Physics 1B
Electricity & Magnetism

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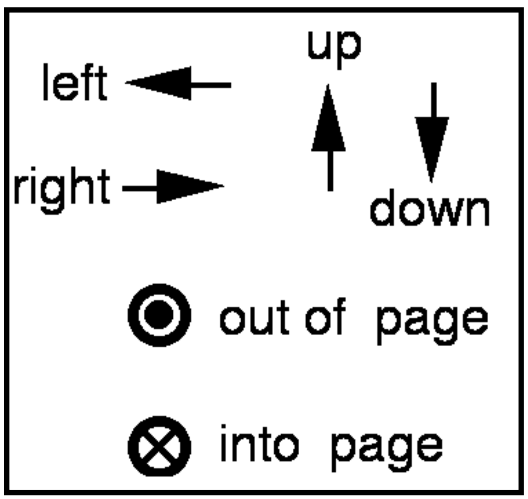
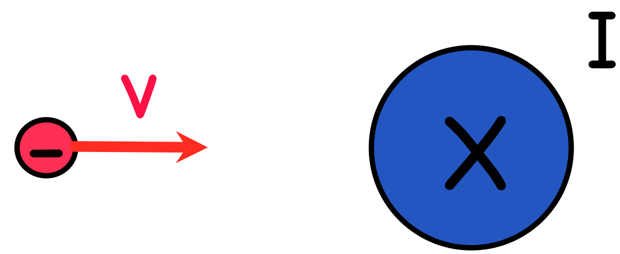
Outline of today

- Continue Chapter 22
  - Magnetic field
- Discussion of topics for quiz 3

Magnetic Forces

- <u>Example</u>
- Consider an electron 1.00cm away from a wire with a current of 0.500A. Calculate the magnitude and describe the direction of the magnetic force exerted on this electron, if it moves at a velocity of 1.00mm/s radially inwards towards the wire.





<u>Answer</u>

First, you must define a coordinate system.

Let's choose the center of the wire as r=0 and have standard directional conventions.

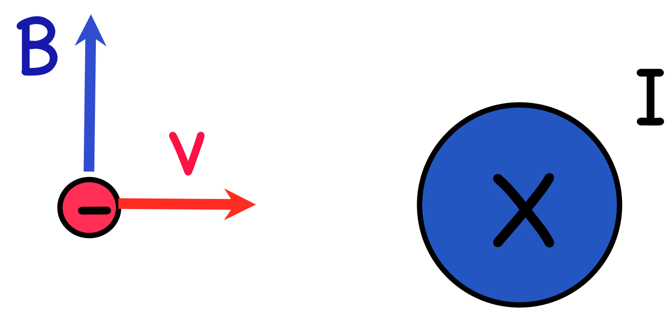
Step 1

<u>Answer</u>

Let's take this step-by-step; first step one: find the magnetic field created by the wire at the location of the electron.

Apply RHR2, and we find that at the location of the electron the magnetic field is upwards.

The magnitude of the magnetic field will be given by:



$$\left|\vec{B}\right| = \frac{\mu_o I}{2\pi r}$$

$$B = \frac{\left(1.26\times10^{-6}\ \mathrm{T\cdot m}/\mathrm{A}\right)\left(0.5\mathrm{A}\right)}{2\pi\left(0.01\mathrm{m}\right)} = 1.00\times10^{-5}\,\mathrm{T}$$

Step 2

Answer

Now, for step two: find the magnetic force caused by the magnetic field.

Apply RHR1, put your thumb in direction of velocity, your forefinger in the direction of the B-field.

The resulting magnetic force is out of the page. But you ask yourself one last question, is the electron positively or negatively charged?

It is negatively charged, so you flip the magnetic force vector so that it is into the page.

So, the magnetic force on the electron is parallel to the direction of the current.

