Force on a Current Carrying Wire

- A 2.5 Tesla B-Field goes into the board. A 10g, 1.00m wire carries a current in that magnetic field. Assuming the angle between I and B is 90°, what is the current necessary to make the wire levitate?

$B = 2.5\ T$

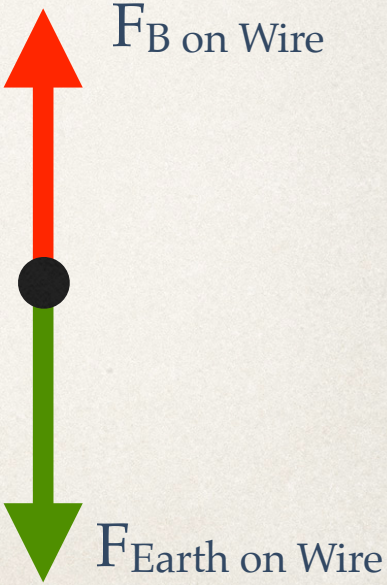
$I = ?$

$\ell = 1.00\ m$

$\theta = 90°$

$F = ?$

B



Right Hand Rule #2

$\sum F = ma!$ NEWTON'S SECOND LAW!

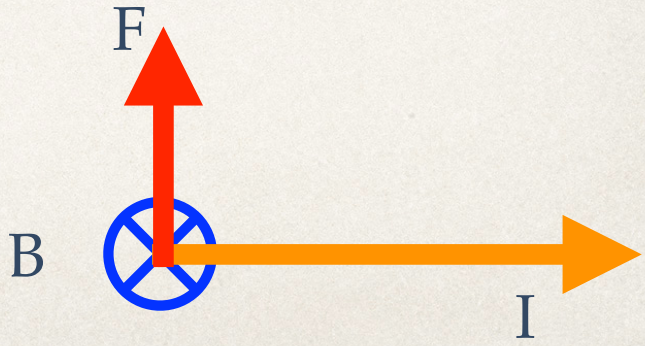
$$F_{\vec{B}} + \left(-mg\right) = 0$$

$$I\ell B\sin\theta + \left(-mg\right) = 0$$

$$I\left(1.0\text{ m}\right)\left(2.5\text{ T}\right)\left(1\right) - \left(0.01\text{ kg}\right)\left(9.8\ {}^{m}\!/_{s^2}\right) = 0$$

$$I\left(2.5\text{ T}\bullet\text{m}\right) = \left(0.098\ N\right)$$

$I = 0.039$ Amperes



Right Hand Rule #3

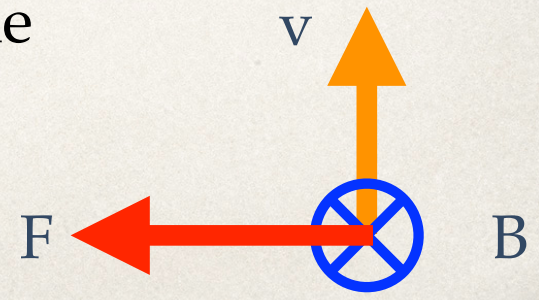
- **PURPOSE:** Determine the direction of the force on a charged particle moving with a velocity in a magnetic field.

1. Fingers point in the direction of the velocity of the positively charged particle.

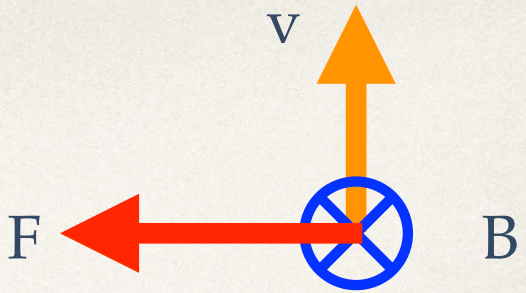
2. Palm points in the direction of the B-Field

3. Thumb points in the direction of the force on the **positively** charged particle*

*Direction of Force is opposite for electron



Right Hand Rule #3



- Derivation:

$$F = I\ell B\sin\theta \qquad \text{but...} \qquad I = \frac{q}{t}$$

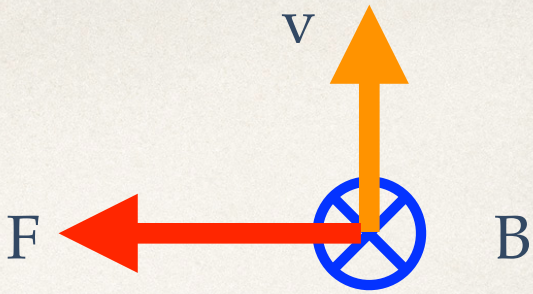
so,
$$F = \frac{q}{t}\ell B\sin\theta$$

then,
$$F = q\frac{\ell}{t}B\sin\theta \qquad \text{but...} \qquad \frac{\ell}{t} = v$$

so,
$$\boxed{F = qvB\sin\theta}$$

*Direction of Force is opposite for electron

Right Hand Rule #3



- A 0.25 Tesla B-Field goes into the board. A proton traveling at 10% of the speed of light* moves perpendicularly through the B-Field, what is the force on the proton?

$$F = qvB\sin\theta$$

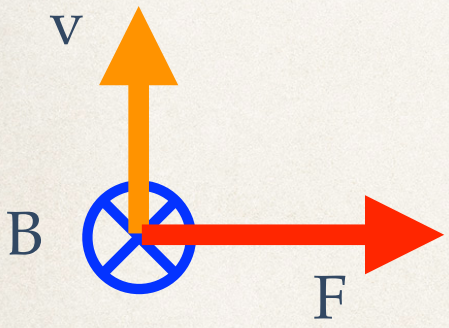
$$F = \left(1.6x10^{-19}\text{C}\right)\left(3.0x10^{7}\ {}^{m}/_{s}\right)\left(0.25\ \text{T}\right)\left(1\right)$$

$$\boxed{F = 1.2x10^{-12}\ \text{N}}$$

*$c = 3.00x10^{8}\ {}^{m}/_{s}$

Right Hand Rule #3

- A 0.25 Tesla B-Field goes into the board. An electron traveling at 10% of the speed of light moves perpendicularly through the B-Field, what is the force on the electron?

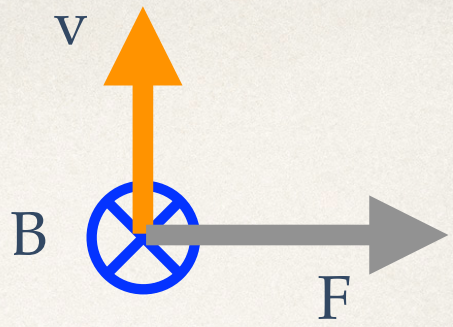


$$F = qvB\sin\theta$$

$$F = \left(1.6x10^{-19}\right)\left(3.0x10^{7}\right)\left(0.25\right)\left(1\right)$$

$$\boxed{F = 1.2x10^{-12}\ \text{N}}$$

Right Hand Rule #3



- What **effect** do these forces have on these charged particles?

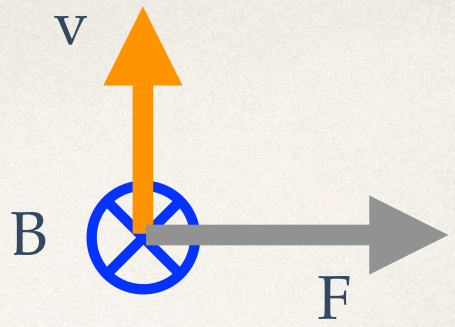
$$\sum F = ma!$$

$$qvB\sin\theta = m\frac{v^2}{r}$$

$$\boxed{r = \frac{mv}{qB\sin\theta}}$$

	p^+	e^-
F	1.2×10^{-12} N	1.2×10^{-12} N
m	1.67×10^{-27} Kg	9.11×10^{-31} Kg
r		

Right Hand Rule #3



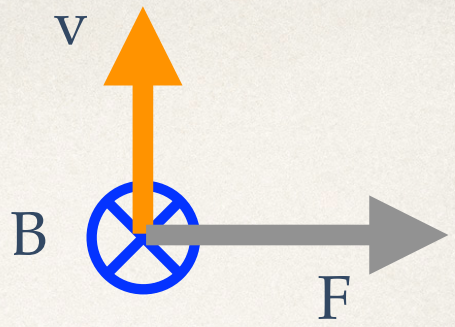
- Proton

$$r = \frac{mv}{qB\sin\theta}$$

$$r = \frac{\left(1.67x10^{-27}\,kg\right)\left(3.0x10^{7}\,{}^{m}/_{s}\right)}{\left(1.6x10^{-19}\right)\left(0.25\ \mathrm{T}\right)\left(1\right)}$$

$$\boxed{r = 1.25\ \mathrm{m}}$$

Right Hand Rule #3



- Electron

$$r = \frac{mv}{qB\sin\theta}$$

$$r = \frac{\left(9.11x10^{-31}\,kg\right)\left(3.0x10^{7}\,{}^{m}\!/_{s}\right)}{\left(1.6x10^{-19}\right)\left(0.25\ \mathrm{T}\right)\left(1\right)}$$

