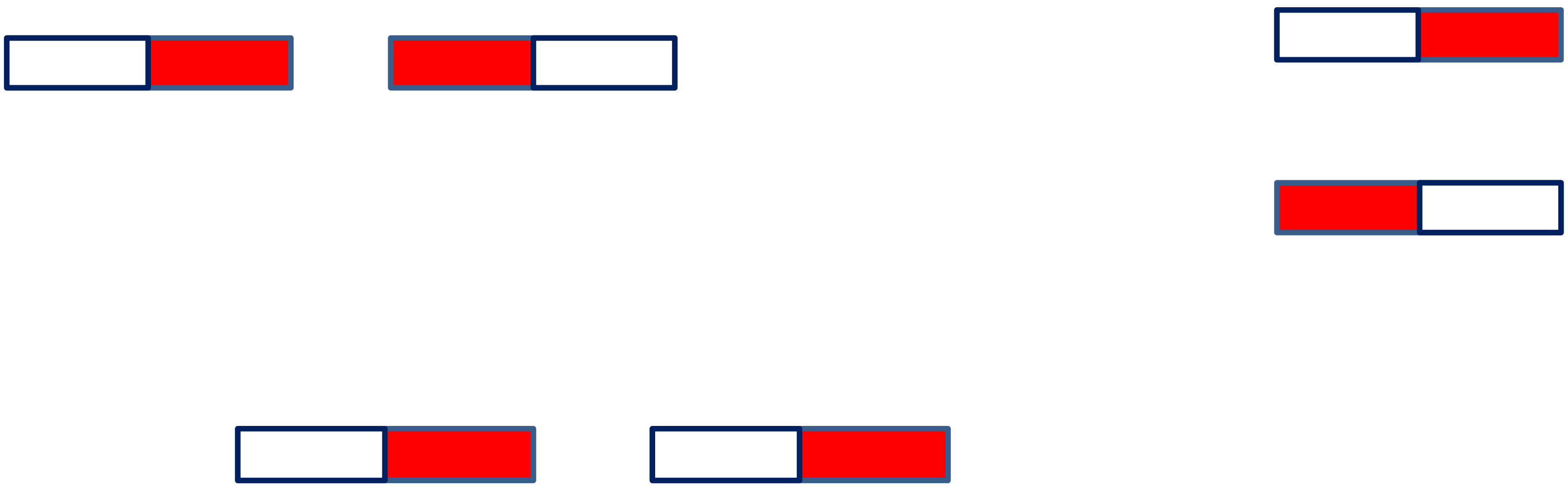
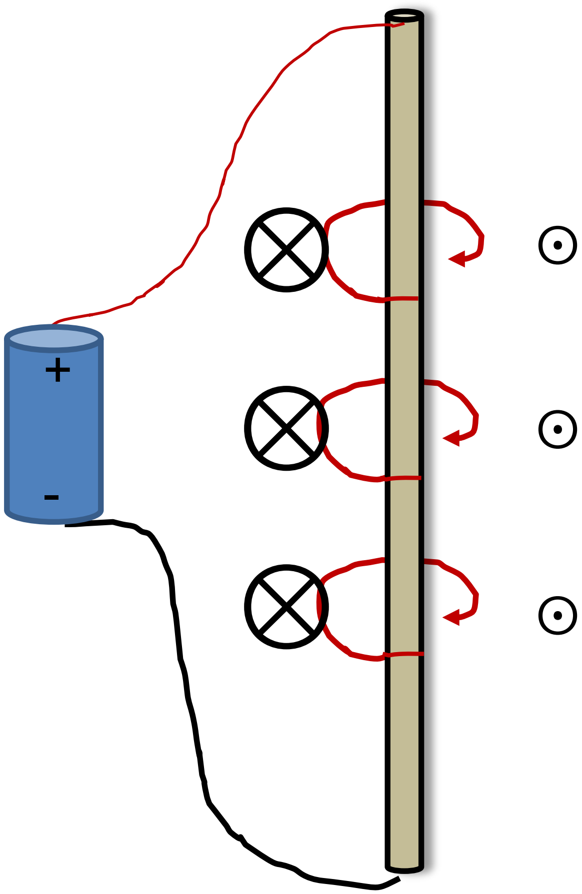
Magnetic field lines again

- We know what a magnetic field looks like around a simple bar magnet. What about when there are multiple magnets?
  - The net magnetic field is just the vector sum of all the field lines at a particular point. Just like an electric field!