Step 2

Answer

Next, to calculate the magnitude use the magnetic force equation:

$$F = q\left|\vec{v}\right|\left|\vec{B}\right|\sin\theta$$

$$F = \left(1.60\times10^{-19}\,\mathrm{C}\right)\left(1.0\times10^{-3}\,{}^{\mathrm{m}}\!/\!_{\mathrm{s}}\right)\left(1.0\times10^{-5}\,\mathrm{T}\right)\sin 90^\circ$$

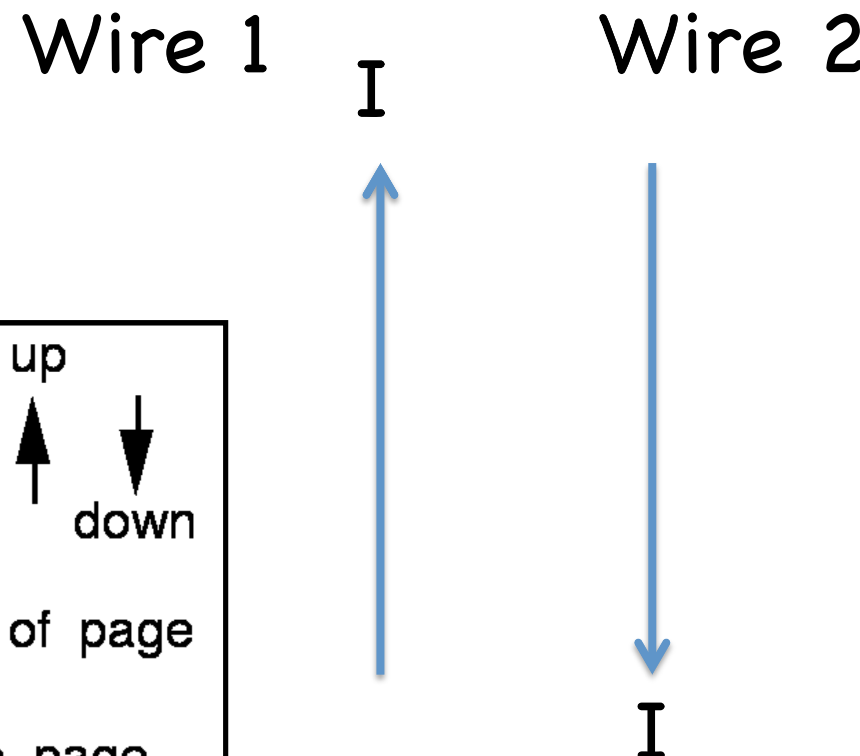
$$F = 1.60\times10^{-27}\,\mathrm{N}$$

The electron will be deflected toward the direction of the current flow.

If we reversed the direction of the current, then the force on the electron would have reversed as well.

Concept Question

- Two current-carrying wires are exactly parallel to one another and both carry 1 Amp of current. The current in wire 1 moves up while the current in wire 2 moves down. What is the direction of the magnetic field caused by wire 1 at the location of wire 2?



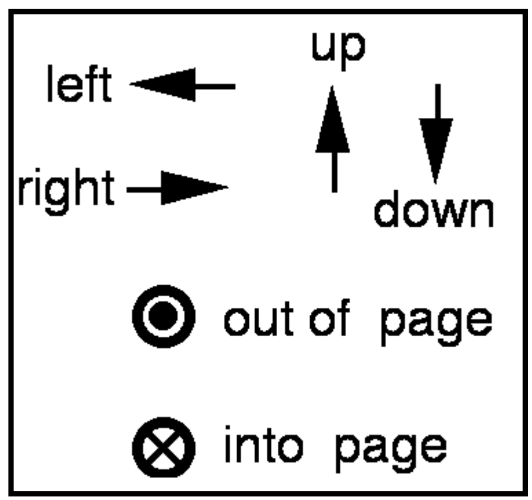
A) Into the page.

B) Out of the page.

C) Up.

D) To the left.

E) To the right.



Concept Question

- Two current-carrying wires are exactly parallel to one another and both carry 1 Amp of current. The current in wire 1 moves up while the current in wire 2 moves down. What is the direction of the magnetic force caused by wire 1 on wire 2?

