

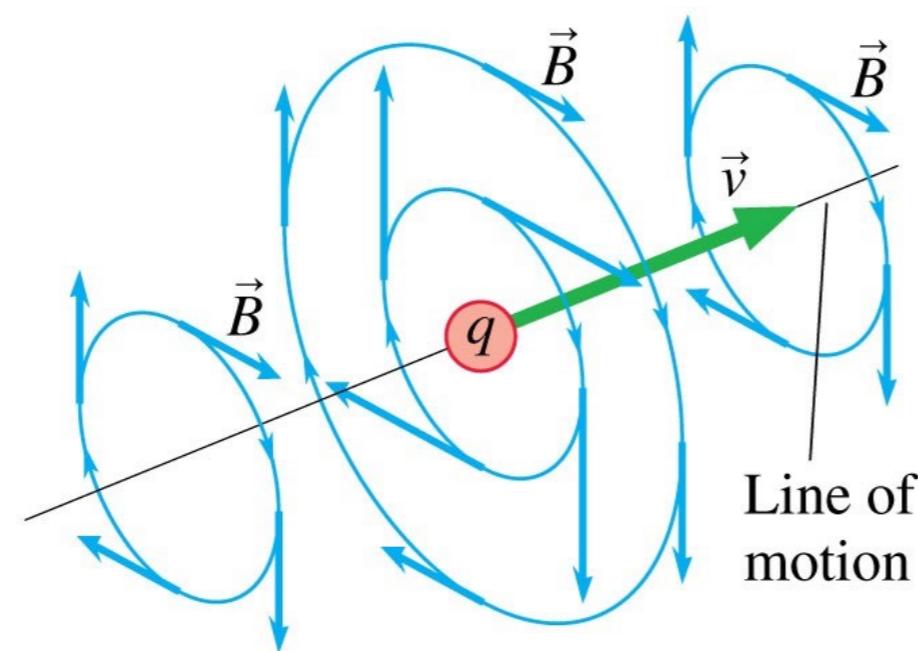


PH 220

Lance Nelson

Unanswered questions

1. What is a magnet and why does it create a magnetic field?
2. Why do magnets have a north and south pole?
3. Why do magnets pick up some objects but not others?
4. Why doesn't breaking a magnet into two pieces separate the poles.



What we know so far

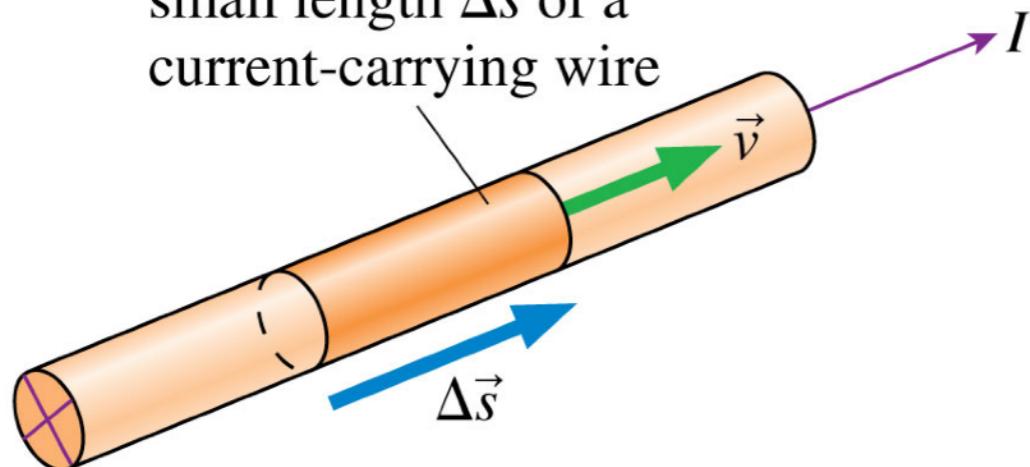
1. A current (charges in motion) creates a magnetic field.

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

Magnetic Field of a Current

For moving point charge...

Charge ΔQ in a small length Δs of a current-carrying wire

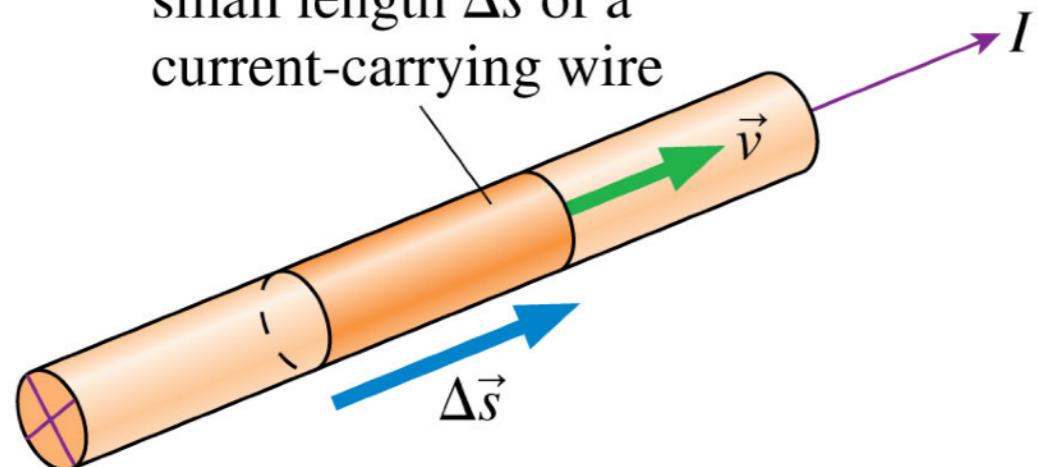


$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

Magnetic Field of a Current

For moving point charge...

Charge ΔQ in a small length Δs of a current-carrying wire



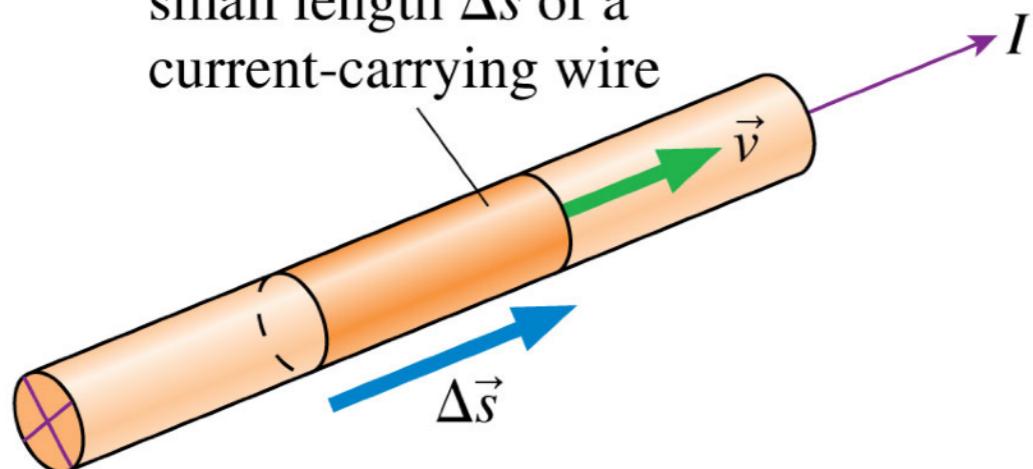
$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$$(\Delta Q)\vec{v} = \Delta Q \frac{\Delta \vec{s}}{\Delta t} = \frac{\Delta Q}{\Delta t} \Delta \vec{s} = I \Delta \vec{s}$$

Magnetic Field of a Current

For moving point charge...

Charge ΔQ in a small length Δs of a current-carrying wire



$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

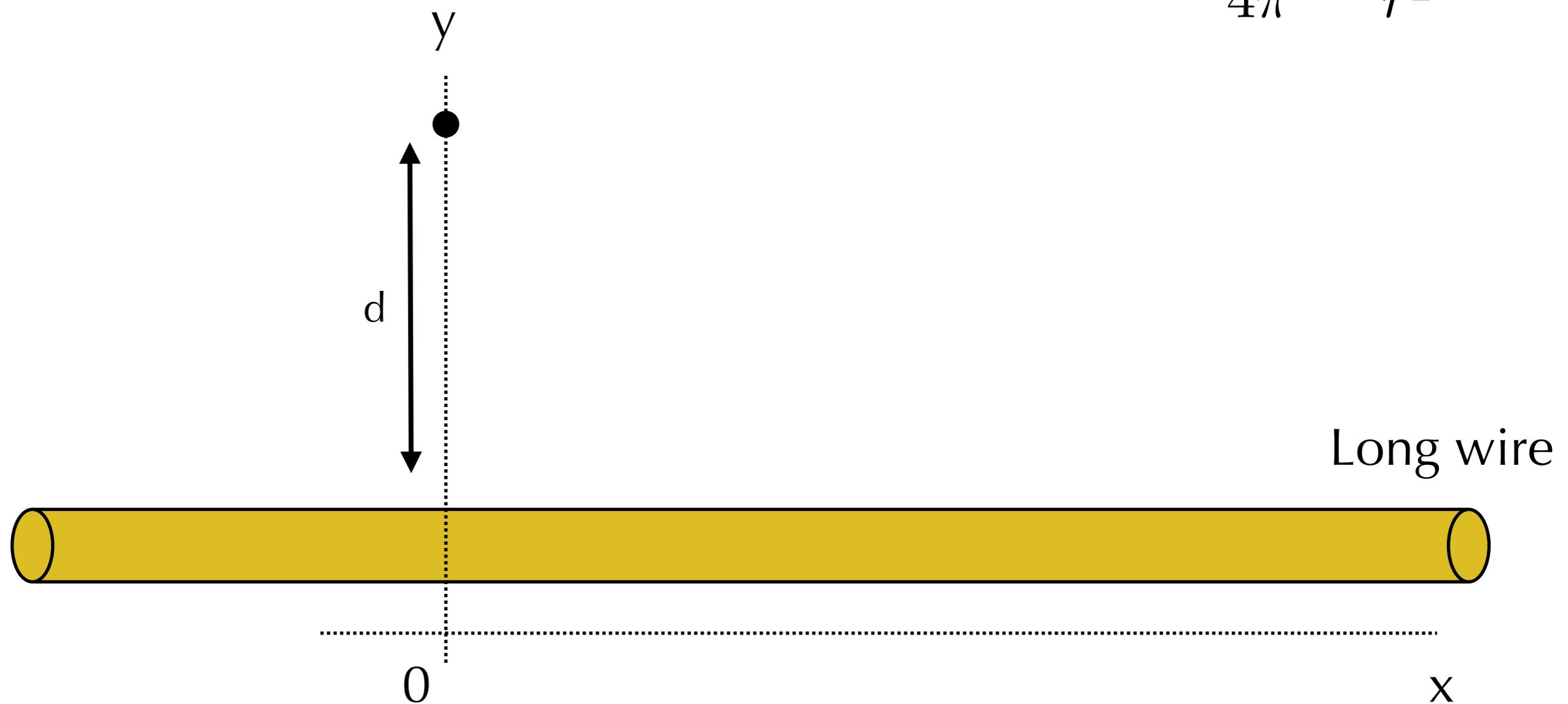
$$(\Delta Q)\vec{v} = \Delta Q \frac{\Delta \vec{s}}{\Delta t} = \frac{\Delta Q}{\Delta t} \Delta \vec{s} = I \Delta \vec{s}$$

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

For small segment of current carrying wire.

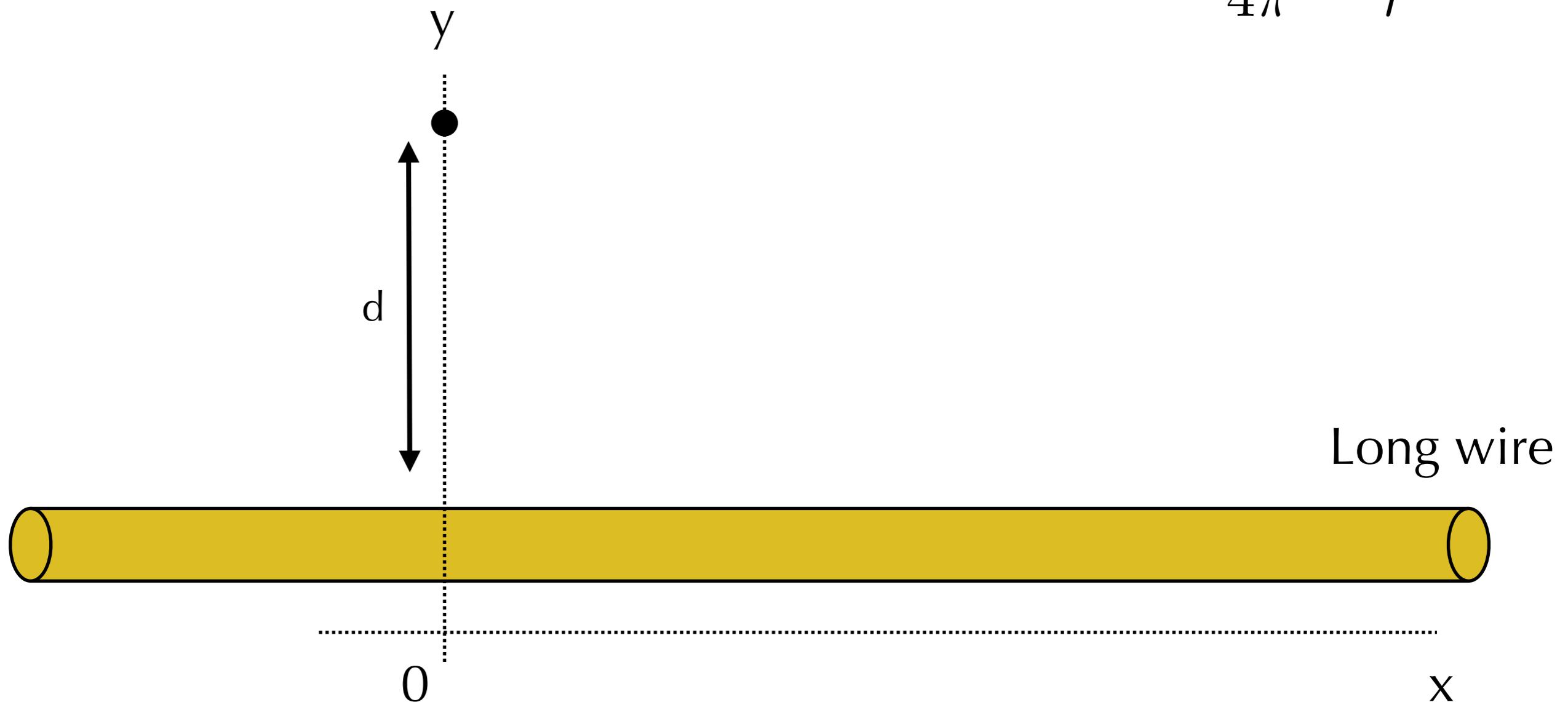
Let's see how to do these integrals!

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



Let's see how to do these integrals!

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



$$\vec{B} = \frac{\mu_0 I}{2\pi d}$$

Let's see how to do these integrals!

$$1 \quad \hat{r} = \frac{-x\hat{i} + d\hat{j}}{\sqrt{x^2 + d^2}}$$

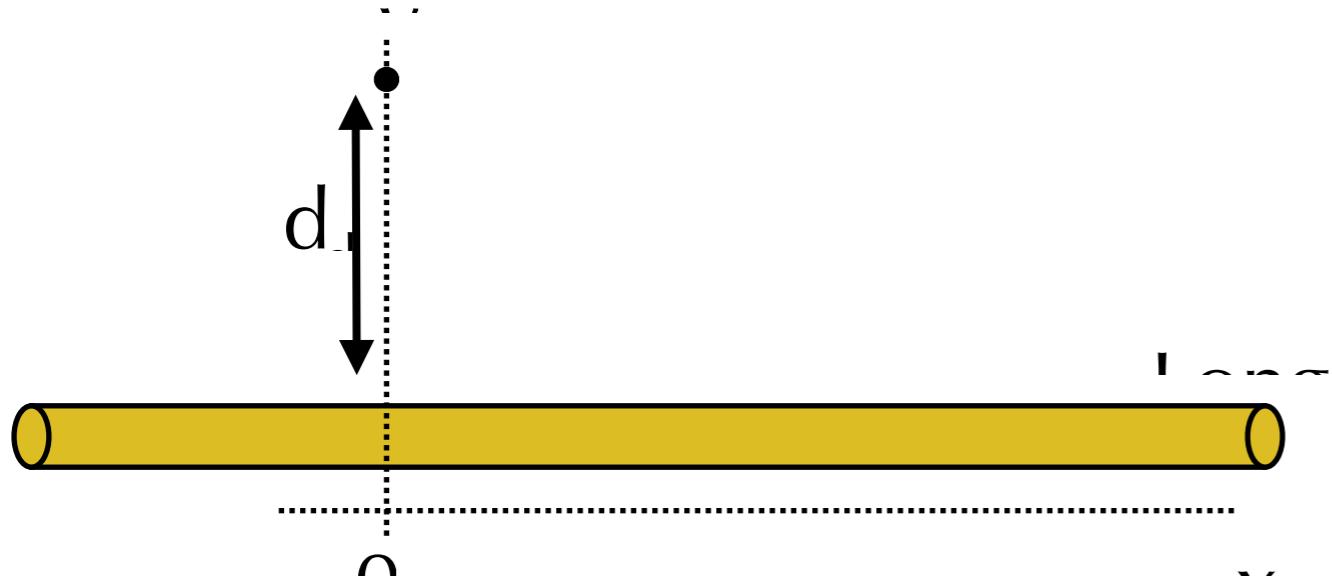
$$2 \quad d\vec{s} = dx\hat{i}$$

$$3 \quad d\vec{s} \times \hat{r} = \frac{ddx}{\sqrt{x^2 + d^2}}$$

$$4 \quad r^2 = x^2 + d^2$$

$$5 \quad \frac{\mu_0 Id}{4\pi} \int_{-\infty}^{\infty} \frac{dx}{(x^2 + d^2)^{3/2}}$$

$$6 \quad \frac{\mu_0 Id}{4\pi} \left| \frac{x}{d^2 \sqrt{x^2 + d^2}} \right|_{-\infty}^{\infty}$$



Let's see how to do these integrals!

