Your Comments

Wow… haven't been this confused in a long, long time. Can you put up a slide summarizing each of the 300 different right hand rules we've learned in the last week and when to use them? Also, the prelecture blew through a lot of calculations, are the end formulas general and given to us on a formula sheet?

I failed to understand the whole concepts, especially when we come to the right-hand rule. MY FINGERS GET DUMB EVERY TIME WHEN I DID THE RIGHT HAND RULE!!!

I have issues figuring out what the torque of something is if I can't see it physically spinning. For example, what is the torque of an object moving in a straight line? Those kind of questions trip me up. I know that's more of a mechanics problem, but ehh….still a hard concept for me at the moment.

How do we find torques on wires? Did I just miss that in the videos?

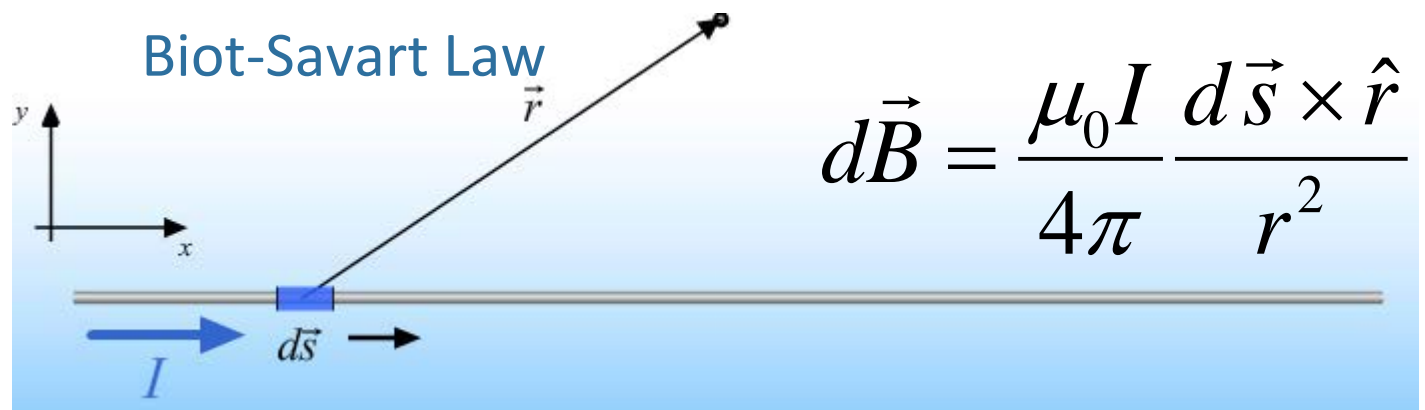how do you find the torque on something that isn't a loop? there's no dipole moment or area vector.

Oooooo..!!! Unofficial's ahead. Must have FUN!!! Incorrect, we are Engineers…

I'm still bad with torque and that stuff, any easy ways to remember how that works?

Physics 212
Lecture 14

Today's Concept:

Biot-Savart Law

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$$
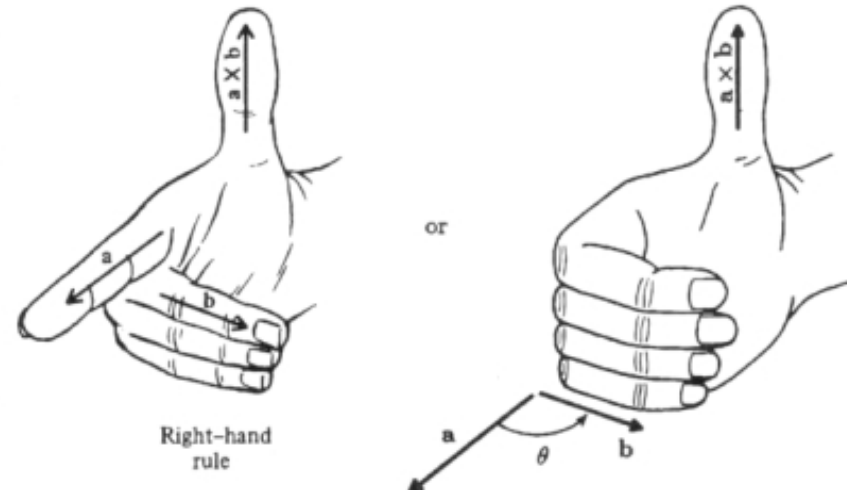
Right Hand Rule Review

1. ANY CROSS PRODUCT

$$\vec{F} = q\vec{v} \times \vec{B} \qquad \vec{F} = I\vec{L} \times \vec{B}$$

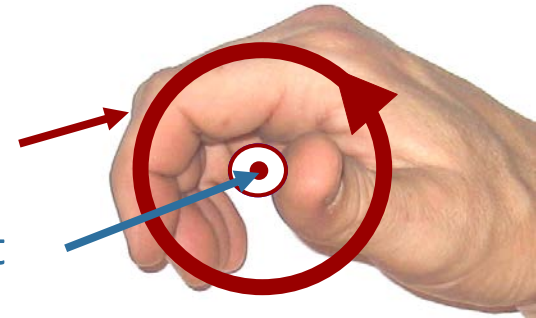$$\tau = \vec{r} \times \vec{F} \qquad \tau = \vec{\mu} \times \vec{B}$$

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$$

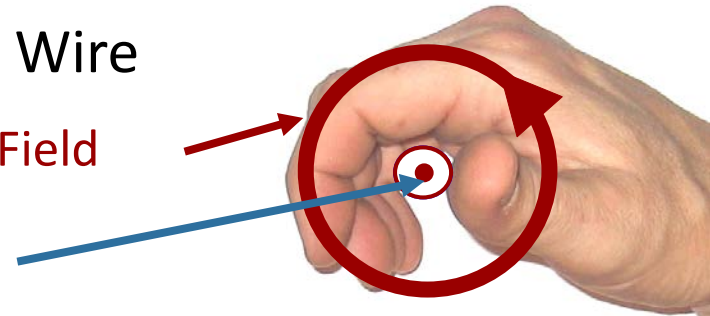### 2. Direction of Magnetic Moment

Fingers: Current in Loop

Thumb: Magnetic Moment

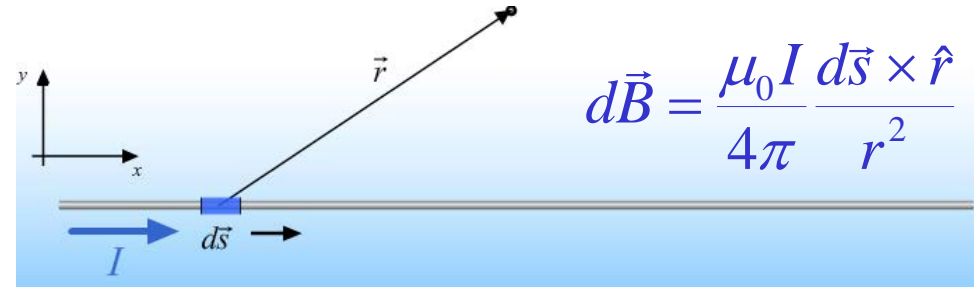### 3. Direction of Magnetic Field from Wire