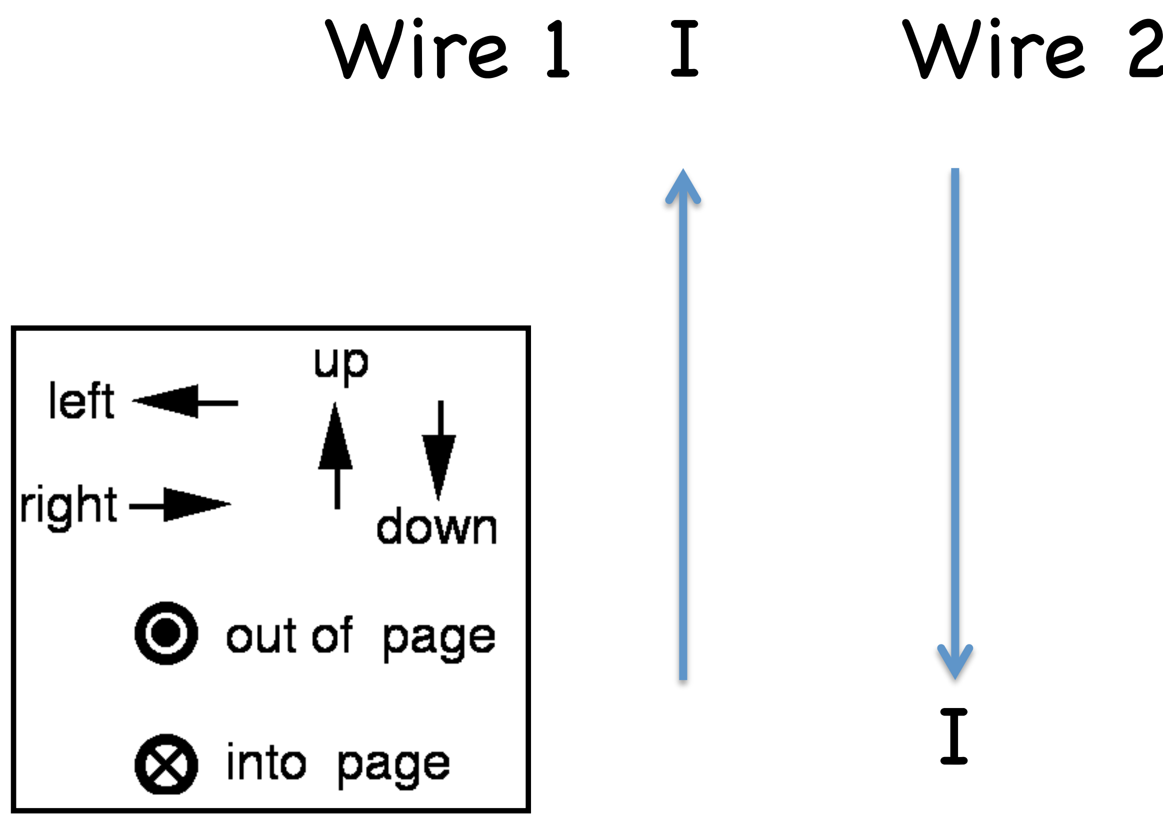
A) Into the page.

B) Out of the page.

C) Up.

D) To the left.

