E9 – Currents Create Magnetic Fields

- A moving charge creates a magnetic field
- Superposition principle for a wire segment
  - Biot-Savart law
- Magnetic field of a long, straight wire
- Magnetic field of a circular loop
- All magnets involve circulating currents
- Axial current distribution - wire
- A solenoidal current distribution
Biot-Savart Law

- Superposition principle for a moving charge

\[
\vec{B}_{\text{bar}} = \frac{\mu_0 c^2}{4\pi} \frac{q}{r_{PC}^2} \left( \frac{\vec{v}}{c} \times \hat{r}_{PC} \right)
\]

- Superposition principle for wire segments

\[
\vec{B}_{\text{bar}} = \frac{k}{c} \sum_{\text{all } i} \frac{dL}{r_{Pi}^2} \frac{q}{r_{PC}^2} \left( \vec{I}_i \times \hat{r}_{Pi} \right)
\]
Electric Currents & Magnetic Fields

- Electric current produces a magnetic field!
  - Hans Christian Oersted (1777-1851)
- Electric current exerts force on magnet

Direction of magnetic field given by Wire Rule
Think-Pair-Share

- Indicate the direction of \( \mathbf{B} \) due to the current-carrying wire at each of the points C, D, and E in the plane of the page.
Indicate direction of magnetic field for the following wires (arrow shows direction of I):

a) [direction arrow]

b) [empty]

c) [direction arrow]

d) [empty]

e) I flowing clockwise

f) I flowing counter-clockwise
Magnetic Field of long straight wire

\[ B = \frac{\mu_0 I}{2\pi r} \]

- You will derive this in lab.
- Equation gives magnitude of B
- Right-Hand-Rule gives direction
- permeability of free space, \( \mu_0 \):

\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \]
Magnetic Field of a Current Loop

Units of Magnetic Field
- Tesla (SI)
  - 1 T = 1 N/(A m)
- Gauss (cgs)
  - 1 G = 10^{-4} T
- Earth’s B field:
  - B = 0.5 G
  - B = 0.5 \times 10^{-4} T

Direction of magnetic field given by **Loop Rule**
Summary of Right-Hand Rules

- Insert Table E9.1
Think-Pair-Share

- Two long wires are oriented so that they are perpendicular to each other. At their closest, they are 20.0-cm apart. What is the magnitude of the magnetic field at a point midway between them?
Calculate B due to wire $I_1$

\[ F_2 = I_2 B_1 l_2 \]

\[ F_2 = \frac{\mu_0 I_1 I_2}{2\pi \frac{l_2}{d}} \]
Find direction of force from Right-Hand-Rule

(a) $F$  $F$

(b) $F$  $F$

Copyright © 2005 Pearson Prentice Hall, Inc.
Think-Pair-Share

- Two long straight parallel wires are 15 cm apart. Wire A carries a 2.0 A current. Wire B’s current is 4.0 A in the same direction. (d) Determine the force per length on wire A due to wire B, and the force on wire B due to wire A.
Practice Problems

- Magnetism:
  - Worksheet 1
  - Worksheet 3

- Exploration in Physics
  - Magnetism – activities in the hints tab

- Group Problems
  - E9B.5, E9B.6, E9S.8