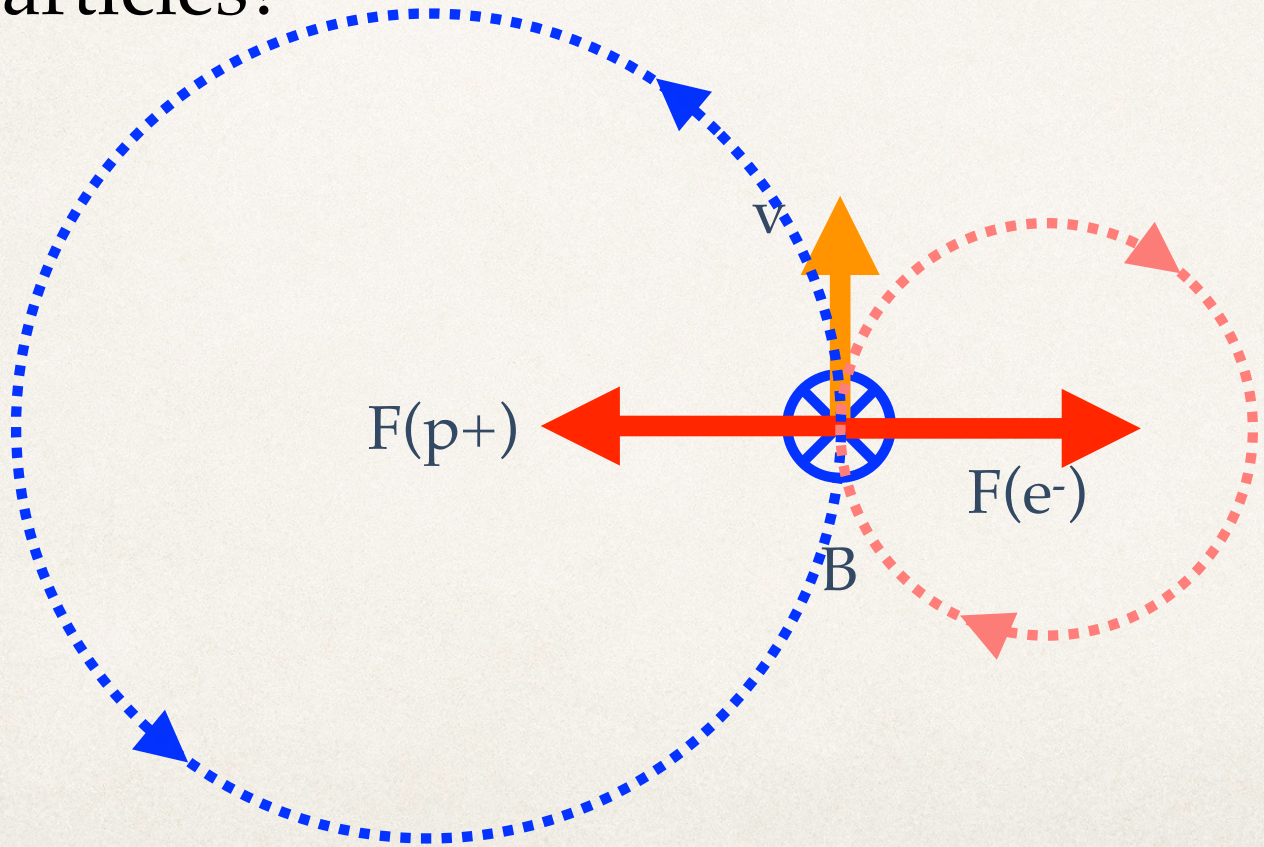
$$\boxed{r = 0.00068\ \mathrm{m}}$$

Right Hand Rule #3

$$r_{p^+} = 2.9225m$$

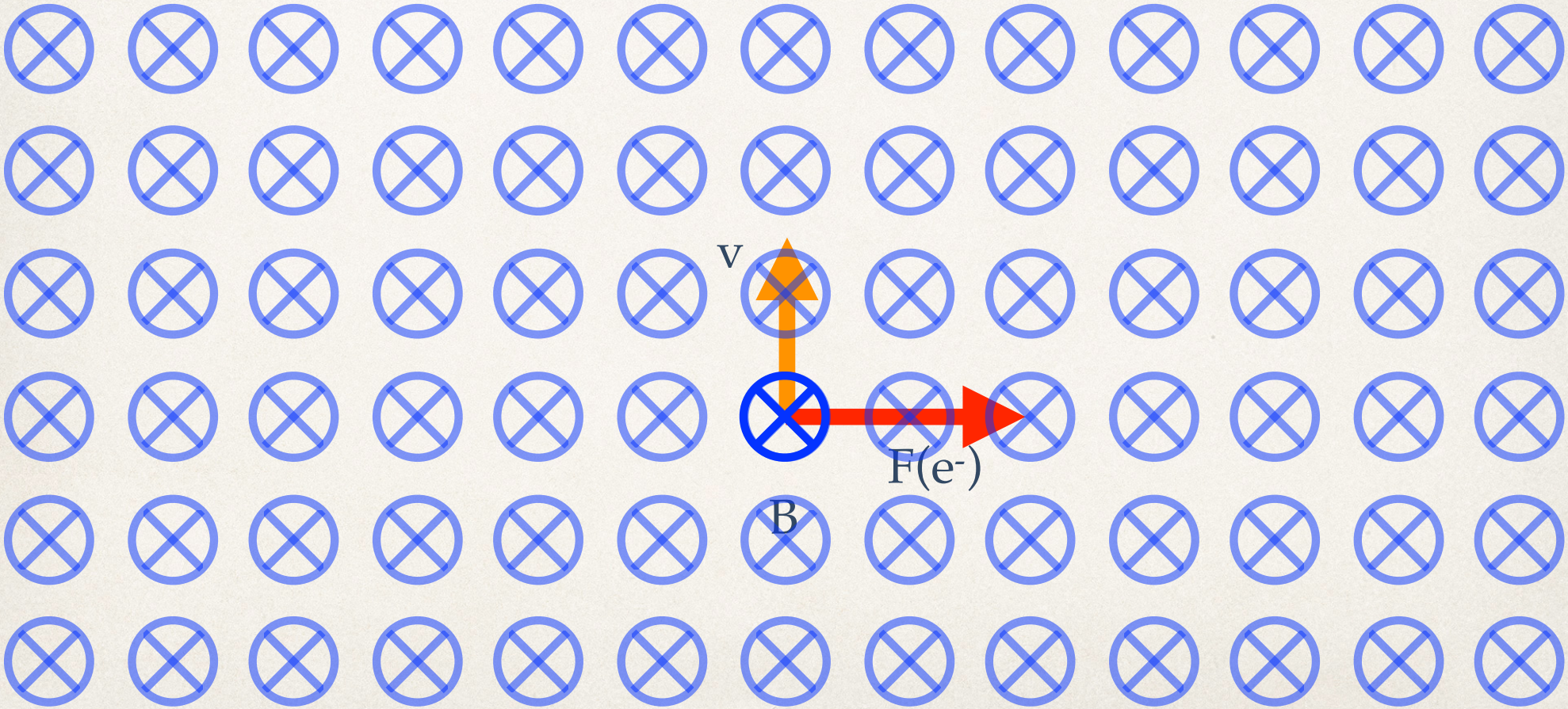
$$r_{e^-} = 0.0016m$$

- What effect do these forces have on these charged particles?



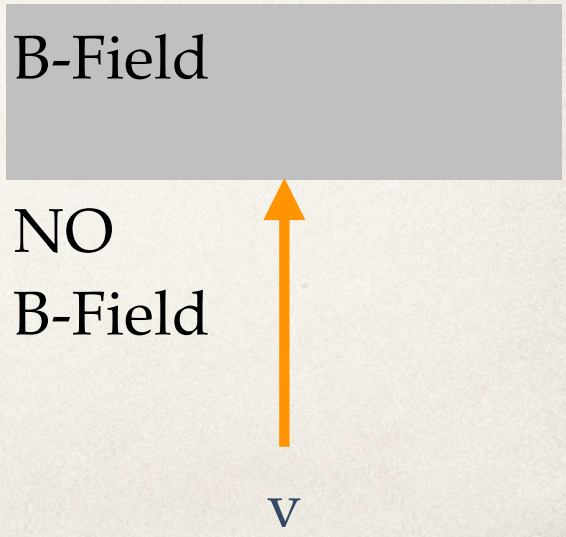
Right Hand Rule #3

- Note: F only occurs in the region where B is present!