Fingers: Magnetic Field

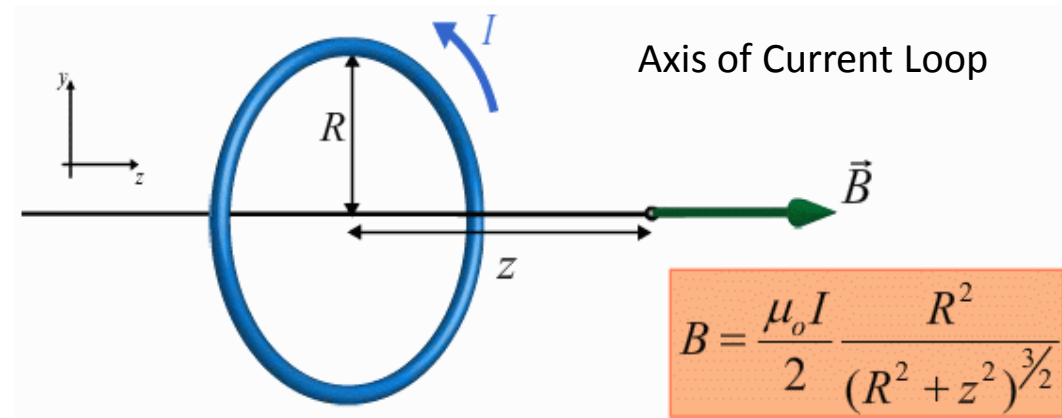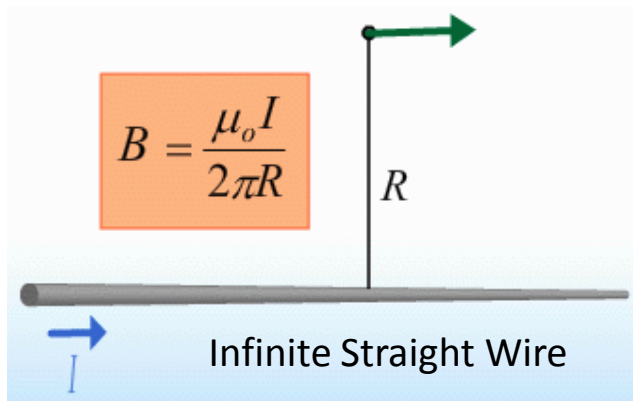Thumb: Current

Biot-Savart Law:

What is it?

Fundamental law for determining the direction and magnitude of the magnetic field due to an element of current

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}$$

We can use this law to calculate the magnetic field produced by ANY current distribution

BUT

Easy analytic calculations are possible only for a few distributions:

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

Infinite Straight Wire

Axis of Current Loop

$$B = \frac{\mu_o I}{2} \frac{R^2}{\left(R^2 + z^2\right)^{3/2}}$$

Plan for Today: Mainly use the results of these calculations!

GOOD NEWS: Remember Gauss' Law? Allowed us to calculate E for symmetrical charge distributions

NEXT TIME: Introduce Ampere's Law   Allows us to calculate B for symmetrical current distributions
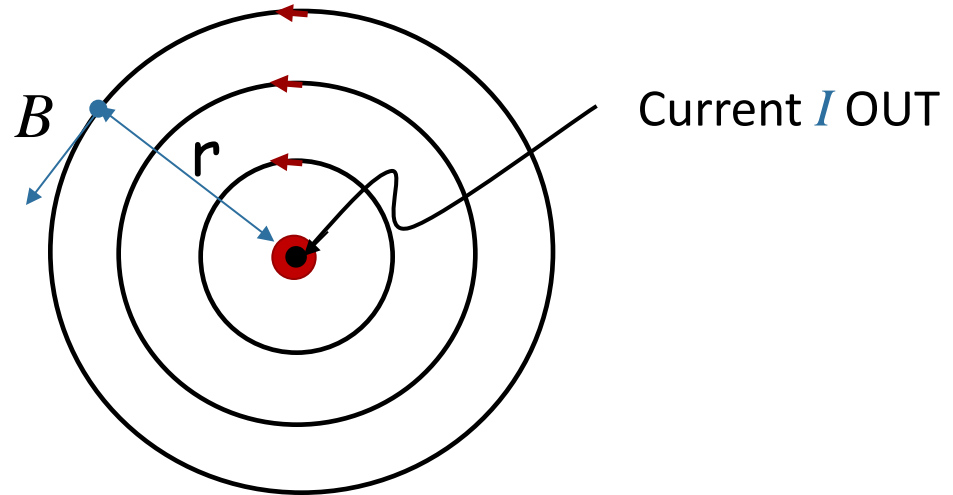
B from Infinite Line of Current

Integrating $d\vec{B} = \dfrac{\mu_0 I}{4\pi}\dfrac{d\vec{s} \times \hat{r}}{r^2}$ gives result

Magnitude:

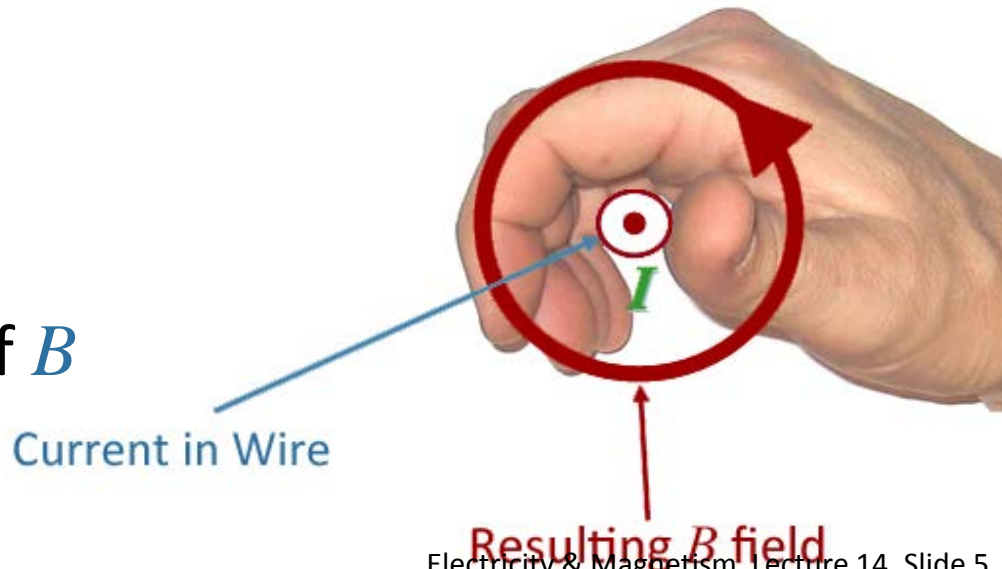$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mu_0 = 4\pi \times 10^{-7}\, Tm/A$$

$r =$ distance from wire

B

r

Current I OUT

Direction:

Thumb: on I
Fingers: curl in direction of B

Current in Wire

Resulting B field

A long straight wire is carrying current from left to right. Two identical charges are moving with equal speed. Compare the magnitude of the force on charge a moving directly to the right, to the magnitude of the force on charge b moving up and to the right at the instant shown (i.e. same distance from the wire).

(a) v B (b) v

F r r F I
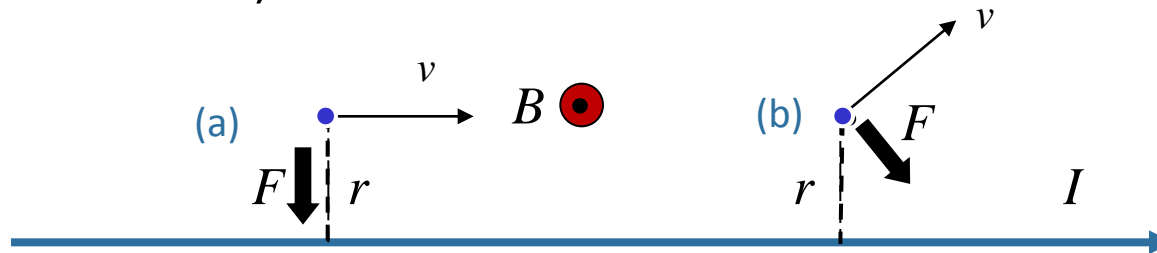
$$\vec{F} = q\vec{v} \times \vec{B}$$