$$1 \quad \hat{r} = \frac{-x\hat{i} + d\hat{j}}{\sqrt{x^2 + d^2}}$$

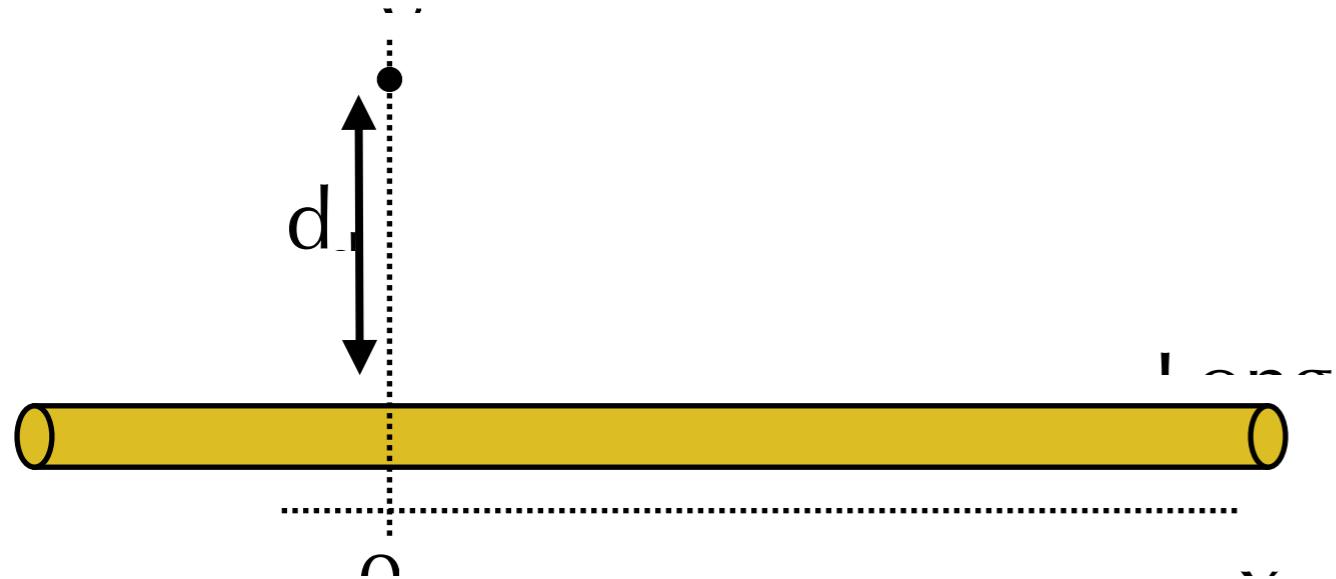
$$2 \quad d\vec{s} = dx\hat{i}$$

$$3 \quad d\vec{s} \times \hat{r} = \frac{ddx}{\sqrt{x^2 + d^2}}$$

$$4 \quad r^2 = x^2 + d^2$$

$$5 \quad \frac{\mu_0 Id}{4\pi} \int_{-\infty}^{\infty} \frac{dx}{(x^2 + d^2)^{3/2}}$$

$$6 \quad \frac{\mu_0 Id}{4\pi} \left| \frac{x}{d^2 \sqrt{x^2 + d^2}} \right|_{-\infty}^{\infty}$$



Let's see how to do these integrals!

$$1 \quad \hat{r} = \frac{-x\hat{i} + d\hat{j}}{\sqrt{x^2 + d^2}}$$

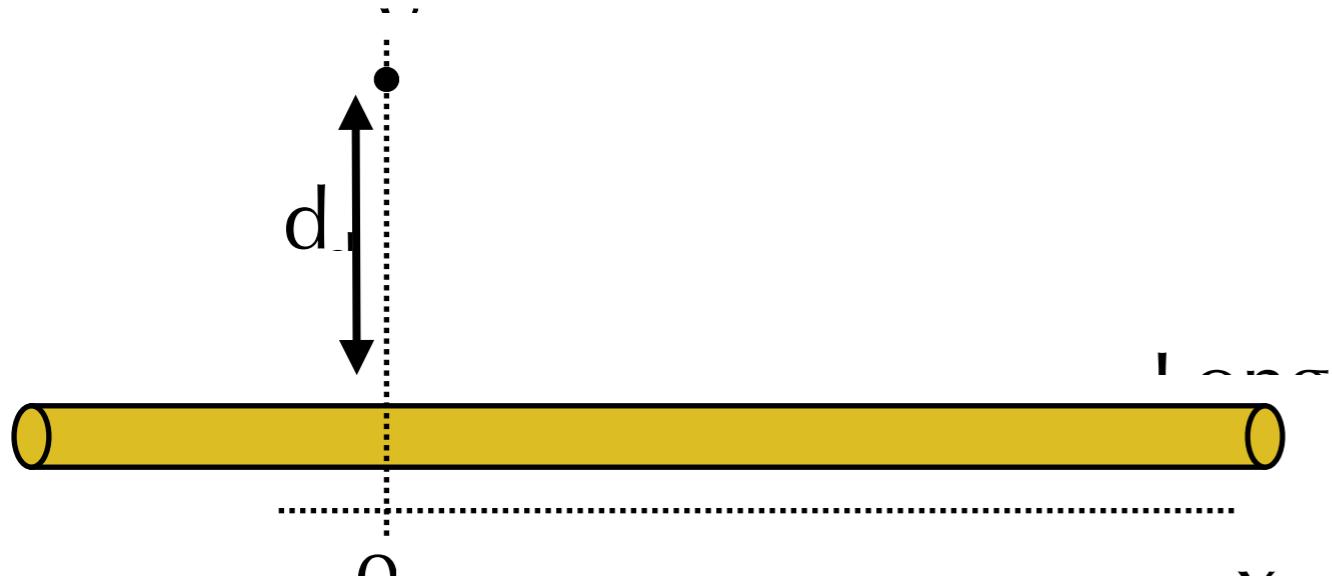
$$2 \quad d\vec{s} = dx\hat{i}$$

$$3 \quad d\vec{s} \times \hat{r} = \frac{ddx}{\sqrt{x^2 + d^2}}$$

$$4 \quad r^2 = x^2 + d^2$$

$$5 \quad \frac{\mu_0 I d}{4\pi} \int_{-\infty}^{\infty} \frac{dx}{(x^2 + d^2)^{3/2}}$$

$$6 \quad \frac{\mu_0 I d}{4\pi} \left| \frac{x}{d^2 \sqrt{x^2 + d^2}} \right|_{-\infty}^{\infty}$$

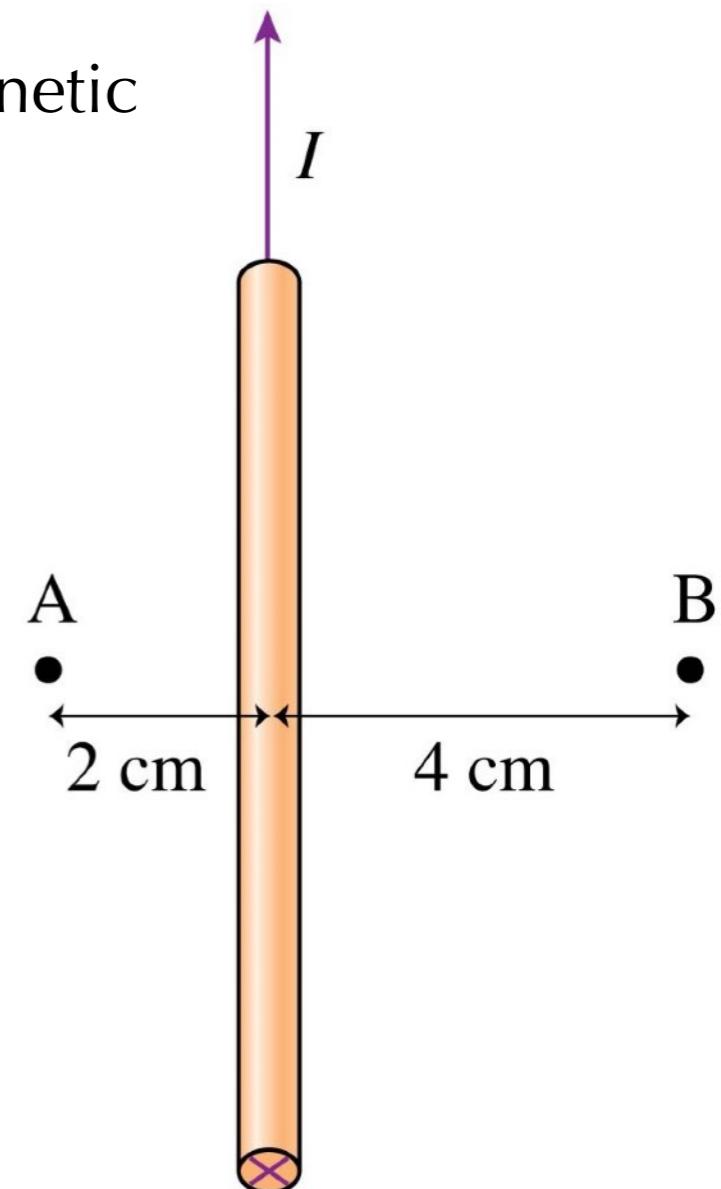


$$\boxed{\vec{B} = \frac{\mu_0 I}{2\pi d}}$$

Question #29

Compared to the magnetic field at point A, the magnetic field at point B is

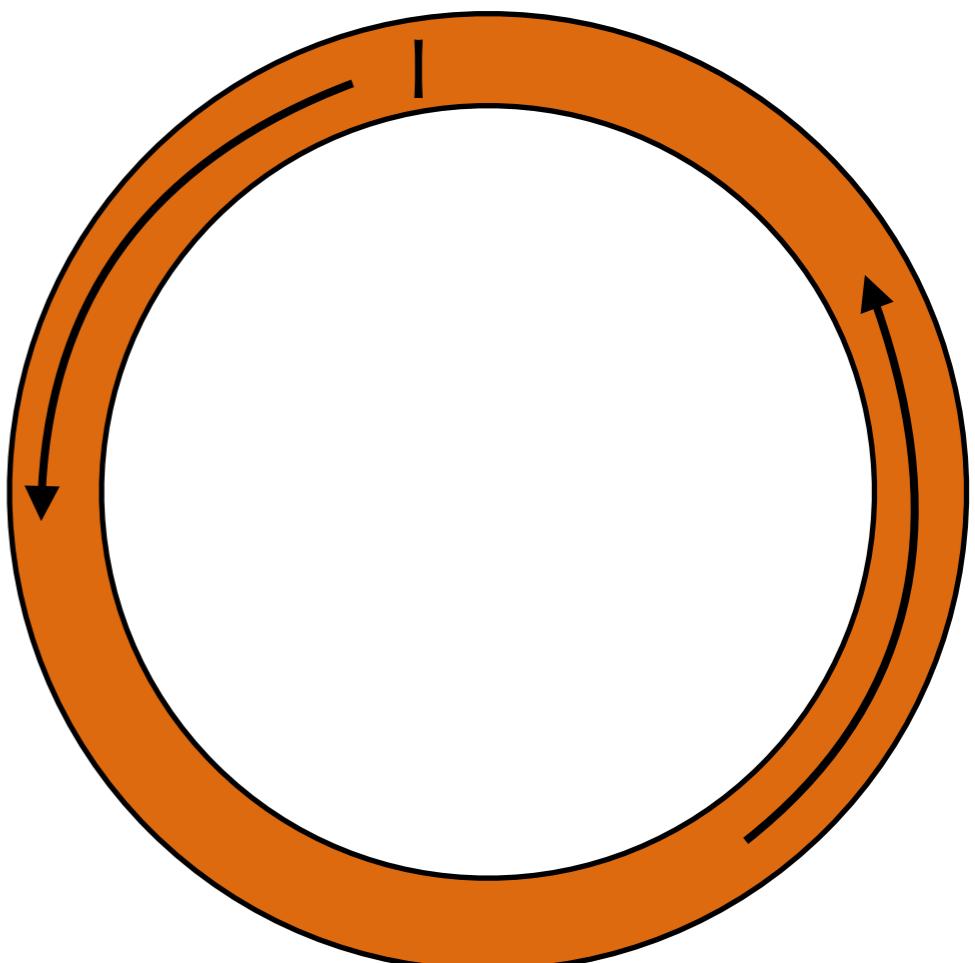
- A. Half as strong, same direction.
- B. Can't compare without knowing I .
- C. One-quarter as strong, same direction.
- D. One-quarter as strong, opposite direction.
- E. Half as strong, opposite direction.



Question #30

What will be the direction of the magnetic field inside the ring and outside the ring?

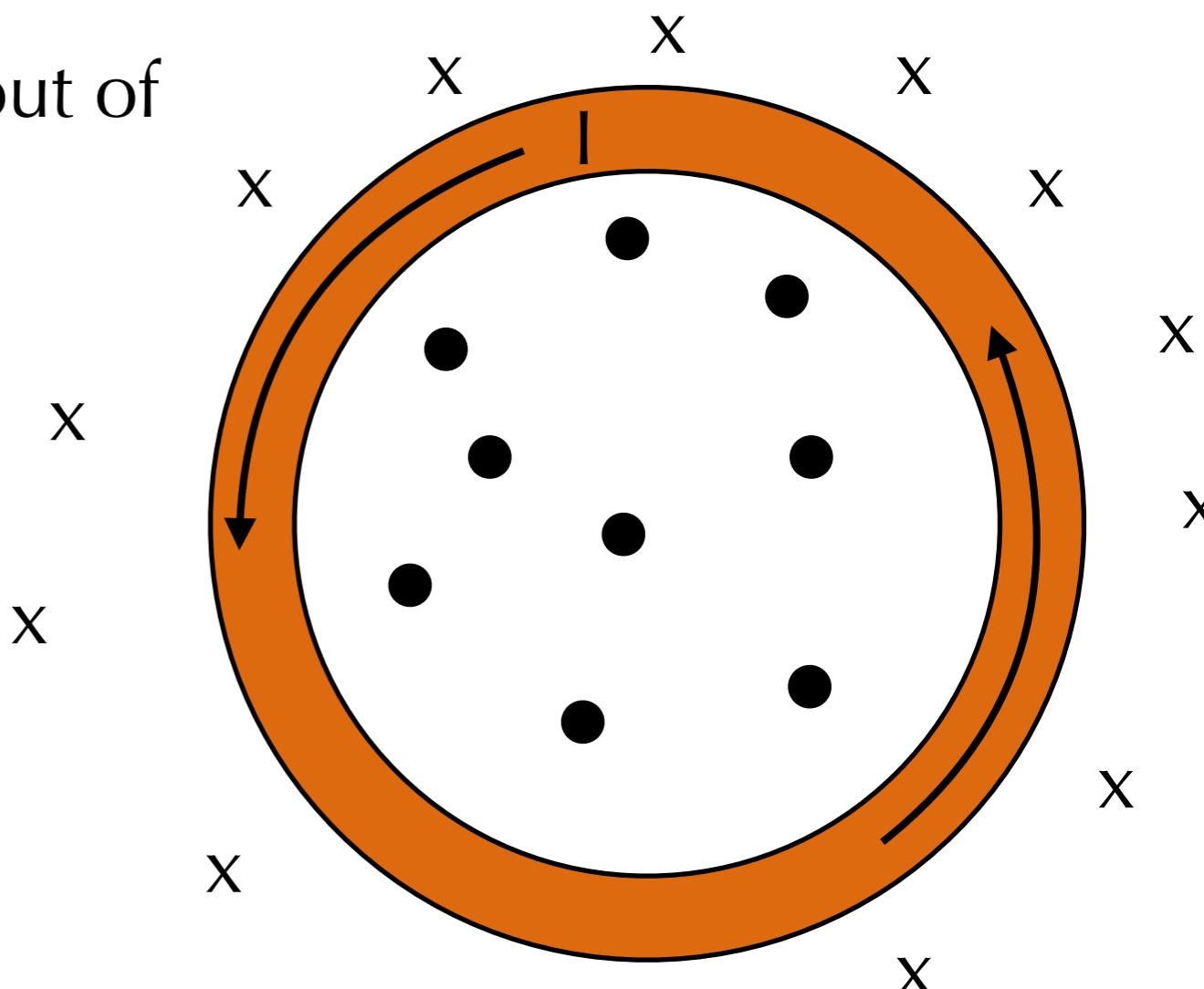
- A Inside: into the screen. Outside: into the screen
- B Inside: out of the screen. Outside: into the screen
- C Inside: into the screen. Outside: out of the screen
- D Inside: into the screen. Outside: out of the screen



Question #30

What will be the direction of the magnetic field inside the ring and outside the ring?