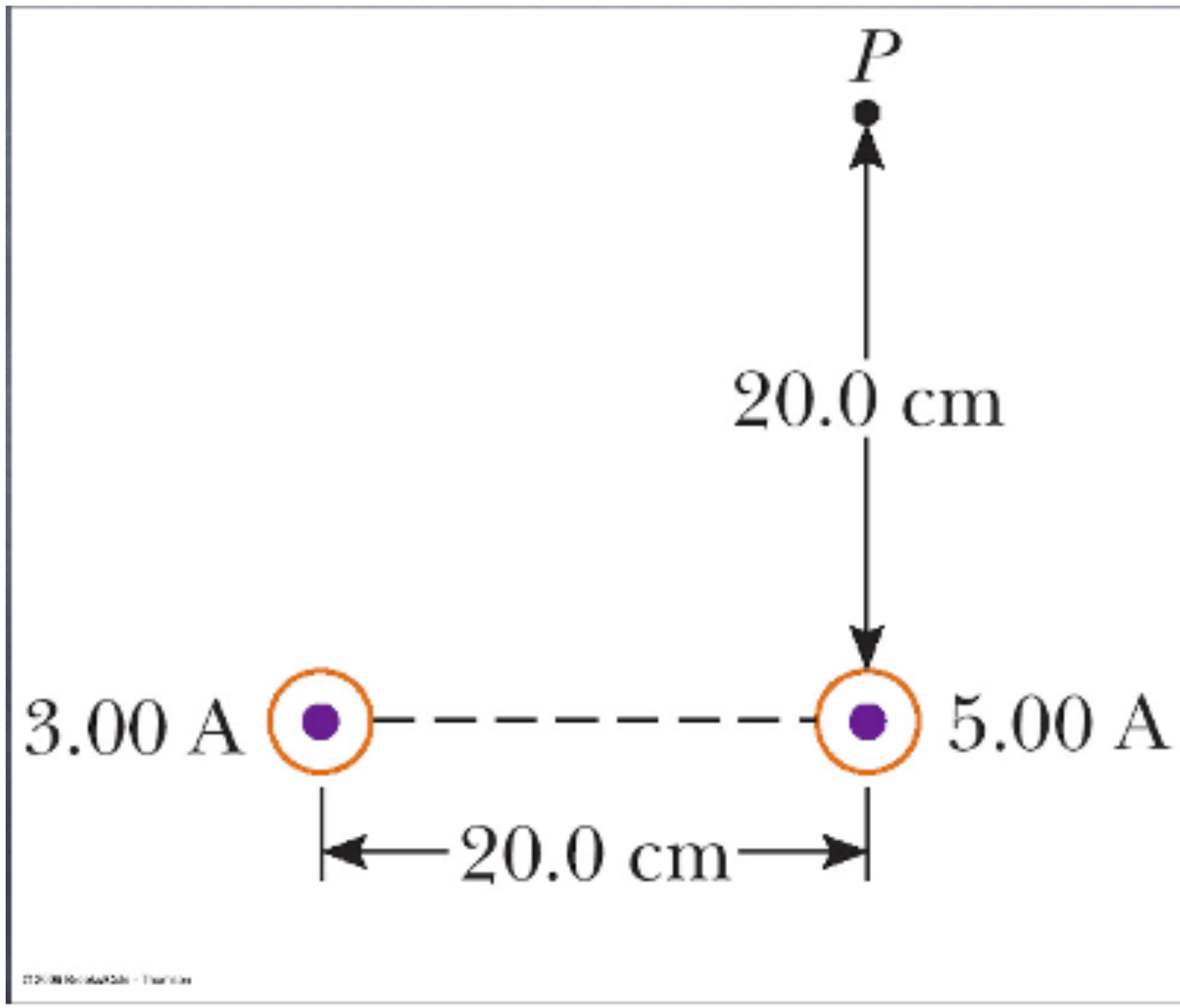
E) To the right.



Superposition

- As with any vectors, magnetic field vectors can be added together by superposition
- You have to take both magnitude and direction into account.

The vectors could get ugly, but just recall RHR2 and vector rules of addition and everything should turn out well in the end.