$$\left|\vec{F}\right| = qvB\sin\theta$$

A) $|F_a| > |F_b|$

B) $|F_a| = |F_b|$

C) $|F_a| < |F_b|$

Same q, $|v|$, B and $\theta\,(=90)$

Forces are in different directions

Adding Magnetic Fields

Two long wires carry opposite current
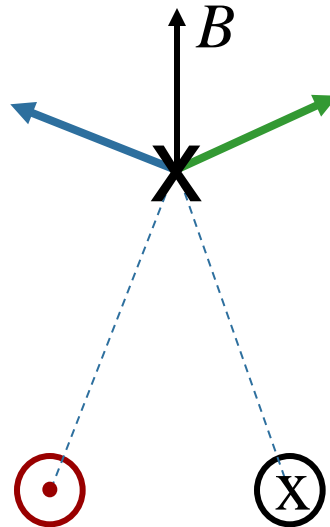
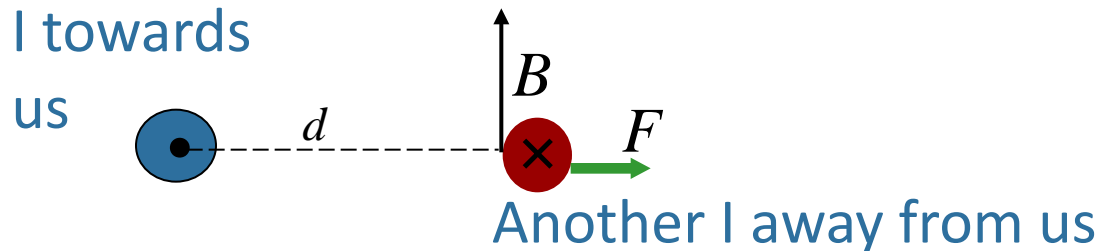What is the direction of the magnetic field above, and midway between the two wires carrying current – at the point marked "X"?

A) Left   B) Right   C) Up   D) Down   E) Zero

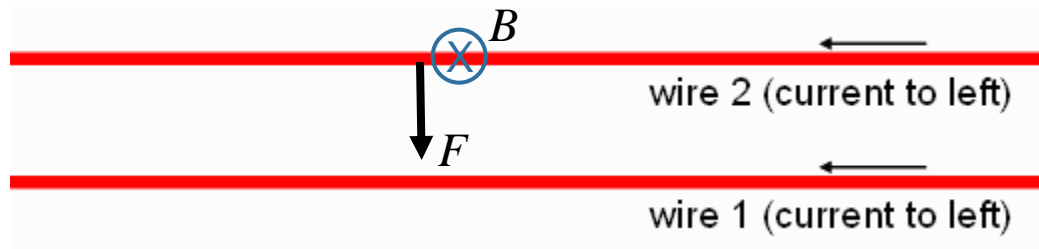# *Force Between Current-Carrying Wires*

I towards us

d

B

F

Another I towards us

$$\vec{F}_{12} = I_2\vec{L} \times \vec{B}$$ → $$F_{12} = I_2 L \cdot \frac{\mu_o}{2\pi d} I_1$$
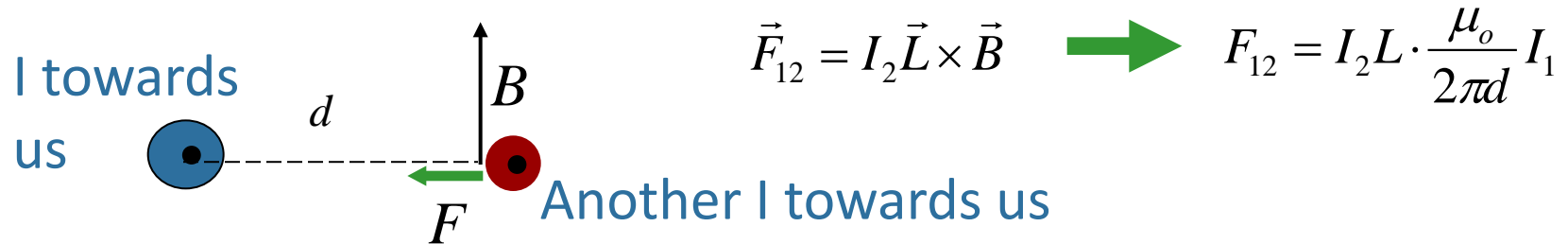
Conclusion: Currents in same direction attract!

I towards us

d

B

F

Another I away from us

Conclusion: Currents in opposite direction repel!

B

X

F

wire 2 (current to left)

wire 1 (current to left)

What is the direction of the force on wire 2 due to wire 1?

A) Up   B) Down   C) Into Screen   D) Out of screen   E) Zero

2 wires with same-direction currents are attracted

What is the direction of the torque on wire 2 due to wire 1?

A) Up   B) Down   C) Into Screen   D) Out of screen   E) Zero

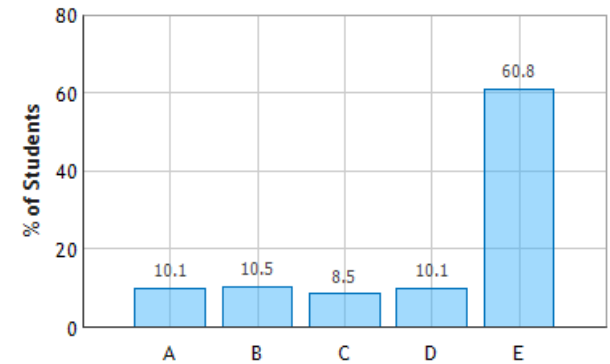Uniform force at every segment of wire

No torque about any axis
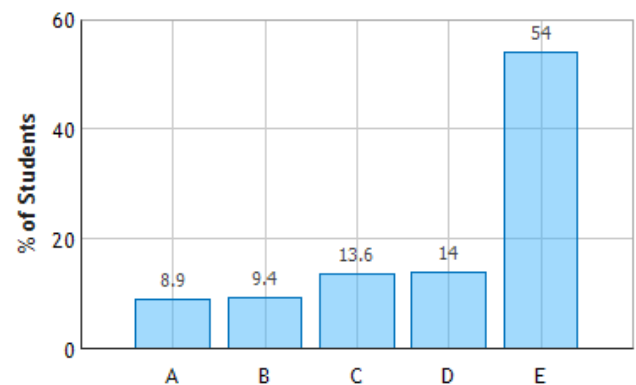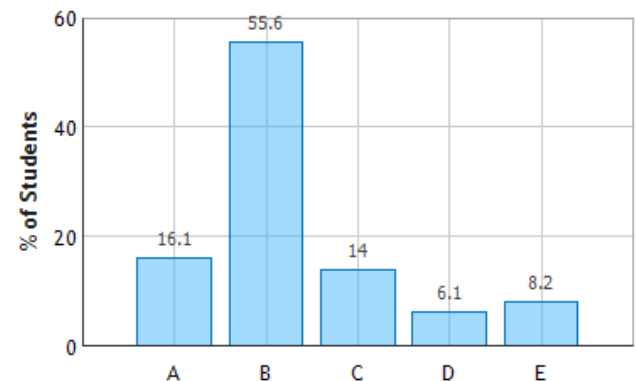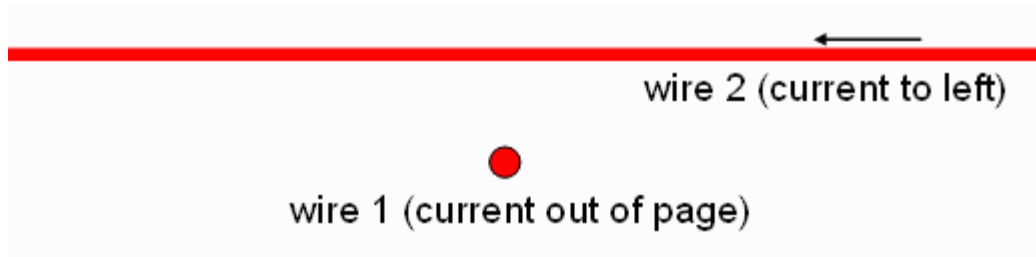
wire 2 (current to left)

wire 1 (current out of page)

What is the direction of the force on wire 2 due to wire 1?