- A Inside: into the screen. Outside: into the screen
- B Inside: out of the screen. Outside: into the screen
- C Inside: into the screen. Outside: out of the screen
- D Inside: into the screen. Outside: out of the screen



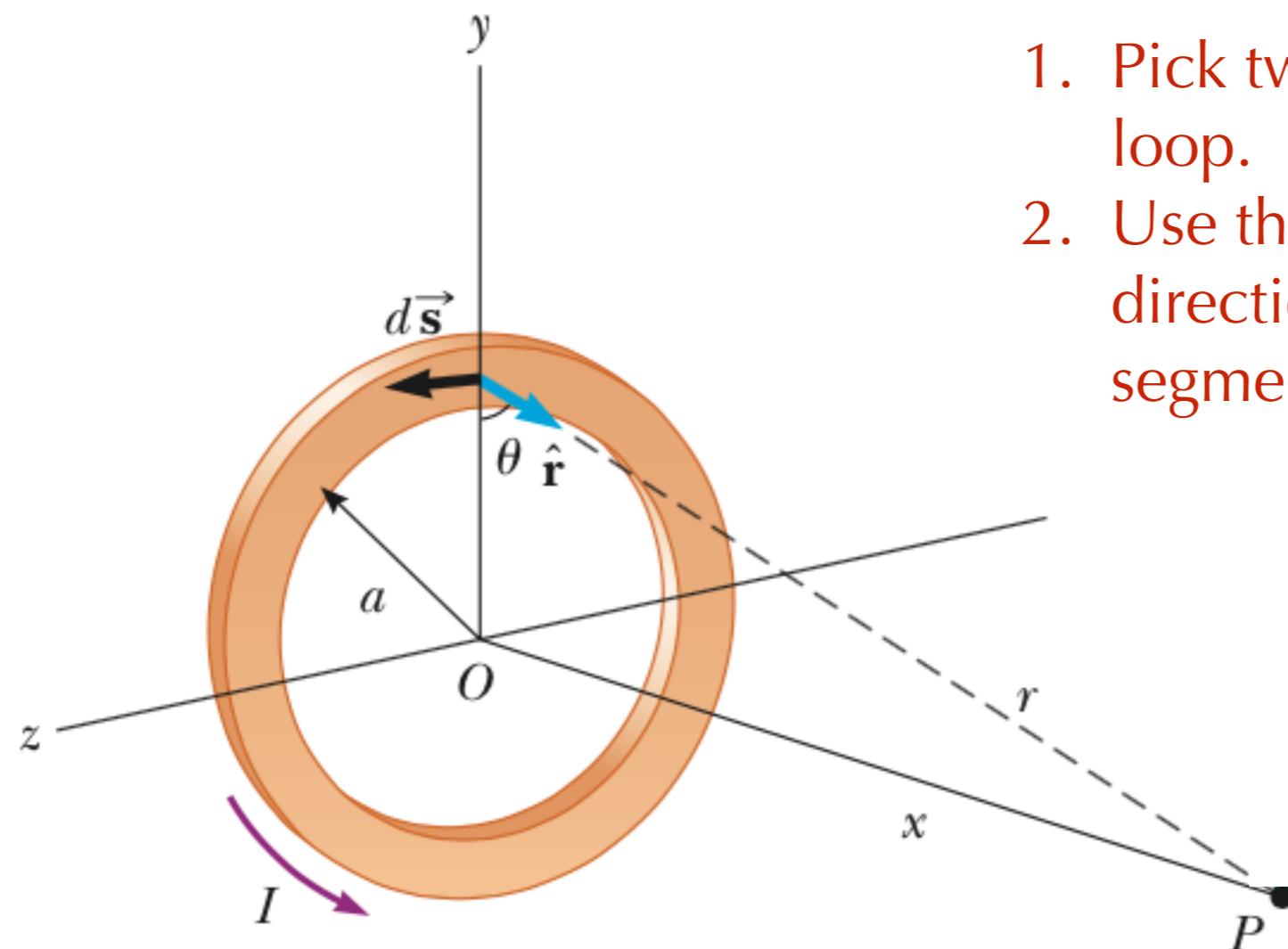
What will be the direction of the magnetic field at the points below?



magnetic field at the

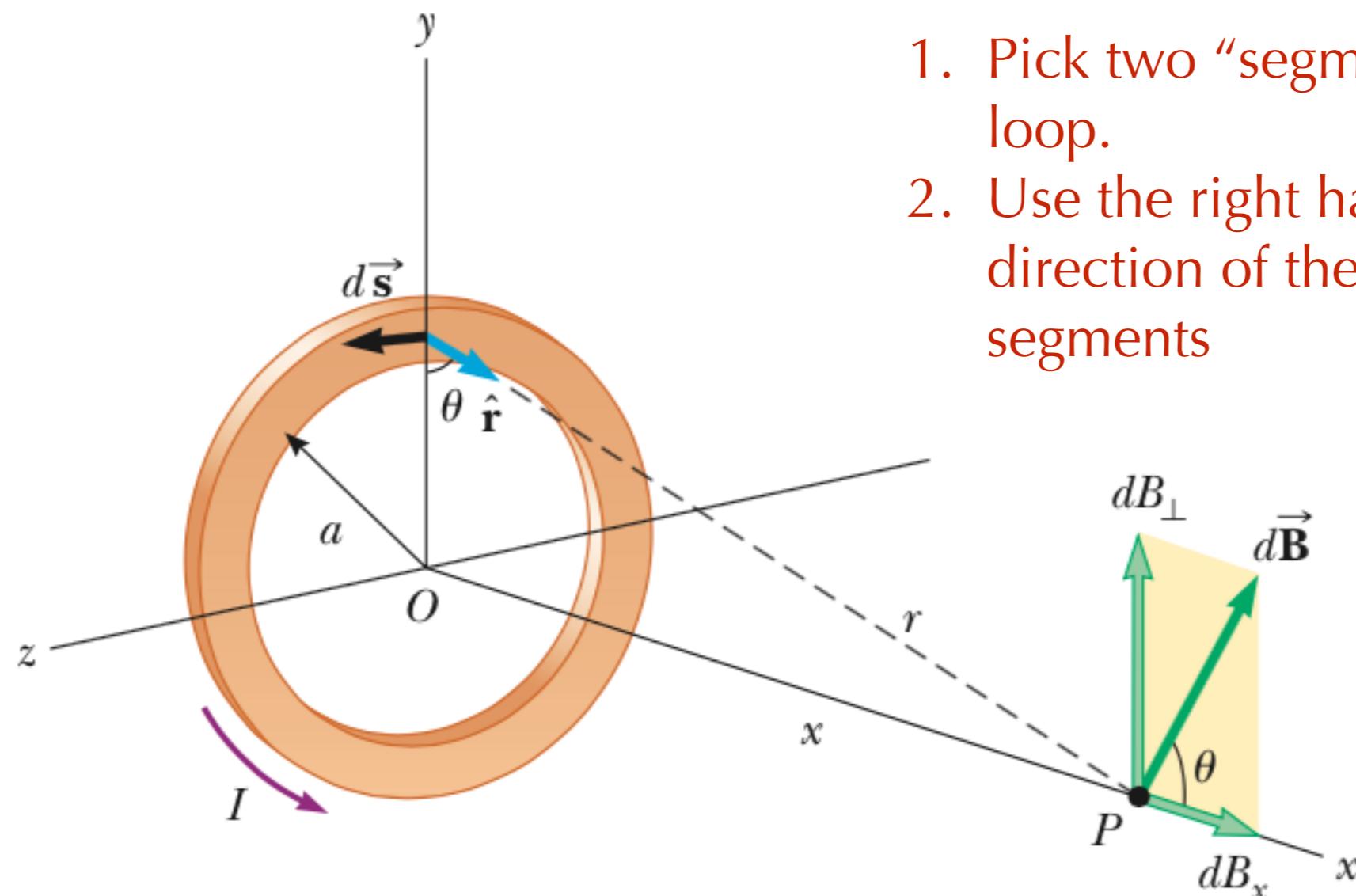


Current Loop



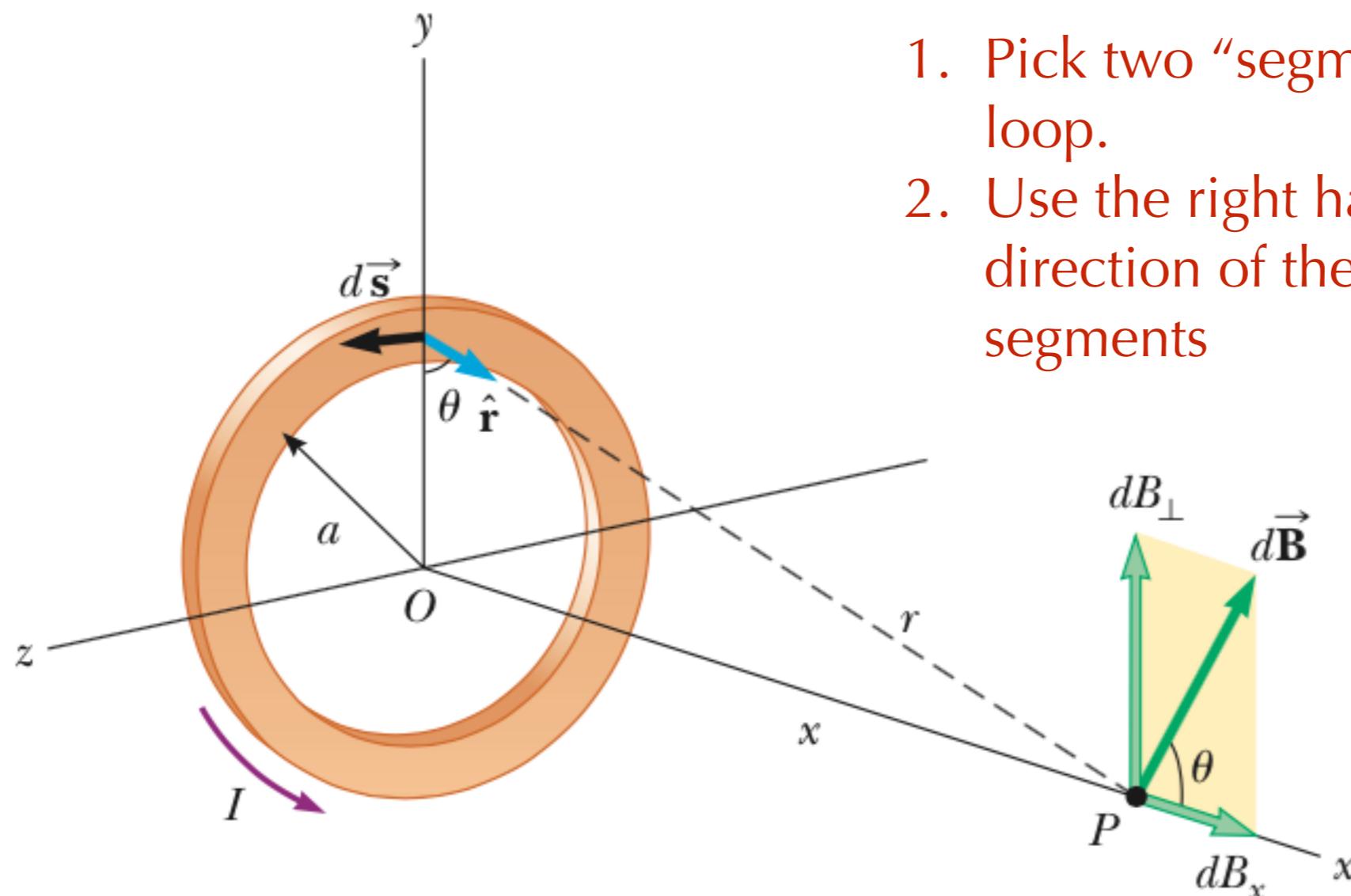
1. Pick two “segments” of current on the loop.
2. Use the right hand rule to determine the direction of the B-field due to those two segments

Current Loop



1. Pick two “segments” of current on the loop.
2. Use the right hand rule to determine the direction of the B-field due to those two segments

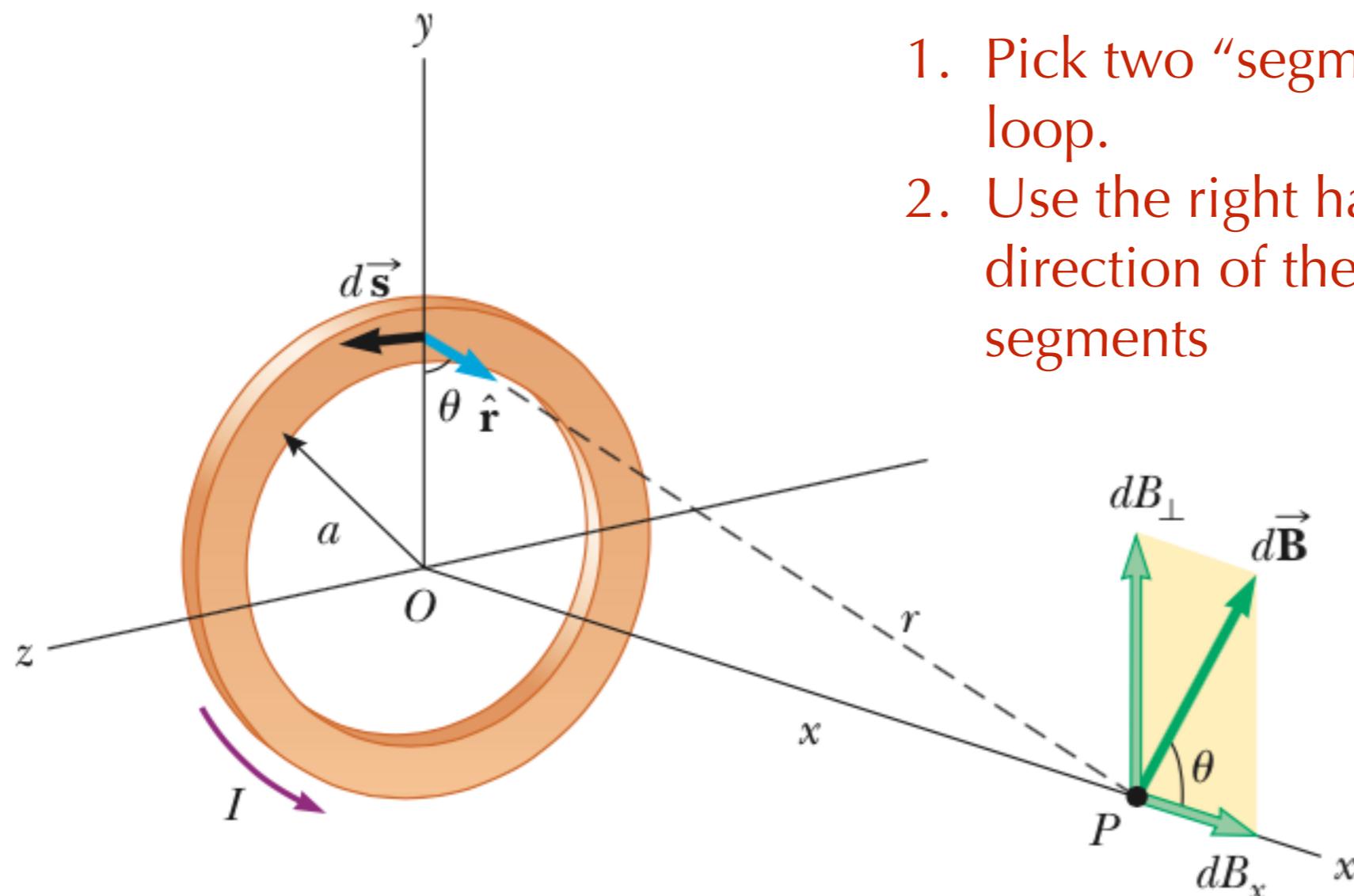
Current Loop



1. Pick two “segments” of current on the loop.
2. Use the right hand rule to determine the direction of the B-field due to those two segments

$$B = \frac{\mu_0}{2} \frac{IR^2}{(z^2 + R^2)^{3/2}}$$

Current Loop

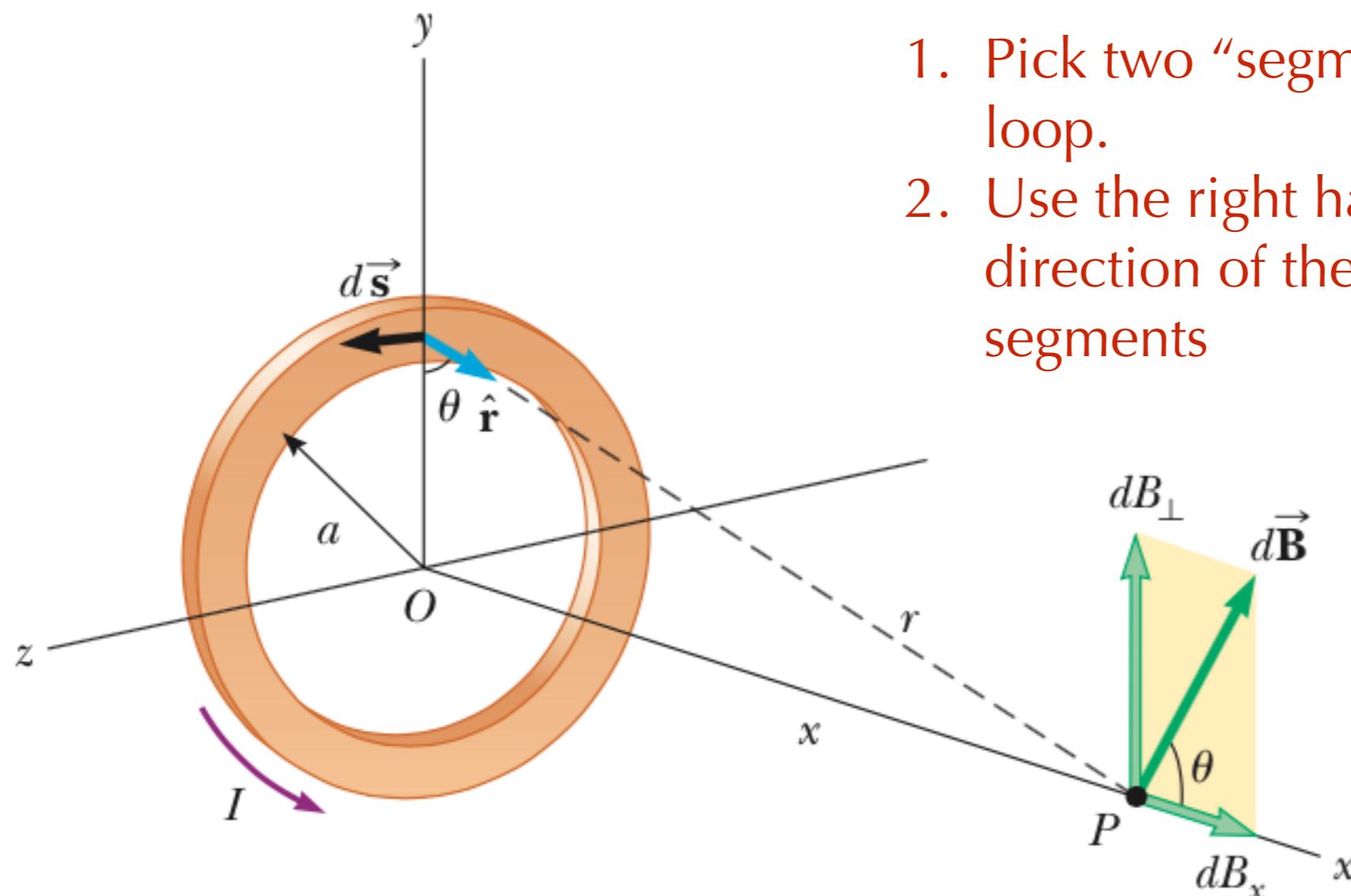


1. Pick two “segments” of current on the loop.
2. Use the right hand rule to determine the direction of the B-field due to those two segments

$$B = \frac{\mu_0}{2} \frac{IR^2}{(z^2 + R^2)^{3/2}}$$

Will the field at the center of the ring be stronger or weaker than away from the center?