Force on a Wire

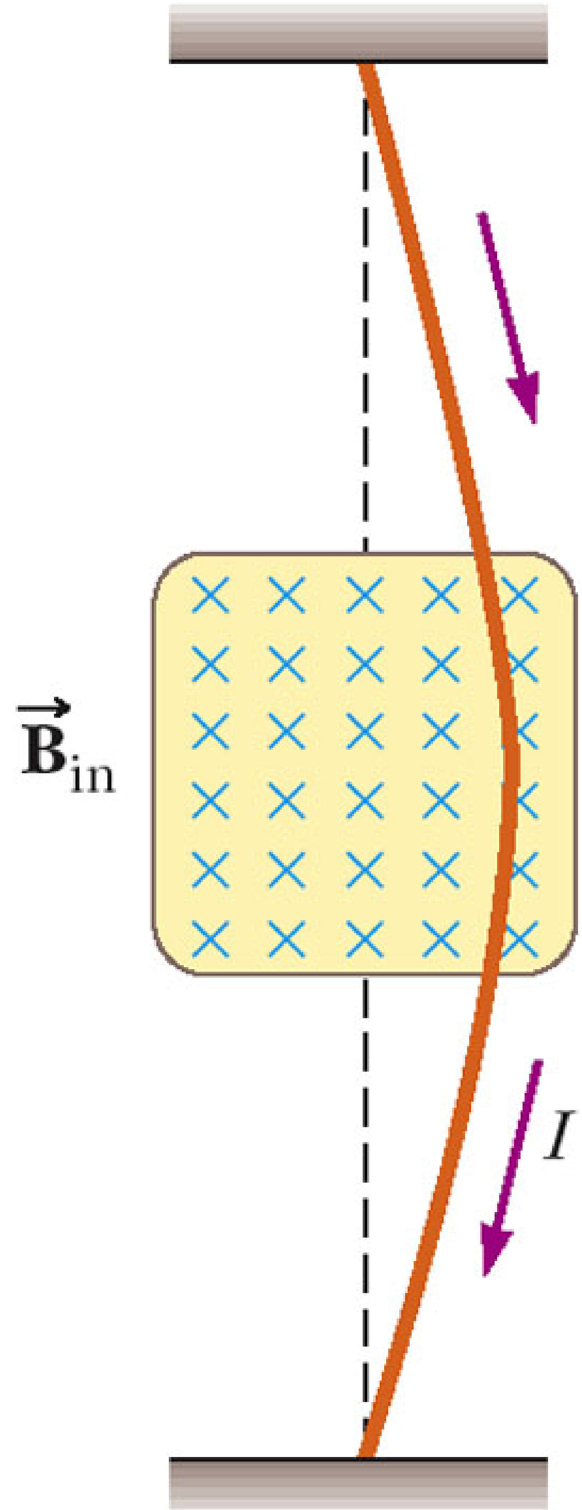
If the current in a wire is moving downward and the magnetic field is into the board apply Right Hand Rule 1:

Your positive current velocity points down (thumb)

Your magnetic field points into the board (forefinger).

Middle finger then points to the right.

Force is to the right since current is defined as positive charge moving.



Force on a Wire

The magnetic force is exerted on each moving charge in the wire.

The total force is the sum of all magnetic forces on all the individual charges producing the current.

$$F = I\ell B \sin\theta$$

where θ is the angle between B and the direction I.

As always the direction of the force is found by Right Hand Rule 1.

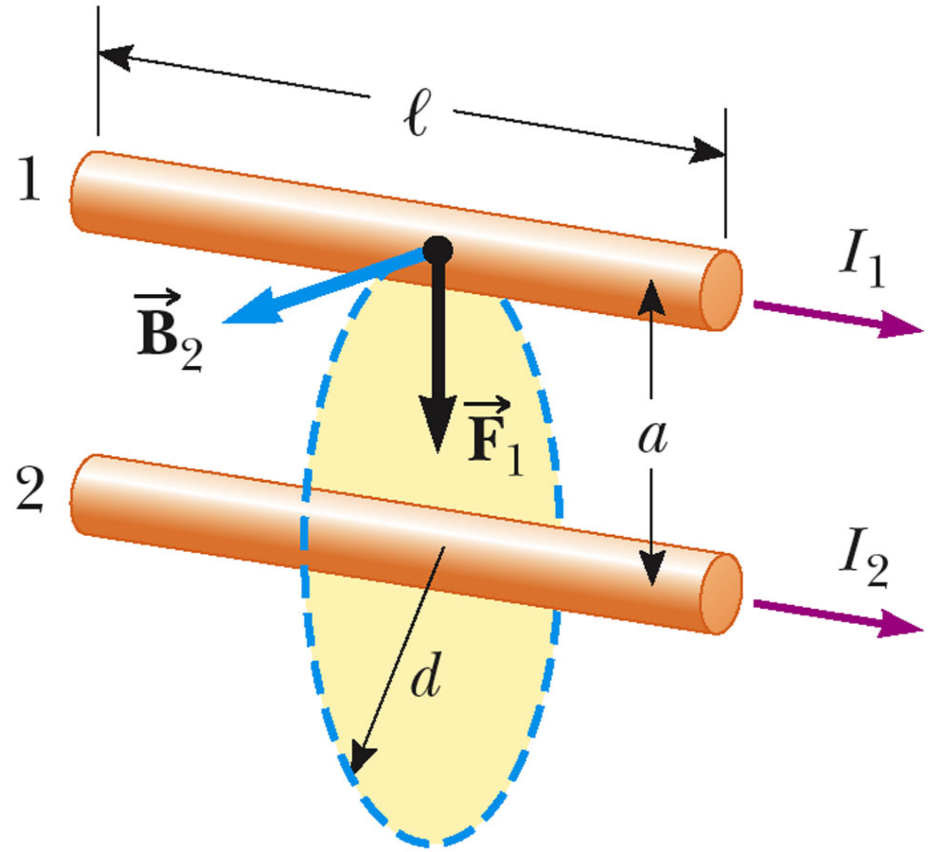
When trying to find the force between two wires separated by a distance, r, recall that the magnetic field from a wire is given by:

$$B = \frac{\mu_o I}{2\pi r}$$

Force Between 2 Wires

Let's say that we have two parallel wires that are separated by a distance, a, and we would like to know the force (magnitude and direction) of wire 2 on wire 1.

Step 1: Wire 2 creates a magnetic field at the location of wire 1.



According to our diagram the direction of the magnetic field will be out of the board (towards us via RHR2).

The magnitude of the magnetic field will be:

$$B_2 = \frac{\mu_o I_2}{2\pi a}$$

Force Between 2 Wires

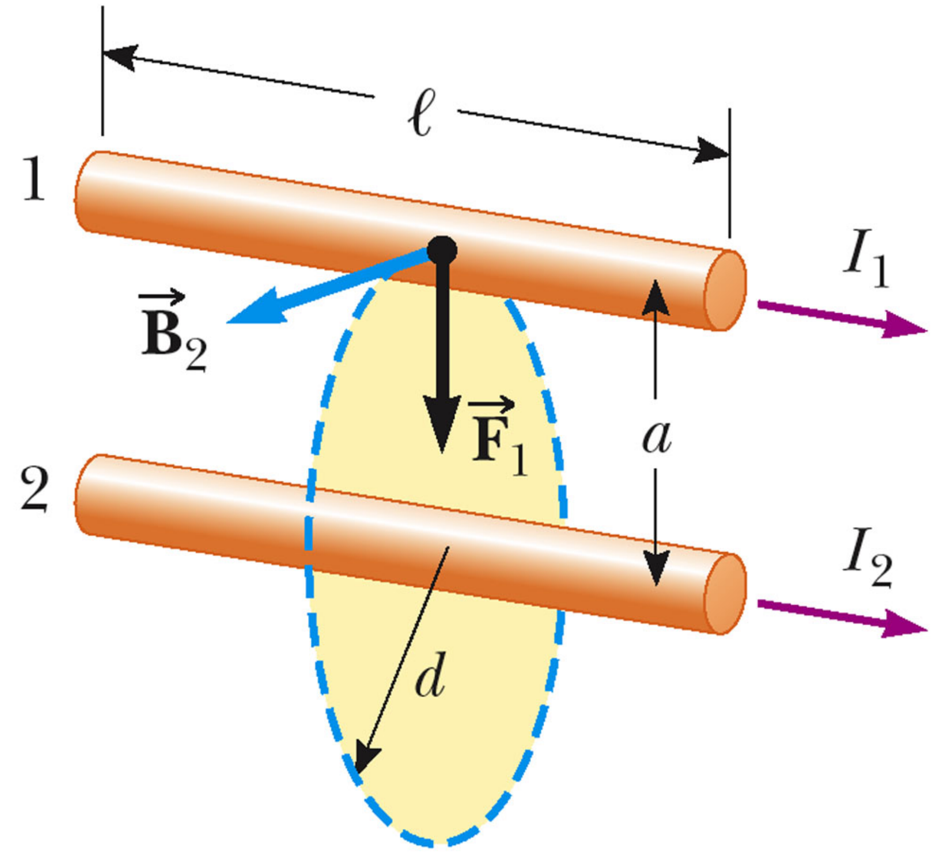
Step 2: The magnetic field due to wire 2 will cause a force on the current in wire 1.

