PHYS12 CH22: Magnetism

Sections 22.1-22.8

Mr. Gullo

April, 2025

Learning Objectives

By the end of this presentation, you should be able to:

- Describe magnets, magnetic fields, and magnetism
- Understand magnetic field lines and their properties
- Calculate the force on charges and currents in magnetic fields
- Apply the right-hand rule for magnetic forces
- Explain the Hall effect and practical applications
- Calculate torque on current loops in magnetic fields

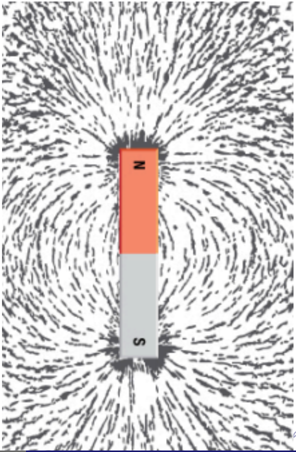
Outline

Basic Concepts of Magnetism

Magnetism

Properties of magnets and their interaction with moving charges and currents.

- Magnetic poles: North and South
- Like poles repel, unlike poles attract
- Poles always occur in pairs—cannot be isolated
- North poles point toward Earth's geographic north



Ferromagnets and Electromagnets

Ferromagnetic Materials

- Materials with strong magnetic effects (iron)
- Form regions called **domains**
- Domains align to create permanent magnets
- Lose magnetism above Curie temperature

Electromagnets

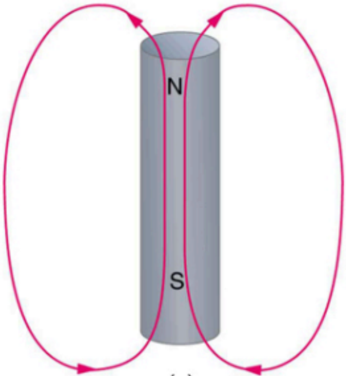
- Use electric currents to create magnetic fields
- Field strength depends on current and coil turns
- Can be turned on and off

Magnetic Field Representation

Magnetic fields are represented by field lines.

Properties of magnetic field lines:

- Field is tangent to the field line
- Line density shows field strength
- Lines never cross
- Lines form continuous loops



(c)

Force on Moving Charge in Magnetic Field

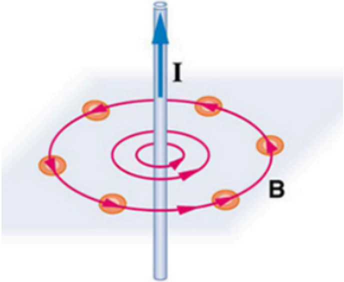
Magnetic Force Formula

The magnitude of the magnetic force on a moving charge:

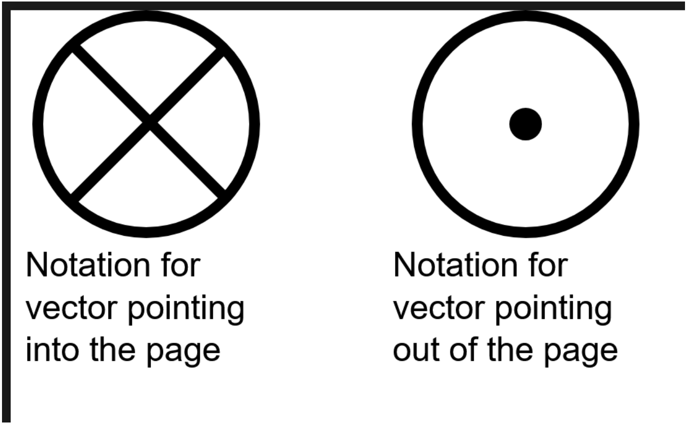
$$F = qvB\sin\theta \tag{1}$$

where θ is the angle between velocity and field.