Magnetic field lines and wires

- What about around a current-carrying wire?



We see a compass deflect sideways next to the wire. As you move the compass in a circle around the wire, the needle also remains tangent to the wire.

Thus, the magnetic field around a current carrying wire is in <u>loops around the wire</u>!

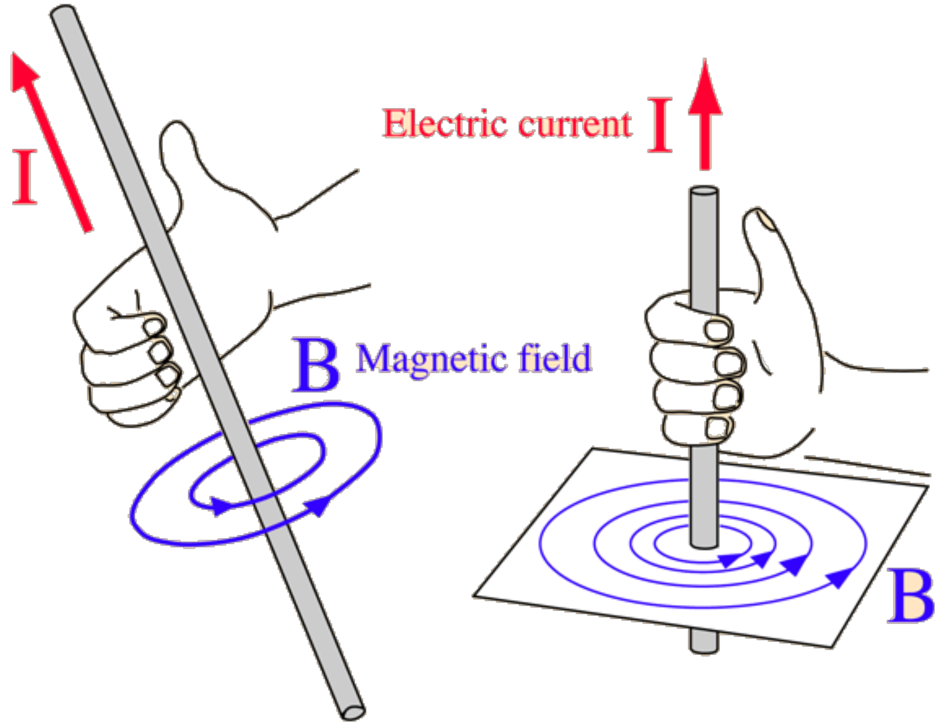
Which way does the loop point?

The compass indicates that the loop's direction depends on the current! In this case, with the current traveling top-to-bottom along the page, the field points into the page on the left side, and out of the page on the right side.

B fields and wires

- A slightly alternate version of the RHR dictates the direction of magnetic field lines around a current-carrying wire.
  - Your thumb points along the current direction, and your fingers curl with the magnetic field lines. This is <u>only applicable</u> for the field lines around a current-carrying wire. If the current reverses direction, the loops also reverse.

This observation was first made by Hans Christian Oersted in 1820 - realizing that currents produce magnetic fields. This prompted Andre Ampere to then determine his law (stay tuned), Michael Faraday to realize that fields can produce currents (stay tuned), and James Maxwell to come up with his equations that formally unified electricity and magnetism. Not bad for a legacy!



http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magcur.html

Magnetic field of a long straight wire

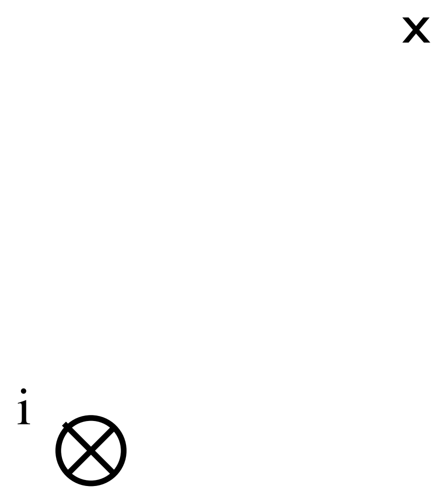
- Experimentally, we see:
  - Farther from the wire, **B** weakens, but it is constant around a circle of constant radius around the wire.
  - More current in the wire means a stronger magnetic field.
- Therefore, we can show that the magnitude of the magnetic field **B** at some distance *r* from a wire carrying a current *I* is:

$$B = \frac{\mu_0 I}{2\pi r}$$

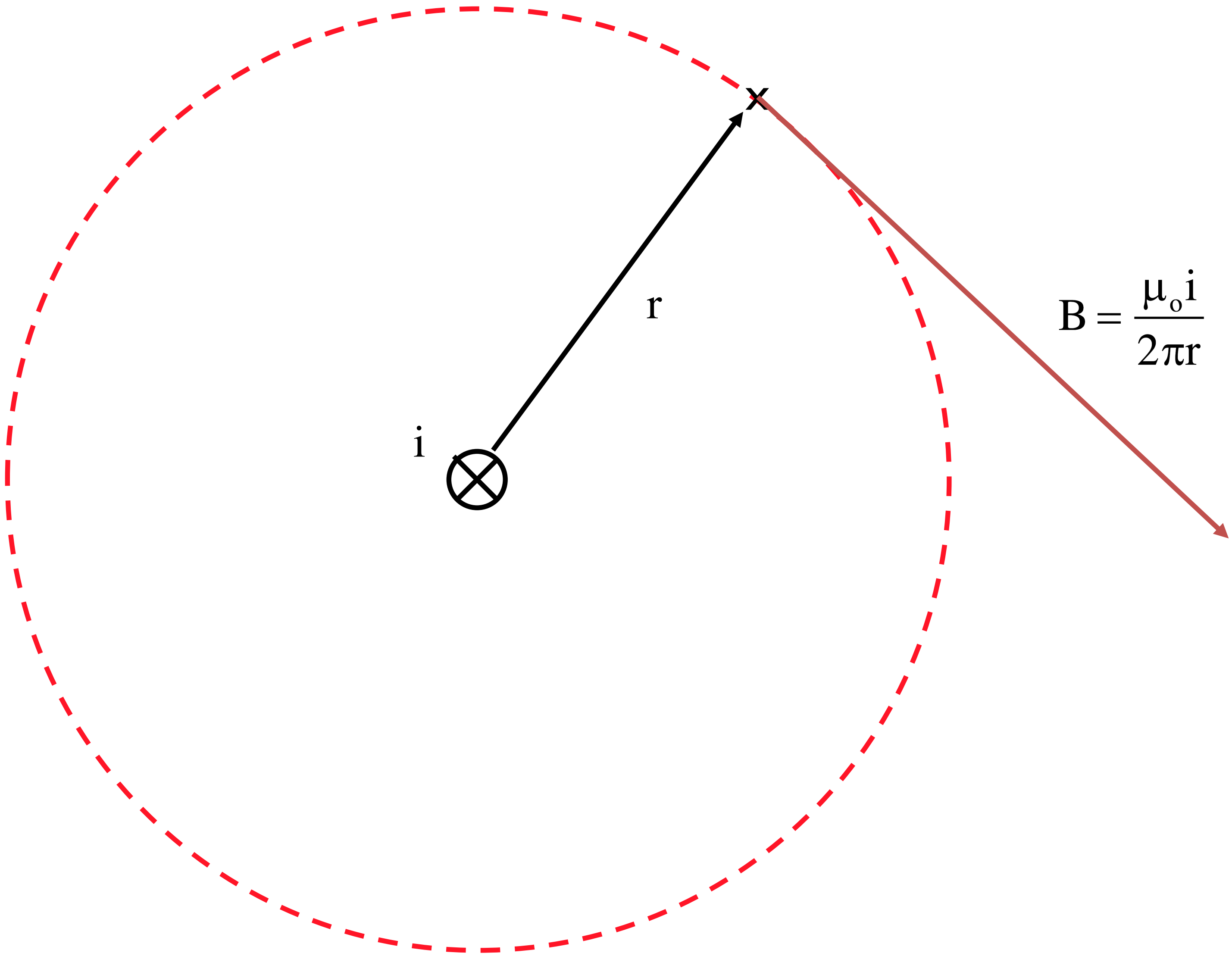
($\mu_0 = 4\pi \times 10^{-7}$ T·m/A)

Example 1

Determine the direction and magnitude of the magnetic field at “x” if the wire carries current “i” and “x” is “r” units from the wire.