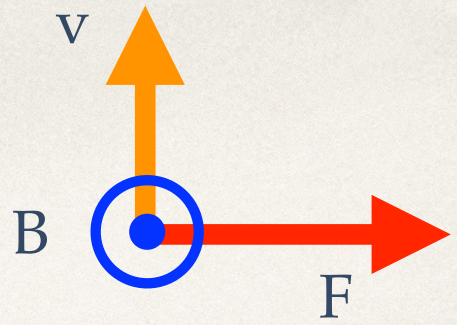


Right Hand Rule #3 - Example

- A protron traveling at 10% of the speed of light enters a region of a 0.17 Tesla B-Field comes out of the board. It moves perpendicularly through the B-Field, what is the force on the proton? What is the path of proton?



RHR #3 - Example

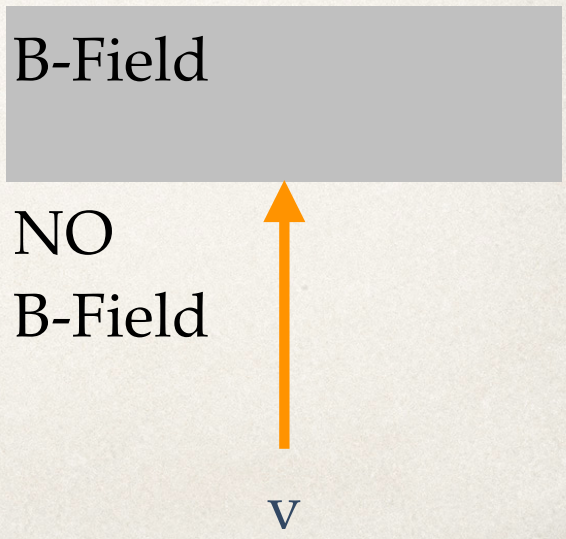


- A protron traveling at 10% of the speed of light enters a region of a 0.17 Tesla B-Field comes out of the board. It moves perpendicularly through the B-Field, what is the force on the proton? What is the path of proton?

$$F = qvB\sin\theta$$

$$F = \left(1.6x10^{-19}\right)\left(3.0x10^{7}\right)\left(0.17\right)\left(1\right)$$

$$\boxed{F = 8.16x10^{-13}\ \text{N}}$$



Hall Effect

- What is the effect of charge moving within a conductor?

$$F = qvB\sin\theta$$

$$qE = qvB$$

$$E = vB$$

but…

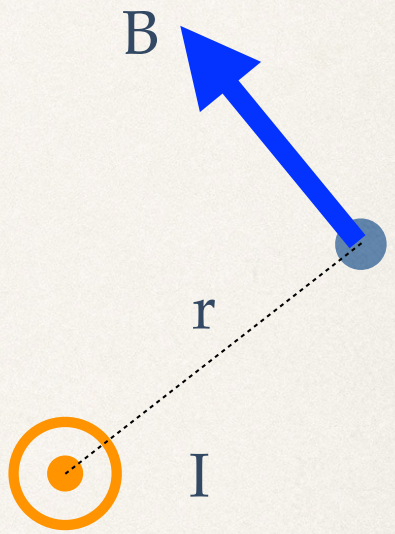
$$E = \frac{V}{\ell}$$

$$\frac{V}{\ell} = vB$$

$$\boxed{V = B\ell v}$$

Magnetic Field: Straight Wire.

- What is the magnitude and direction of the B-Field near a long straight wire?



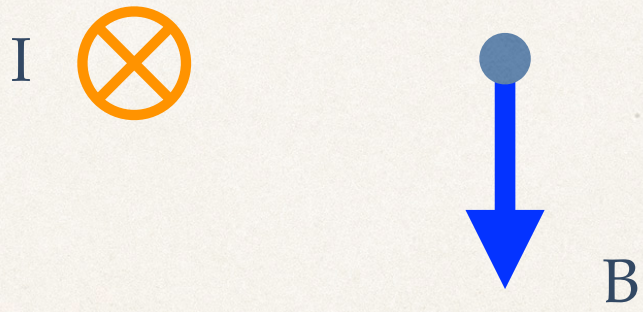
Magnitude ?

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

Direction ? RHR #1

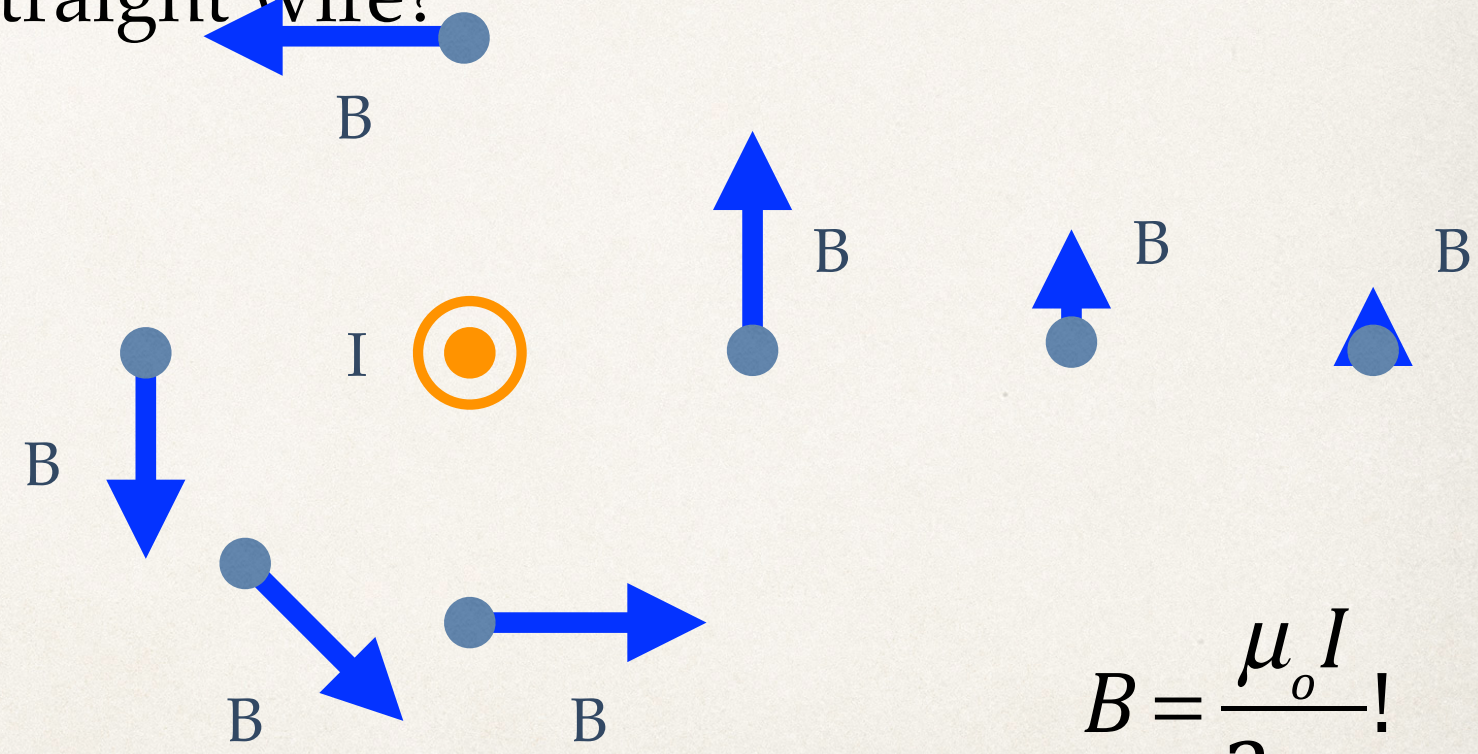
Magnetic Field: Straight Wire.

- What is the magnitude and direction of the B-Field near a long straight wire?



Magnetic Field due to a straight wire.

- What is the direction of the B-Field at various points near a long straight wire?

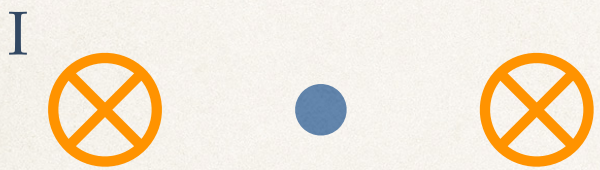


$$B = \frac{\mu_o I}{2\pi r}!$$

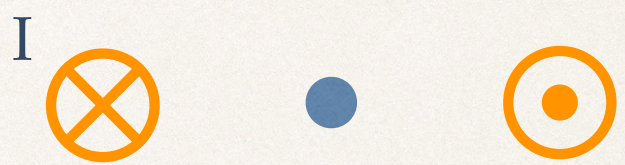
B-Fields: Two Parallel Wires

- Determine the direction of total magnetic field between two long, parallel wires.