Forces and Torques on Current-Carrying Wires:
Question 1 (N = 812)

A) Up   B) Down   C) Into Screen   D) Out of screen   E) Zero

WHY?
DRAW PICTURE!

Consider Force on Symmetric Segments

I F out of screen I F into screen

B

B

r r
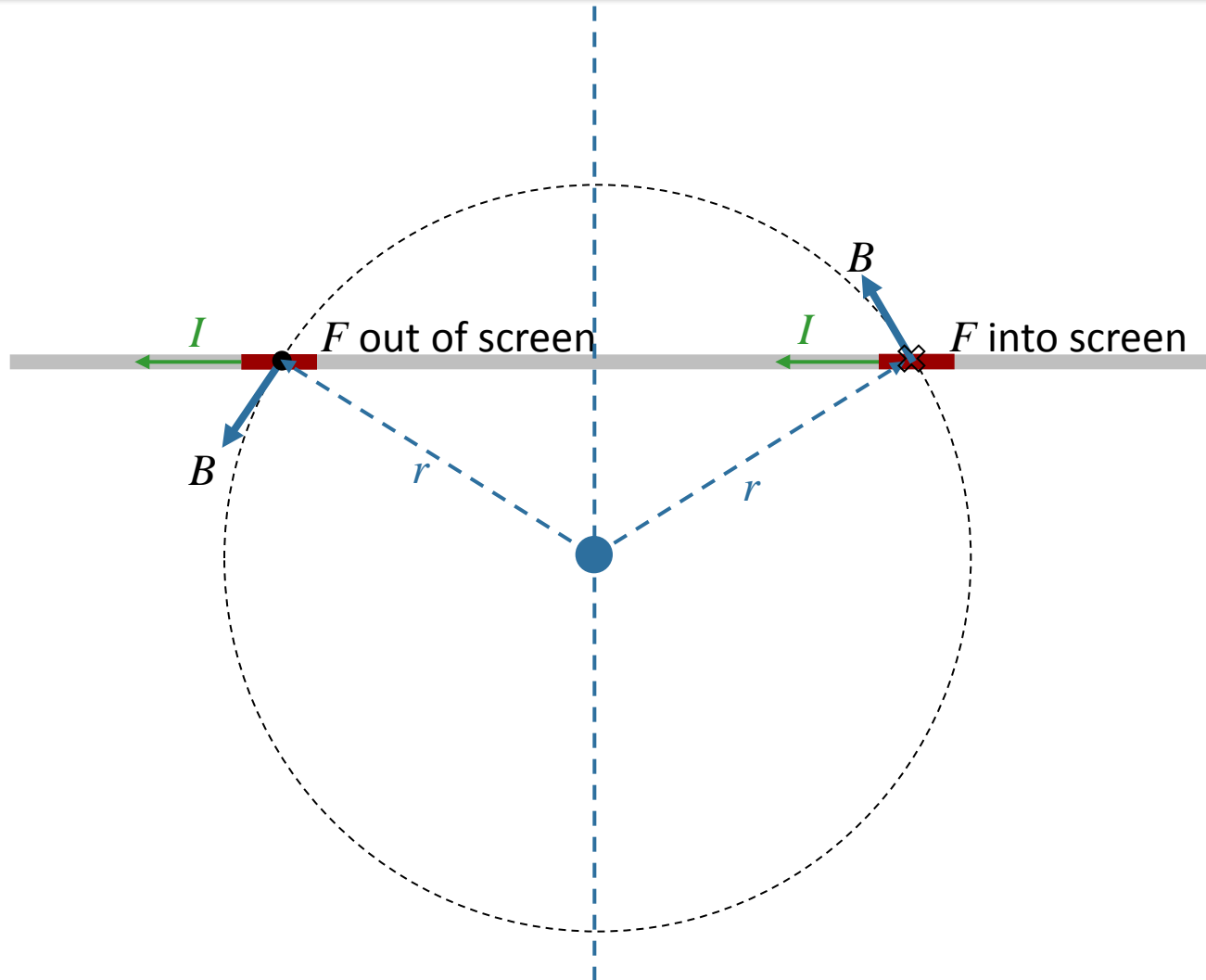
Net Force is Zero!

CheckPoint 3b

What is torque on wire 2, due to wire 1?

wire 2 (current to left)

wire 1 (current out of page)

There is a net force on the right side pointing into the screen and a net force on the left side pointing out of the screen. Using the right hand rule, this means that the torque is pointing up.

The wire will try to aline with wire 1.

A) Up   B) Down   C) Into Screen   D) Out of screen   E) Zero

I I B

F out of screen F into screen

B

40

35.5

30   26

% of Students

20

13.4   14.3
10.8

10
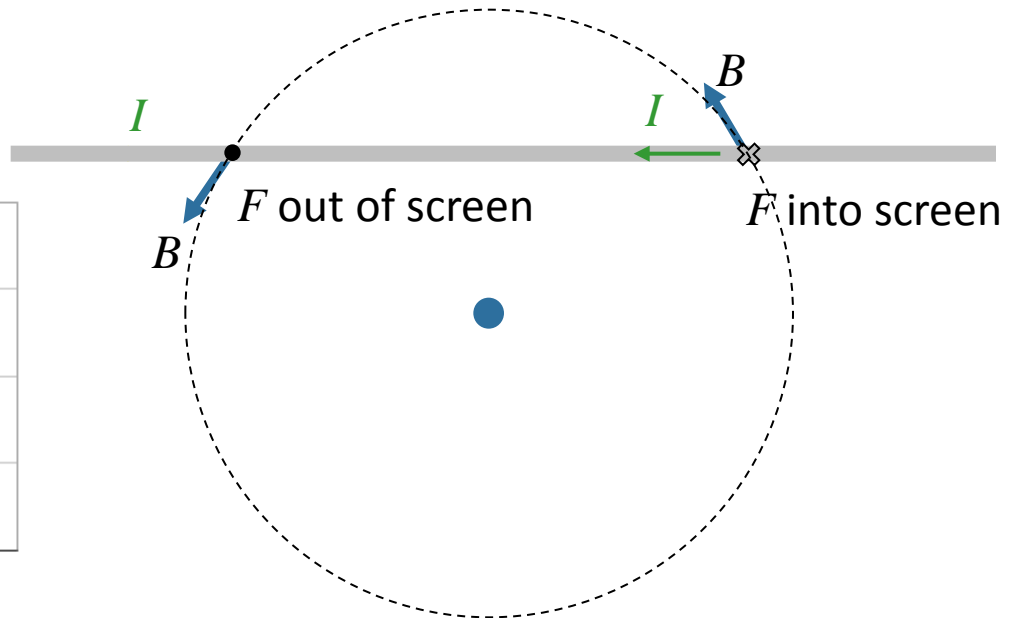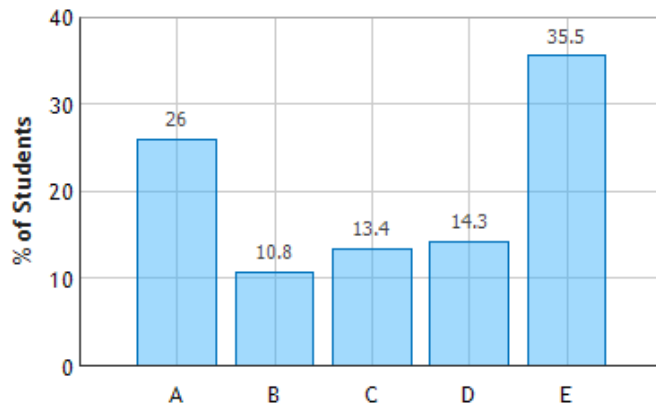
0
    A   B   C   D   E

A loop of wire with current flowing in a counterclockwise direction is located to the right of a long wire with current flowing up. As shown below.

