

# PHYS12 CH22: Magnetism

Sections 22.1-22.8

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# 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

- 1 Magnets and Magnetic Fields
- 2 Magnetic Forces on Charges and Currents
- 3 Example Problems

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1 Magnets and Magnetic Fields

2 Magnetic Forces on Charges and Currents

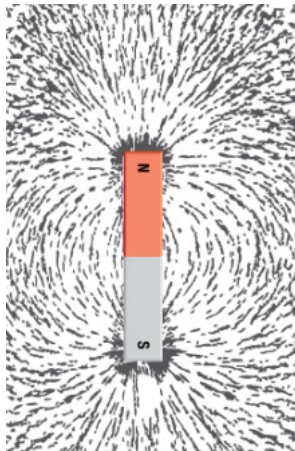
3 Example Problems

# 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

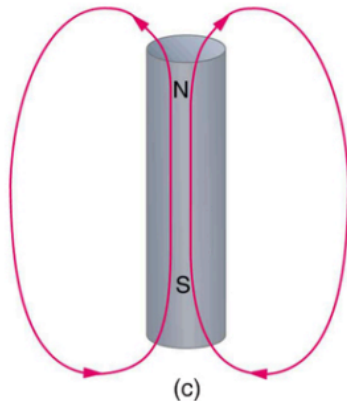
# Magnetic Field Lines

## 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



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# Force on Moving Charge in Magnetic Field

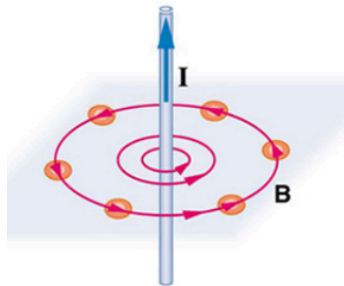
## Magnetic Force Formula

The magnitude of the magnetic force on a moving charge:

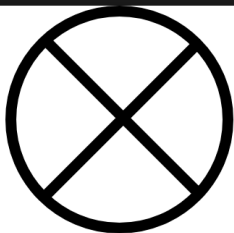
$$F = qvB \sin \theta \quad (1)$$

where  $\theta$  is the angle between velocity and field.

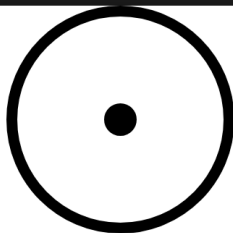
- SI unit: tesla (T)
- Force direction given by right-hand rule
- Force is perpendicular to  $v$  and  $B$
- No force when  $v$  is parallel to  $B$



# Force on Moving Charge in Magnetic Field

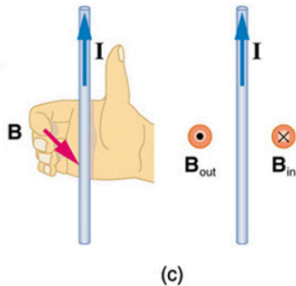
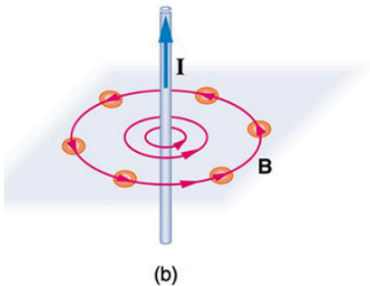


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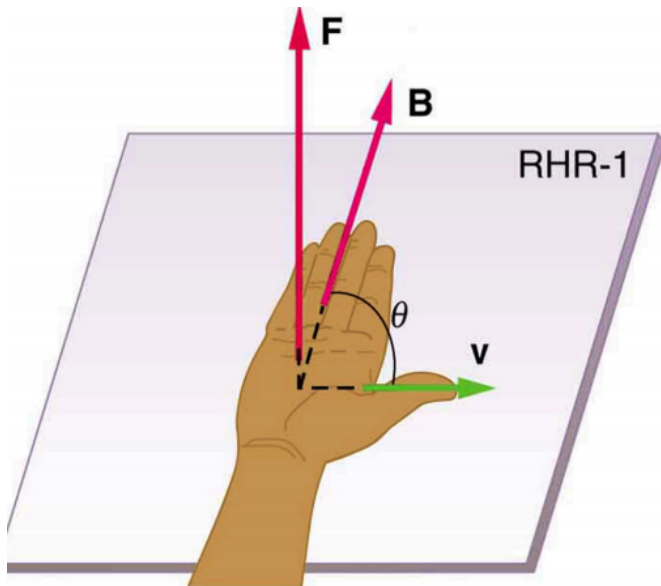


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# Force on Moving Charge in Magnetic Field



# Force on Moving Charge in Magnetic Field



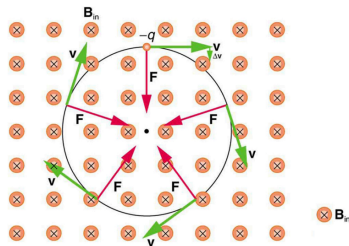
# Applications of Force on Moving Charges

## Circular Motion in Magnetic Field

Radius of a charged particle's circular path:

$$r = \frac{mv}{qB} \quad (2)$$

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



# The Hall Effect

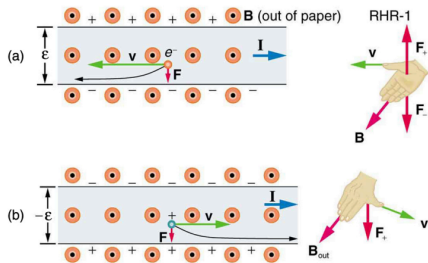
## Hall Effect

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

- Hall voltage:

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

- $B$ ,  $I$ , 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:

$$F = I l B \sin \theta \quad (4)$$

where  $I$  is current,  $l$  is length,  $B$  is field strength, and  $\theta$  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

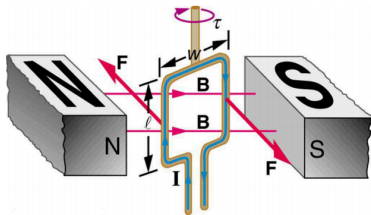
## Torque Formula

The torque on a current-carrying loop:

$$\tau = NIAB \sin \theta \quad (5)$$

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





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## Example 1: "I do"

### Problem

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

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### Solution

Given:

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

## Example 1: "I do"

### Solution

Given:

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

Using  $F = qvB \sin \theta$ :

## Example 1: "I do"

### Solution

Given:

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

Using  $F = qvB \sin \theta$ :

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

$$F = -4.0 \times 10^{-13} \text{ N} \quad (7)$$

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  $3.0 \times 10^6$  m/s in a magnetic field of 0.75 T when the proton velocity is perpendicular to the field.

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### Solution

Given:

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

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Given:

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- Charge of proton:  $1.60 \times 10^{-19}$  C
- Velocity:  $3.0 \times 10^6$  m/s
- Magnetic field: 0.75 T

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

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### Solution

Given:

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

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

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

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

## 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  $30^\circ$  with the field, what is the magnetic force on the wire?

## Example 3: "You do"

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### Hints

- Use  $F = I l B \sin \theta$
- 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  $30^\circ$  with the field, what is the magnetic force on the wire?

### Hints

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

### Answer (to check your work)

$$F = 0.125 \text{ N}$$

# Key Equations

## Magnetic Forces

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

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

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

$$F = I l B \sin \theta \quad (\text{Force on current-carrying conductor}) \quad (13)$$

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

## 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

## Textbook

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