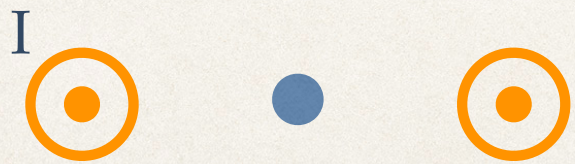
I)



II)



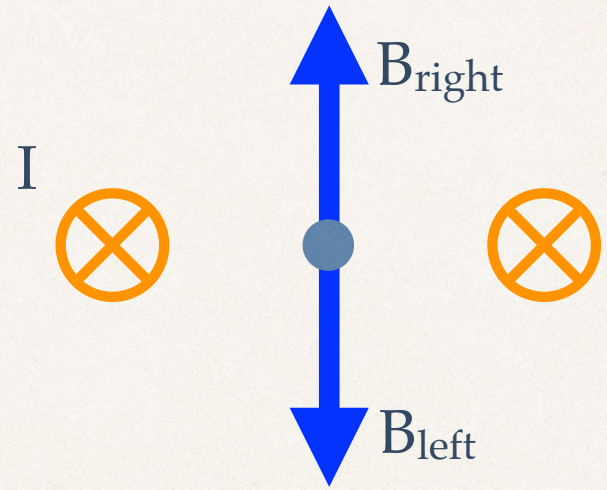
III)



IV)

B-Fields: Two Parallel Wires

I)

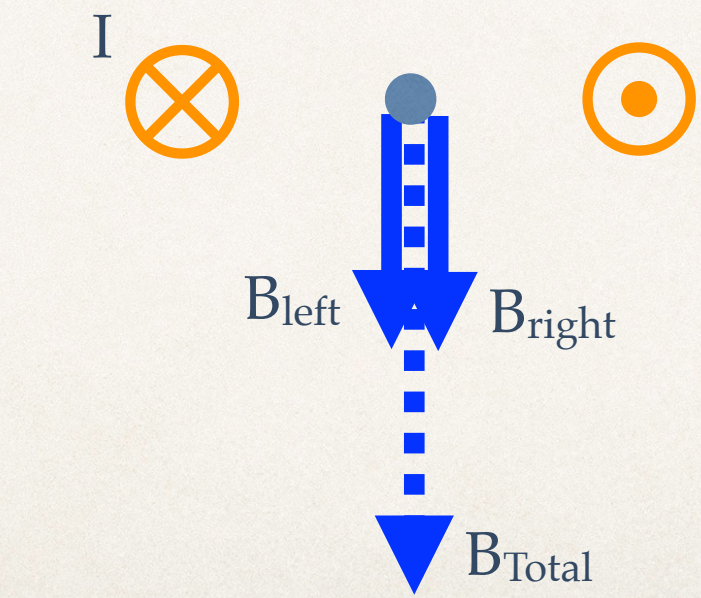


$B_{total}=0!$

B-Fields: Two Parallel Wires

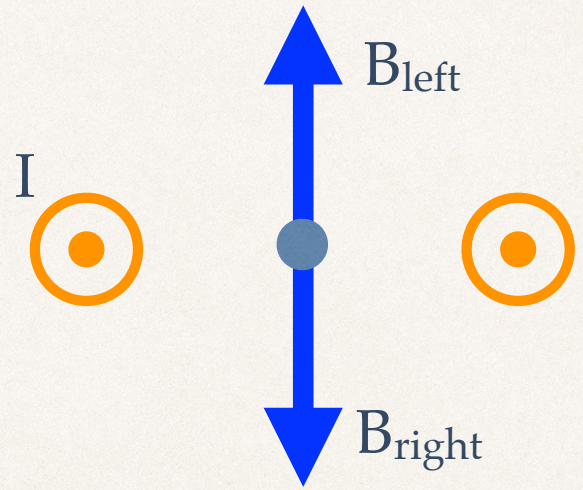
B_{total} = large, downward

II)



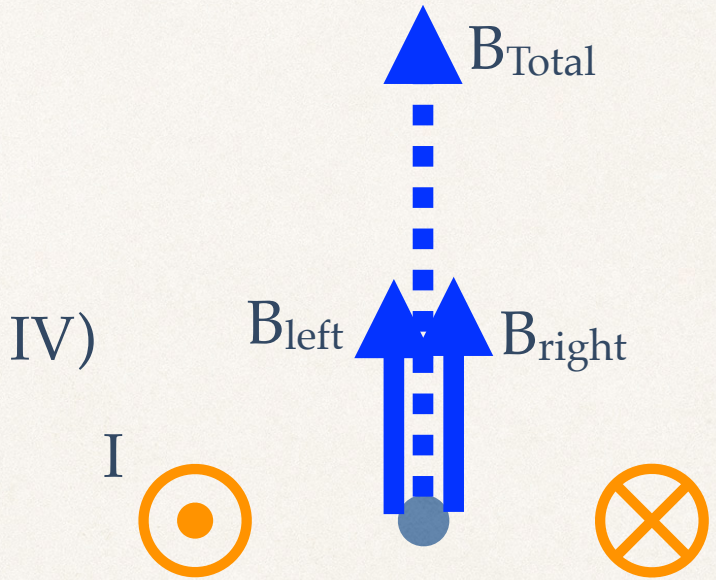
B-Fields: Two Parallel Wires

III)



$B_{total}=0!$

B-Fields: Two Parallel Wires



B_{total} = large, upward

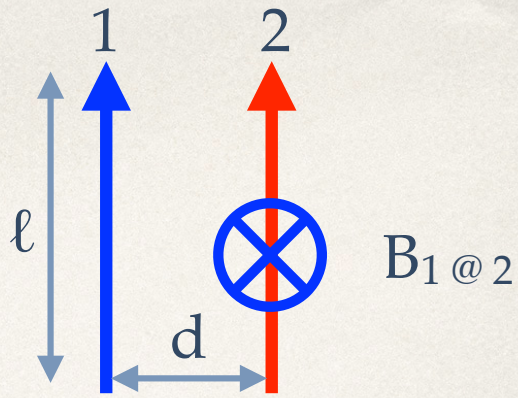
Forces: Two Parallel Wires

Process

1. Determine the magnitude and direction of the B-field **caused** by Wire #1

2. **THEN** Determine the force that B-field (from Step #1) applies on to Wire #2.

Force: Two Parallel Wires



What is the force on two parallel wires, carrying 2.0 A of current in the same direction, if the wires are 50.0 cm in length and spaced 10.0 cm apart?

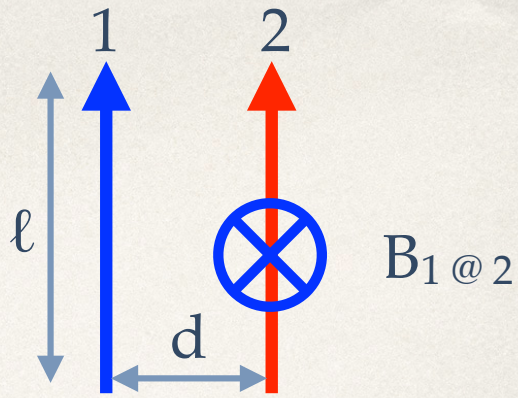
$I_1 = 2.0$ A
$I_2 = 2.0$ A
$\ell_1 = 0.50$ m
$\ell_2 = 0.50$ m
d = 0.1 m
$\mu_o = 4\pi x10^{-7}$

$$B_{1\,@\,2} = \frac{\mu_o I_1}{2\pi r}$$ but r = d in this case!

$$B_{1\,@\,2} = \frac{\left(4\pi x10^{-7}\right)\left(2\text{ A}\right)}{2\pi\left(0.1\text{ m}\right)}$$

$$\boxed{B_{1\,@\,2} = 4.0x10^{-6}\text{ T}}$$

Force: Two Parallel Wires



What is the force on two parallel wires, carrying 2.0 A of current in the same direction, if the wires are 50.0 cm in length and spaced 10.0 cm apart?