What is the direction of the net force on the loop?

A) Up   B) Down   C) Left   D) Right   E) Zero


$B \sim 1/R$ ➡ $B_1 > B_2$ ➡ $F_1 > F_2$
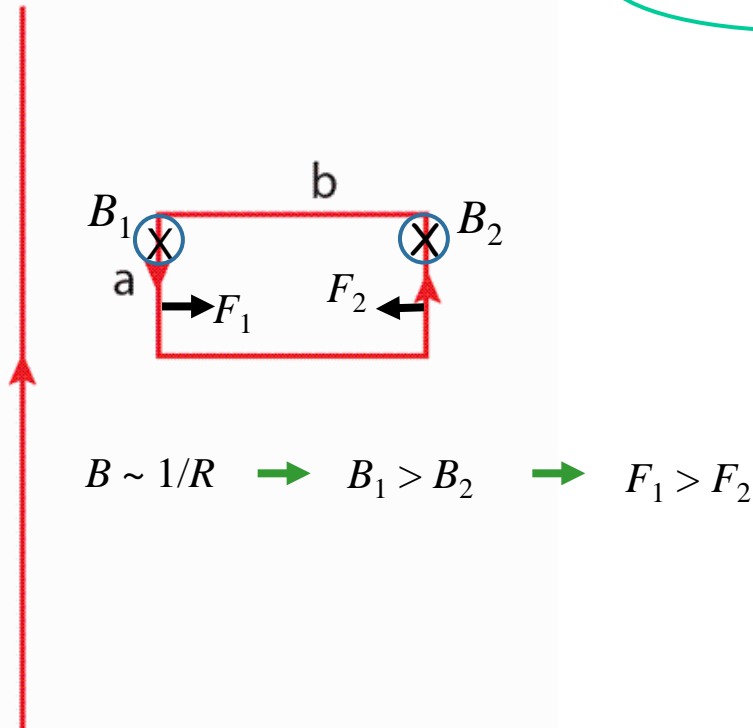
CheckPoint 2

A current carrying loop of width *a* and length *b* is placed near a current carrying wire. How does the net force on the loop compare to the net force on a single wire segment of length *a* carrying the same amount of current placed at the same distance from the wire?

$$F_{top} + F_{bottom} = 0$$

b

B_1 ⊗ B_2

a F_1 F_2

$B \sim 1/R$ → $B_1 > B_2$

F_{net}

⊗ B_1

a

F_1
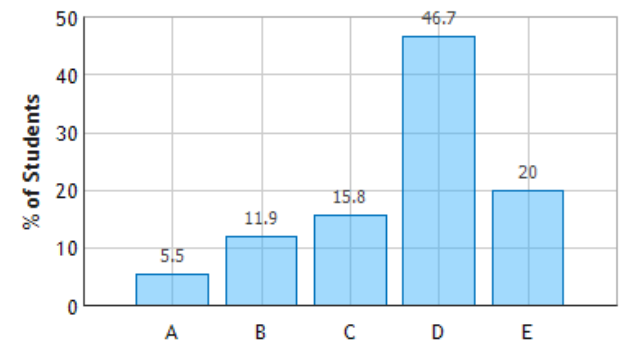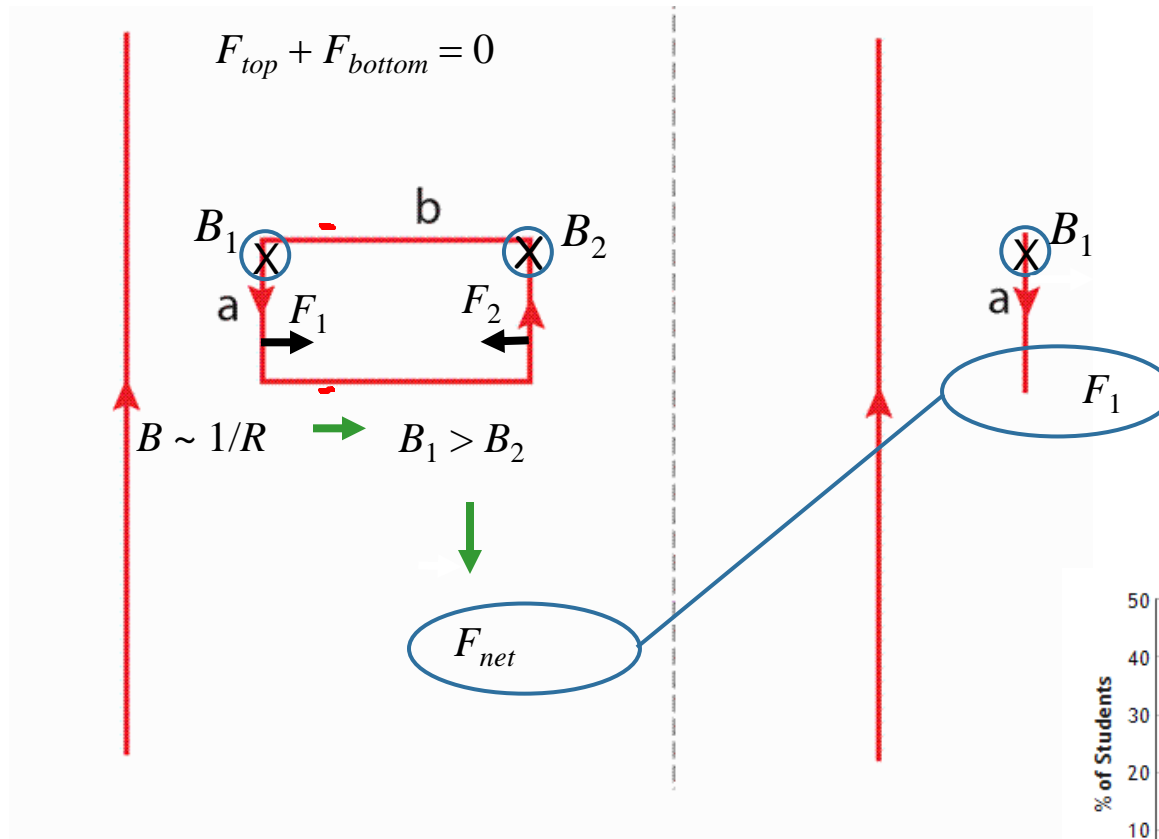
A. The forces are in opposite directions
B. The net forces are the same
C. The net force on the loop is greater than the net force on the wire segment
D. The net force on the loop is smaller than the net force on the wire segment
E. There is no net force on the loop