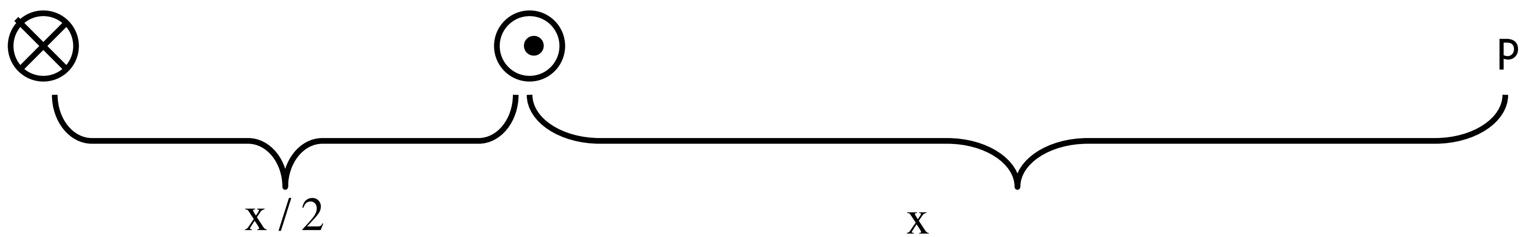


Solution



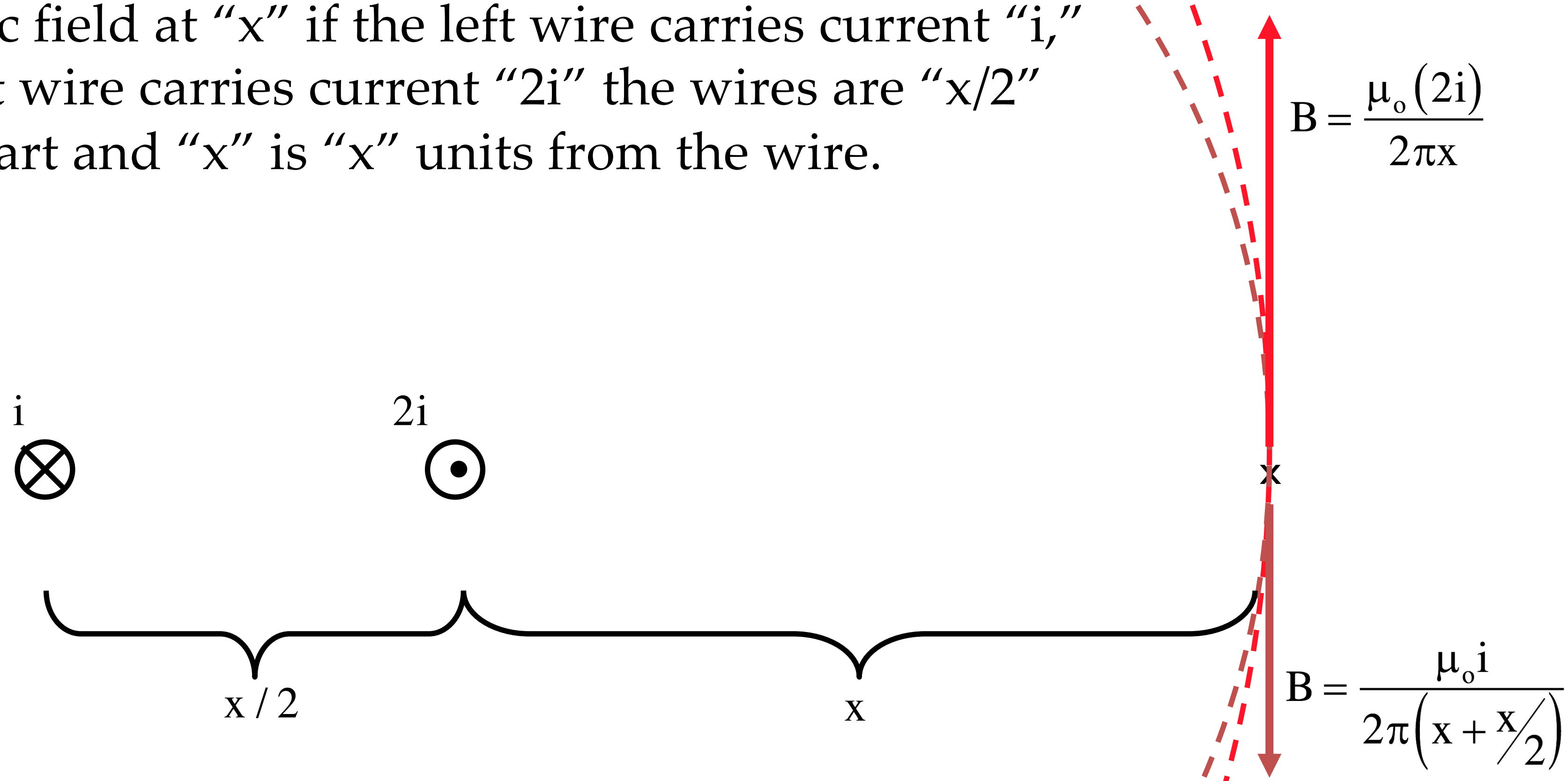
Example 2

Determine the direction and magnitude of the magnetic field at "p" if the left wire carries current "i," the right wire carries current "2i" the wires are "x/2" units apart and "x" is "x" units from the 2i wire.