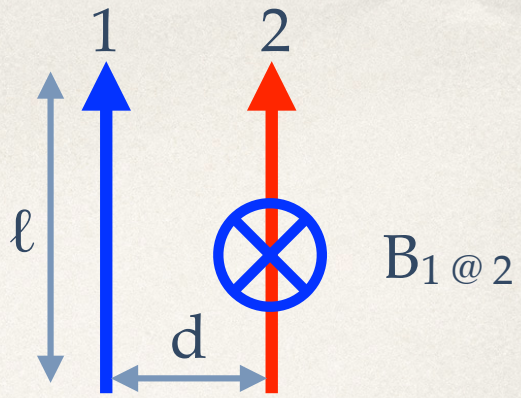
$I_1 = 2.0$ A
$I_2 = 2.0$ A
$\ell_1 = 0.50$ m
$\ell_2 = 0.50$ m
d = 0.1 m
$\mu_o = 4\pi x10^{-7}$

$$F_{1 \text{ on } 2} = I_2 \ell_2 B_{1 @ 2} \sin\theta \quad \text{but} \quad B_{1 @ 2} = \frac{\mu_o I_1}{2\pi r}$$

$$F_{1 \text{ on } 2} = I_2 \ell_2 \left(\frac{\mu_o I_1}{2\pi r} \right) \sin\theta$$

$$F_{1 \text{ on } 2} = \left(\frac{\mu_o}{2\pi} \right) \left(\frac{I_1 I_2 \ell_2}{r} \right)$$

Force: Two Parallel Wires



What is the force on two parallel wires, carrying 2.0 A of current in the same direction, if the wires are 50.0 cm in length and spaced 10.0 cm apart?

$I_1 = 2.0$ A
$I_2 = 2.0$ A
$\ell_1 = 0.50$ m
$\ell_2 = 0.50$ m
d = 0.1 m
$\mu_o = 4\pi x10^{-7}$

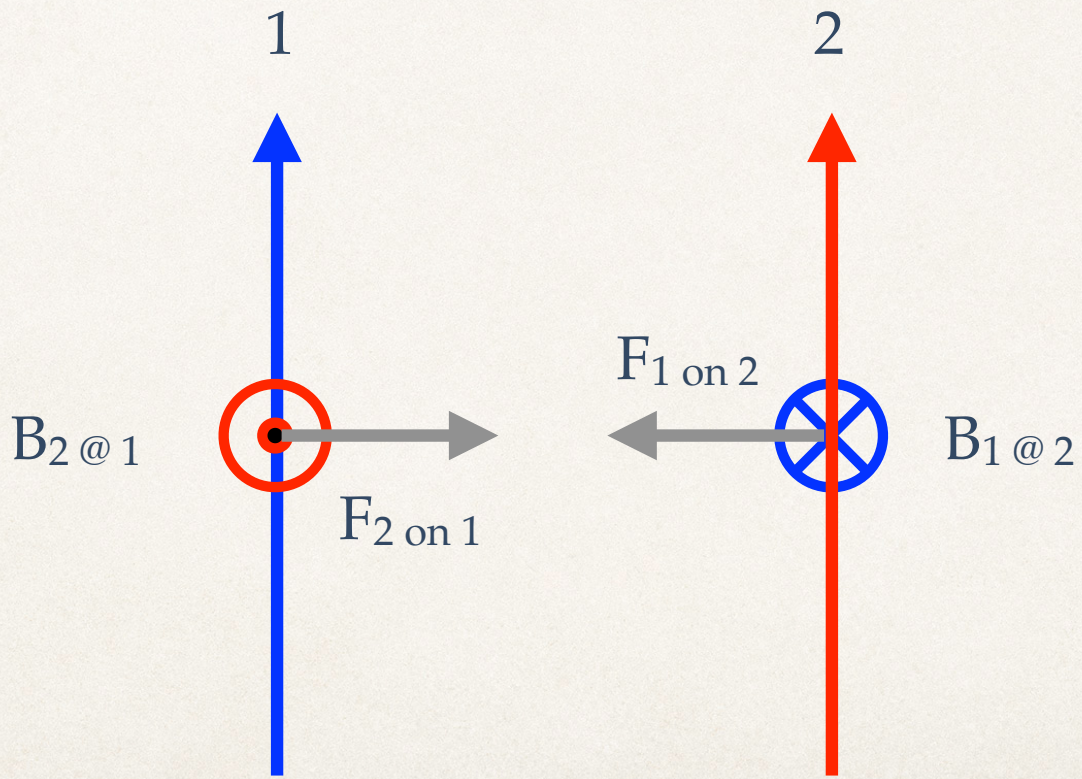
$$F_{1 \text{ on } 2} = \left(\frac{\mu_o}{2\pi}\right)\left(\frac{I_1 I_2 \ell_2}{r}\right)$$

$$\boxed{F_{1 \text{ on } 2} = 4.0x10^{-6}\,N}$$

but, which way?

Force: Two Parallel Wires

Which direction is the force on two parallel wires?

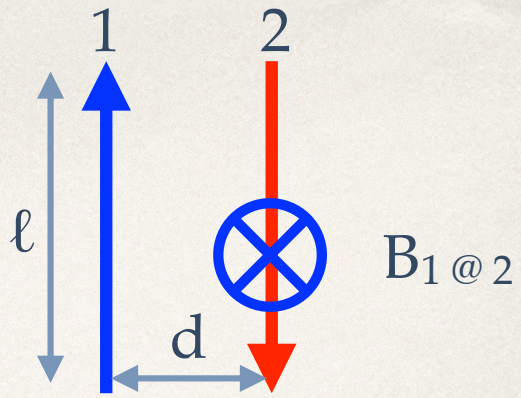


Force: Two Parallel Wires

Group: What is the force on two anti-parallel wires, one carrying $I_1 = 2.0$ A of current and the other carrying $I_2 = 6.5$ A of current, in the opposite direction, if the wires are 1.50 m in length and spaced 0.03 m apart?

- Determine the magnitude and direction of the Force on Wire #2 from Wire #1
- Determine the magnitude and direction of the Force on Wire #1 from Wire #2

Force: Two Parallel Wires



What is the force on two anti-parallel wires, one carrying $I_1 = 2.0$ A of current and the other carrying $I_2 = 6.5$ A of current, in the opposite direction, if the wires are 1.50 m in length and spaced 0.03 m apart?

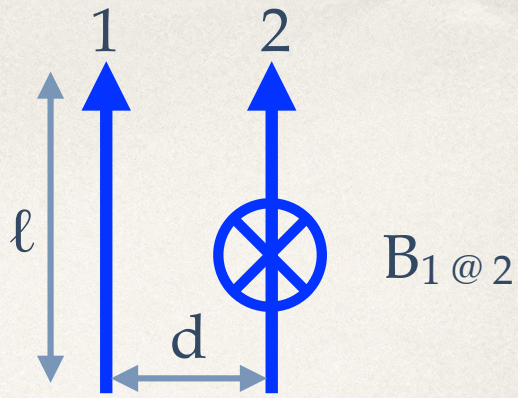
$I_1 = 2.0$ A
$I_2 = 6.5$ A
$\ell_1 = 1.50$ m
$\ell_2 = 1.50$ m
$d = 0.03$ m
$\mu_o = 4\pi x10^{-7}$

$$B_{1\,@\,2} = \frac{\mu_o I_1}{2\pi r}$$ but r = d in this case!

$$B_{1\,@\,2} = \frac{\left(4\pi x10^{-7}\right)\left(2\text{ A}\right)}{2\pi\left(0.03\text{ m}\right)}$$

$$\boxed{B_{1\,@\,2} = 1.33x10^{-5}\text{ N}}$$

Force: Two Parallel Wires



What is the force on two anti-parallel wires, one carrying $I_1 = 2.0$ A of current and the other carrying $I_2 = 6.5$ A of current, in the opposite direction, if the wires are 1.50 m in length and spaced 0.03 m apart?

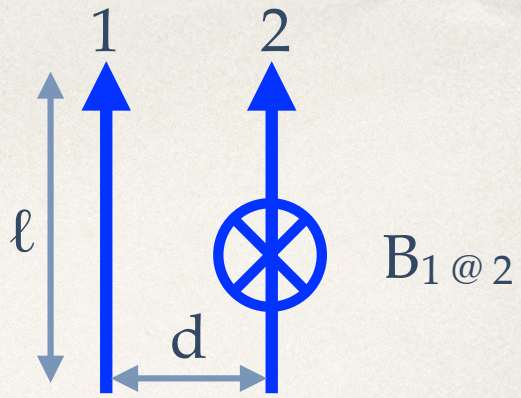
$I_1 = 2.0$ A
$I_2 = 6.5$ A
$\ell_1 = 1.50$ m
$\ell_2 = 1.50$ m
$d = 0.03$ m
$\mu_o = 4\pi x10^{-7}$

$$F_{1\text{ on }2} = I_2 \ell_2 B_{1@2} \sin\theta \quad \text{but} \quad B_{1@2} = \frac{\mu_o I_1}{2\pi r}$$

$$F_{1\text{ on }2} = I_2 \ell_2 \left(\frac{\mu_o I_1}{2\pi r} \right) \sin\theta$$

$$\boxed{F_{1\text{ on }2} = \left(\frac{\mu_o}{2\pi} \right) \left(\frac{I_1 I_2 \ell_2}{r} \right)}$$

Force: Two Parallel Wires



What is the force on two anti-parallel wires, one carrying $I_1 = 2.0$ A of current and the other carrying $I_2 = 6.5$ A of current, in the opposite direction, if the wires are 1.50 m in length and spaced 0.03 m apart?

