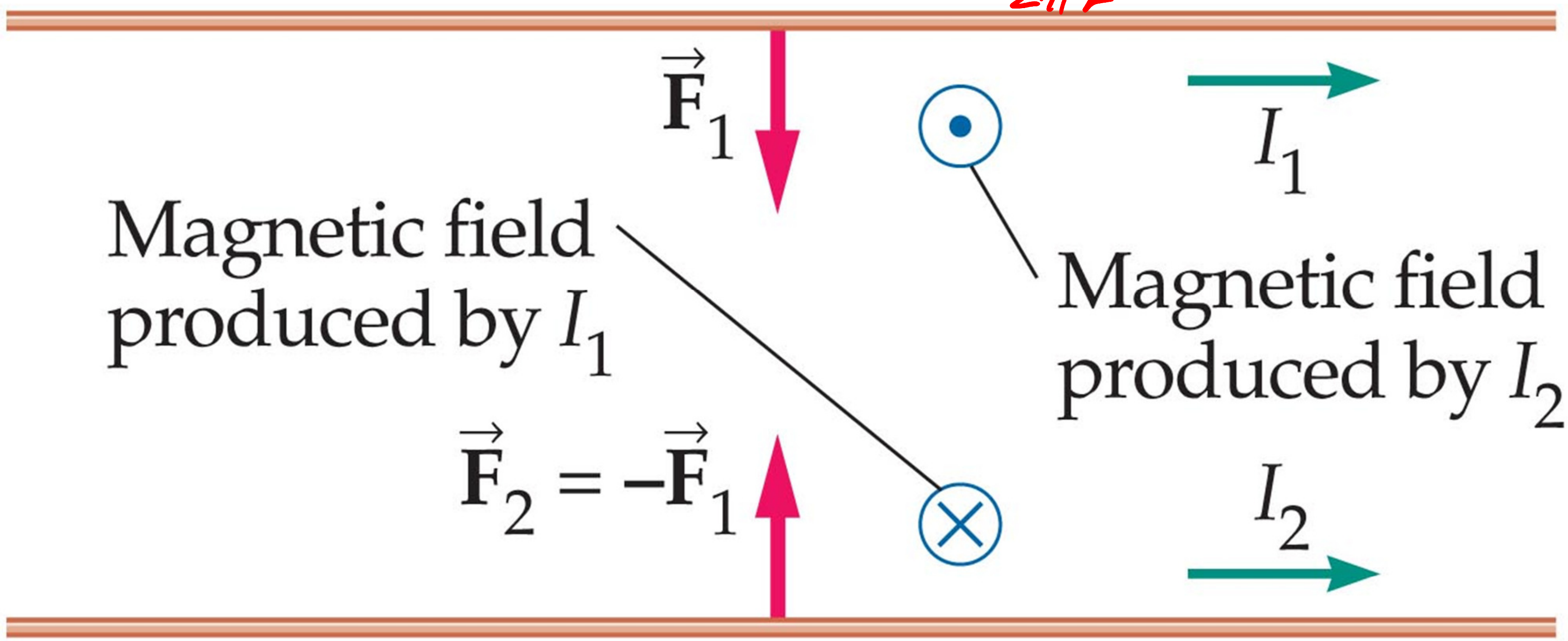
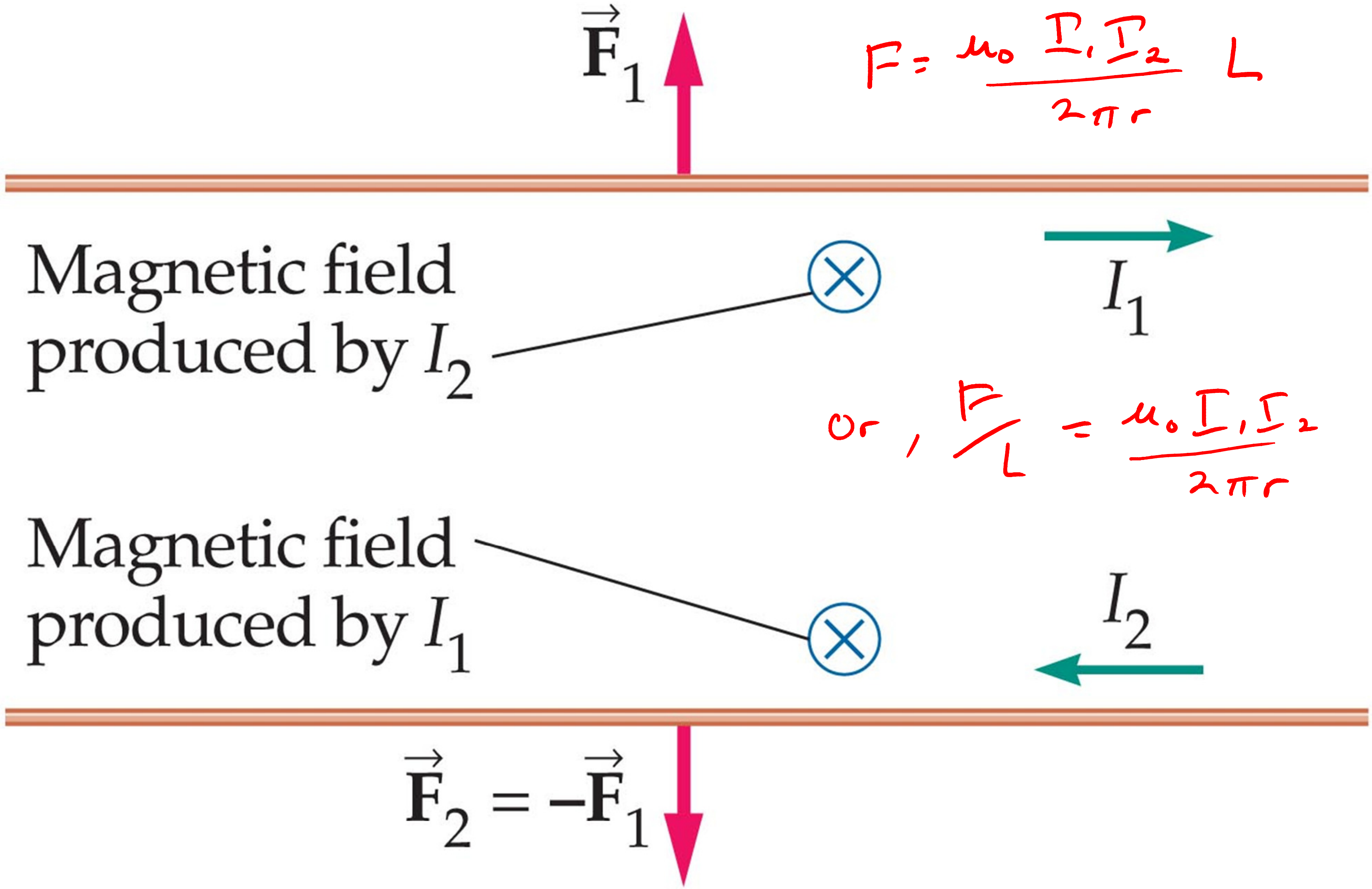
$$\vec{B}_2 = \frac{\mu_0 I_2}{2\pi r}$$

$$\vec{F}_1 = I_1 \vec{L} \times \vec{B} = I_1 L B_2 \cancel{\sin 90^\circ}^{\,1}$$

