Current and Magnetism

Forces Caused by Magnetic Fields

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Current Carrying Wires

- The magnetic fields around two current carrying wires placed next to each other will interact, causing a force between them.
  - When parallel conductors carrying charge in the same direction are placed near each other, they are attracted to one another.
  - When the charges in the conductors are flowing in the opposite direction,
    the wires are repelled from one another.

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Current Carrying Wires

- The strength of this magnetic force can be found by using the equation:

$$F = \frac{(2kL)I_1 I_2}{d}$$

Where

k = 1 x 10^{-7} N/A^2

L = the length of the conductors

I_1 and I_2 = current flowing through the two wires

d = the distance between the conductors

- Notice that the direction of the current will determine if it is a repulsive or attractive force

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Example Problem

- The force between two wires each with a current of 8.0 A is 3.4 x 10^{-4} N. If each wire is 170 cm long, what is the distance between the wires?

$$F = \frac{2kLI_1I_2}{d}$$

$$3.4\times10^{-4} = \frac{2(1\times10^{-7})(1.7)(8)(8)}{d}$$

$$d = \frac{2(1\times10^{-7})(1.7)(8)(8)}{3.4\times10^{-4}} = .064m$$

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A Wire in a Magnetic Field

- The magnetic field around a current carrying wire can interact with an existing magnetic field causing a force on the wire.
- The direction of the force on the wire can be found by using the Third Right Hand Rule.

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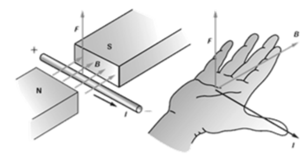
Third Right Hand Rule

- Place your fingers in the direction of the magnetic field and your thumb in the direction of the current.
- Your palm will show the direction of the force on the wire.



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Size of the Force on a Wire in a Magnetic Field

- To find the size of the force on a current carrying wire, we can use:

$$F = BIL$$

where
- B is the magnetic field strength in Teslas
- I is the current in Amps
- L is the length of the wire in the B-field

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Sample Problem

- A 45 cm wire carrying 3.0 A of current to the right is placed in a 0.55 T magnetic field directed upward. What is the size and direction of the force on the wire?

$F = BIL$
$= .55(3)(.45)$
$= .7425$ N

(F = .7425 N)

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Common Magnetic Fields

- Here are a few common magnetic fields and there strengths:

TABLE 24–1	
Typical Magnetic Field	
Source and Location	Strength (T)
Surface of neutron star (predicted)	10^8
Strong laboratory electromagnet	10
Small bar magnet	0.01
Earth's magnetic field	5×10^{-5}

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Forces on Single Charges

- A single charge moving through a magnetic field acts like a current in a wire and therefore will have a force applied to it.
- The direction of the force on the charge can be found by using the Third Right Hand Rule.
  - It will be the same direction for a positive particle.
  - It will be the opposite direction for a negative particle.

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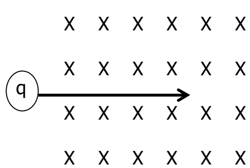
Forces on Single Charges

- Use the Right Hand Rule to find the direction of the force on the charged particle.



UP

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Third Right Rule Examples

- **Protons**

  Example #1
  - Current: Right
  - B-Field Lines: Into
  - Force: Up

  Example #2
  - Current: Down
  - B-Field Lines: Left
  - Force: Into

- **Electrons**

  Example #3
  - Current: Up
  - B- Field Lines: Out of
  - Force: Left

  Example #4
  - Current: Left
  - B-Field Lines: Down
  - Force: Into

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Forces on Single Charges

- The size of the force can be found by using the equation:

$$F = Bqv$$

where:
- B is the magnetic field strength in Teslas
- q is the size of the charge in Coulombs
  - Remember protons and electrons have a charge of $\pm 1.6 \times 10^{-19}$ C.
- v is the velocity of the charge in m/s

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Sample Problem

- An electron is shot upward at 4.0×10^6 m/s through a 0.35 T magnetic field that is directed toward the left. What is the size and direction of the force on the electron?

$F = Bqv$

$= .35(-1.6 \times 10^{-19})(4 \times 10^6)$

$= -2.24 \times 10^{-13}$ N

OUT → INTO

($F = -2.24 \times 10^{-13}$ N)

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