Current Loop



1. Pick two “segments” of current on the loop.
2. Use the right hand rule to determine the direction of the B-field due to those two segments

$$B = \frac{\mu_0}{2} \frac{IR^2}{(z^2 + R^2)^{3/2}}$$

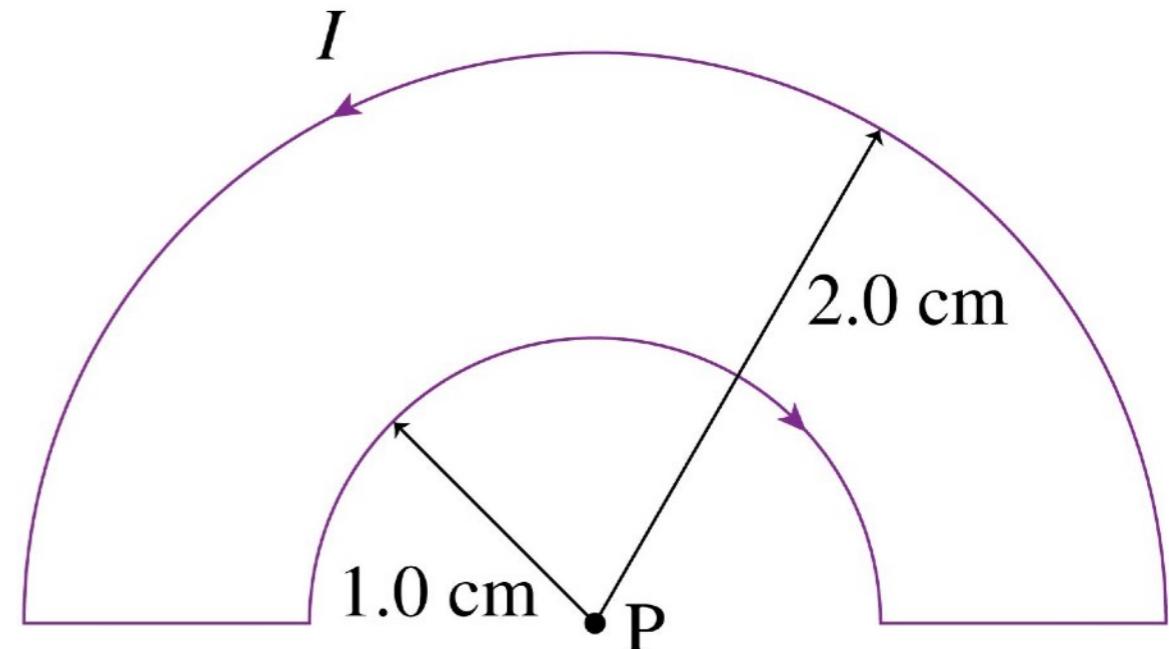
$$B = \frac{\mu_0 I}{2R}$$

Will the field at the center of the ring be stronger or weaker than away from the center?

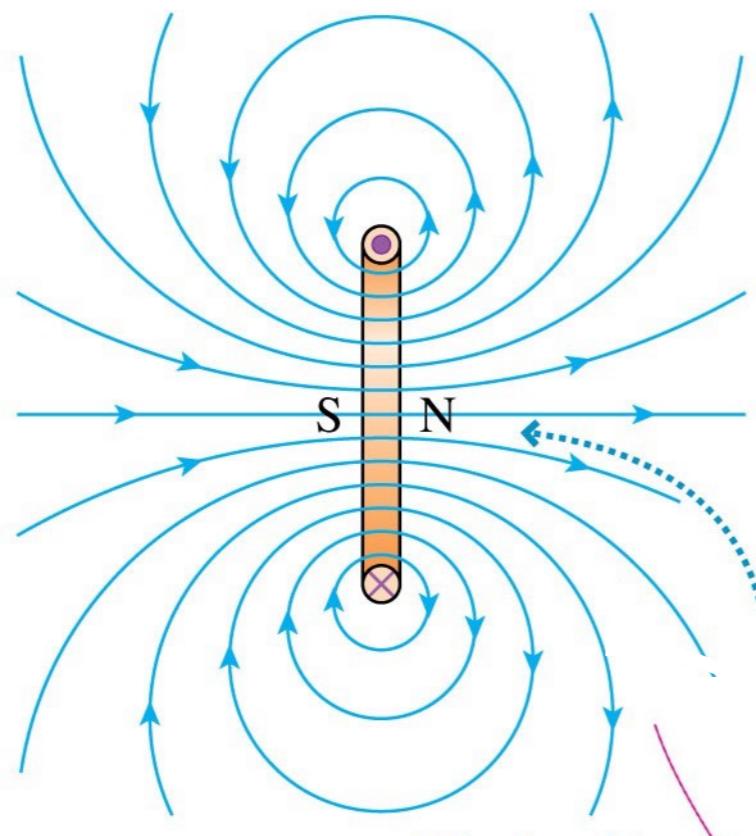
Question #31

The magnet field at point P is

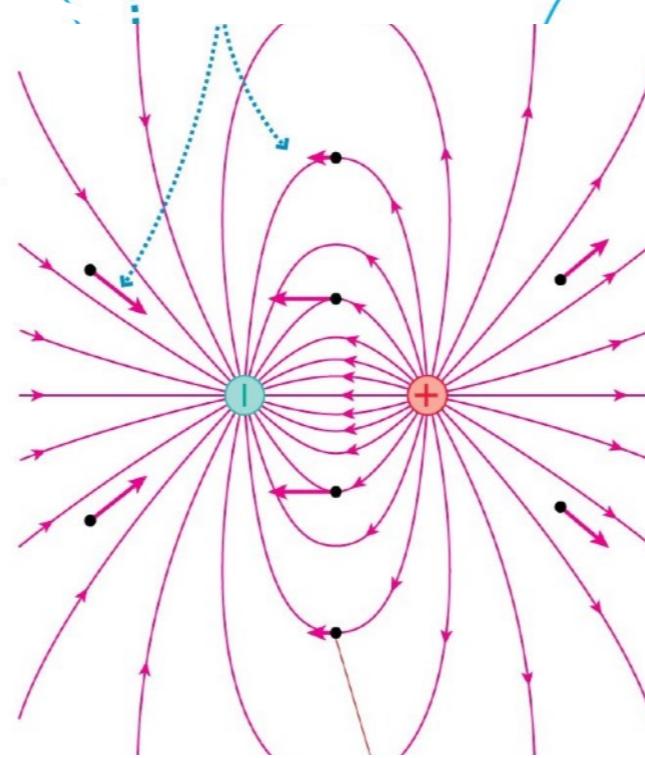
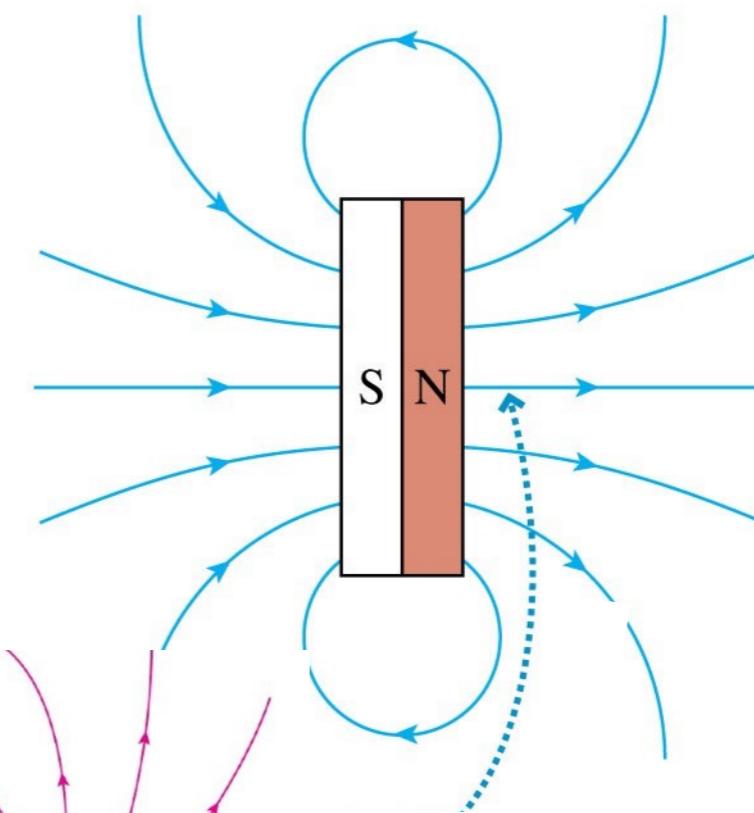
- A. Out of the screen.
- B. Into the screen.
- C. Zero.



Current Loop



Permanent Magnet



Electric Dipole

Question #32

Where is the north magnetic pole of this current loop?

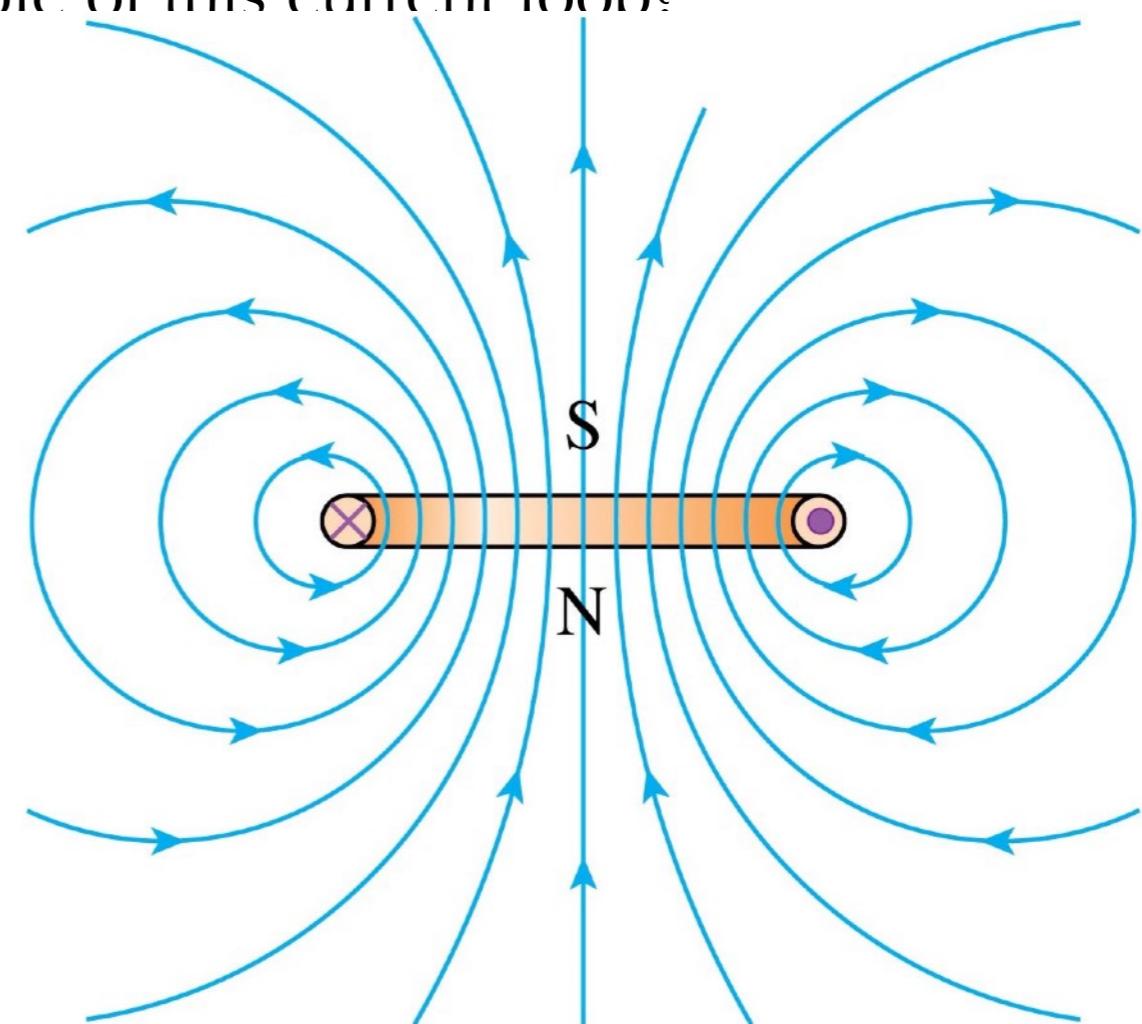
- A. Top side.
- B. Right side.
- C. Bottom side.
- D. Left side.
- E. Current loops don't have north poles.



Question #32

Where is the north magnetic pole of this current loop?

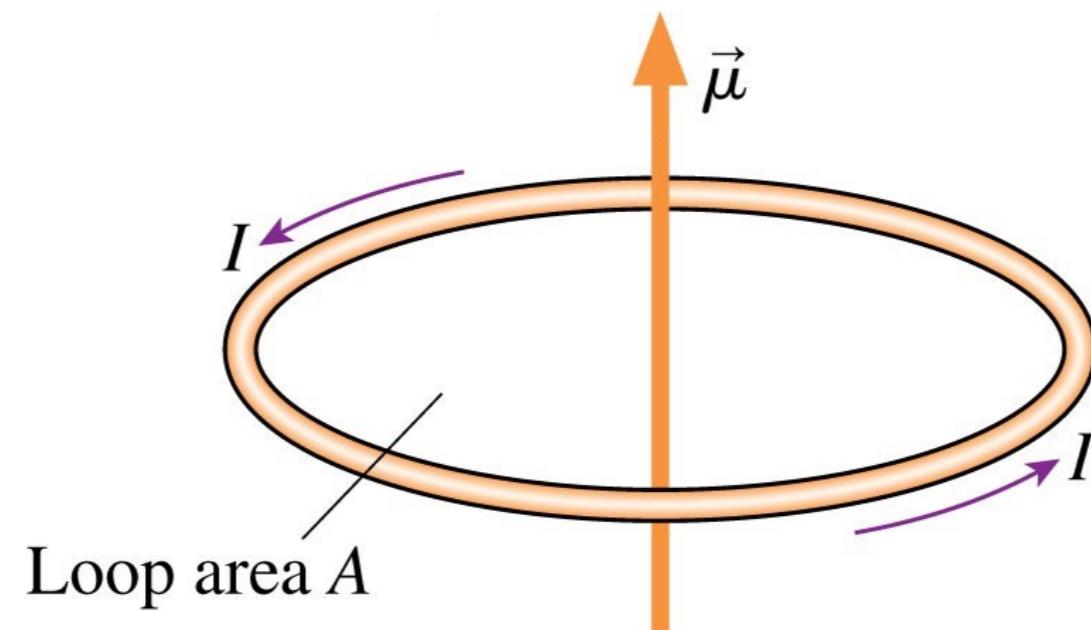
- A. Top side.
- B. Right side.
- C. Bottom side.
- D. Left side.
- E. Current loops don't have north poles.



The dipole moment

$$B = \frac{\mu_0}{2} \frac{IR^2}{(z^2 + R^2)^{3/2}}$$

If z is much bigger than R what does this expression reduce to?

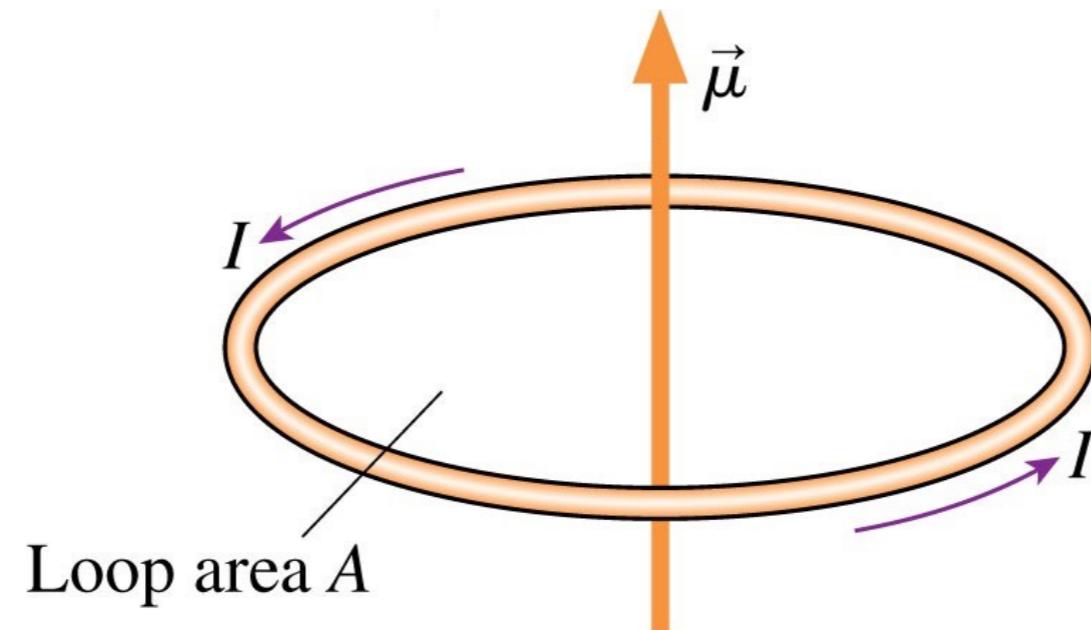


$$\vec{\mu} = (AI, \text{ from the south pole to the north pole})$$

The dipole moment

$$B = \frac{\mu_0}{2} \frac{IR^2}{(z^2 + R^2)^{3/2}}$$

If z is much bigger than R what does this expression reduce to?

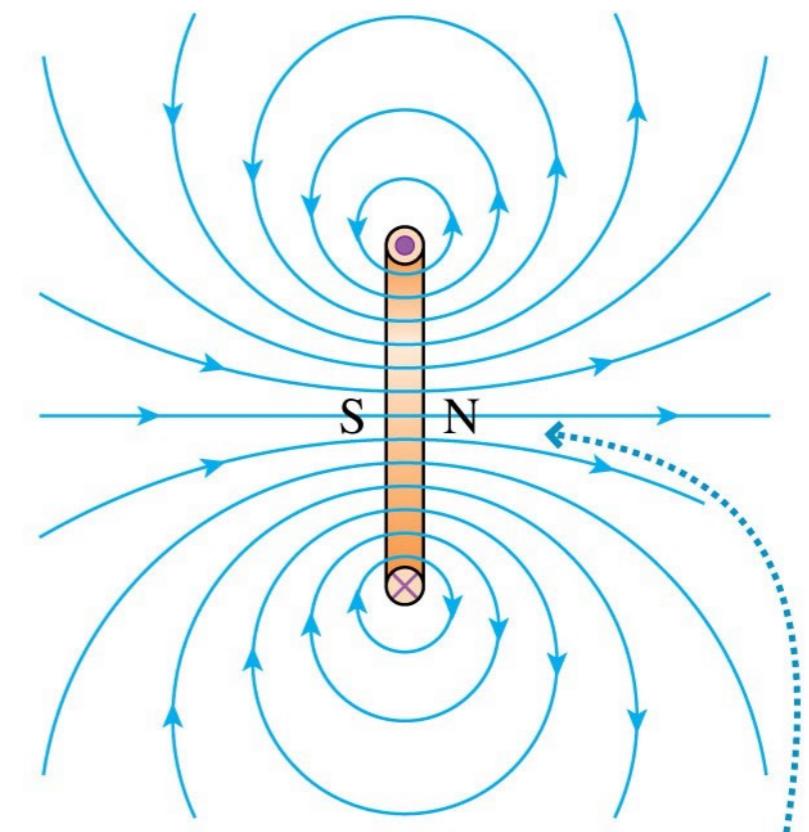


$$\vec{\mu} = (AI, \text{ from the south pole to the north pole})$$

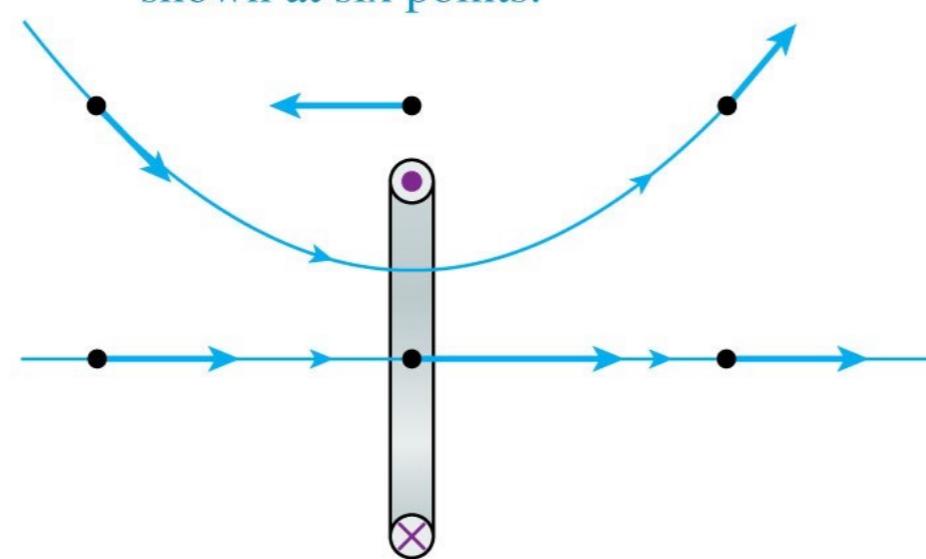
$$\vec{B}_{\text{dipole}} = \frac{\mu_0}{4\pi} \frac{2\vec{\mu}}{z^3} \quad (\text{on the axis of a magnetic dipole})$$

What if I put multiple coils next to each other?