$$= I_1 L \frac{\mu_0 I_2}{2\pi r}$$



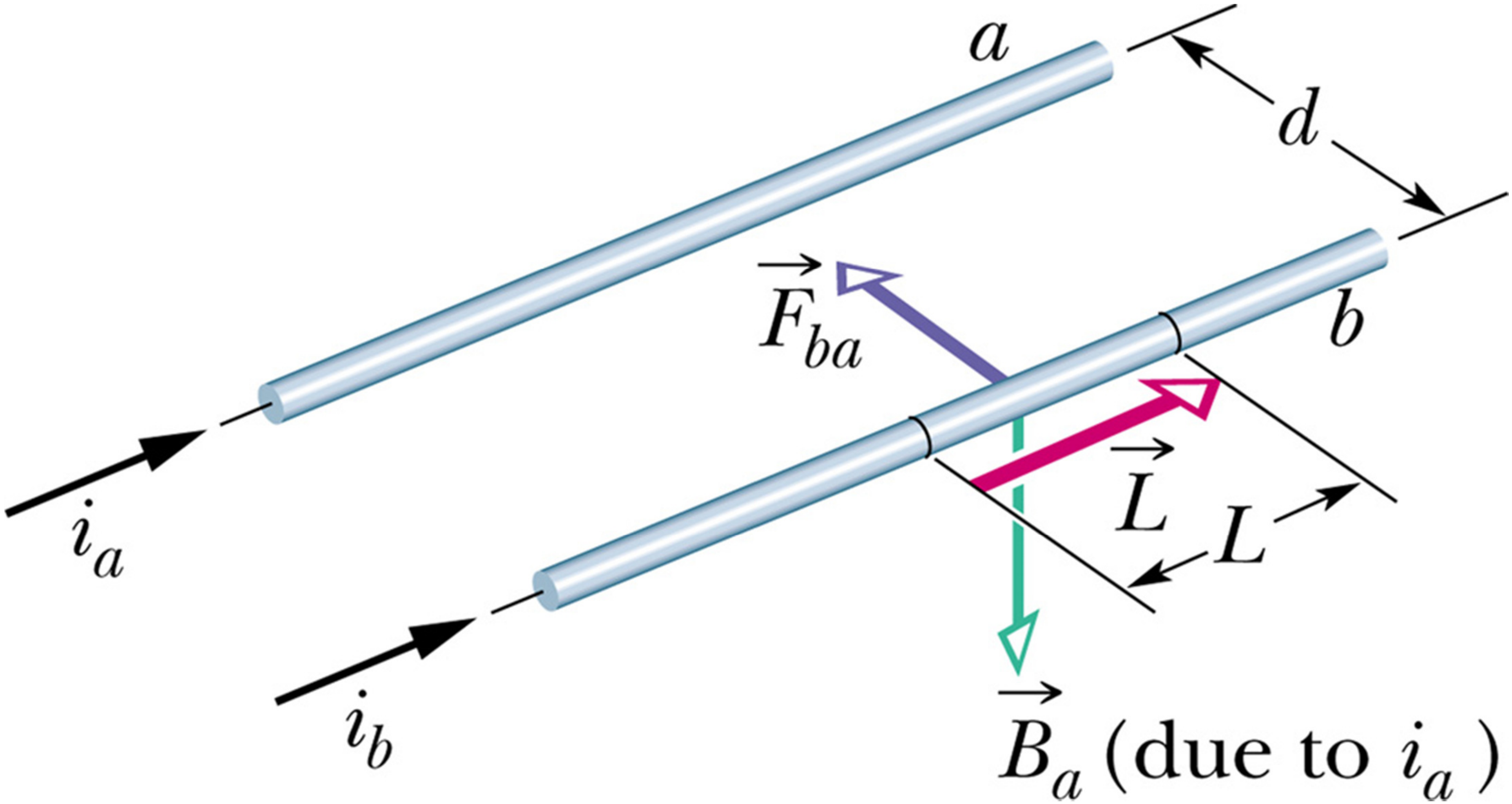
(a) Currents in same direction



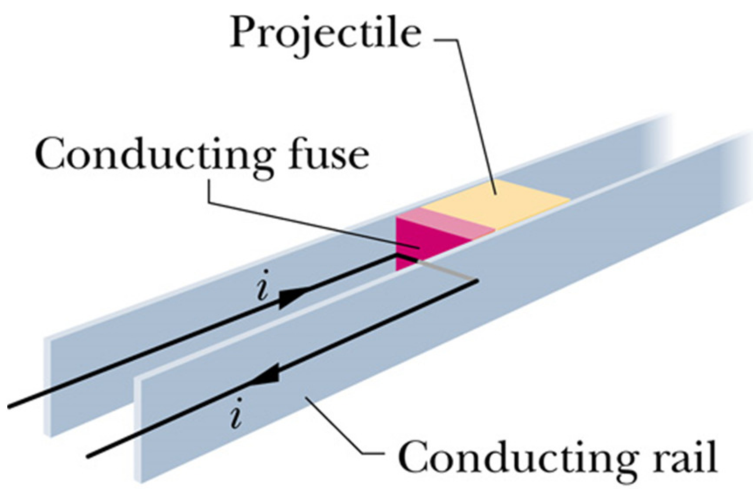
$$F = \frac{\mu_0 I_1 I_2}{2\pi r} L$$

$$\text{or, } F/L = \frac{\mu_0 I_1 I_2}{2\pi r}$$

(b) Currents in opposite directions

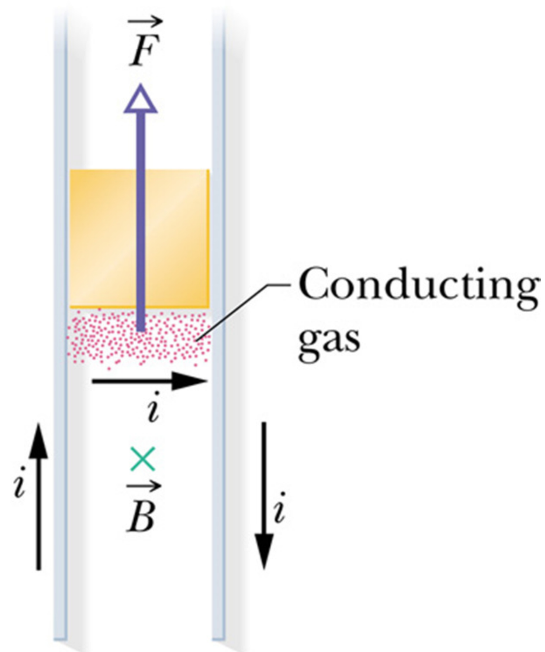


a
d
$\vec{F}_{ba}$
b
$\vec{L}$
L
i_a
i_b
$\vec{B}_a$ (due to i_a)



(a)

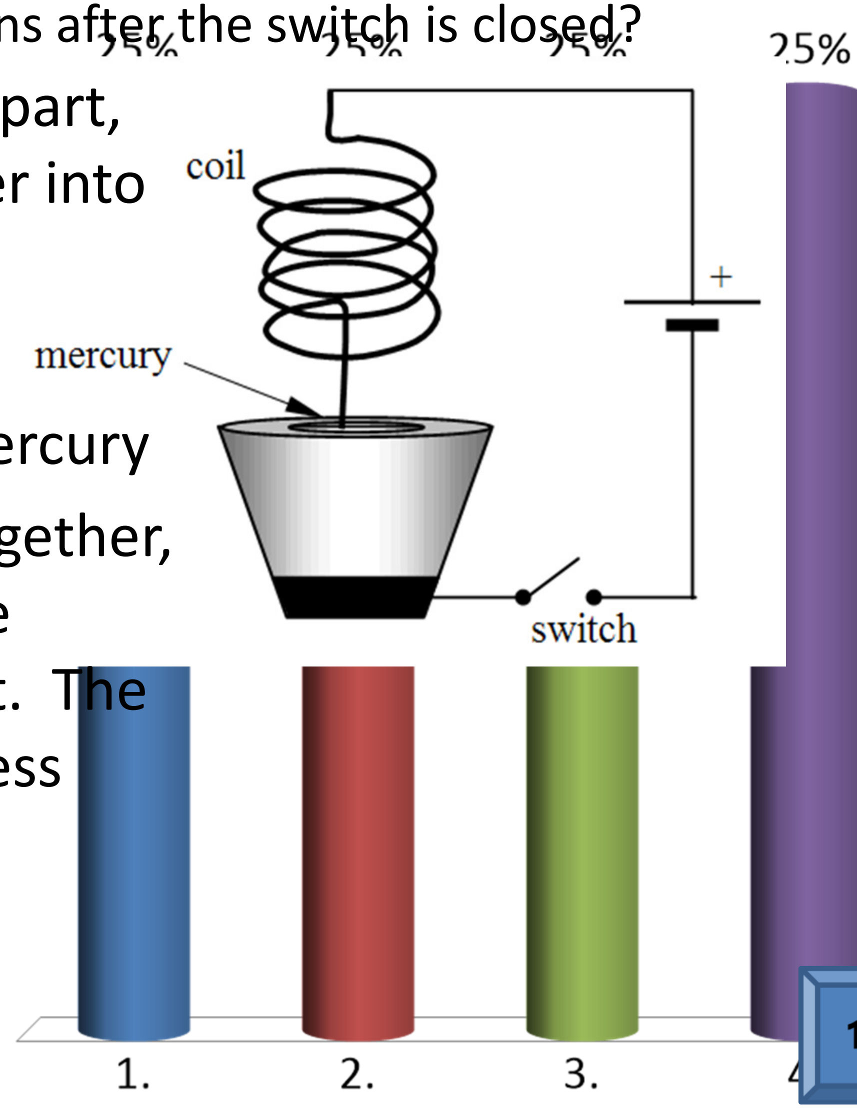
$$\vec{F} = I\vec{L} \times \vec{B}$$



(b)

A coil of wire is hanging vertically - its windings are parallel to one another. One end is connected to a battery, the other is touching the surface of a cup of mercury. The bottom of the cup is a connected by a switch to the battery. What happens after the switch is closed?

1. Current flows, the coils push apart, and the spiral is pushed deeper into the mercury
2. Nothing happens
3. The current boils away the mercury
4. Current flows, the coils pull together, and the coil tip pulls out of the mercury and breaks the circuit. The coil then relaxes and the process starts over.