B on axis from Current Loop

$$B = \frac{\mu_o I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}}$$

$$B_{max} = \frac{\mu_o I}{2R}$$

Resulting B Field

Current in Wire
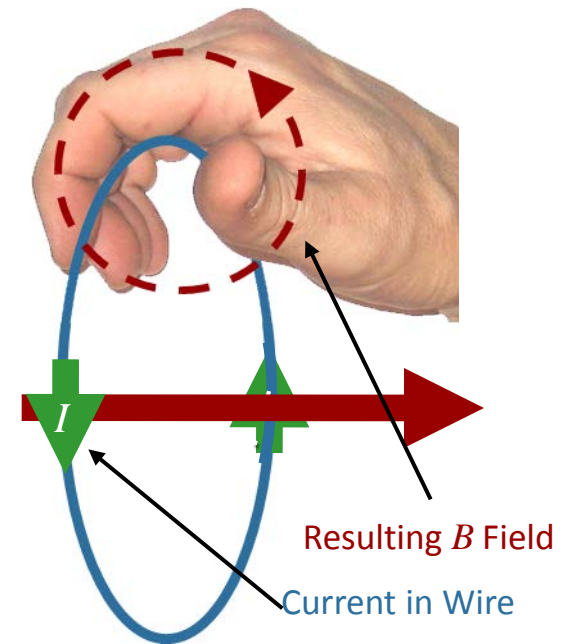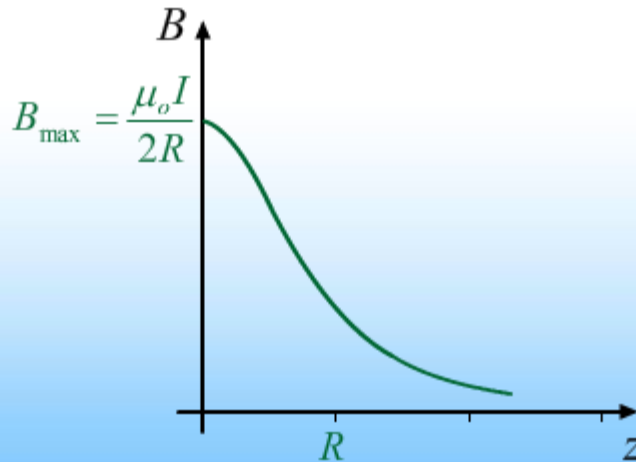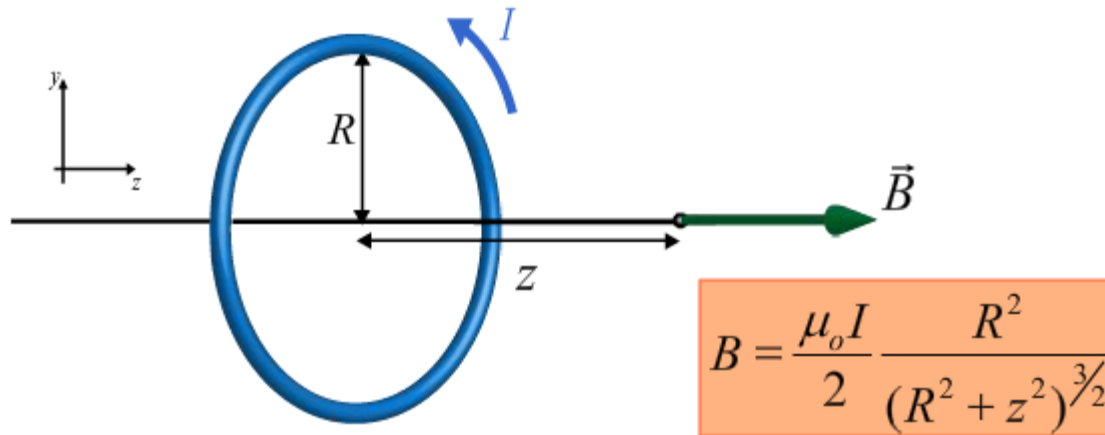
Two Current Loops

Two identical loops are hung next to each other. Current flows in the same direction in both.

The loops will:

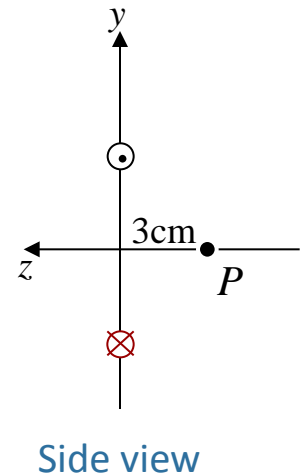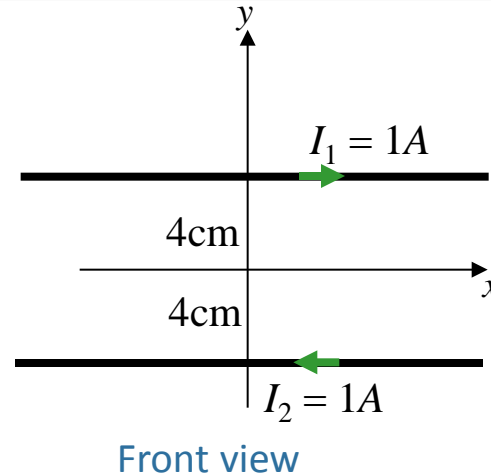A) Attract each other   B) Repel each other
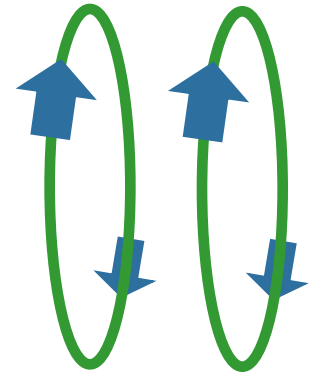
Two ways to see this:

1) Like currents attract

2) Look like bar magnets
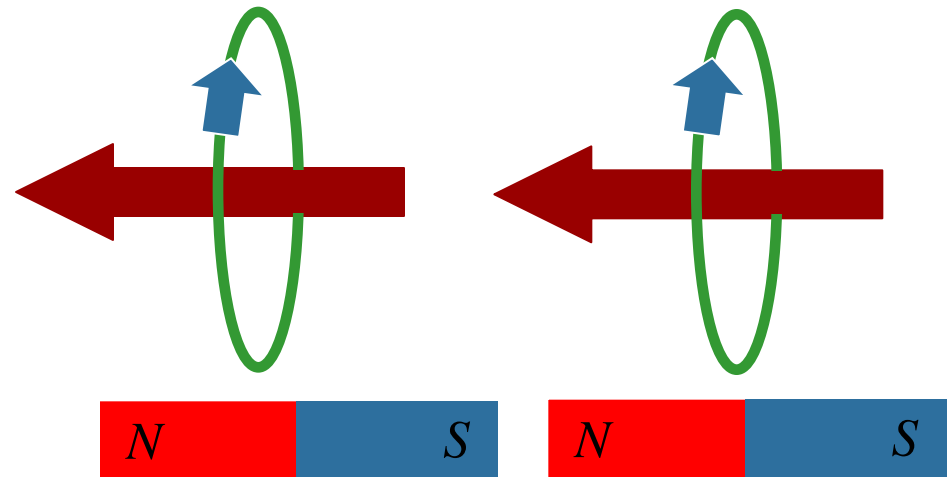
N S N S

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.
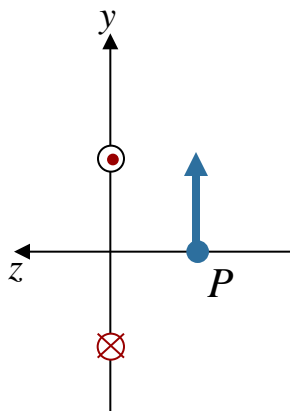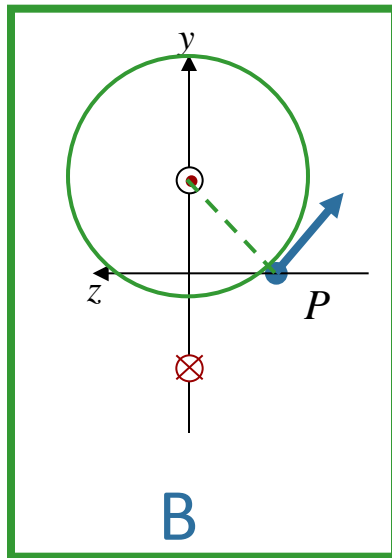
What is the B field at point P?
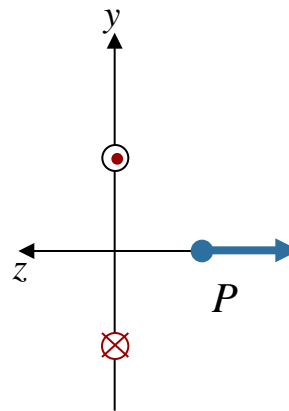

Front view

Side view

Conceptual Analysis

Each wire creates a magnetic field at P

B from infinite wire: $B = \mu_0 I / 2\pi r$

Total magnetic field at P obtained from superposition

Strategic Analysis

Calculate B at P from each wire separately

Total B = vector sum of individual B fields

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.