Draw two more coils on either side of this one and determine the strength and direction of the magnetic field inside and outside of the coils.

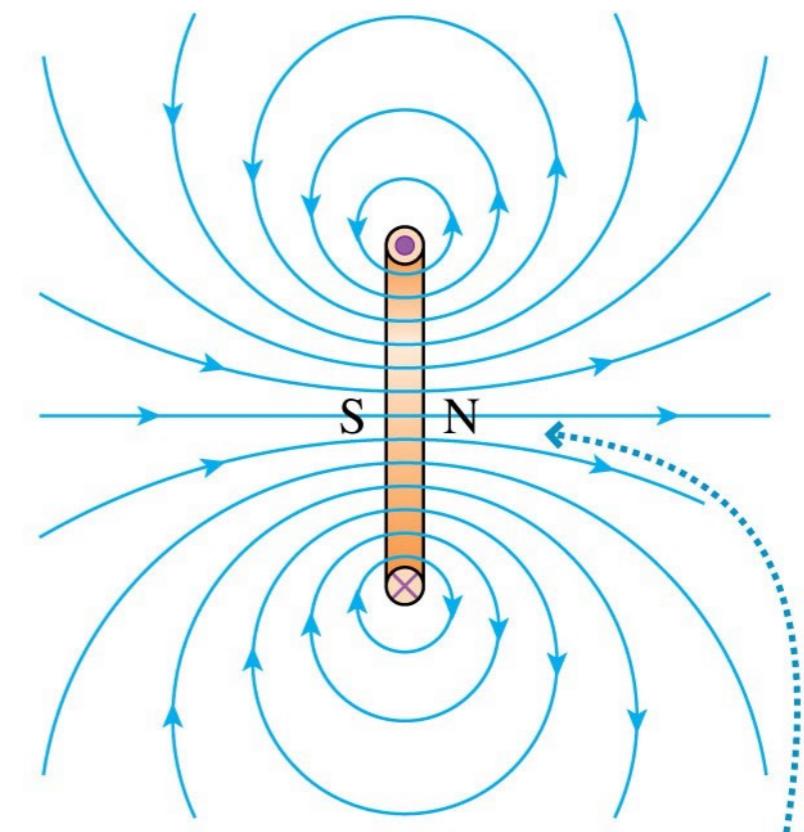


shown at six points.

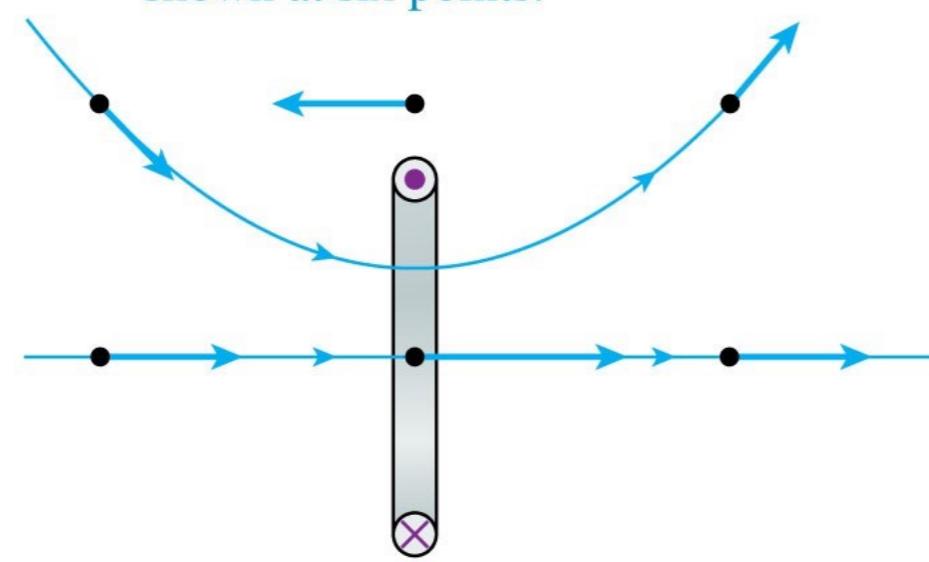


What if I put multiple coils next to each other?

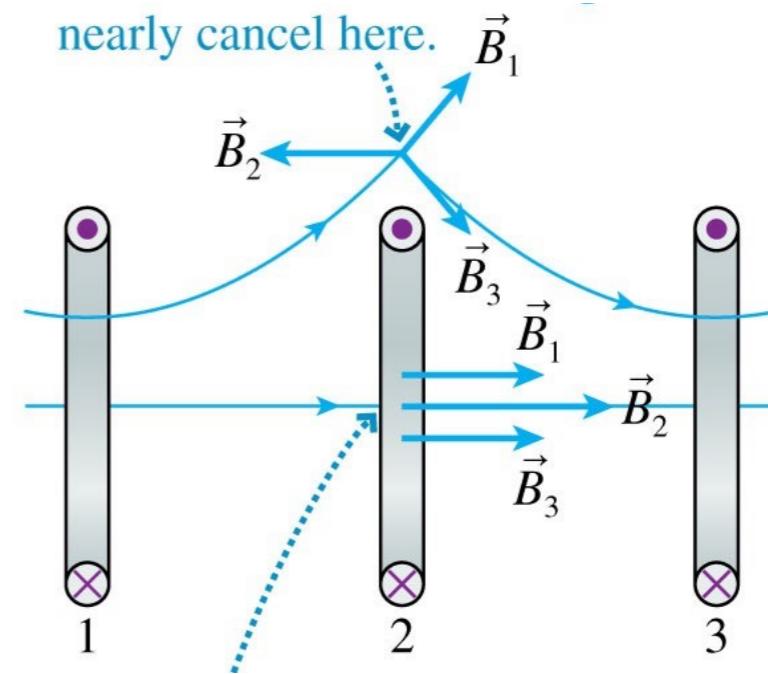
Draw two more coils on either side of this one and determine the strength and direction of the magnetic field inside and outside of the coils.



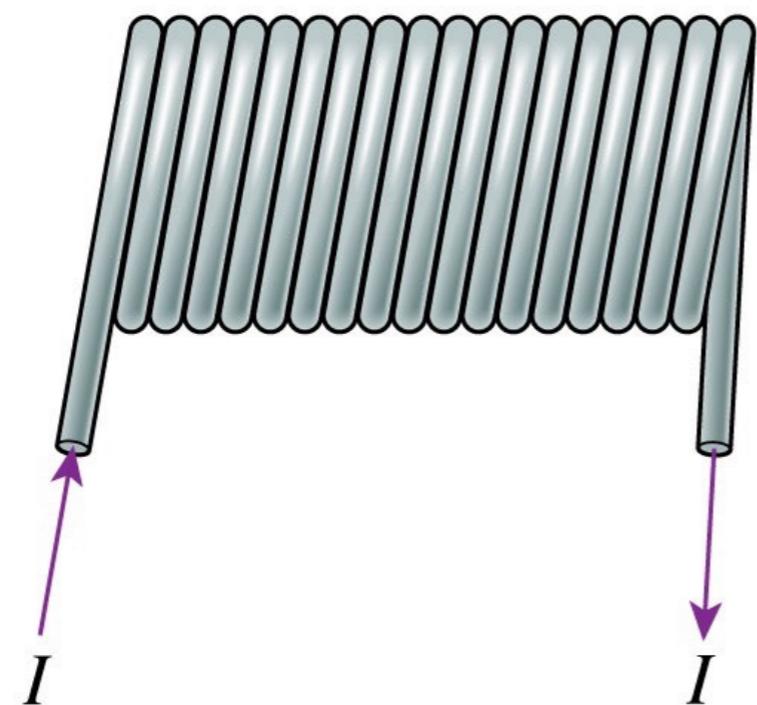
shown at six points.



nearly cancel here.



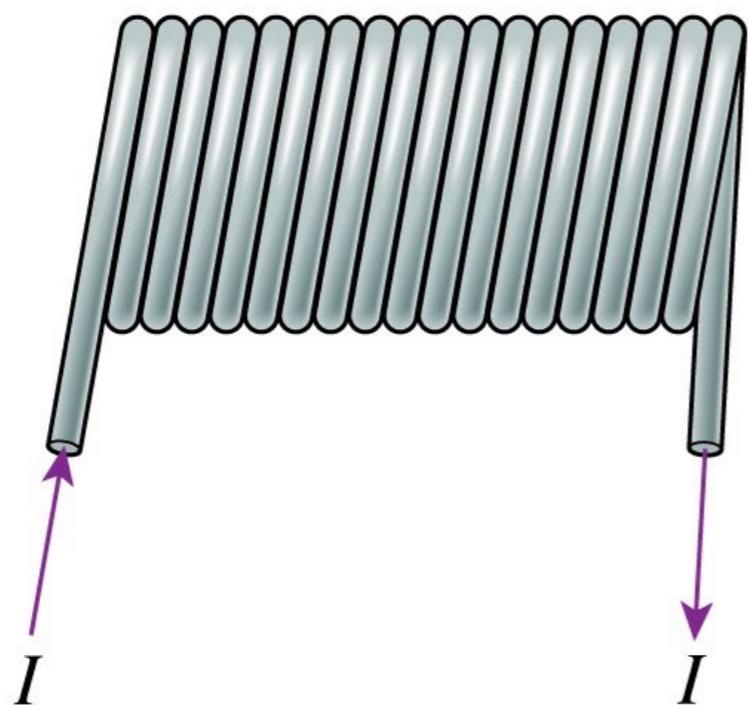
Solenoid



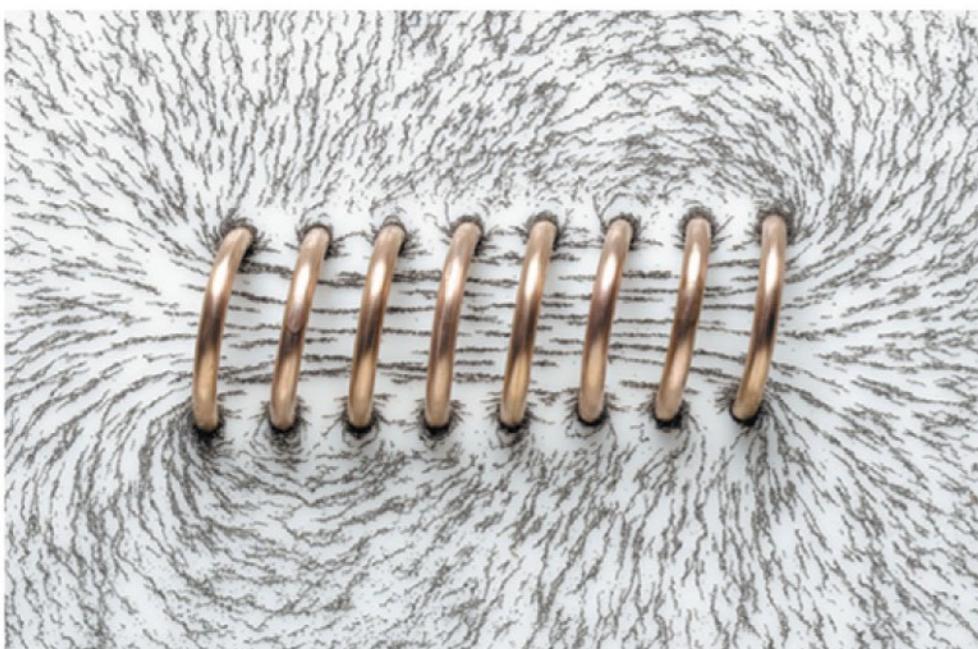
What if I put many coils next to each other.



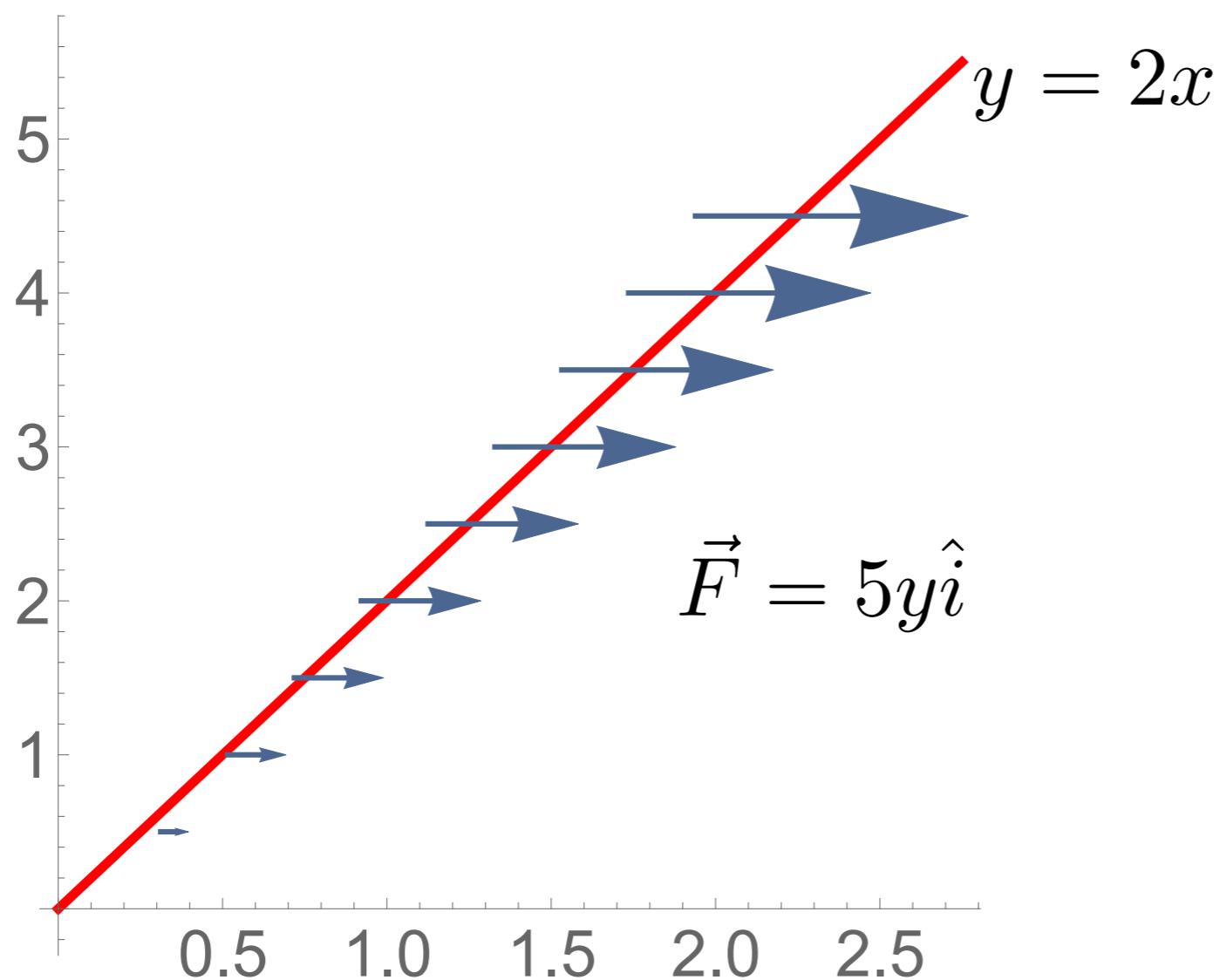
Solenoid



What if I put many coils next to each other.