Response Counter

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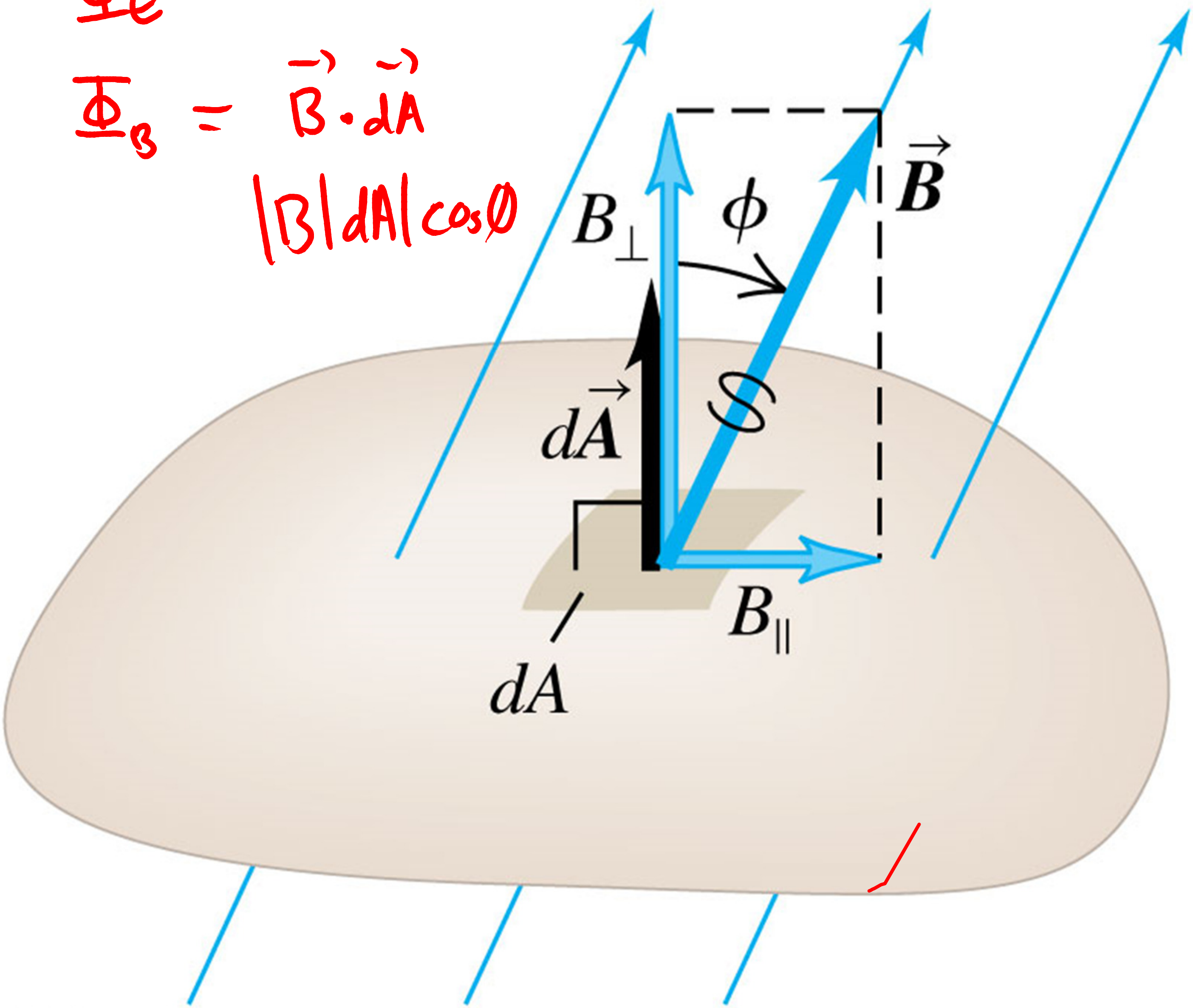
Φ_E