$I_1 = 2.0$ A
$I_2 = 6.5$ A
$\ell_1 = 1.50$ m
$\ell_2 = 1.50$ m
$d = 0.03$ m
$\mu_o = 4\pi x10^{-7}$

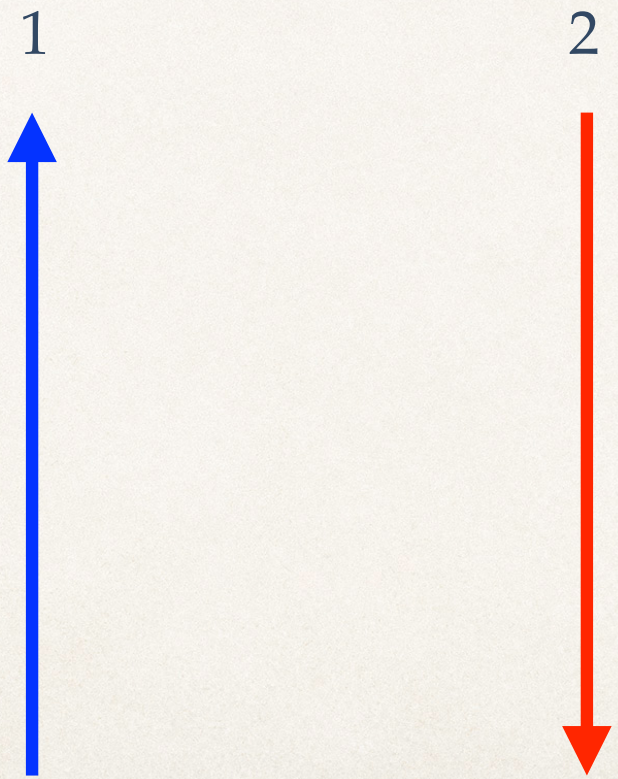
$$F_{1 \text{ on } 2} = \left(\frac{\mu_o}{2\pi} \right) \left(\frac{I_1 I_2 \ell_2}{r} \right)$$

$$\boxed{F_{1 \text{ on } 2} = 1.33x10^{-4}\, N}$$

but, which way?

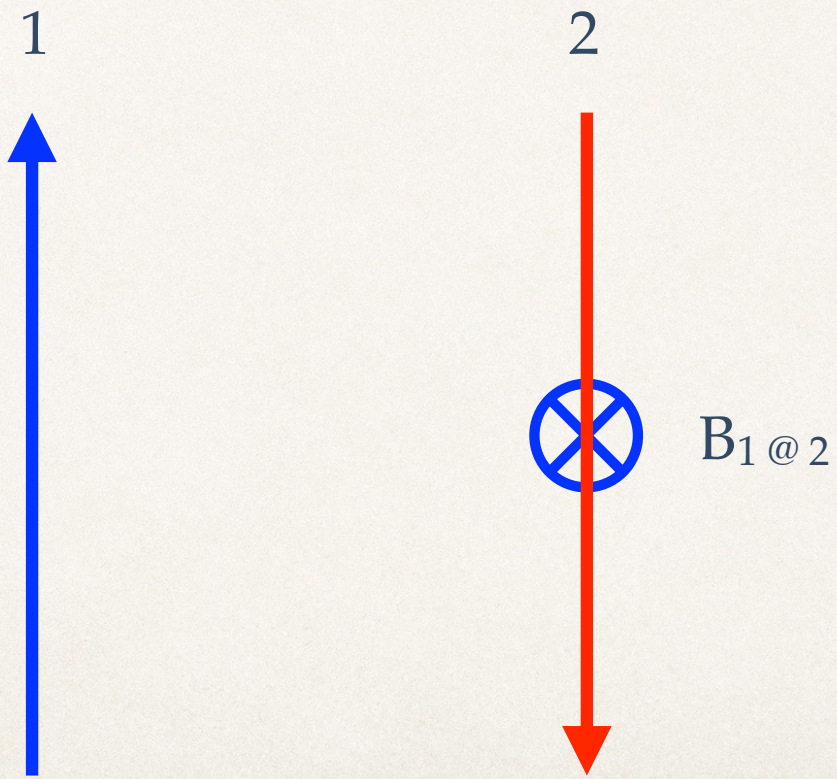
Force: Two Parallel Wires

Which direction is the force on two parallel wires?



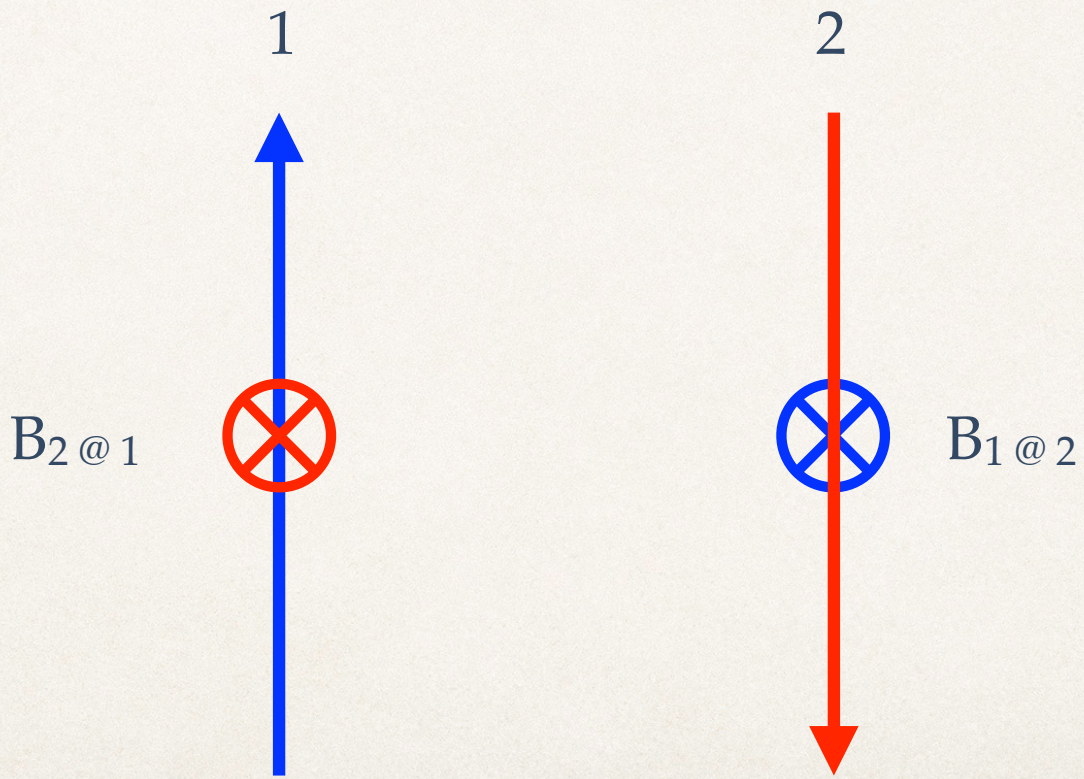
Force: Two Parallel Wires

Which direction is the force on two parallel wires?