Intro to Ampere's law

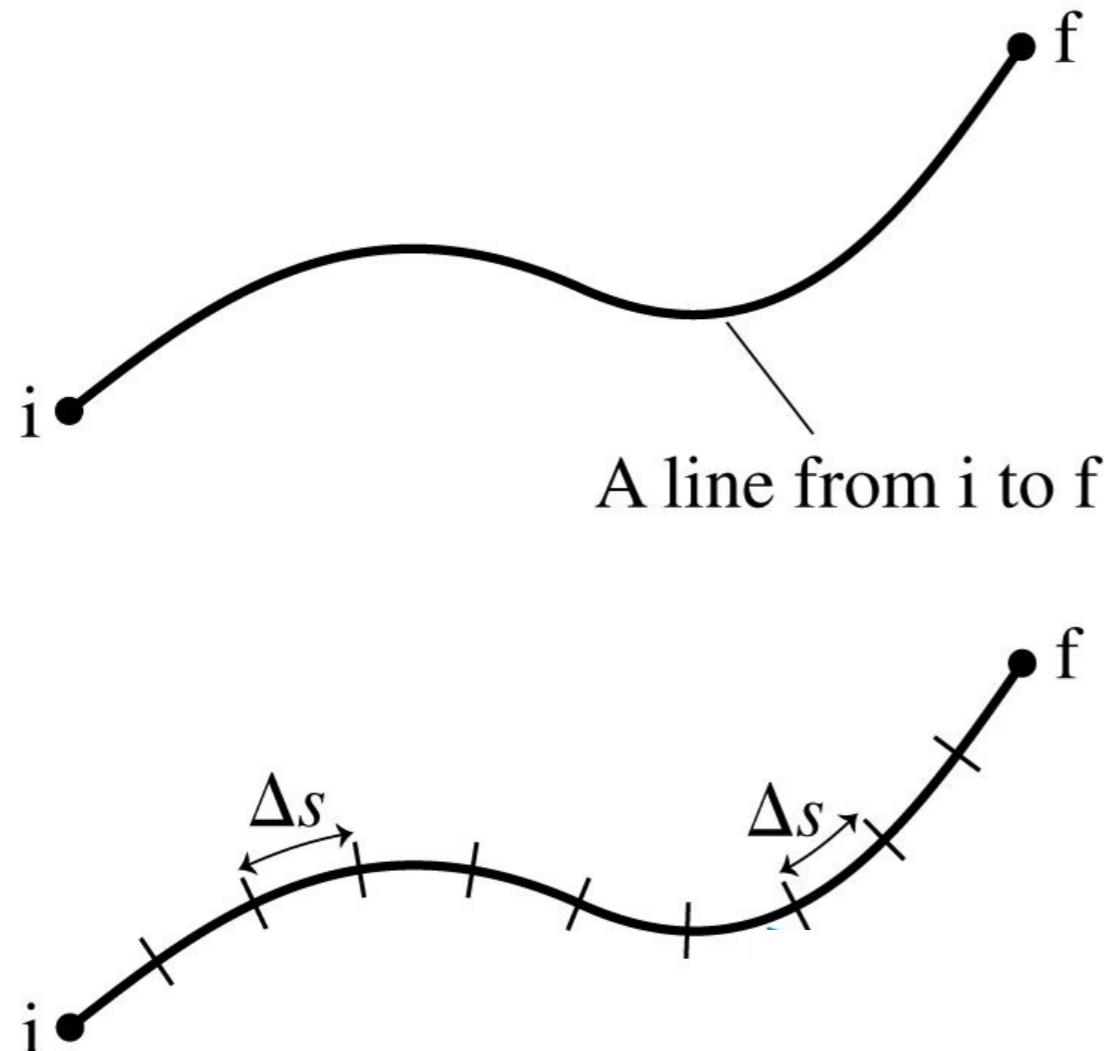


$$\int \vec{F} \cdot d\vec{s}$$

$$d\vec{s} = dx\hat{i} + dy\hat{j}$$

$$x = t \quad y = 2t$$

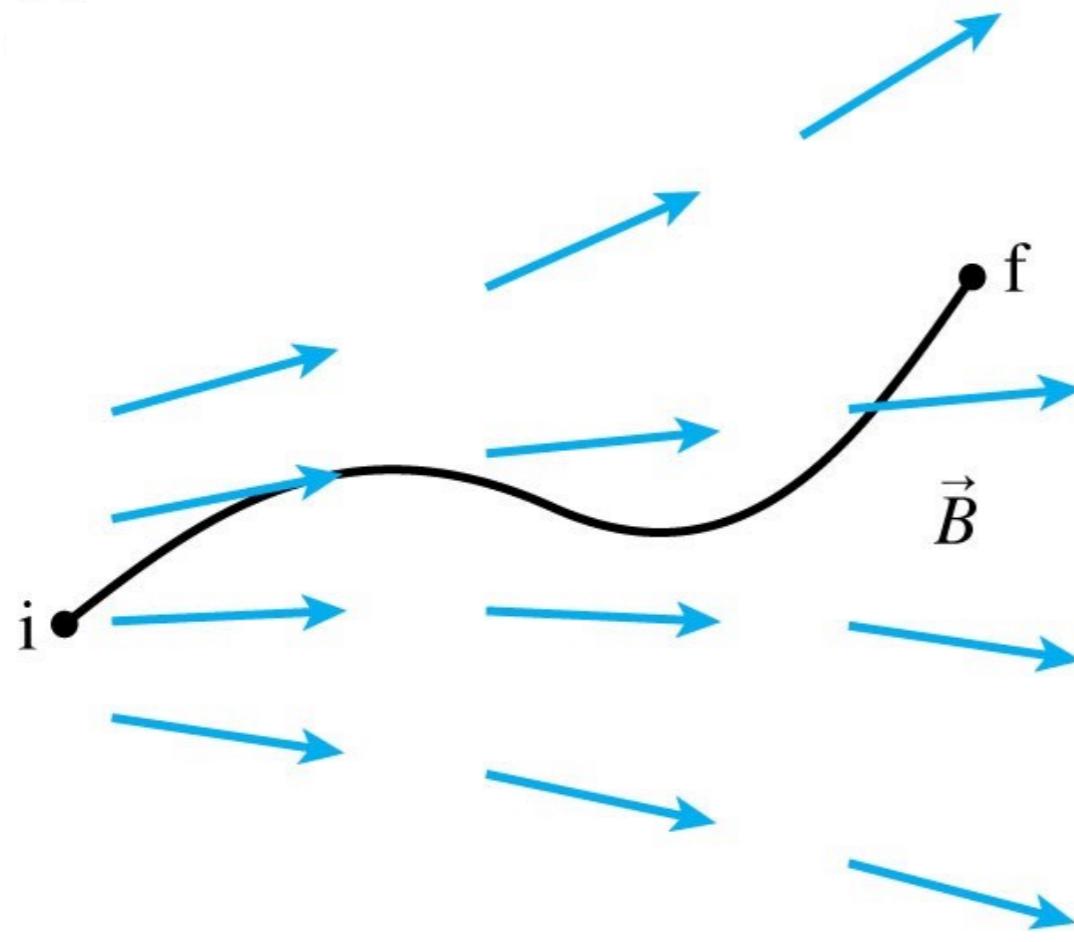
Line Integrals



Calculus Review: How would you find the length of this line?

$$l = \sum_k \Delta s_k \rightarrow \int_i^f ds$$

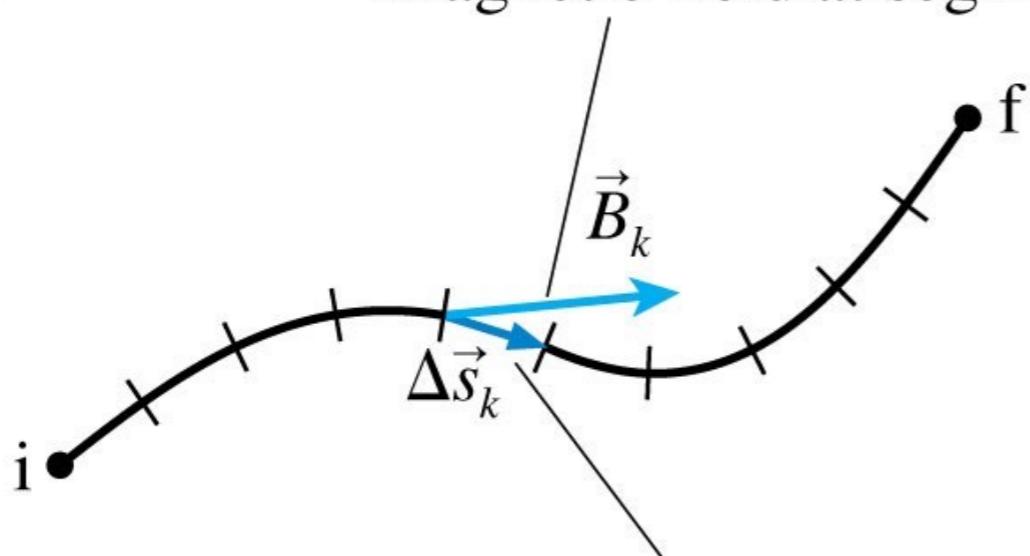
Line Integrals



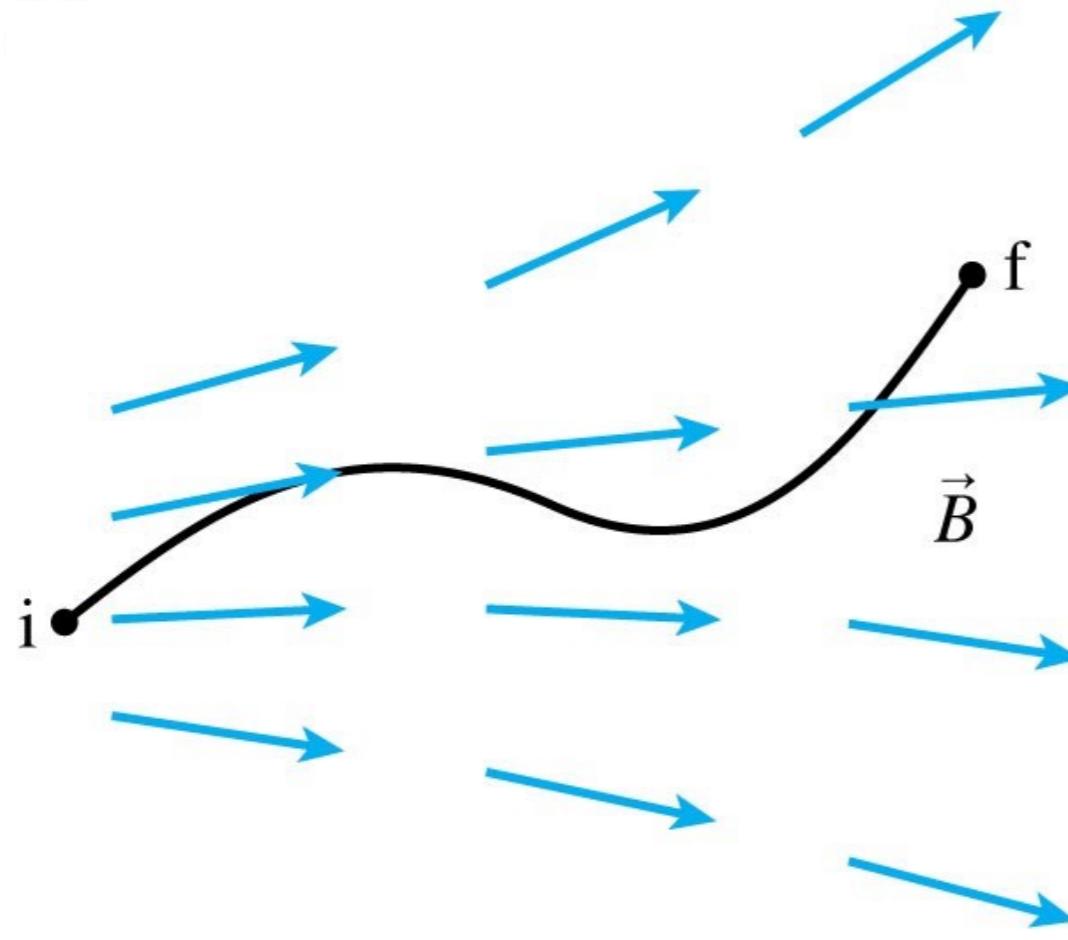
Calculus Review: How would you find the length of this line?

$$l = \sum_k \Delta s_k \rightarrow \int_i^f ds$$

Magnetic field at segment k



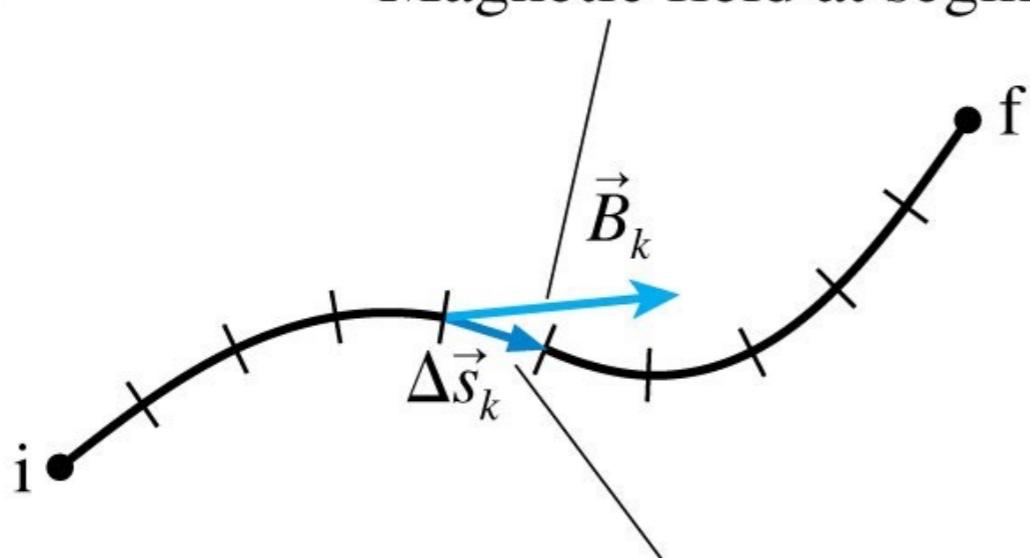
Line Integrals

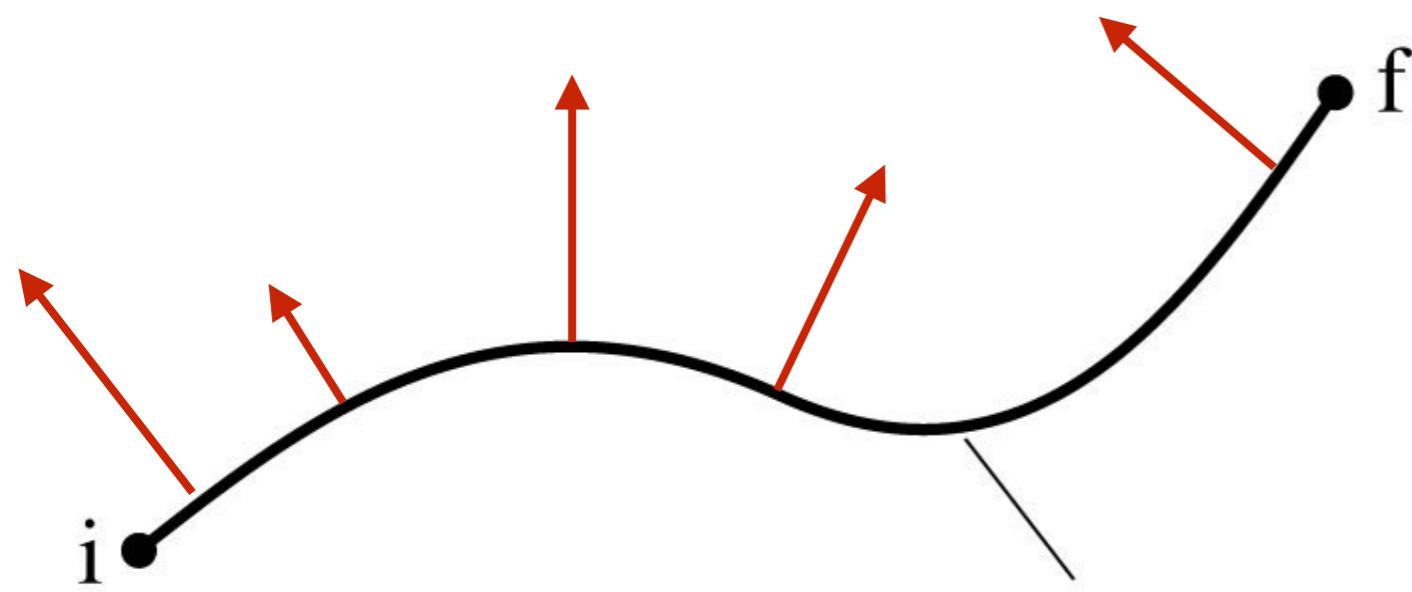


Calculus Review: How would you find the length of this line?

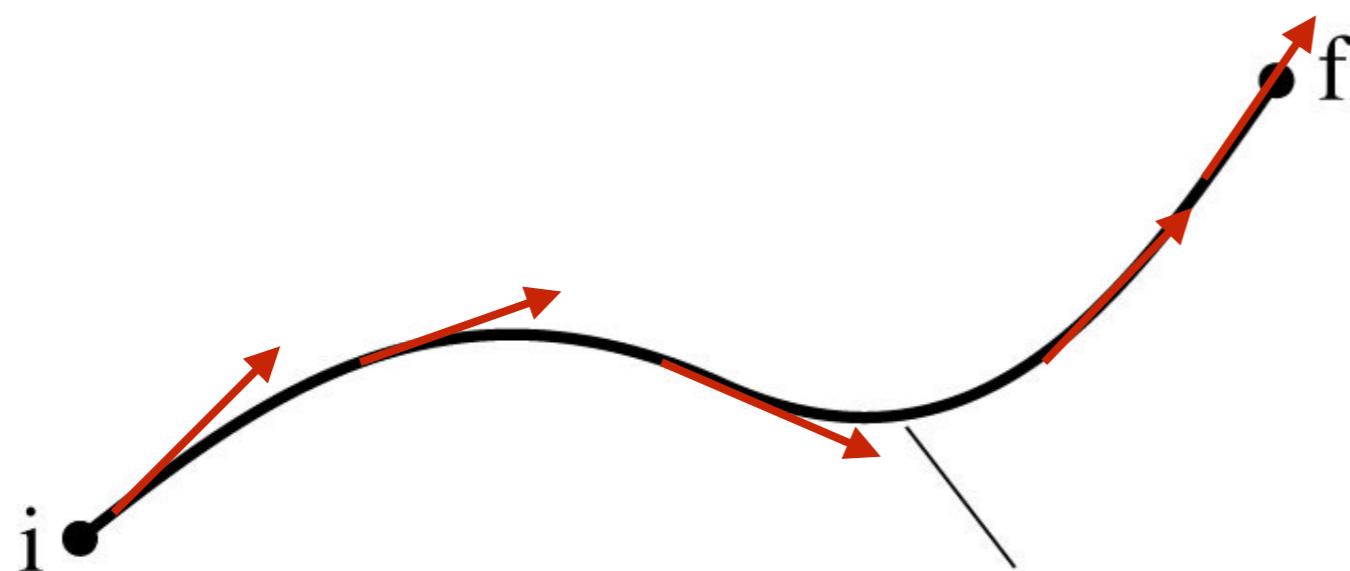
$$\sum_k \vec{B}_k \cdot \Delta \vec{s}_k \rightarrow \int_i^f \vec{B} \cdot d\vec{s}$$