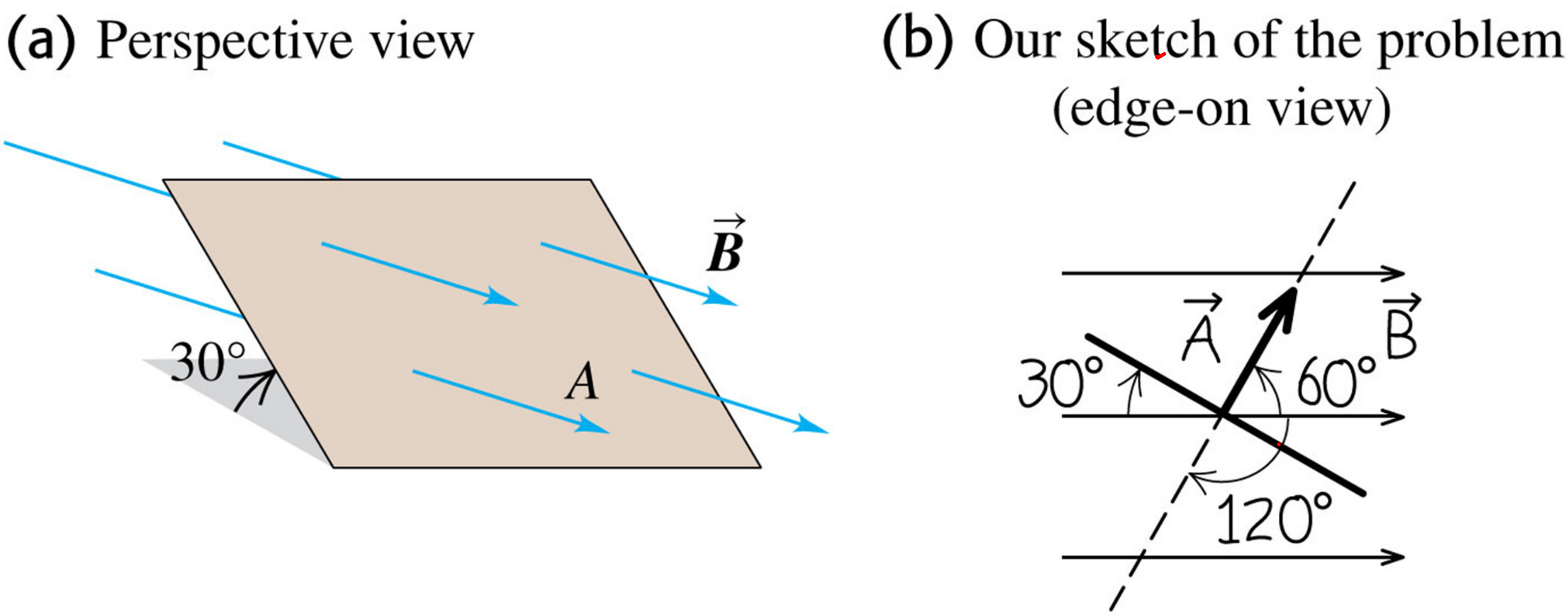
$\Phi_B = \vec{B} \cdot d\vec{A}$

$|B||dA|\cos\theta$



$$\Phi_B = \vec{B} \cdot d\vec{A}$$

units in Webers Wb Tm^2

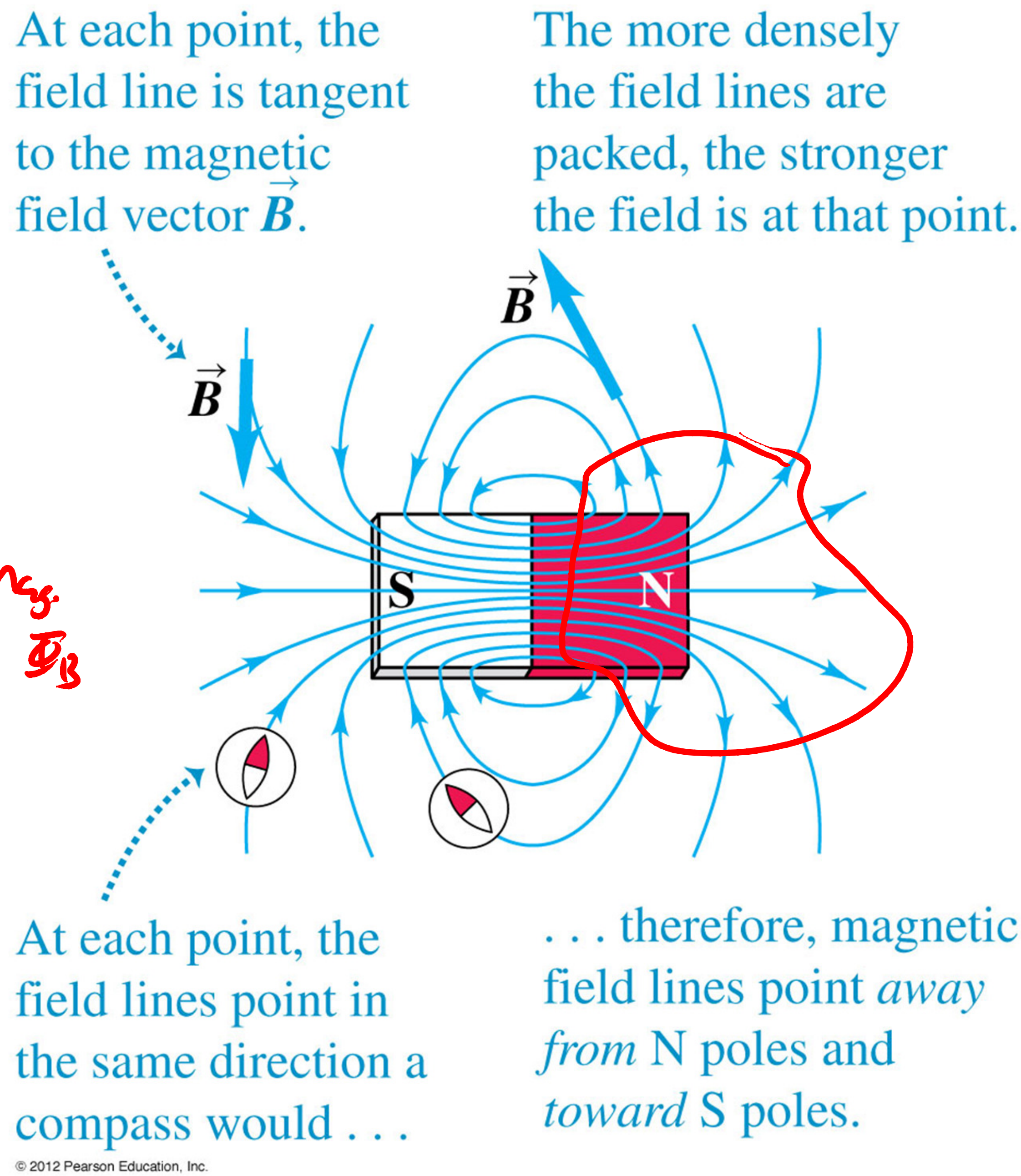


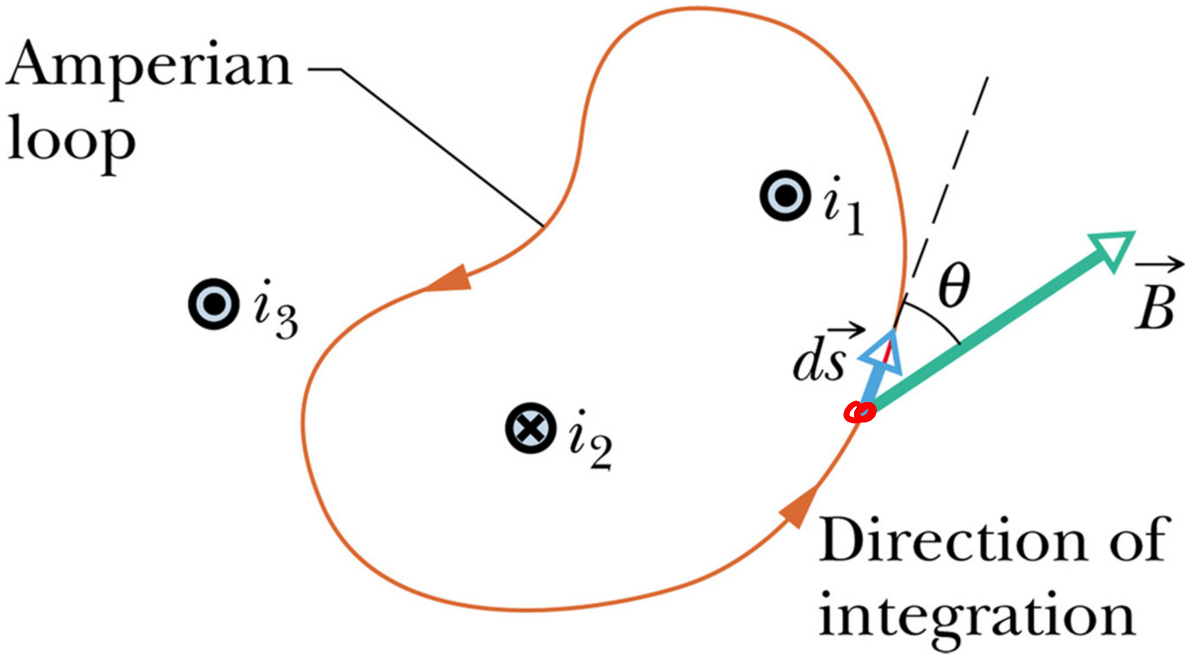
Gauss' Law for Magnetism:

$$\oint \vec{B} \cdot d\vec{A} = \text{net Mag. flux } \Phi_B$$

$$= 0$$

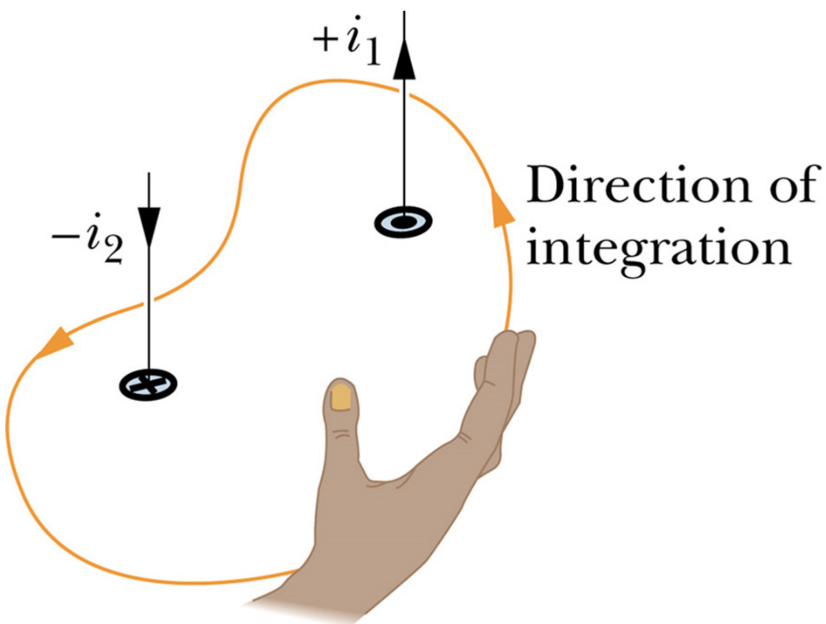
$$\oint \vec{B} \cdot d\vec{A} = 0$$





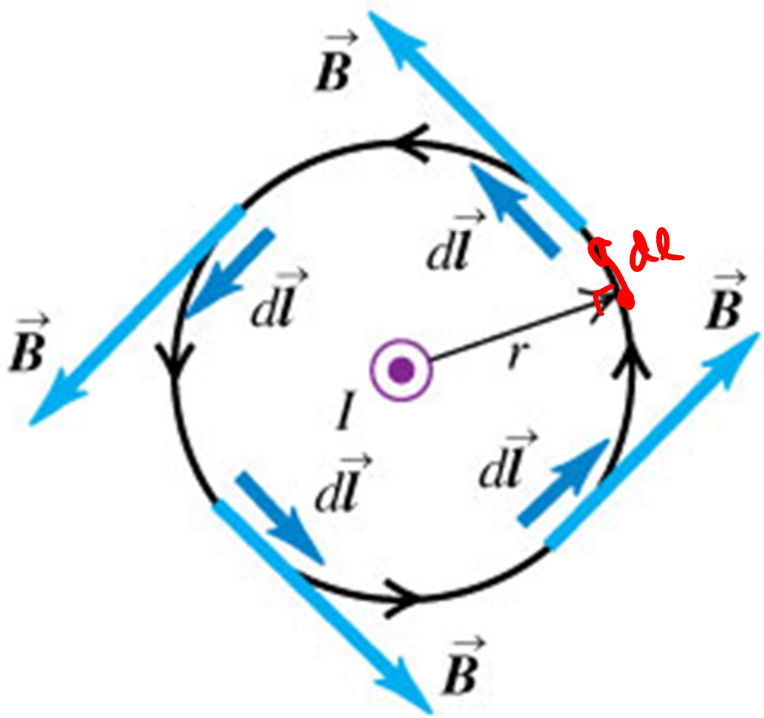
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$

Ampere's Law



(a) Integration path is a circle centered on the conductor; integration goes around the circle counterclockwise.

Result: $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$



$$\vec{B}\cdot\vec{dl} = |B||dl|\cancel{\cos\theta}\ 1$$

$$\int |B||dl| = \mu_0 I$$

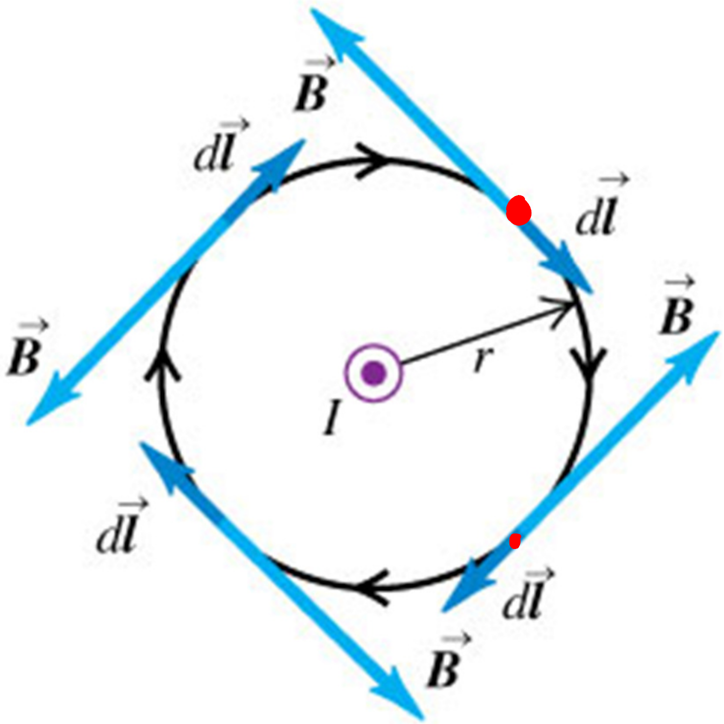
$$B\int dl = \mu_0 I$$

$$B(2\pi r) = \mu_0 I$$

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

(b) Same integration path as in (a), but integration goes around the circle clockwise.