Via RHR1:

Current to the right.

Magnetic field out of the board.

Force is down toward wire 2.



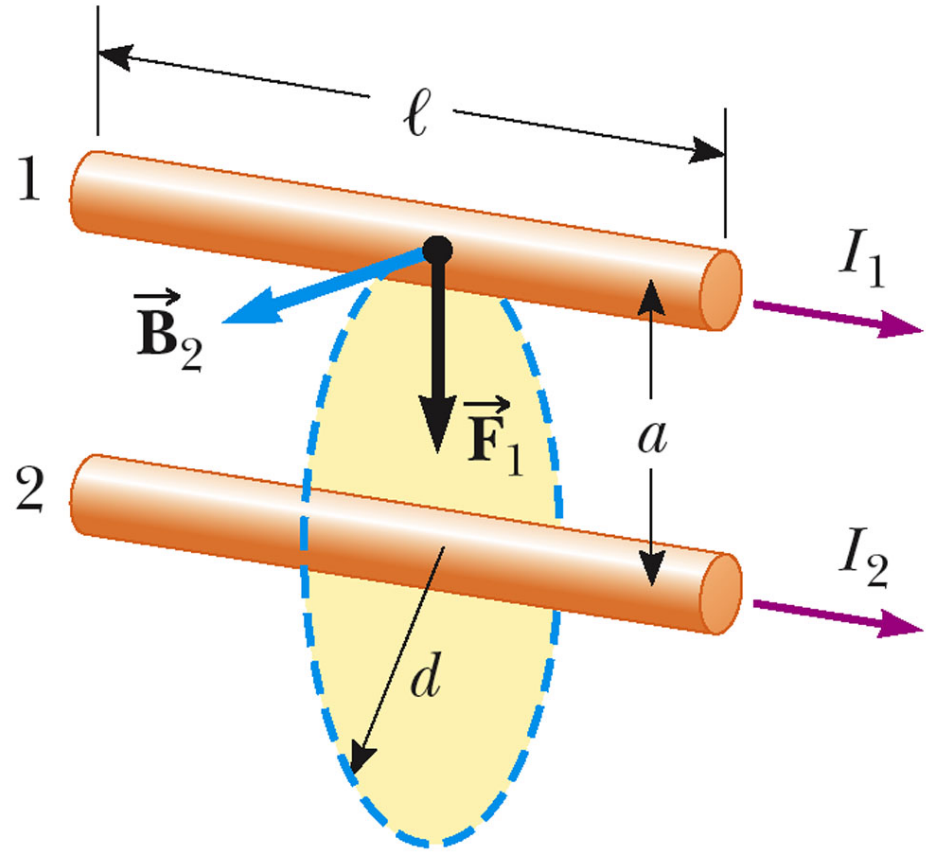
The magnitude of the force will be:

$$F = I_1 \ell B_2 \sin\theta = I_1 \ell \frac{\mu_o I_2}{2\pi a}$$

Force Between 2 Wires

In general, the force per unit length for two wires separated by a distance d is:

$$\frac{F}{\ell} = \frac{\mu_o \, I_1 \, I_2}{2 \, \pi \, d}$$



The directions can be reduced to:

Parallel conductors carrying currents in the same direction attract each other.

Parallel conductors carrying currents in the opposite directions repel each other.

Quiz 3 Topics

- Know how to analyze a circuit and calculate V,I, and power, etc.
- Know how to calculate an RC time constant
- Know B field and right hand rules
- Know units for Q,C,I,V,B,F, etc.
- Know how to deal with charged particles flying through B fields
- Know the force on a current in a wire
- Know how to add forces and fields

For Next Time (FNT)

Keep reading Chapter 22

Continue working on the homework for Chapter 22