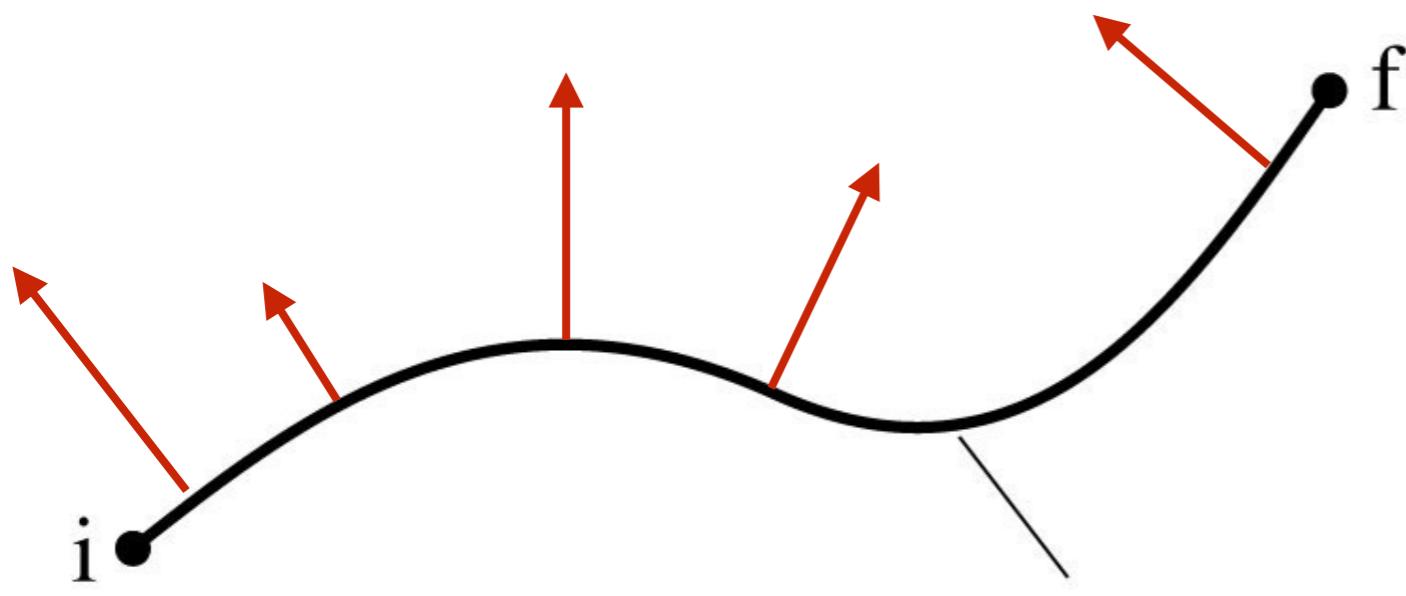
Magnetic field at segment k





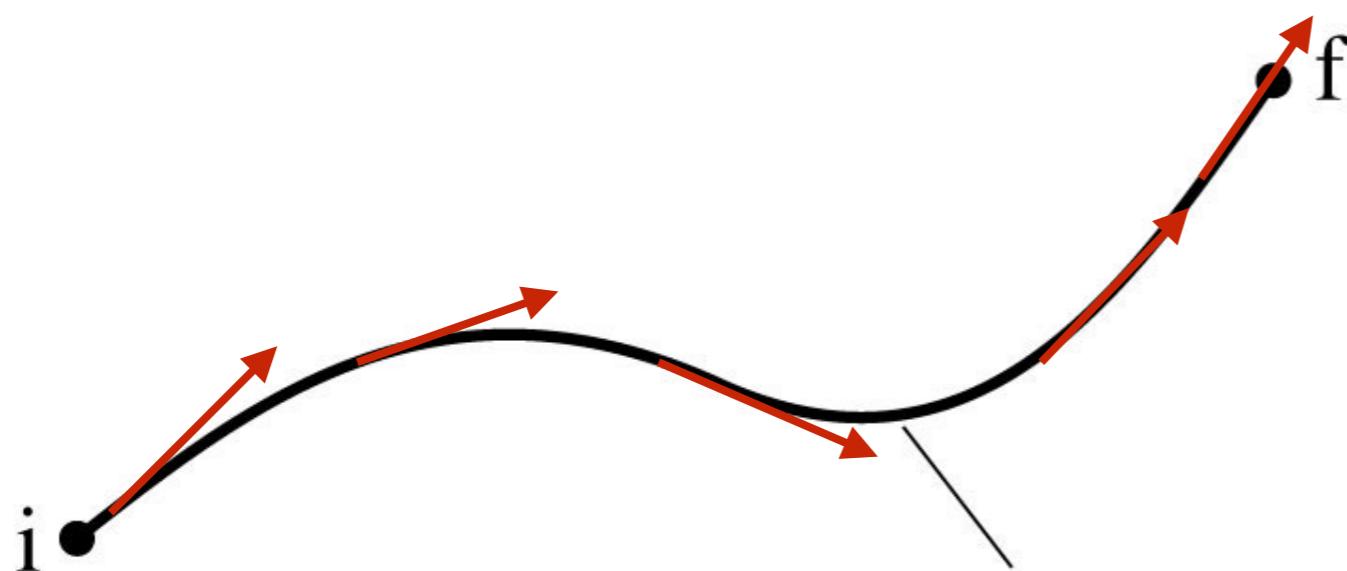
What would these line integrals be?





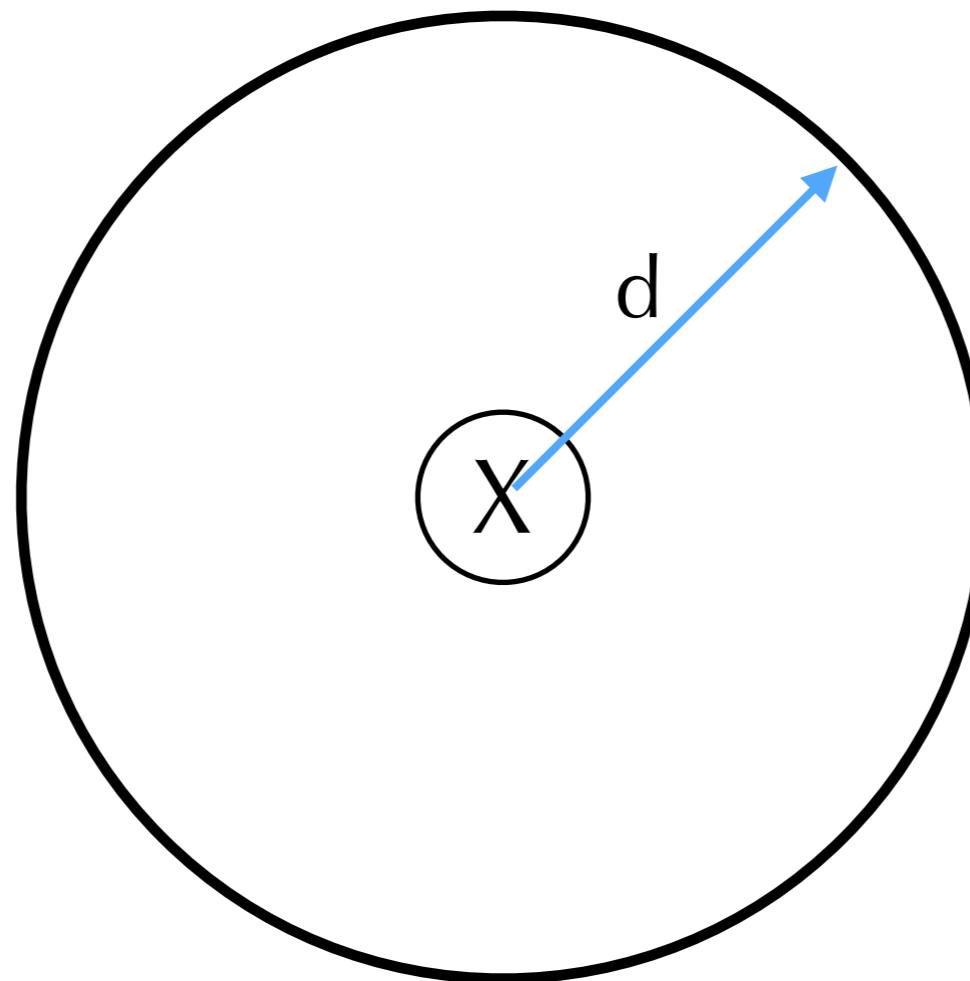
What would these line integrals be?

$$\int_i^f \vec{B} \cdot d\vec{s}$$



Ampere's Law: Like Gauss's law but for magnetism

What is the value of this integral?

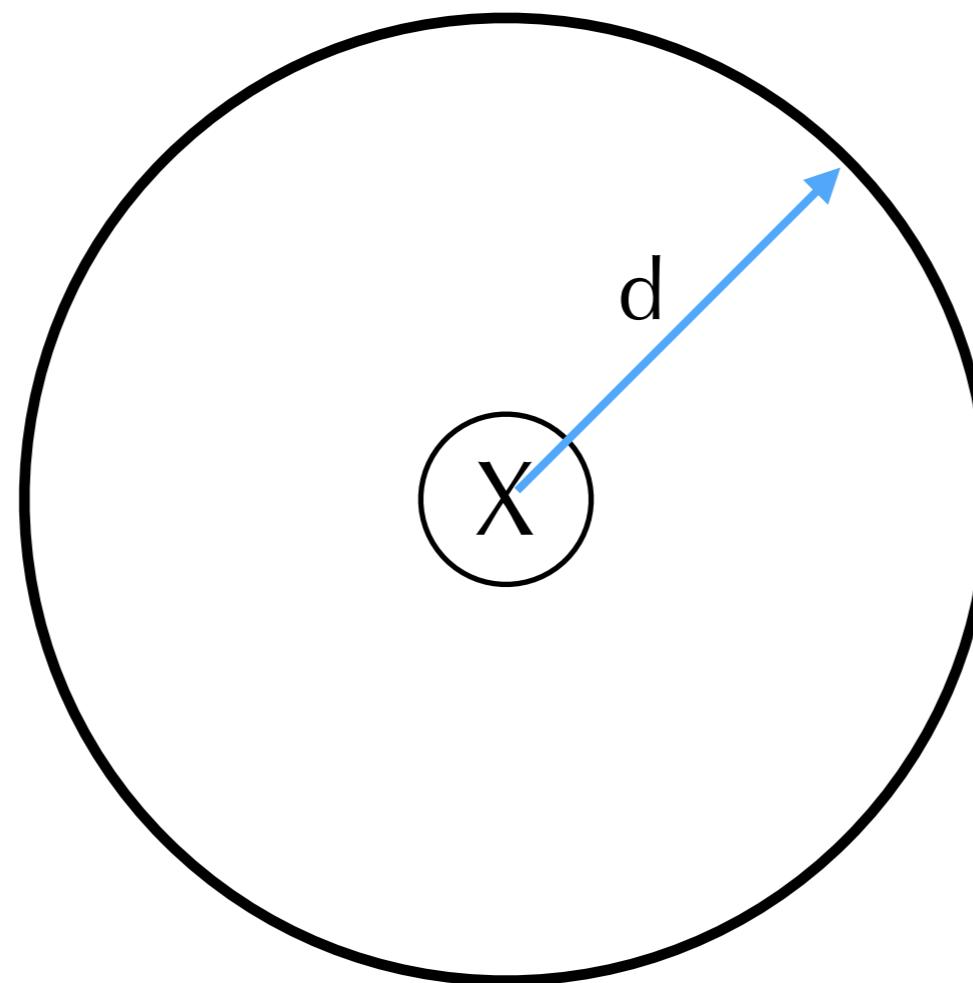


$$\oint \vec{B} \cdot d\vec{s}$$

Ampere's Law: Like Gauss's law but for magnetism

What is the value of this integral?

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$



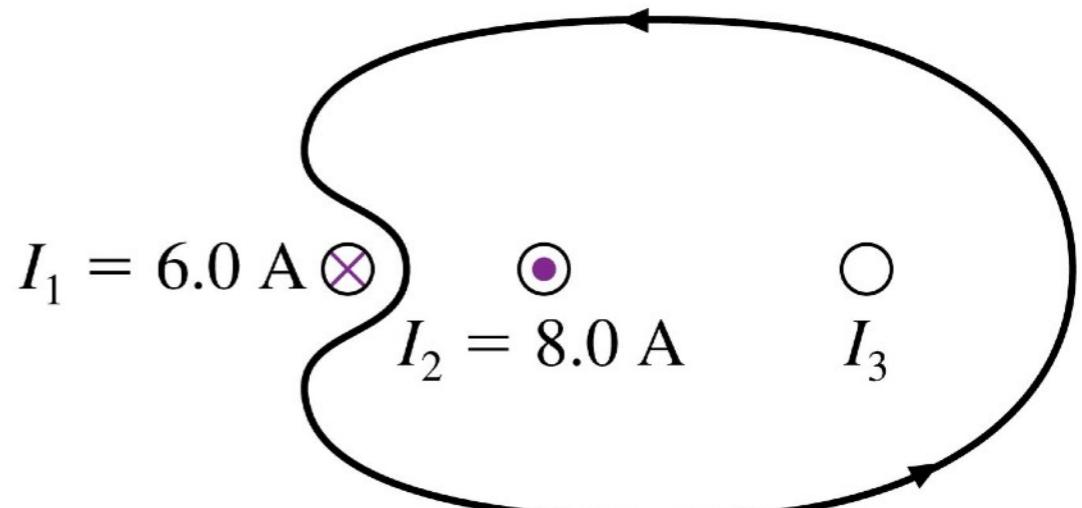
$$\oint \vec{B} \cdot d\vec{s}$$

Question #33

The line integral of B around the loop is $\mu_0 \cdot 7.0 \text{ A}$.

Current I_3 is

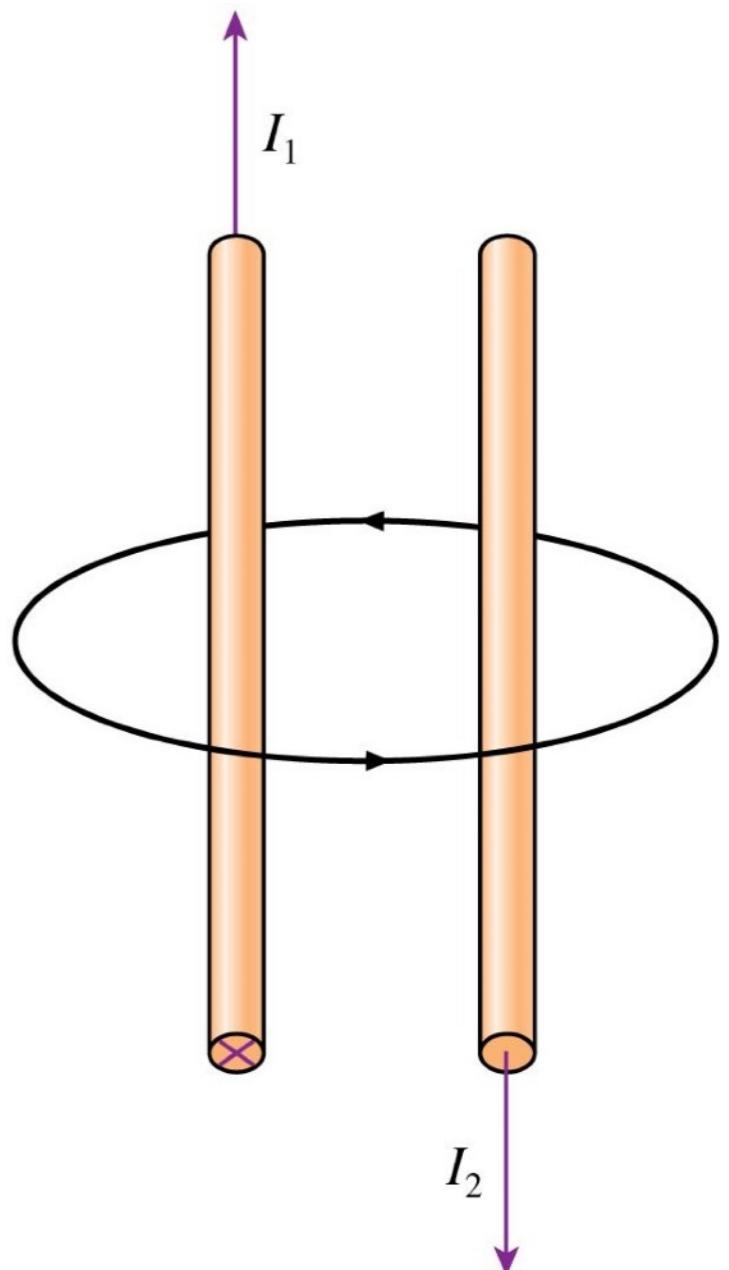
- A. 1 A into the screen.
- B. 1 A out of the screen.
- C. 0 A.
- D. 5 A out of the screen.
- E. 5 A into the screen.