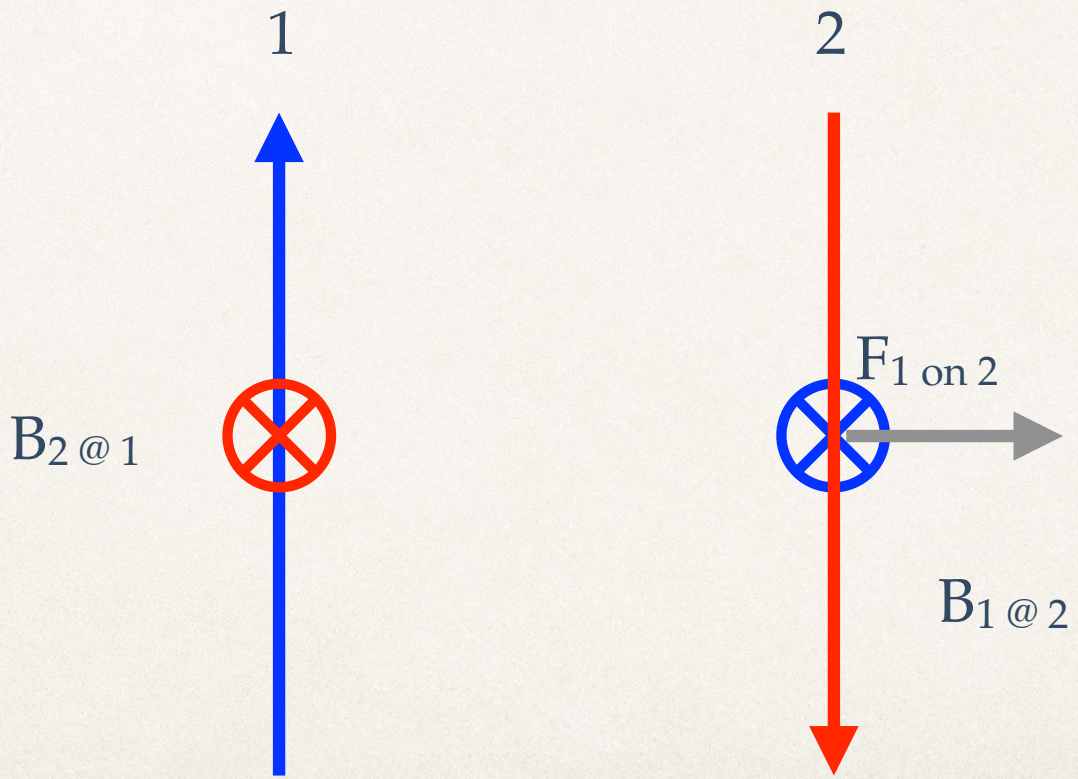
Force: Two Parallel Wires

Which direction is the force on two parallel wires?



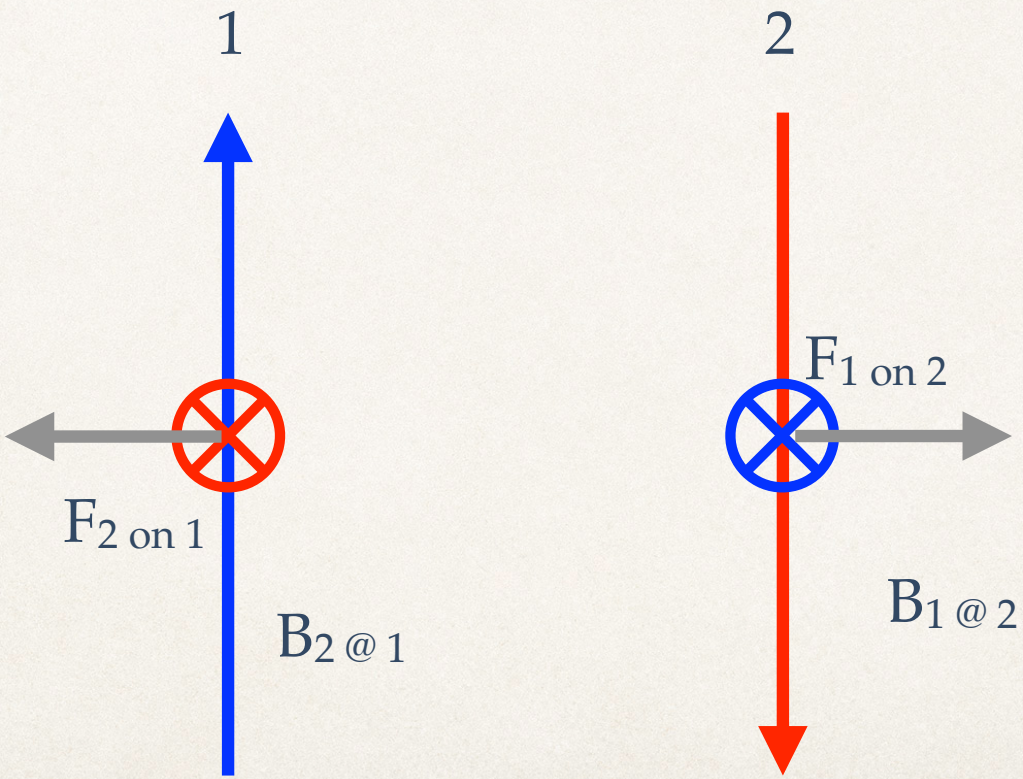
Force: Two Parallel Wires

Which direction is the force on two parallel wires?



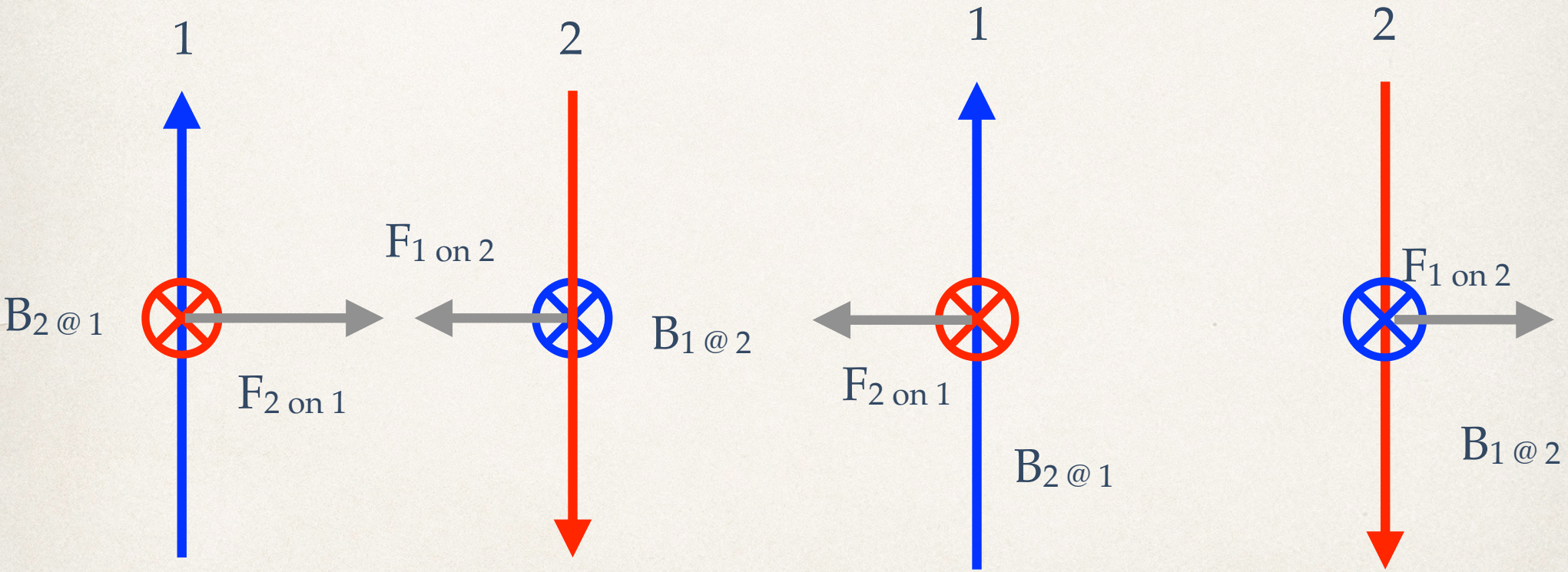
Force: Two Parallel Wires

Which direction is the force on two parallel wires?

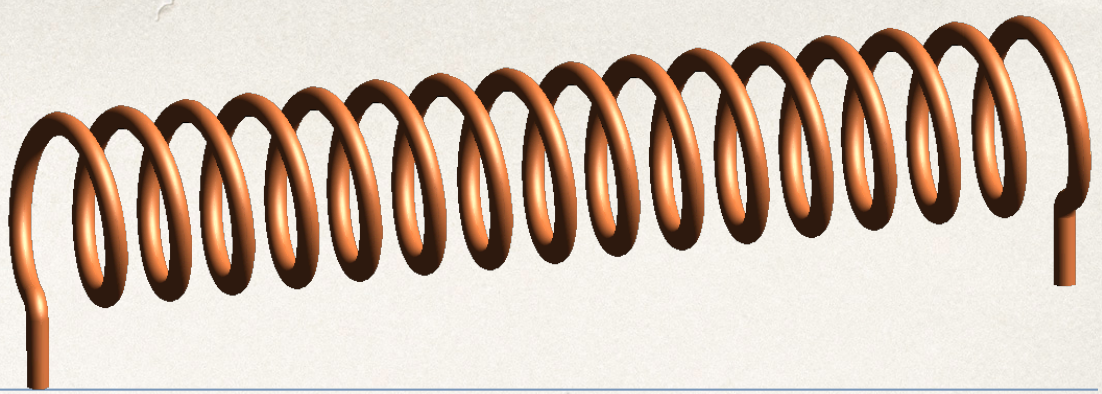


Force: Two Parallel Wires

Which direction is the force on two parallel wires?

