenz's Law

- Faraday's Law of Electromagnetic Induction

$$emf = -N\left(\frac{\Phi - \Phi_0}{t - t_0}\right) = -N\frac{\Delta\Phi}{\Delta t}$$

- where
  - N = number of loops
  - Φ = magnetic flux
  - t = time
- Remember

$$\Phi = BA\cos\phi$$

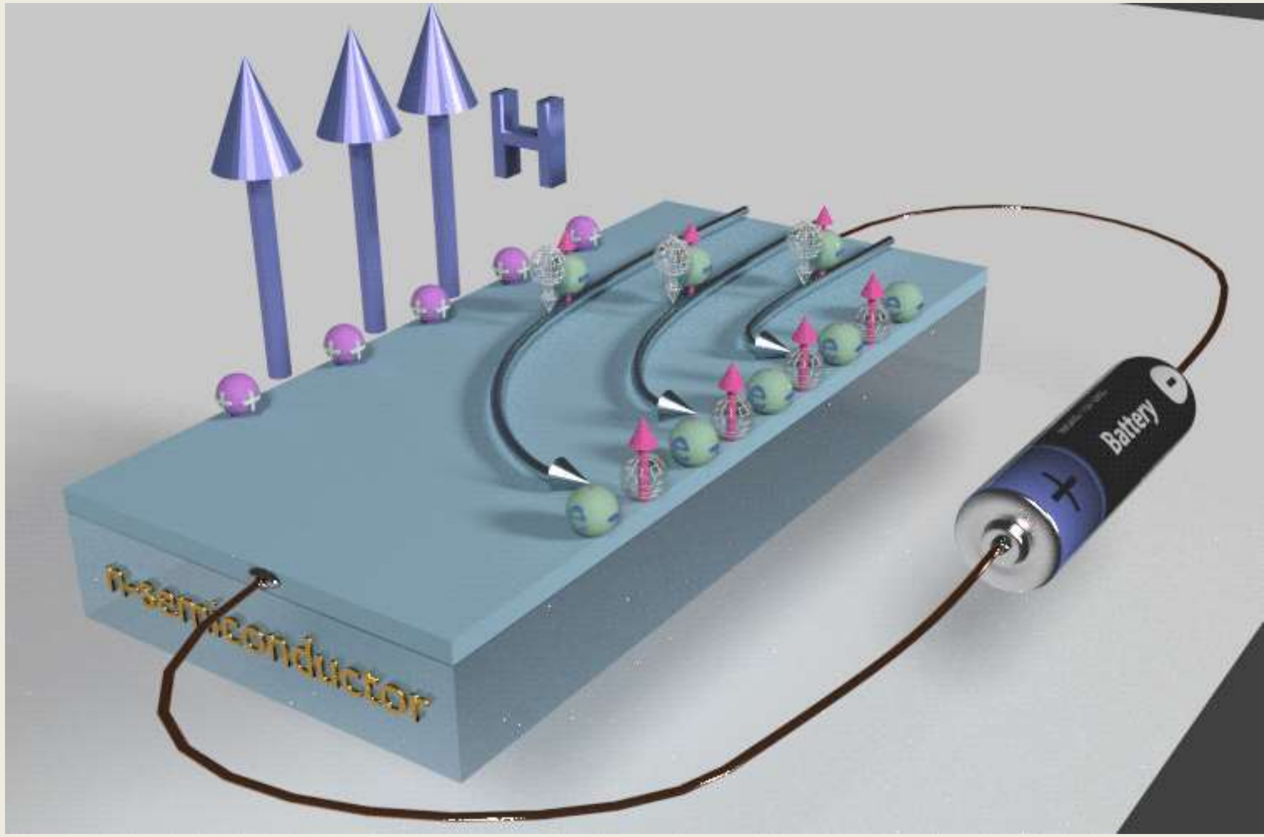
- So changing B, A, or ϕ will produce an emf

Faraday's Law of Induction and Lenz's Law

- Lenz's Law
  - The induced emf resulting from a changing magnetic flux has a polarity that leads to an induced current whose direction is such that the induced magnetic field opposes the original flux change.
- Reasoning Strategy
  - Determine whether the magnetic flux is increasing or decreasing.
  - Find what direction the induced magnetic field must be to oppose the change in flux by adding or subtracting from the original field.
  - Having found the direction of the magnetic field, use the right-hand rule to find the direction of the induced current.

Hall Effect

- The **Hall effect** is a phenomenon in applied physics where a voltage difference (the Hall voltage) is generated across a conductor when it carries an electric current and is placed in a magnetic field perpendicular to the current. This effect is named after physicist Edwin Hall, who first discovered it in 1879



Mathematical Expression

$$V_H = \frac{B \cdot I}{n \cdot e \cdot d}$$

Where:

- V_H is the Hall voltage,
- B is the magnetic field strength,
- I is the current,
- n is the charge carrier density,
- e is the elementary charge,
- d is the thickness of the material.

Induction Furnace

- An **induction furnace** is a type of electric furnace that uses **electromagnetic induction** to heat and melt materials, typically metals, by inducing an electric current within the material itself. This process is widely used in industries such as steel production, metal refining, and alloy manufacturing.