What is the B field at point P?
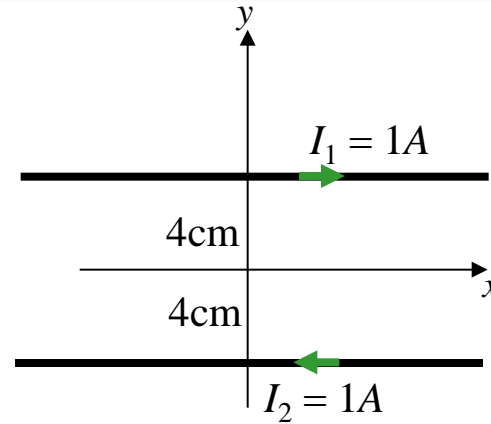
Front view
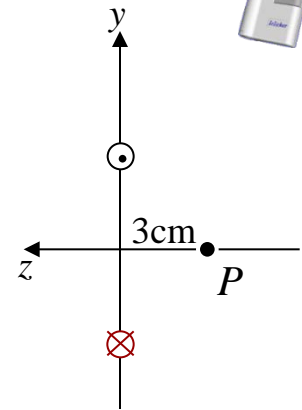
Side view

What is the direction of *Magnetic Field* at P produced by the top current I_1?
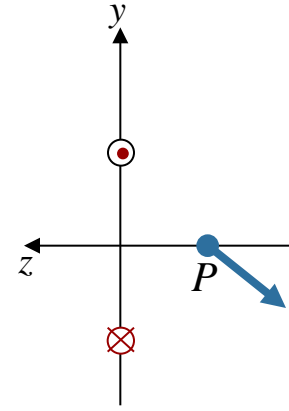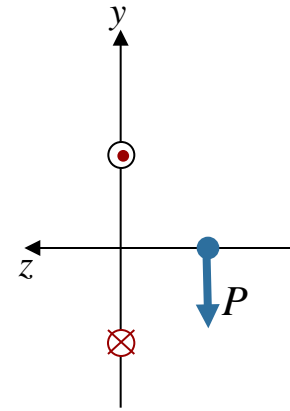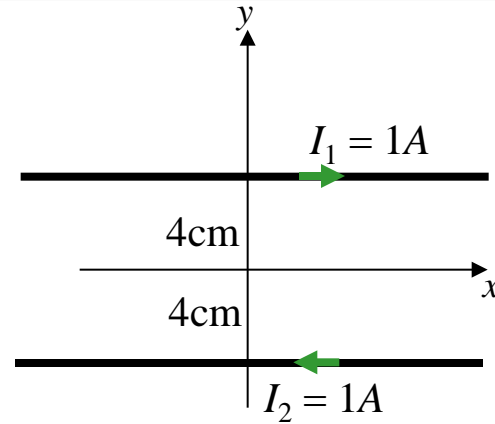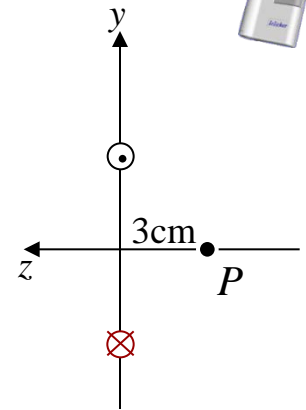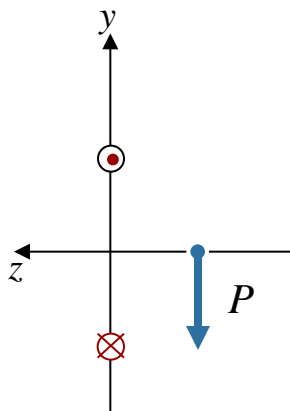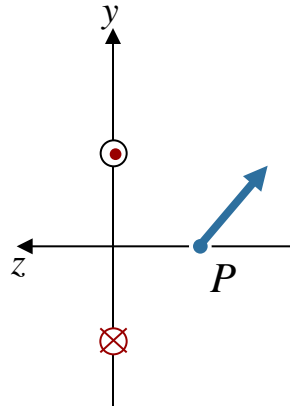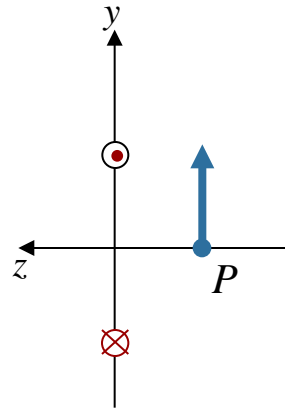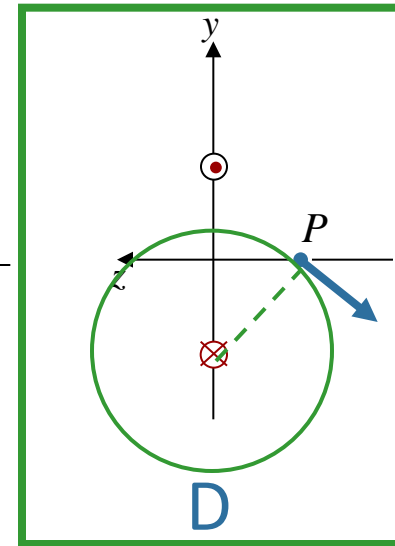

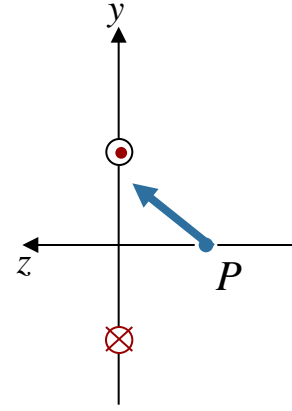A   B   C   D   E

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.

What is the B field at point P?

Front view

$I_1 = 1A$

y

4cm

4cm

x

$I_2 = 1A$

Side view

y

3cm

P

z

What is the direction of *Magnetic Field* at P produced by the bottom current I_2?
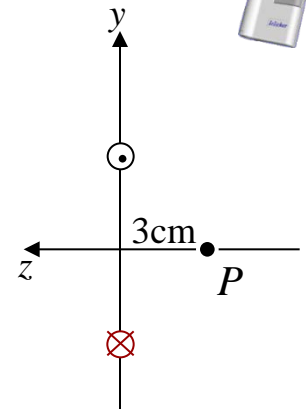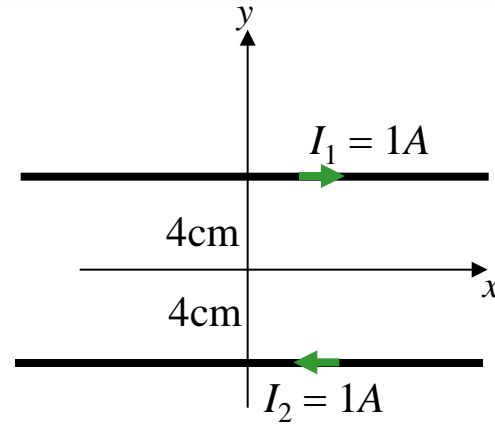
A

B

C

D

E

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.
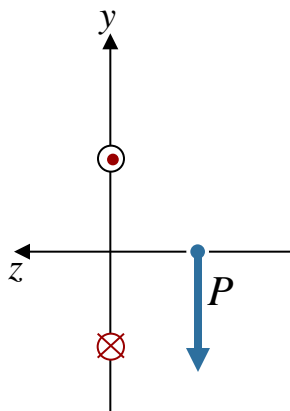
What is the B field at point P?

