Announcements

- WebAssign HW Set 6 due this Friday
  - Problems cover material from Chapters 19
- Estimated course grades available on e-learning
- My office hours are 2 - 3 pm today, room 2265
  - also, can schedule by appointment
- Always check out http://www.phys.ufl.edu/courses/phy2054/spring11/ for more announcements

QUESTIONS? PLEASE ASK!

Example Problem 19.42

- A cosmic ray proton in interstellar space has an energy of 10 MeV and executes a circular orbit having a radius equal to that of Mercury’s orbit around the Sun (5.8 x $10^{10}$ m). What is the magnetic field in that region of space?

From last time...

- Torque on a current loop:
  \[ \tau = B I A \sin \theta \]
  - Magnetic Moment: \[ \mu = I A \]
- Electric Motors
  - Force on a moving charged particle in a magnetic field
    - Equate centripetal and magnetic forces:
      \[ F = qvB = \frac{mv^2}{r} \]
      - Radius of orbit:
        \[ r = \frac{mv}{qB} \]

Magnetic Fields – Long Straight Wire

- A current-carrying wire produces a magnetic field \( B \)
  - Right hand rule # 2 to determine direction of \( B \)
- Magnitude of \( B \) at a distance \( r \) from a wire carrying current of \( I \) is:
  \[ B = \frac{\mu_0 I}{2\pi r} \]
  - \( \mu_0 = 4 \times 10^{-7} \text{T m / A} \)
  - \( \mu_0 \) is called the permeability of free space
Ampère’s Law: General

- relationship between \( I \) in an arbitrarily shaped wire and \( B \) produced by the wire:
  \[ \sum B \Delta l = \mu_0 I \]
- Choose an arbitrary closed path around the current
- Sum all the products of \( B \Delta l \) around the closed path

Ampère’s Law Applied to a Long Straight Wire

- Use a closed circular path
- The circumference of the circle is \( 2\pi r \)
  \[ B = \frac{\mu_0 I}{2\pi r} \]
- This is identical to the result previously shown

Example Problem 19.54

- Two long parallel wires separated by a distance \( 2d \) carry equal currents in the same direction. The currents are out of the page in the figure. (a) What is the direction of the magnetic field at \( P \) on the \( x \)-axis set up by the two wires? (b) Find an expression for the magnitude of the field at \( P \). (c) From (b), determine the field midway between the two wires.

Magnetic Force Between Two Parallel Conductors

- The force on wire 1 is due to the current in wire 1 and the magnetic field produced by wire 2.
- The force per unit length is:
  \[ \frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d} \]
- Parallel conductors carrying currents in the same direction attract each other
- Parallel conductors carrying currents in the opposite directions repel each other
Magnetic Field of a Current Loop

- The magnitude of the magnetic field at the center of a circular loop with a radius R and carrying current I is:
  \[ B = \frac{nI}{2R} \]
- With N loops in the coil, this becomes:
  \[ B = N \frac{\mu_0 I}{2R} \]

Magnetic Field of a Solenoid

- Solenoid – long straight wire is bent into a coil of several closely spaced loops
  - Electromagnet - acts like a magnet only when it carries a current
- \( B \) field lines inside the solenoid are nearly parallel, uniformly spaced, and close together
  - \( B \) is nearly uniform and strong
- The exterior field is nonuniform, much weaker, and in the opposite direction to the field inside the solenoid

Magnetic Field in a Solenoid, Magnitude

- The magnitude of the field inside a solenoid is constant at all points far from its ends
  - \( B = \mu_0 n I \)
    - \( n \) is the number of turns per unit length
    - \( n = N / \ell \)
- The same result can be obtained by applying Ampère’s Law to the solenoid

Example Problem 19.60

- A certain superconducting magnet in the form of a solenoid of length 0.5 m can generate a magnetic field of 9.0T in its core when the coils carry a current of 75 A. The windings, made of a niobium-titanium alloy, must be cooled to 4.2K. Find the number of turns in the solenoid.
Solution to 19.42

19.42 Since the path is circular, the particle moves perpendicular to the magnetic field, and the magnetic force supplies the centripetal acceleration. Hence, \( \mathbf{F} = m\mathbf{a} \), or \( \mathbf{B} = \frac{m\mathbf{a}}{q} \). But the momentum is given by \( p = mv = \sqrt{2mE_k} \), and the kinetic energy of this proton is

\[
E_k = \left[ \frac{1}{2} m v^2 \right] = \frac{1}{2} m v^2 = \frac{1}{2} m \left( \frac{2mE_k}{m} \right) = \frac{1}{2} (2mE_k) = mE_k.
\]

We then have

\[
\mathbf{B} = \frac{\sqrt{2mE_k}}{q} = \frac{2(1.67 \times 10^{-27} \text{ kg}) (1.60 \times 10^{-19} \text{ J})}{2(1.60 \times 10^{-19} \text{ C})(2.80 \times 10^{10} \text{ m/s})} = 7.88 \times 10^{-11} \text{ T}.
\]

Solution to 19.54

(a) Point P is equidistant from the two sources, which cancel each other out. Thus, the contributions of the two sources will be zero in the region. The horizontal component of the magnetic field from the current is directed to the left, and the vertical component will be directed upward. The horizontal components of the magnetic field from charges \( q_1 \) and \( q_2 \) cancel each other out, while the vertical components of the same charges add up to the horizontal component of the magnetic field from the current. The net magnetic field at point P is then

\[
\mathbf{B}_{\text{net}} = \frac{\mu_0}{4\pi} \frac{2q}{r^2} \hat{y}.
\]

(b) The distance between the two sources is the origin (0,0). From the above result, the net field at the origin (0,0) is

\[
\mathbf{B}_{\text{net}} = \frac{\mu_0}{4\pi} \frac{2q}{r^2} \hat{y}.
\]

The horizontal component of the magnetic field at point P is then

\[
\mathbf{B}_{\text{horizontal}} = 0.
\]

(c) The point halfway between the two sources is the origin (0,0). From the above result, the field at the origin (0,0) is

\[
\mathbf{B}_{\text{net}} = \frac{\mu_0}{4\pi} \frac{2q}{r^2} \hat{y}.
\]

Solution to 19.60

19.60 The magnetic field inside of a solenoid is \( \mathbf{B} = \mu_0 n I / (2\pi r) \). Thus, the number of turns on this solenoid must be

\[
N = \frac{\mu_0 I}{4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A}} \left( 2.80 \times 10^{19} \text{ turns} \right) = 5.80 \times 10^{14} \text{ turns}.
\]