Result: $\oint \vec{B} \cdot d\vec{l} = -\mu_0 I$



$\vec{B} \cdot d\vec{l} = |B||dl|\cos 180°$

$= -B\,dl$

$\oint \vec{B} \cdot d\vec{l} = -B \int dl$

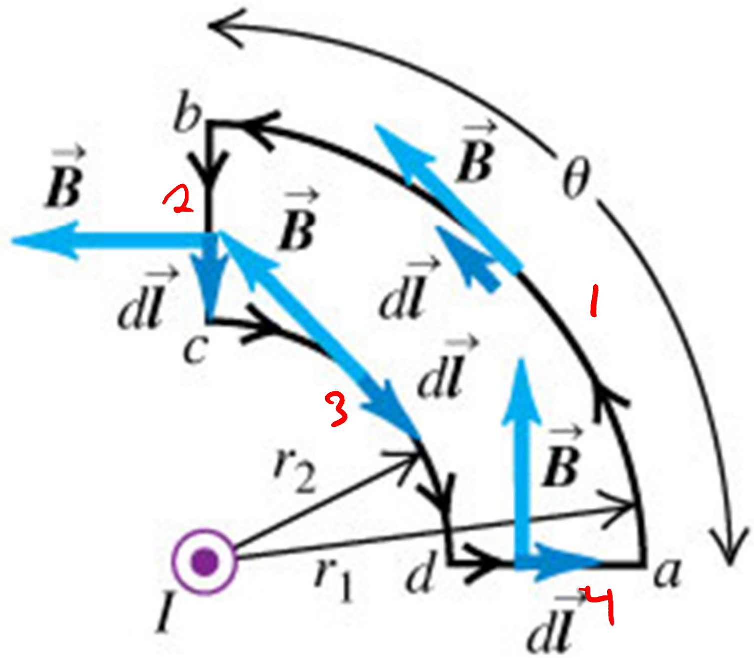
$= -B\,2\pi r$

$\mu_0 I = -B\,2\pi r$

$B = -\dfrac{\mu_0 I}{2\pi r}$

(c) An integration path that does not enclose the conductor

Result: $\oint \vec{B}\cdot d\vec{l} = 0$



$$\oint \vec{B}\cdot d\vec{l} = B_1\int_a^b dl + \int_b^c \cancel{\vec{B}_{bc}\cdot d\vec{l}}^{\,0} + B_3\int_c^d dl(-1) + \int_d^a \cancel{B_{da}\cdot dl}^{\,0}$$

$$= B_1(r_1\cdot\theta) - B_2(r_2\theta)$$

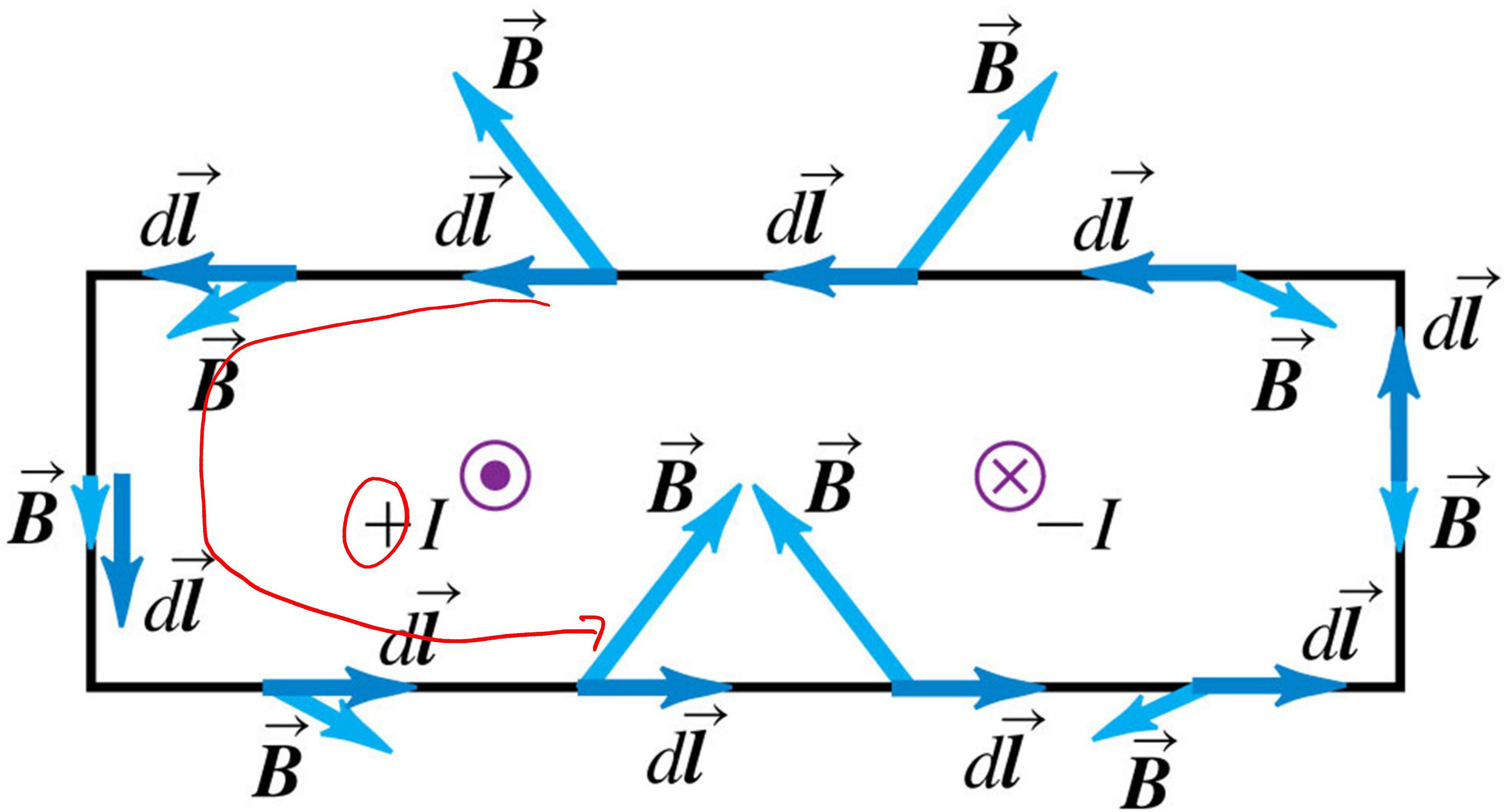
$$= \frac{\mu_0 I}{2\pi \cancel{r_1}}(\cancel{r_1}\theta) - \frac{\mu_0 I}{2\pi \cancel{r_2}}(\cancel{r_2}\theta)$$

$$= \frac{\mu_0 I}{2\pi}\theta - \frac{\mu_0 I}{2\pi}\theta$$

$$= 0$$

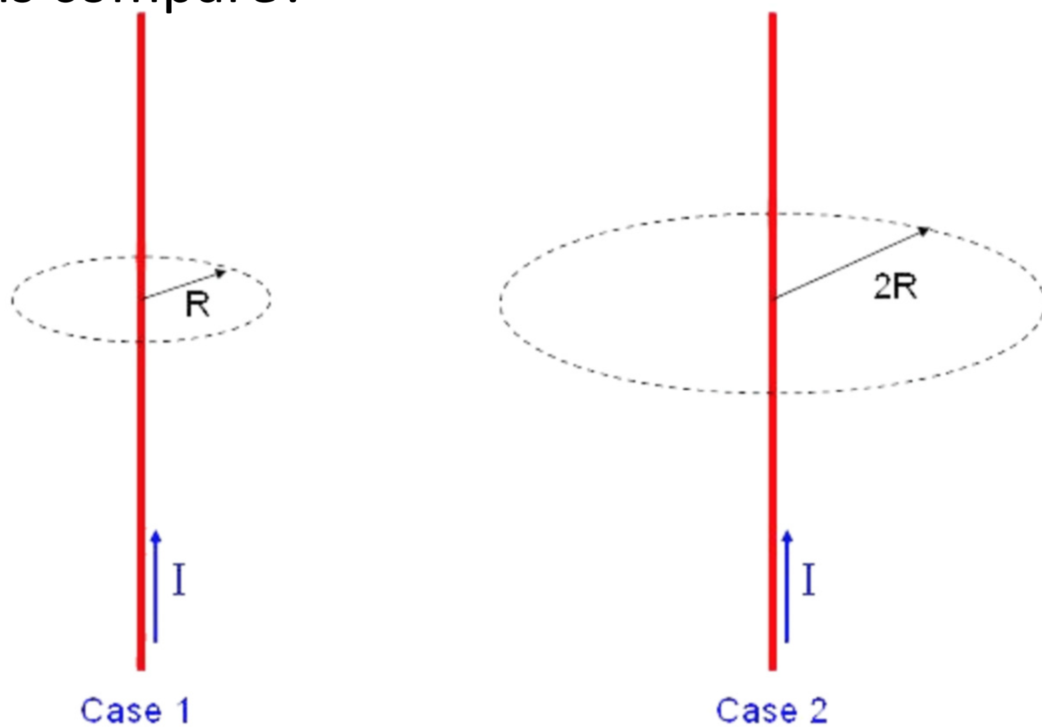
$$i_{enclosed} = 0$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc} = 0 \quad (+I - I)$$

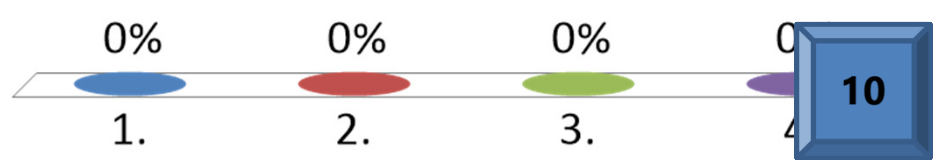


A current *I* flows in a long straight wire. In Case 1 we consider the integral of ***B***·*d**L*** along a circular path of radius *R* centered on the wire, and in Case 2 we consider the integral of ***B***·*d**L*** along a circular path of radius 2*R* centered on the wire: How do the magnitudes of the integral of ***B***·*d**L*** around the two different closed paths compare?