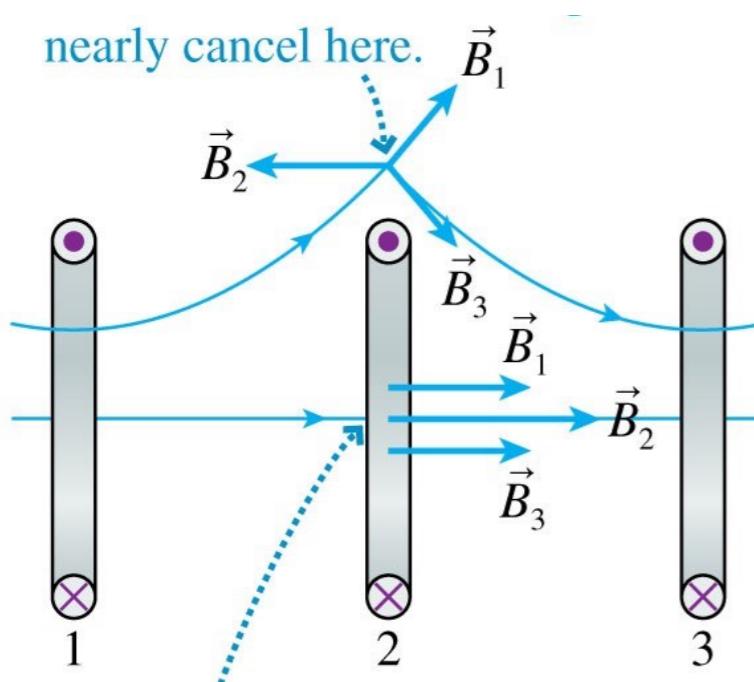
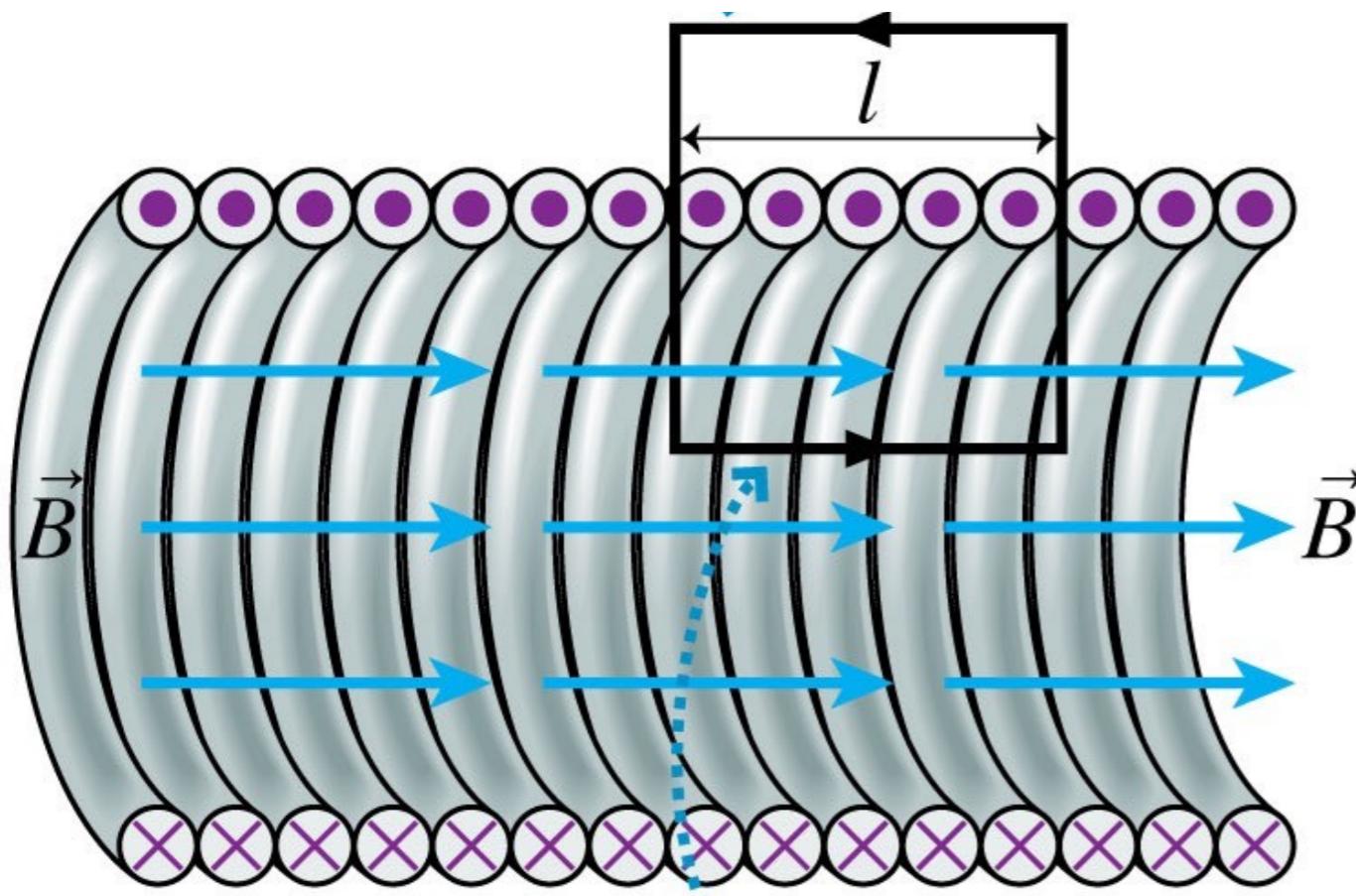
Question #34

For the path shown,

- A. 0.
- B. $\mu_0(I_1 + I_2)$.
- C. $\mu_0(I_2 - I_1)$.
- D. $\mu_0(I_1 - I_2)$.

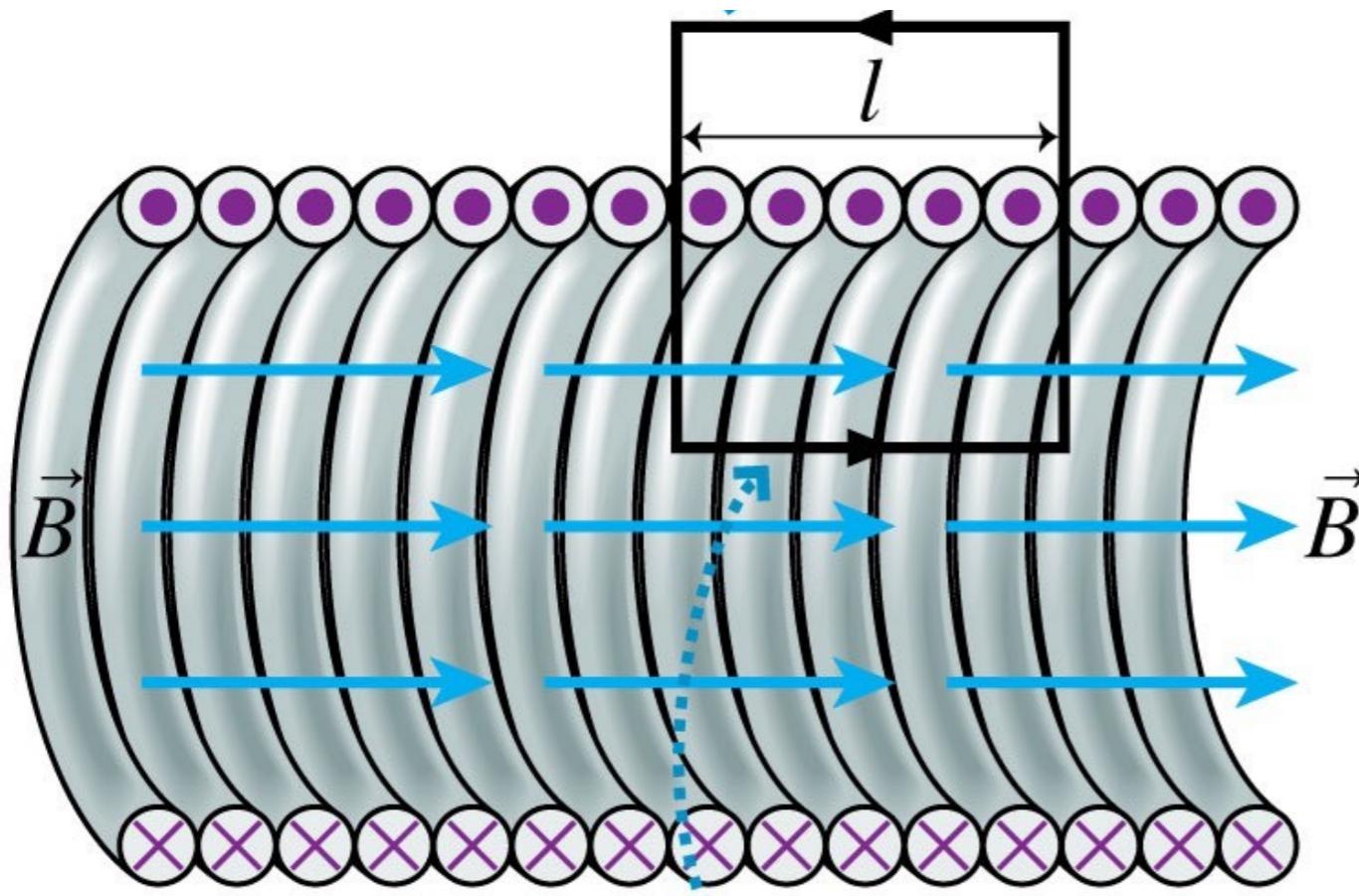


Let's use Ampere's law

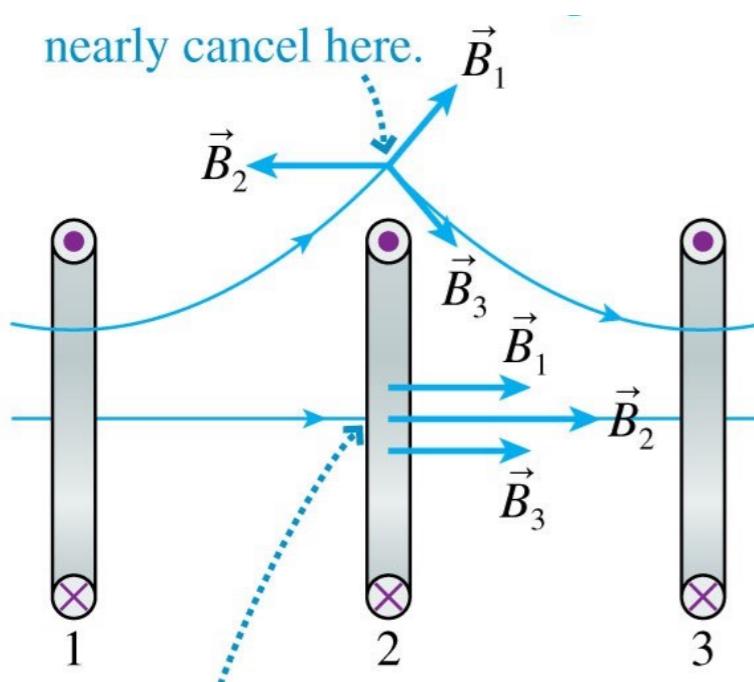


- a) What can you say about the B field along the path shown?
- b) Can you simplify the integral on the left hand side?
- c) How much current is flowing through this loop?

Let's use Ampere's law

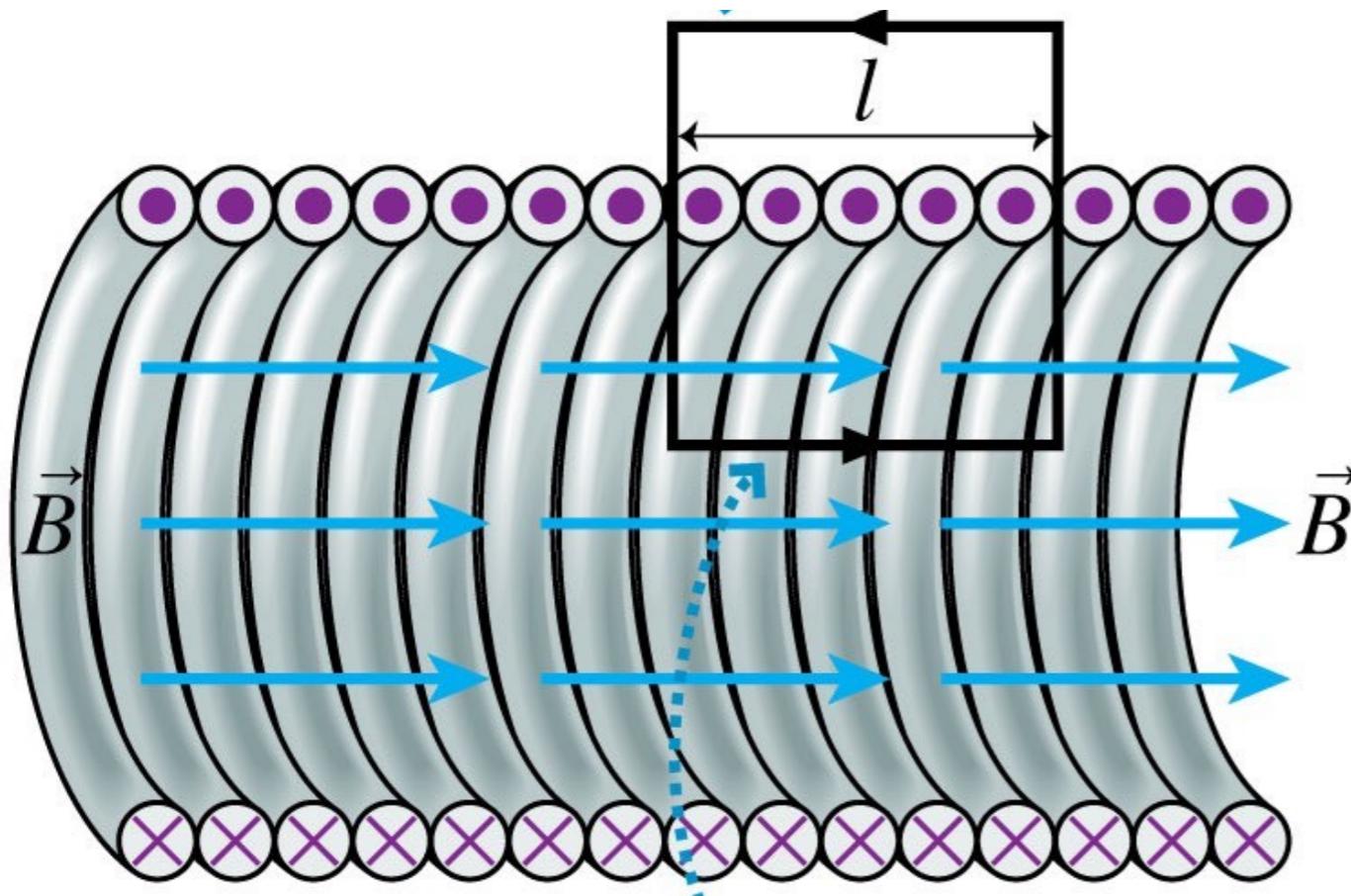


$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

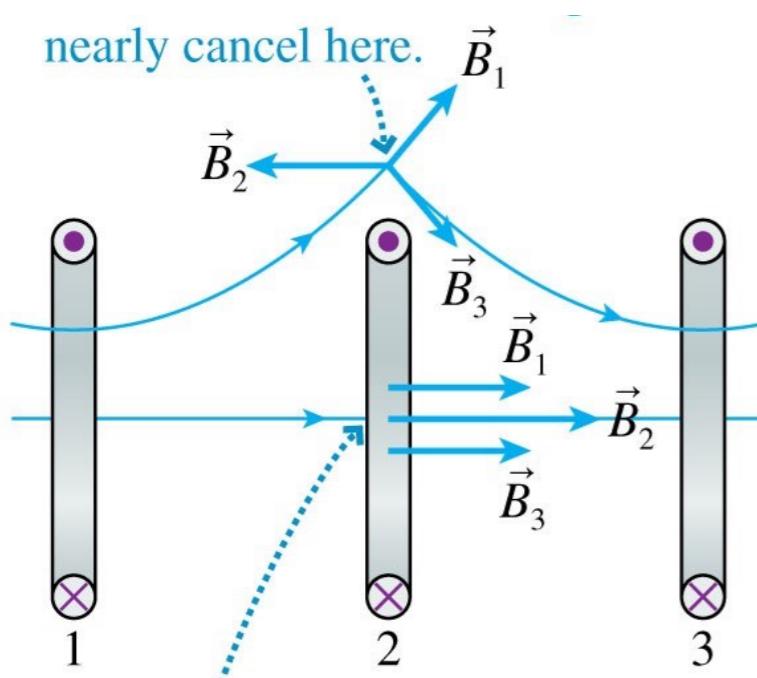


- a) What can you say about the B field along the path shown?
- b) Can you simplify the integral on the left hand side?
- c) How much current is flowing through this loop?

Let's use Ampere's law



$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$



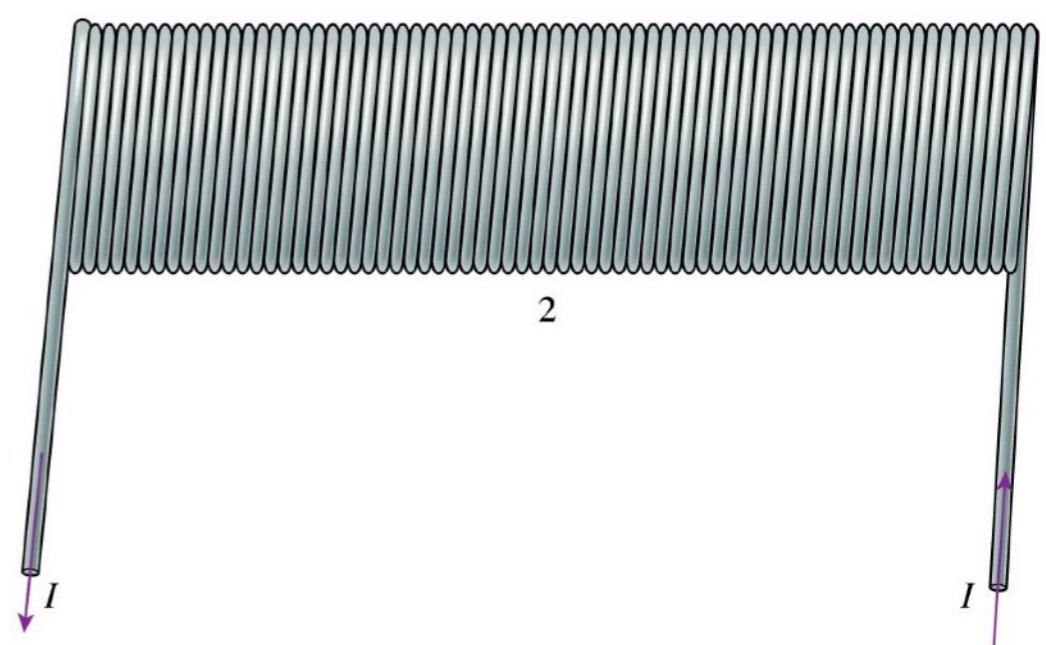
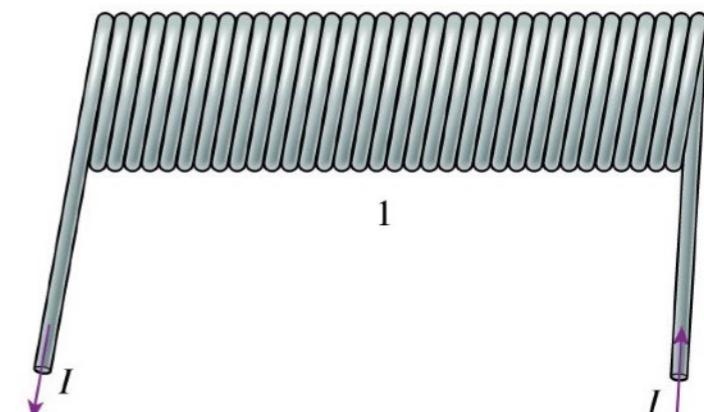
- What can you say about the B field along the path shown?
- Can you simplify the integral on the left hand side?
- How much current is flowing through this loop?

$$B = \frac{\mu_0 N I}{l} = \mu_0 n I$$

Question #35

Solenoid 2 has twice the diameter, twice the length, and twice as many turns as solenoid 1. How does the field B_2 at the center of solenoid 2 compare to B_1 at the center of solenoid 1?

- A. $B_2 = B_1/4.$
- B. $B_2 = B_1/2.$
- C. $B_2 = 2B_1.$
- D. $B_2 = B_1.$
- E. $B_2 = 4B_1.$



Question #36

The current in this solenoid

- A. Enters on the left,
leaves on the right.
- B. Either A or C would
produce this field.
- C. Enters on the right,
leaves on the left.