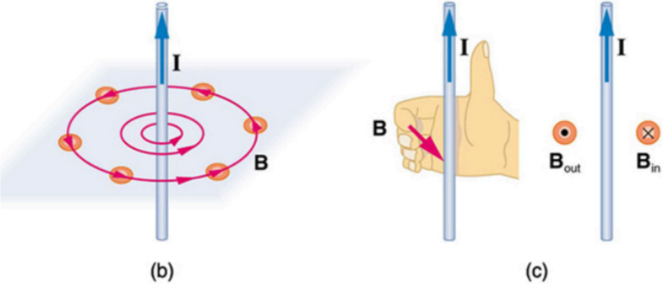
- SI unit: tesla (T)
- Force direction given by right-hand rule
- Force is perpendicular to v and B
- No force when v is parallel to B



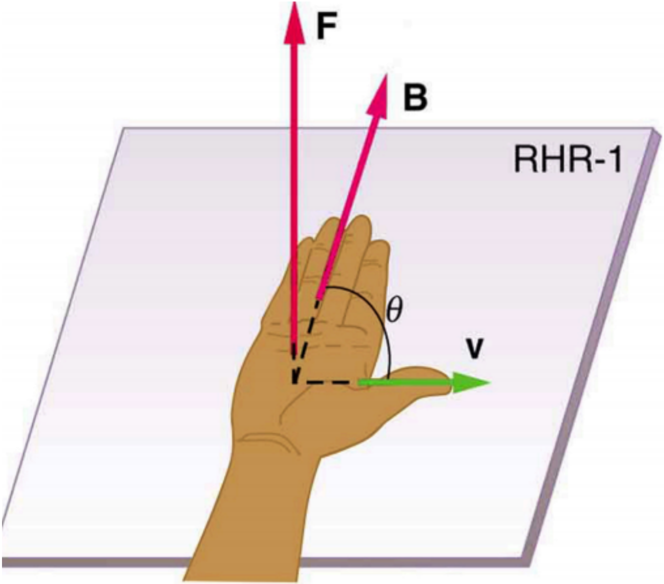
Force on Moving Charge in Magnetic Field



Force on Moving Charge in Magnetic Field



Force on Moving Charge in Magnetic Field



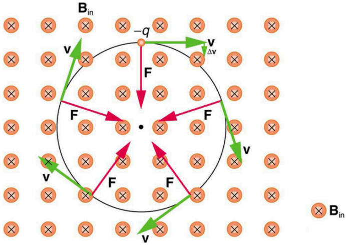
Applications of Force on Moving Charges

Circular Motion in Magnetic Field

Radius of a charged particle's circular path:

$$r = \frac{mv}{qB} \tag{2}$$

- Applications:
  - Mass spectrometers
  - Particle accelerators
  - Particle detectors
- Only affects moving charges



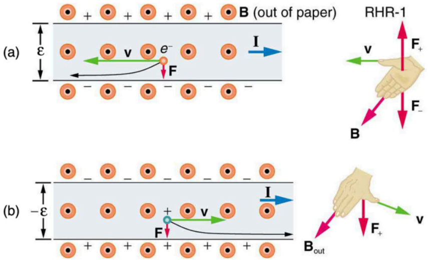
Hall Effect

Voltage created across a current-carrying conductor by a magnetic field.

- Hall voltage:

$$\varepsilon = Blv \qquad (3)$$

- B, I, and v must be perpendicular
- Applications:
  - Measuring magnetic fields
  - Hall effect sensors



Magnetic Force on a Current-Carrying Conductor

Force Formula

The magnetic force on a current-carrying conductor:

$$F = IlB \sin\theta \tag{4}$$

where I is current, l is length, B is field strength, and θ is the angle.

- Direction follows right-hand rule
- Maximum force when conductor is perpendicular to field
- No force when conductor is parallel to field
- Basis for electric motors

Torque on a Current Loop: Motors and Meters

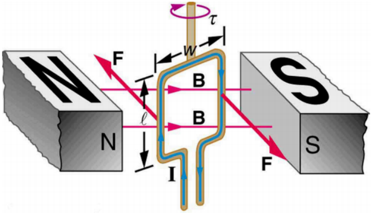
Torque Formula

The torque on a current-carrying loop:

$$\tau = NIAB \sin\theta \tag{5}$$

where N is turns, I is current, A is area, B is field strength.

- Maximum torque: loop parallel to field
- Zero torque: loop perpendicular to field
- Applications:
  - Electric motors
  - Measuring instruments



Example 1: "I do"

Problem

Calculate the force on an electron moving at 5.0×10^6 m/s perpendicular to a magnetic field of 0.50 T.

Example 1: "I do"

Problem

Calculate the force on an electron moving at 5.0×10^6 m/s perpendicular to a magnetic field of 0.50 T.