1. It is biggest for Case 1
2. It is biggest for Case 2
3. They are the same
4. Not sure

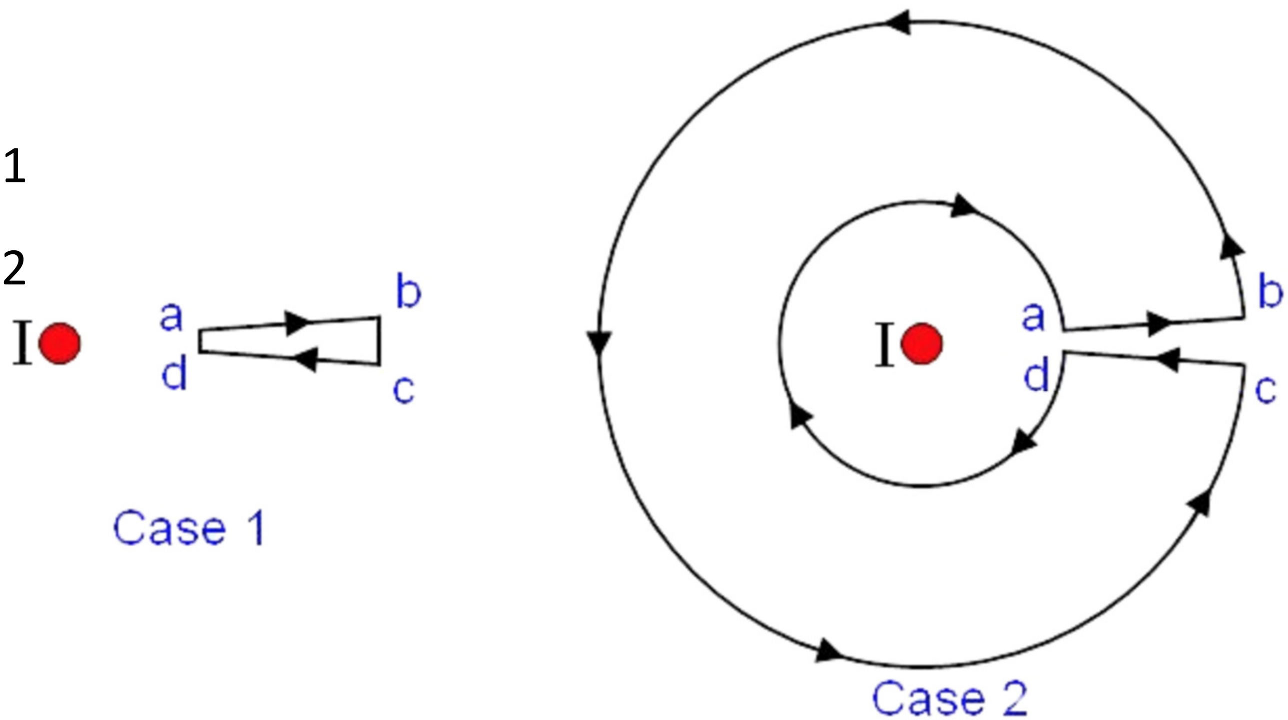


Response Counter



A long straight wire (the red dot in the diagram below) carries current *I* directly out of the plane of the page. Consider the two closed integration paths shown in Case 1 and Case 2:
How do the magnitudes of the integral of ***B***·***dL*** around the closed paths compare?

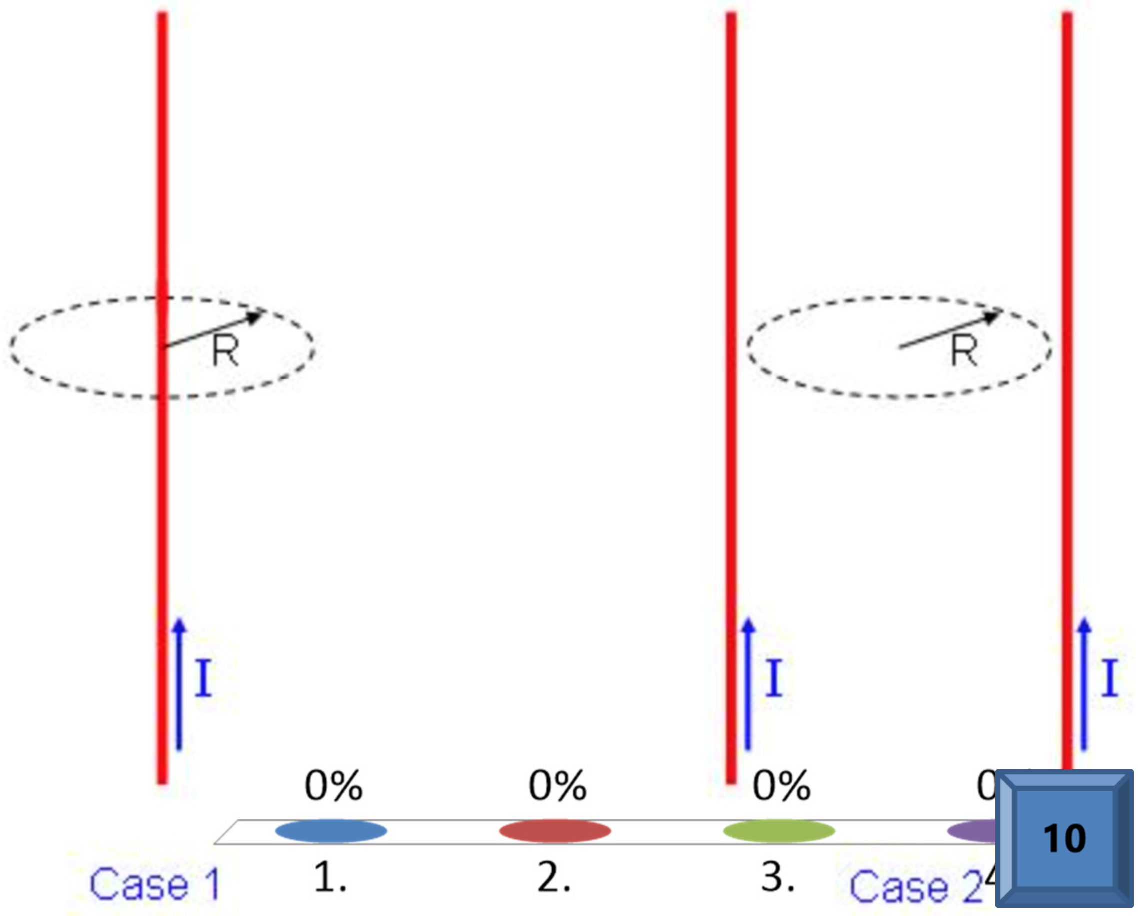
1. It is biggest for Case 1
2. It is biggest for Case 2
3. They are the same
4. Not sure



Response Counter

A long straight wire (the red dot in the diagram below) carries current *I* directly out of the plane of the page. Consider the two closed integration paths shown in Case 1 and Case 2:
How do the magnitudes of the integral of ***B·dL*** around the closed paths compare?