Where will the net magnetic field be zero?

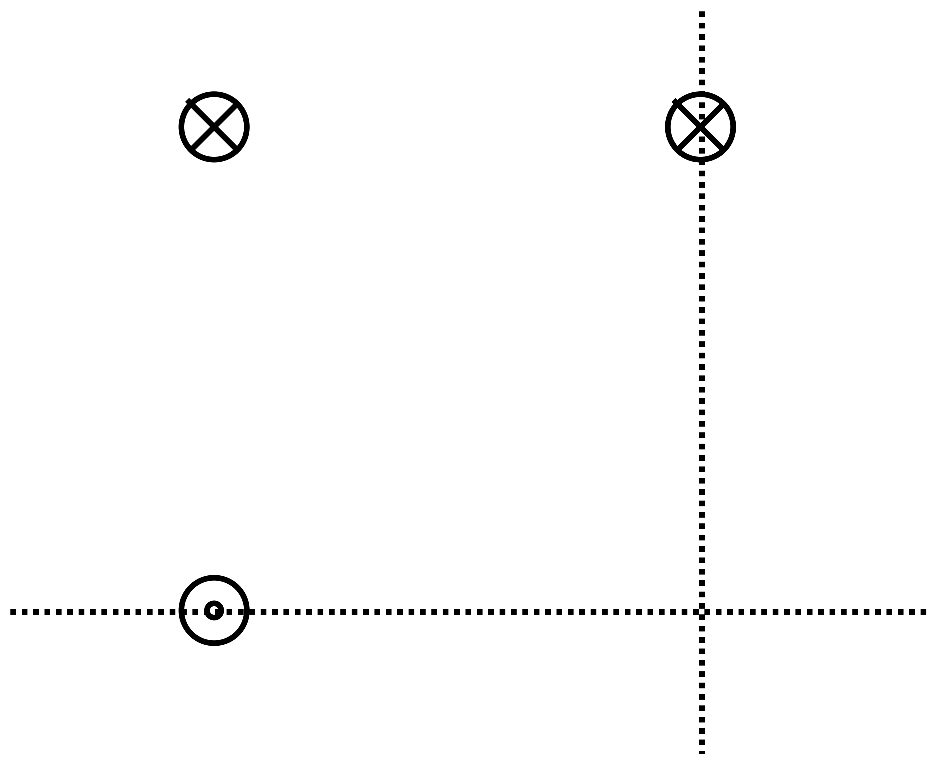
Determine the direction and magnitude of the magnetic field at "x" if the left wire carries current "i," the right wire carries current "2i" the wires are "x/2" units apart and "x" is "x" units from the wire.