Solution

Given:

- Charge of electron: -1.60×10^{-19} C
- Velocity: 5.0×10^6 m/s
- Magnetic field: 0.50 T
- Angle: 90 (perpendicular)

Example 1: "I do"

Solution

Given:

- Charge of electron: -1.60×10^{-19} C
- Velocity: 5.0×10^{6} m/s
- Magnetic field: 0.50 T
- Angle: 90 (perpendicular)

Using $F = qvB \sin\theta$:

Example 1: "I do"

Solution

Given:

- Charge of electron: -1.60×10^{-19} C
- Velocity: 5.0×10^{6} m/s
- Magnetic field: 0.50 T
- Angle: 90 (perpendicular)

Using $F = qvB \sin\theta$:

$$F = (-1.60 \times 10^{-19}\ \text{C})(5.0 \times 10^{6}\ \text{m/s})(0.50\ \text{T})(\sin 90) \tag{6}$$

$$F = -4.0 \times 10^{-13}\ \text{N} \tag{7}$$

The negative sign indicates force direction opposite to the right-hand rule.

Example 2: "We do"

Problem

Find the radius of the circular path of a proton with speed 3.0×10^6 m/s in a magnetic field of 0.75 T when the proton velocity is perpendicular to the field.

Example 2: "We do"

Problem

Find the radius of the circular path of a proton with speed 3.0×10^6 m/s in a magnetic field of 0.75 T when the proton velocity is perpendicular to the field.

Solution

Given:

- Mass of proton: 1.67×10^{-27} kg
- Charge of proton: 1.60×10^{-19} C
- Velocity: 3.0×10^6 m/s
- Magnetic field: 0.75 T

Example 2: "We do"

Example 2: "We do"

Solution

Given:

- Mass of proton: 1.67×10^{-27} kg
- Charge of proton: 1.60×10^{-19} C
- Velocity: 3.0×10^{6} m/s
- Magnetic field: 0.75 T

Using $r = \frac{mv}{qB}$:

Example 2: "We do"

Solution

Given:

- Mass of proton: 1.67×10^{-27} kg
- Charge of proton: 1.60×10^{-19} C
- Velocity: 3.0×10^{6} m/s
- Magnetic field: 0.75 T

Using $r = \frac{mv}{qB}$:

$$r = \frac{(1.67 \times 10^{-27}\ \text{kg})(3.0 \times 10^{6}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{C})(0.75\ \text{T})} \tag{8}$$

$$r = 4.2 \times 10^{-2}\ \text{m} = 4.2\ \text{cm} \tag{9}$$

Example 3: "You do"

Problem

A straight wire carrying a 5.0 A current is placed in a uniform magnetic field of 0.25 T. If the wire is 10 cm long and makes an angle of 30° with the field, what is the magnetic force on the wire?

Example 3: "You do"

Problem

A straight wire carrying a 5.0 A current is placed in a uniform magnetic field of 0.25 T. If the wire is 10 cm long and makes an angle of 30° with the field, what is the magnetic force on the wire?

Hints

- Use $F = IlB \sin\theta$
- Convert length to meters
- Calculate sin(30)

Example 3: "You do"

Problem

A straight wire carrying a 5.0 A current is placed in a uniform magnetic field of 0.25 T. If the wire is 10 cm long and makes an angle of 30° with the field, what is the magnetic force on the wire?

Hints

- Use $F = IlB \sin\theta$
- Convert length to meters
- Calculate sin(30)

Answer (to check your work)

$F = 0.125$ N

Key Equations

Magnetic Forces

$$F = qvB\sin\theta \qquad \text{(Force on moving charge)} \qquad (10)$$

$$r = \frac{mv}{qB} \qquad \text{(Radius of circular path)} \qquad (11)$$

$$\varepsilon = Blv \qquad \text{(Hall emf)} \qquad (12)$$

$$F = IlB\sin\theta \qquad \text{(Force on current-carrying conductor)} \qquad (13)$$

$$\tau = NIAB\sin\theta \qquad \text{(Torque on current loop)} \qquad (14)$$

Right-Hand Rule

Thumb: velocity/current direction, Fingers: magnetic field, Palm: force direction

Summary

- Magnets have north and south poles that cannot be isolated
- Like poles repel, unlike poles attract
- All magnetism arises from electric current
- Magnetic fields affect moving charges and currents
- The Hall effect creates voltage in conductors in magnetic fields
- Torque on current loops enables motors and meters

Applications

Electromagnets, motors, generators, particle accelerators, MRI, sensors

References

Textbook

OpenStax Physics, Chapter 22: Magnetism, Sections 22.1-22.8