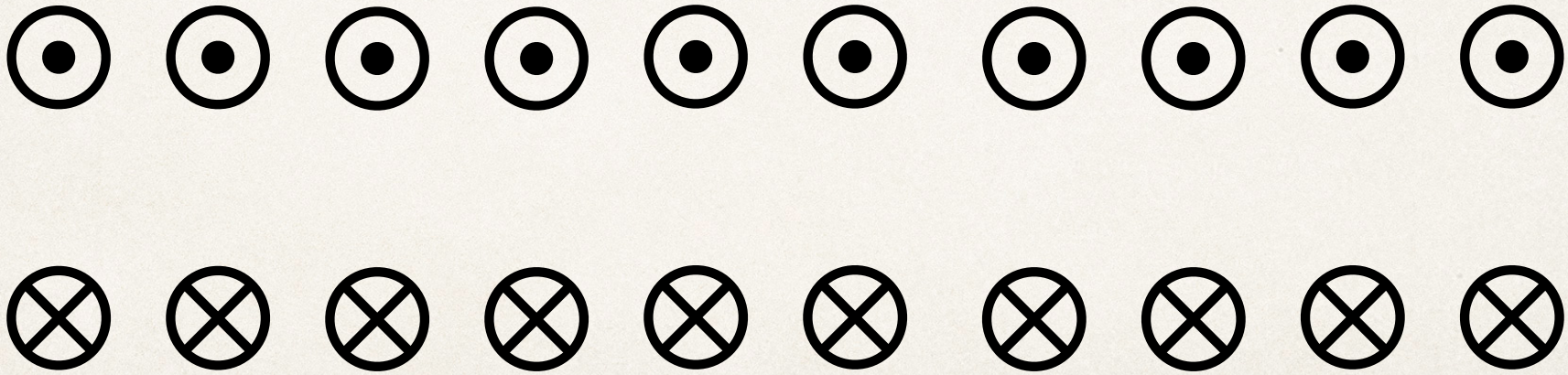


Solenoid



What is the magnitude and direction of the magnetic field inside a solenoid that is 10.0 cm long, and 20 coils, and carries a current of 0.75A?

$$B = \frac{\mu_o N I}{\ell}$$



https://en.wikipedia.org/wiki/Solenoid

Solenoid

What is the magnitude and direction of the magnetic field inside a solenoid that is 10.0 cm long, and 20 coils, and carries a current of 0.75A?

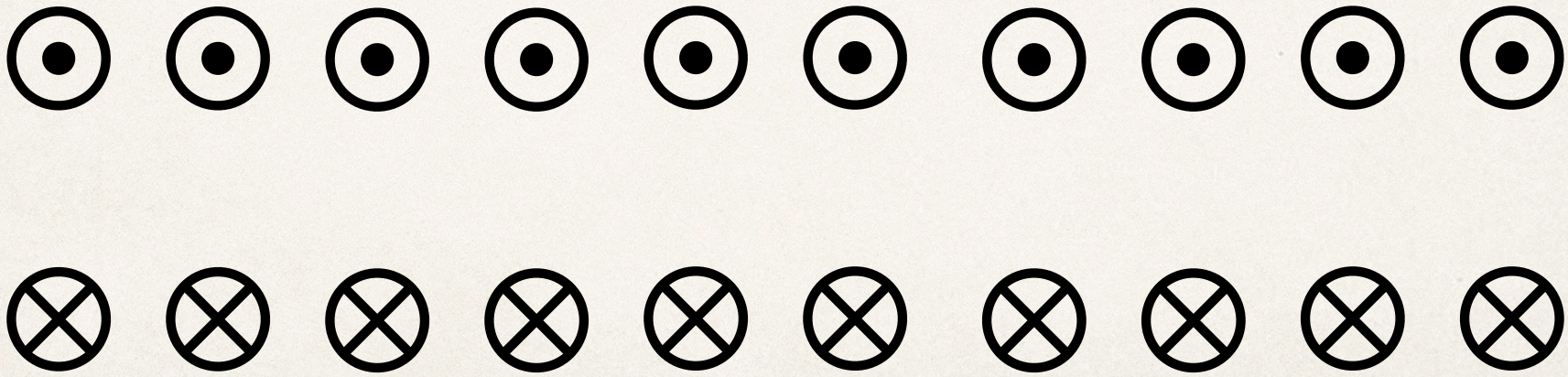
$$B = \frac{\mu_o NI}{\ell} = \frac{\left(4\pi x 10^{-7}\right)\left(20\text{ Coils}\right)\left(0.75\text{ A}\right)}{0.10\text{ m}}$$

$$\boxed{B = 0.000188\text{ T}}$$

Solenoid

What is the magnitude and direction of the magnetic field inside a solenoid that is 10.0 cm long, and 20 coils, and carries a current of 0.75A?

Which RHR? #1 !



Chapter 22

- If I double the current in a long straight wire, what happens to the strength of the magnetic field produced by that current?

A. It halves

B. It remains unchanged

C. It doubles

D. None of the above

Chapter 22

- What is the force on a current carrying wire if the angle between the wire and an external magnetic field is 90° (they are perpendicular)?

  A. The force is zero

  B. The force varies between zero and a maximum

  C. The force is a maximum

  D. The force cannot be determined without the value of the current

Chapter 22

- A wire extends from the floor to the ceiling. You are looking from a top-down prospective. If the current travels from the ceiling to the floor, which way will the magnetic field move?

  A. Clockwise around the wire

  B. Counter-Clockwise around the wire

  C. Uniformly to the right

  D. Uniformly to the left

Chapter 22

- What is the maximum force on a 10.0 cm wire carrying a 0.25A current in a 5.0 Tesla magnetic field?

  A. 0.00 N

  B. 0.13 N

  C. 12.5 N

  D. More information required

Chapter 22

- In the Right-Hand Rule #2, your thumb represents which of the following?

A. The direction of force

B. The direction of current

C. The direction of magnetic field

D. The direction of the electric field

Chapter 22

- If I double the current in a long straight wire, what happens to the strength of the magnetic field produced by that current?

A. It halves

B. It remains unchanged

C. It doubles

D. None of the above

Chapter 22

- What is the force on a current carrying wire if the angle between the wire and an external magnetic field is 90° (they are perpendicular)?

A. The force is zero

B. The force varies between zero and a maximum

C. The force is a maximum

D. The force cannot be determined without the value of the current

Chapter 22

- A wire extends from the floor to the ceiling. You are looking from a top-down prospective. If the current travels from the ceiling to the floor, which way will the magnetic field move?

A. Clockwise around the wire

B. Counter-Clockwise around the wire

C. Uniformly to the right

D. Uniformly to the left

Chapter 22

- What is the maximum force on a 10.0 cm wire carrying a 0.25A current in a 5.0 Tesla magnetic field?

A. 0.00 N

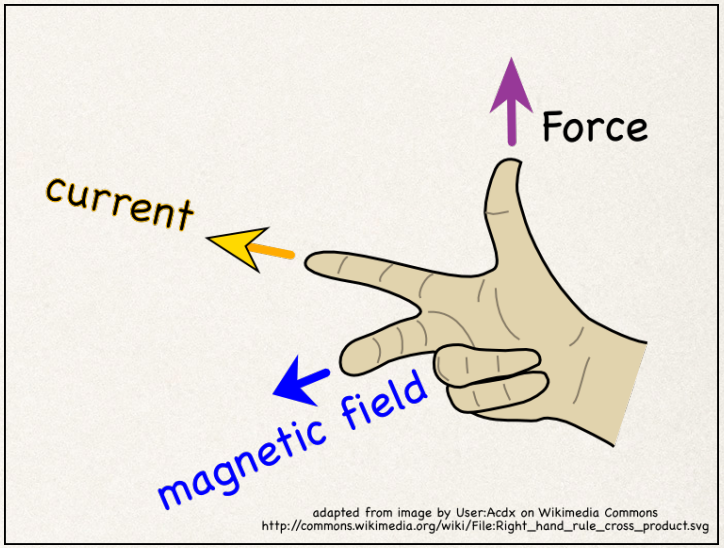
B. 0.13 N

C. 12.5 N

D. More information required

Chapter 22

- In the Right-Hand Rule #2, your thumb represents which of the following?



A. The direction of force

B. The direction of current

C. The direction of magnetic field

D. The direction of the electric field