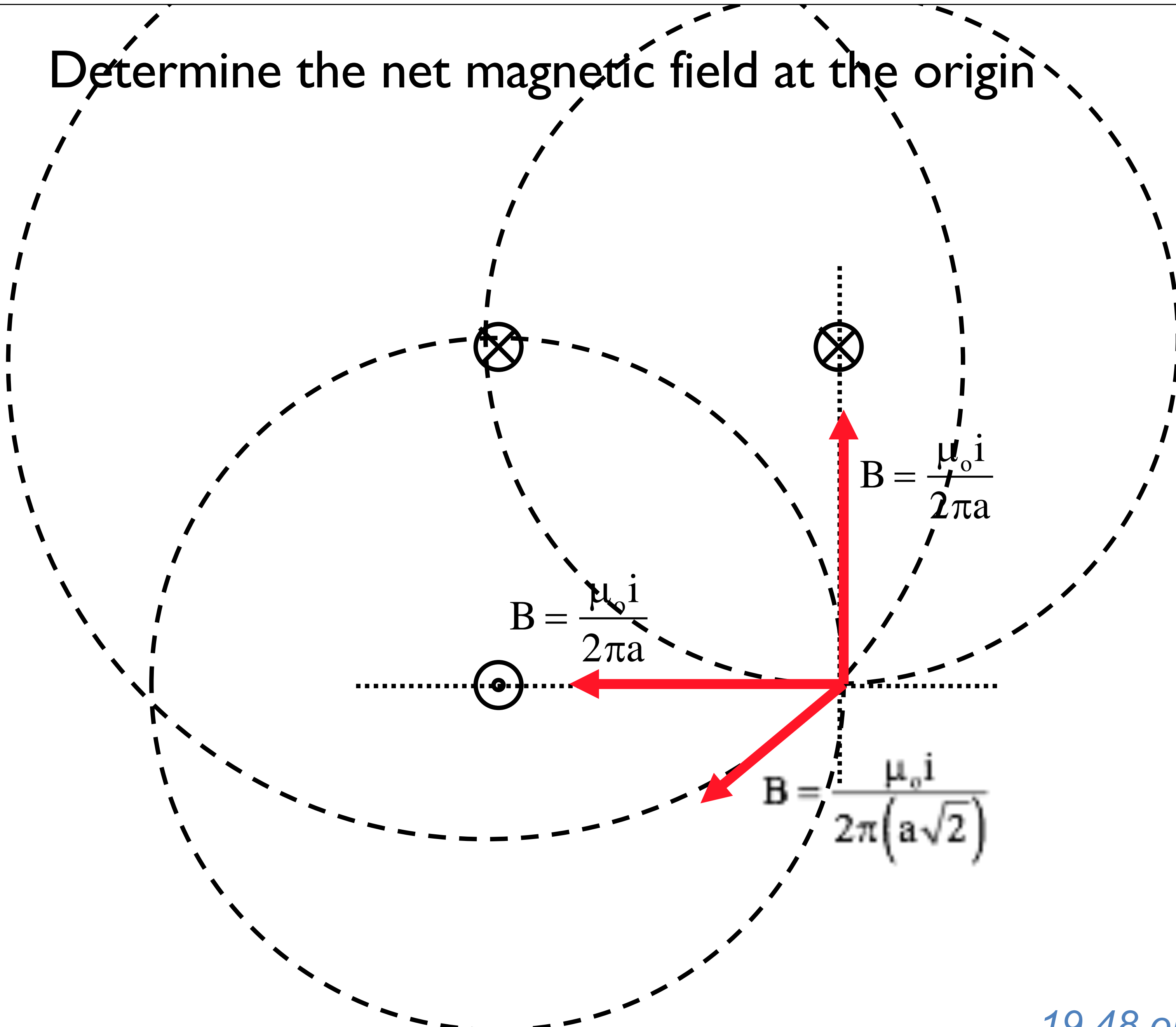
Where will the net magnetic field be zero?

To the left of the "i" wire - the fields will be opposite in direction, and it's farther from the 2i wire.

Determine the net magnetic field at the origin



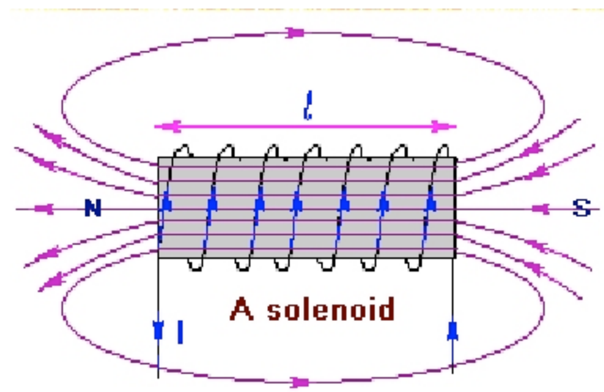
Determine the net magnetic field at the origin



19.48 on class Website is a good one to practice with!