$I_1 = 1A$

4cm

4cm

$I_2 = 1A$

Front view

3cm

P

Side view

What is the direction of *Magnetic Field* at P?

P

A

P

B

90°

P

C

P

D

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.
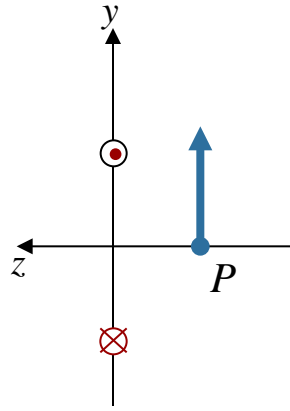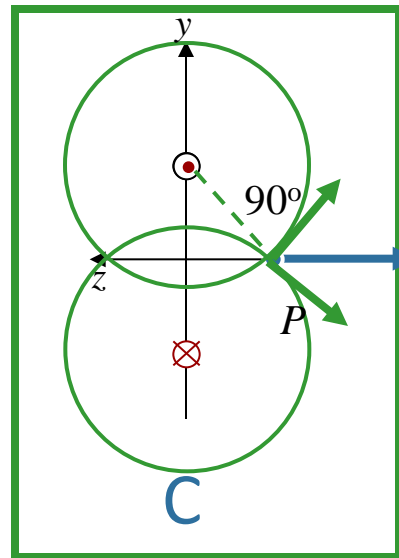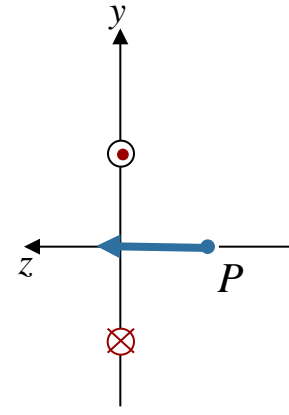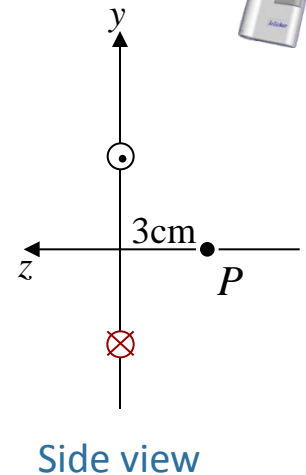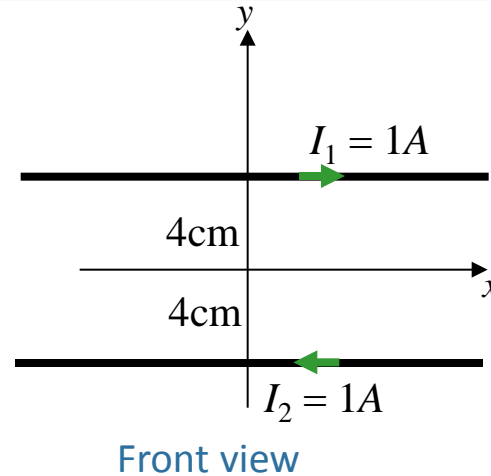
What is the B field at point P?

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

$I_1 = 1A$

4cm

4cm

$I_2 = 1A$

Front view

3cm

P

Side view

What is the magnitude of B at P produced by the top current I_1?

$(\mu_0 = 4\pi \times 10^{-7} \, T{-}m/A)$
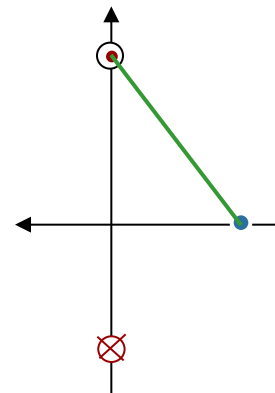
A) $4.0 \times 10^{-6} \, T$ B) $5.0 \times 10^{-6} \, T$ C) $6.7 \times 10^{-6} \, T$

What is r?

r = distance from wire axis to P

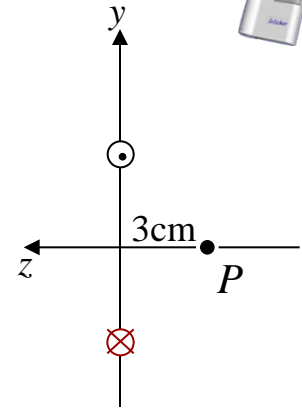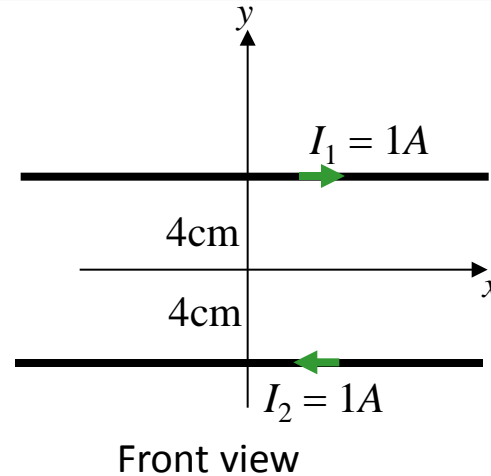$$B = \frac{\mu_0 I}{2\pi r} = \frac{\left(4\pi \times 10^{-7}\right) \times 1}{2\pi r} = 40 \times 10^{-7}$$

$$r = \sqrt{3^2 + 4^2} = 5cm$$

Calculation

Two parallel horizontal wires are located in the vertical (x,y) plane as shown. Each wire carries a current of $I = 1A$ flowing in the directions shown.
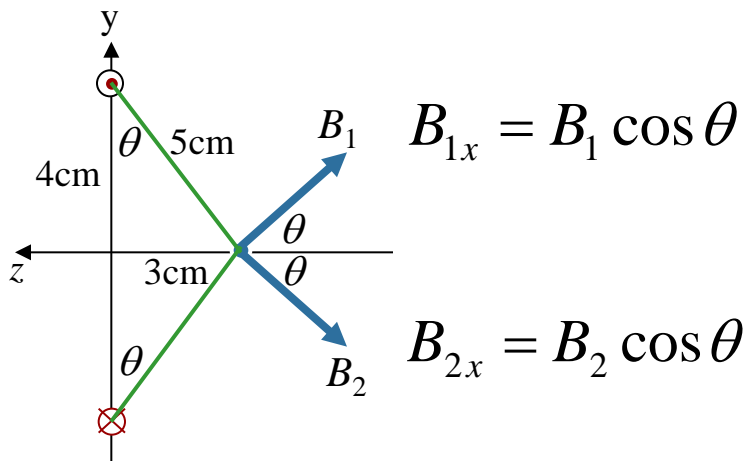
What is the B field at point P?

$$\boxed{B_{top} = 4 \times 10^{-6}\,T}$$

What is the magnitude of B at P? $(\mu_0 = 4\pi \times 10^{-7}\,T - m/A)$

A) $3.2 \times 10^{-6}\,T$ **B)** $4.8 \times 10^{-6}\,T$ **C)** $6.4 \times 10^{-6}\,T$ **D)** $8.0 \times 10^{-6}\,T$

$I_1 = 1A$

4cm

4cm

$I_2 = 1A$

Front view

3cm

P

B_1

$B_{1x} = B_1 \cos\theta$

$B_{2x} = B_2 \cos\theta$

B_2

5cm

4cm

3cm

$$B_x = 2B_1 \cos\theta = 2 \times 4 \times 10^{-6} \times \left(\frac{4}{5}\right) = 6.4 \times 10^{-6}$$