1. It is biggest for Case 1
2. It is biggest for Case 2
3. They are the same
4. Not sure



Response Counter

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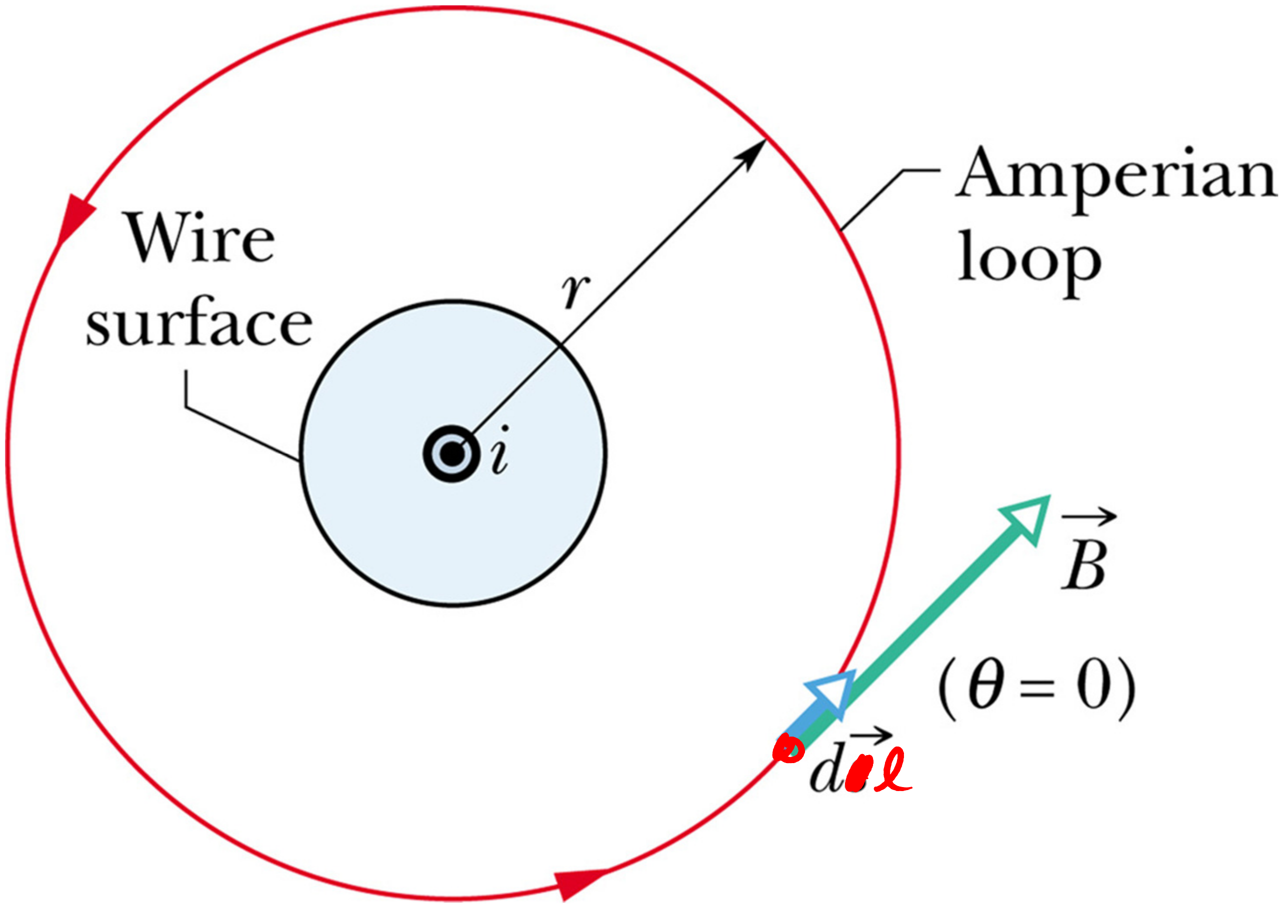
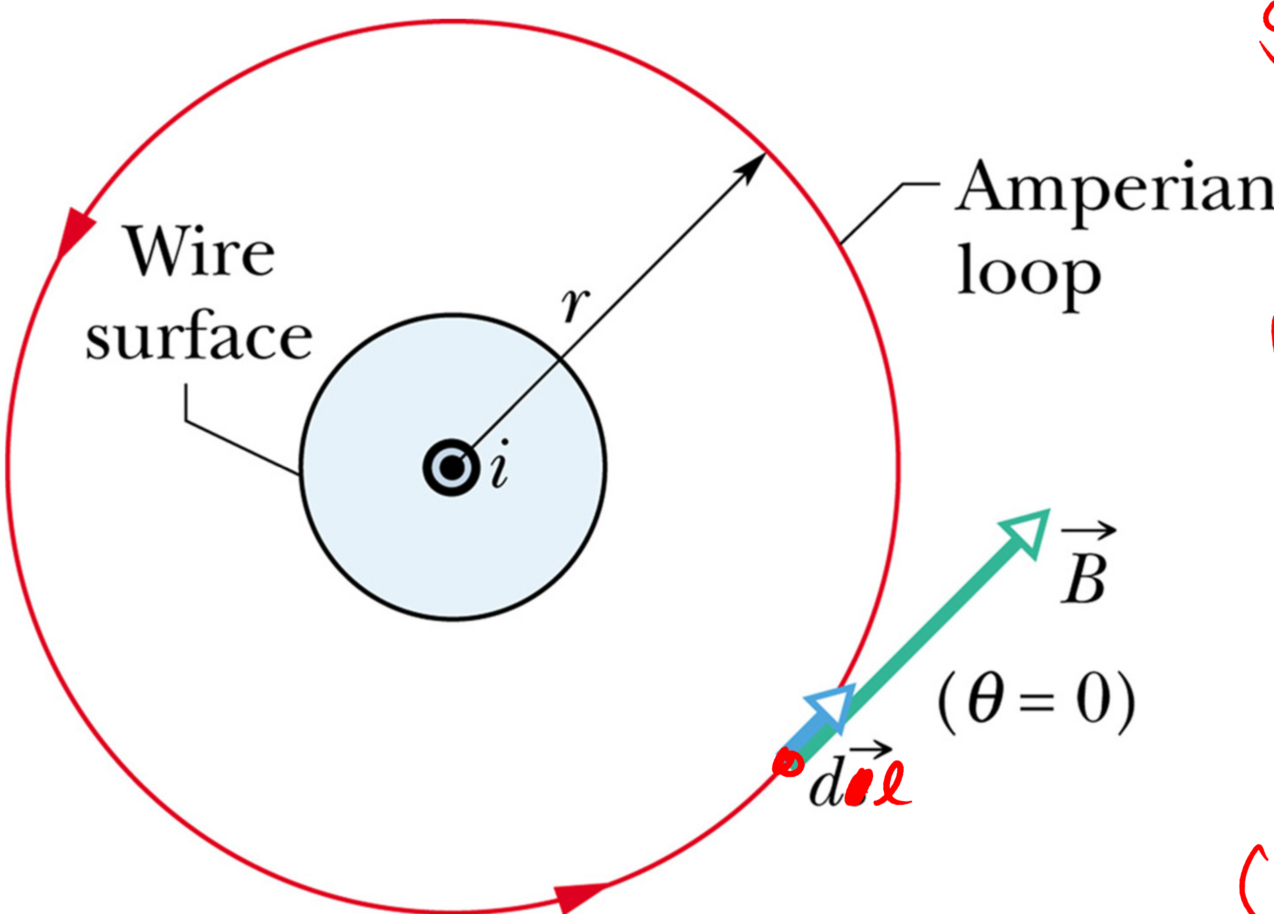
Ampere’s Law worksheet


Wire
surface
r
i
Amperian
loop
$\vec{B}$
$(\theta = 0)$
$d\vec{\ell}$



$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{en}$$

$$\oint |B||dl|\cancel{\cos\theta}^{1} = \mu_0 I_{en}$$

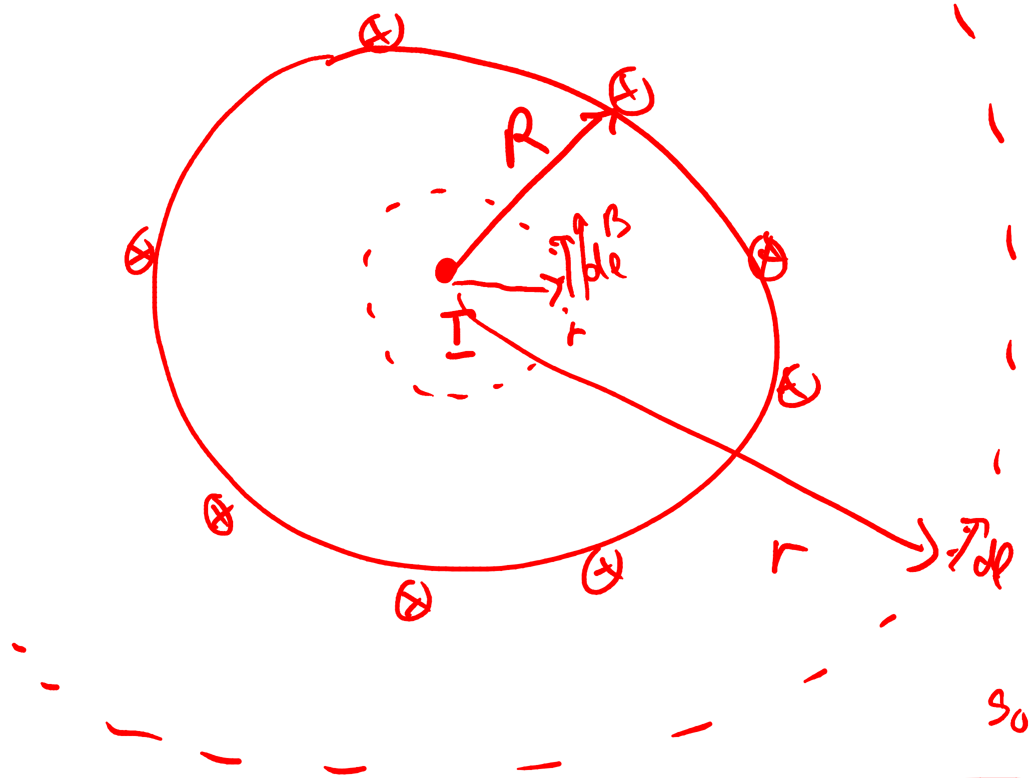
$$B \oint dl = \mu_0 I_{en}$$

$$B\, 2\pi r = \mu_0 i$$

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

(#1 - a wire, i out of screen, makes this B)

Co-ax cable?



Small r: around inner copper, inside outer braid.

Choose circle again.