Solenoids

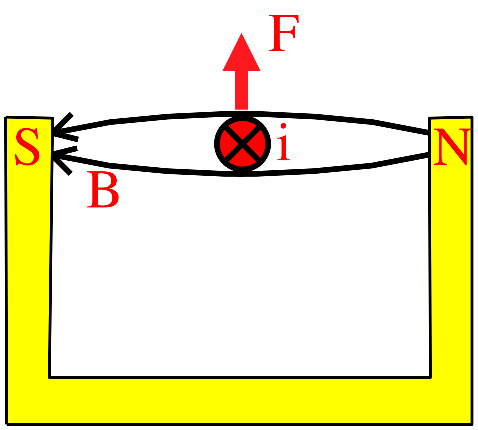
- A long coil of wire with many loops (or turns) is called a **solenoid**.
- The magnetic field inside the solenoid can be fairly large when current flows through the wire as each loop adds to the overall magnetic field strength.
- The magnetic field within the solenoid is fairly uniform and runs in one direction, down the middle of the coils, resulting in the coil acting like a magnet with a north and south pole.
- If a piece of iron is placed in the core of the loop, this becomes an **electromagnet.**
  - Why iron? What happens?

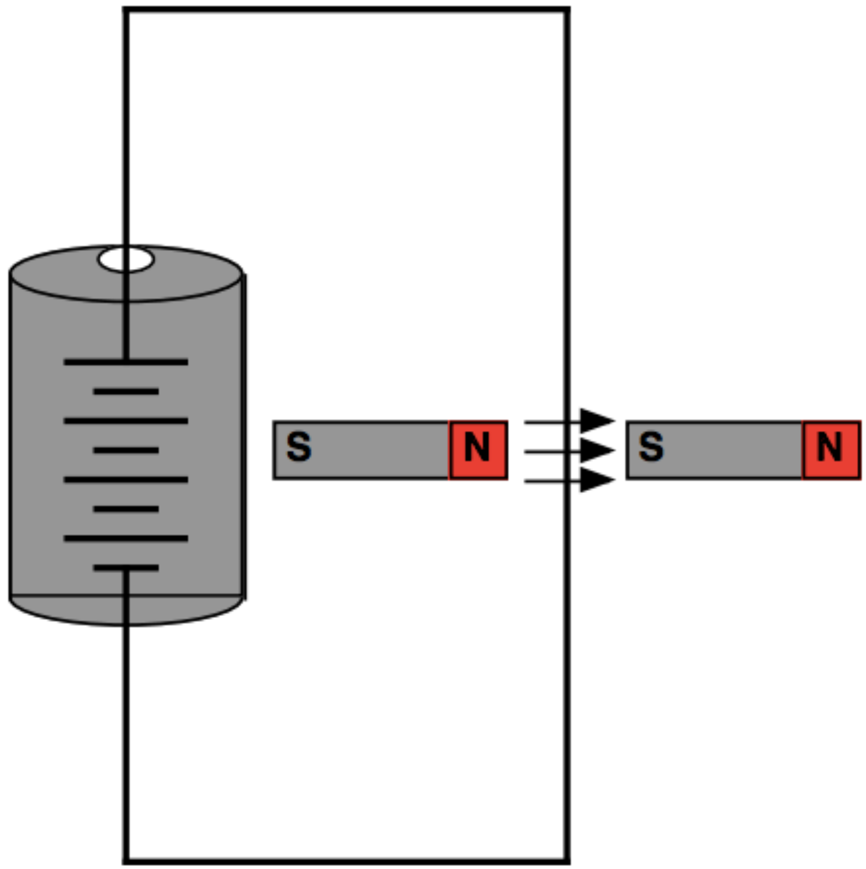


Magnetism and wires

Based on what we've seen so far, what do you think happens when the circuit below is connected?

Current will flow clockwise from the + terminal of the battery. This means current will flow towards the bottom of the page between the poles of the magnet, with a magnetic field towards the right. Using the RHR, we'd expect a force on the wire **out** of the page -- it should move! A side view is shown below, looking down the wire.





Magnetic force on a current-carrying wire

- Mathematically:
  - The wire carries a current *I*, due to the overall motion of lots and lots of charges. We can define the average velocity of those charges as the distance (length) they travel per unit time, or L/t
  - Using our definition of magnetic force:

$$\vec{F} = q\vec{v}x\vec{B}$$

$$\Rightarrow \vec{F}_{wire} = q\left(\frac{\vec{L}}{t}\right)x\vec{B}$$

$$= i\vec{L}x\vec{B}$$

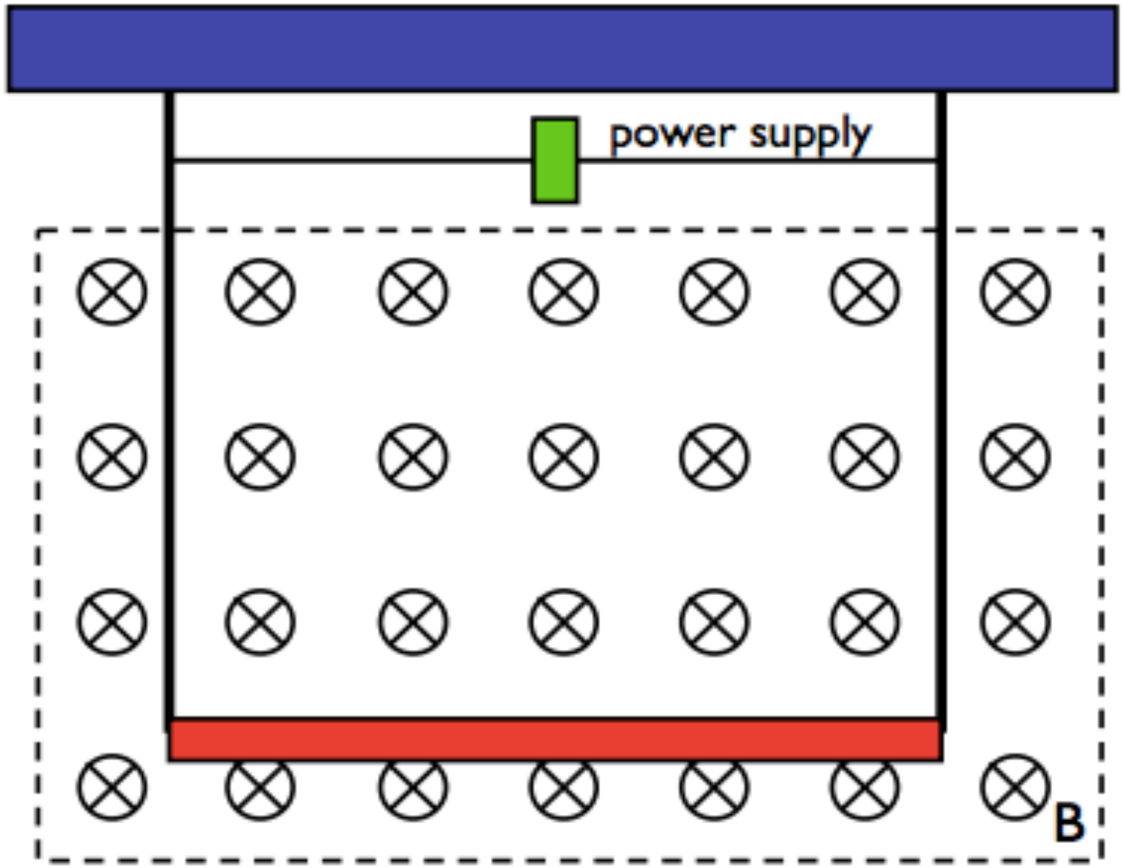
Remember that q/t is current!

- We still use the RHR here - instead of v, however, your index finger points in the direction of conventional current (I). Same idea, just a different application.

Problem 19.20

Problem 19.20

A conductor suspended by two flexible wire has a mass per unit length of .04 kg/m. What current is required (and in what direction must the current flow) to support the conductor in equilibrium if the magnetic field strength is 3.6 Teslas?



Solution is posted on class Website