$\oint \vec{B}\cdot\vec{dl} = \mu_0 I_{enc}$

$B \parallel dl$ again, so $\cos 0 = 1$

$\int |B||dl| = \mu_0 I_{enc}$

B const on circle, $B\oint dl = \mu_0 I_{enc}$

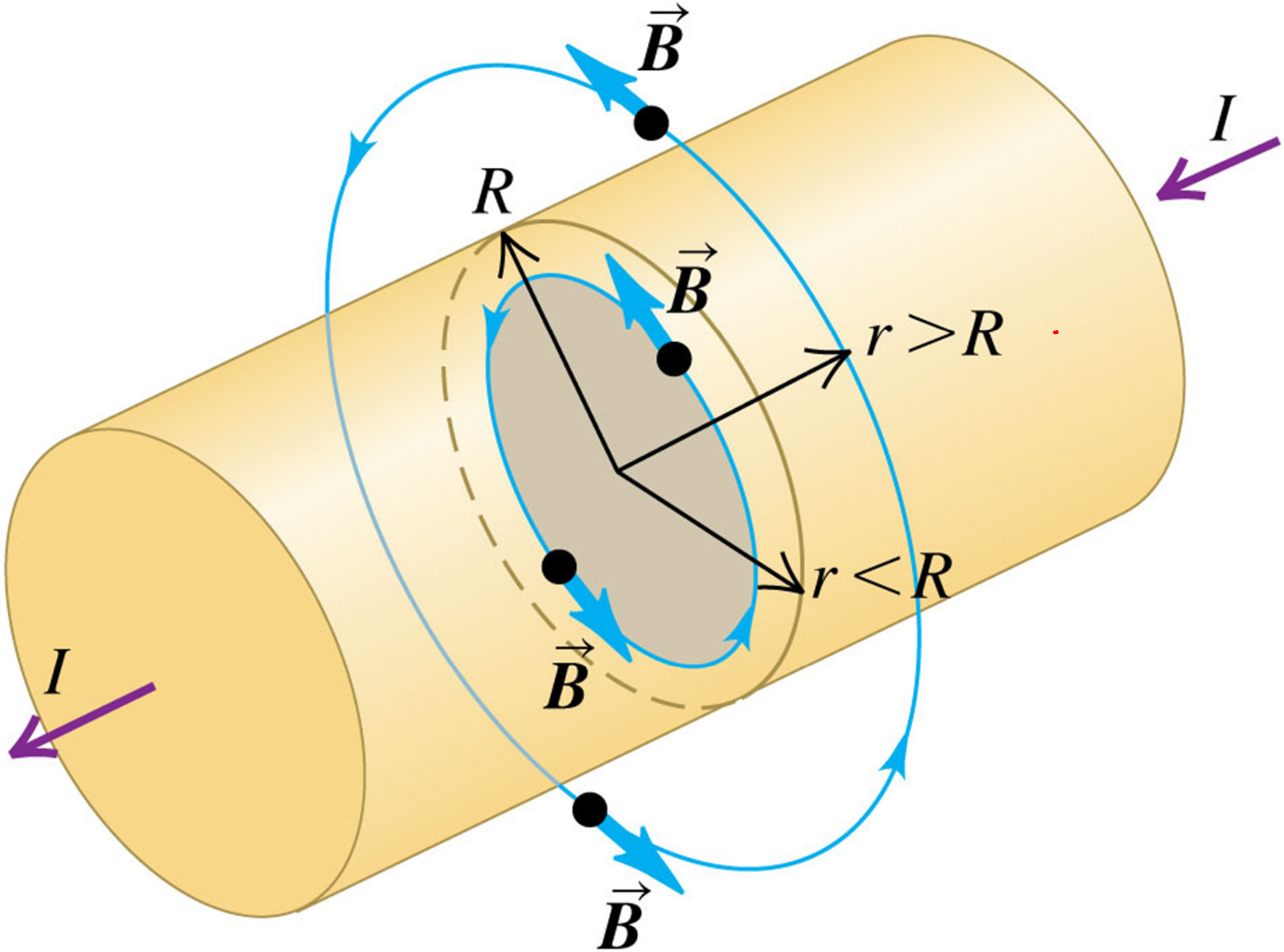
$B(2\pi r) = \mu_0 I$ (I out of page)

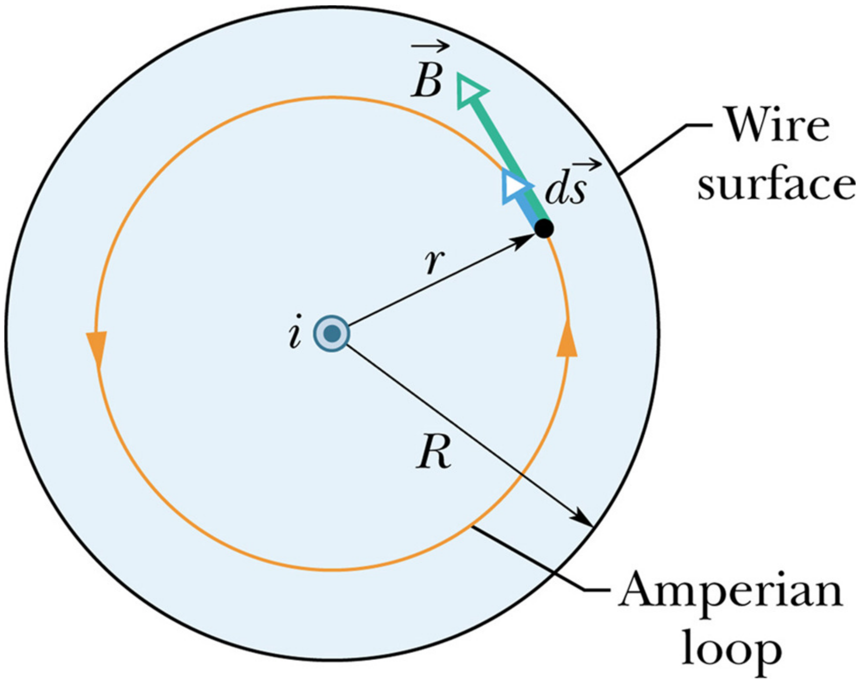
so $B = \frac{\mu_0 I}{2\pi r}$ again!

Outside: same geometry, $\oint \vec{B}\cdot\vec{dl} = 0$

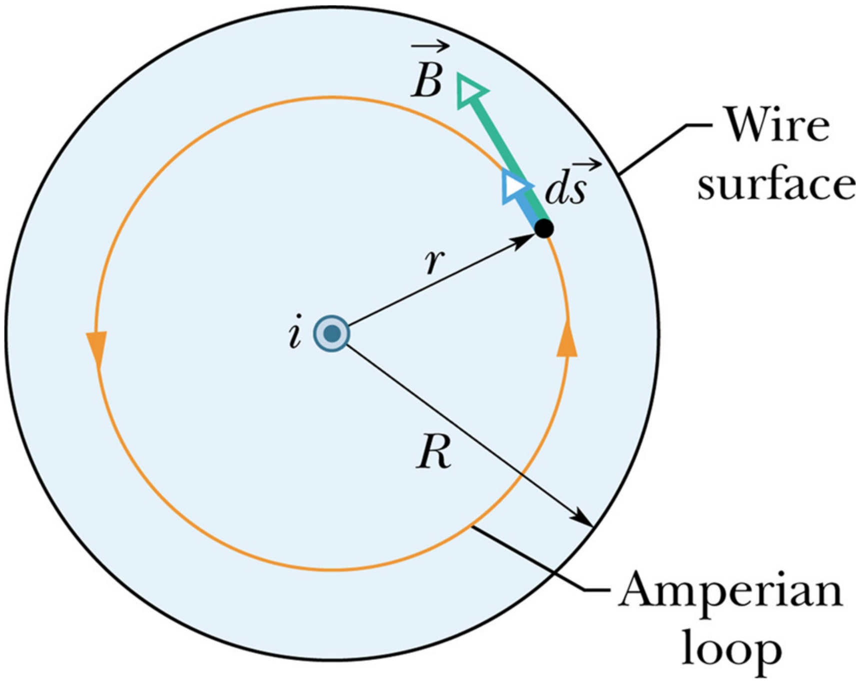
But $I_{enc} = I - I = 0$

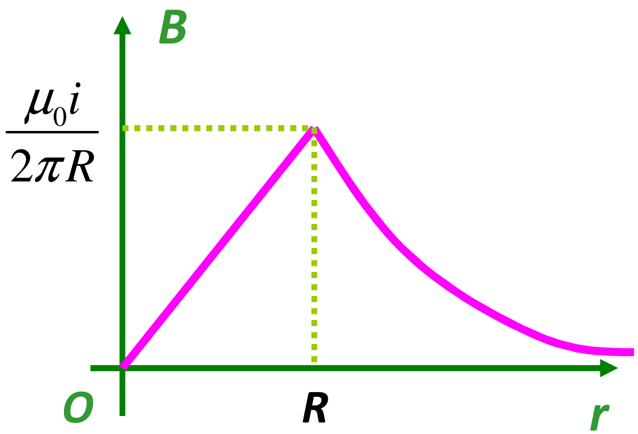
Thick wire?


$\vec{B}$
I
R
$\vec{B}$
$r > R$
$r < R$
$\vec{B}$
I
$\vec{B}$



$\vec{B}$
$d\vec{s}$
Wire surface
r
i
R
Amperian loop





$$\oint \vec{B} \cdot d\vec{s} = B \oint ds = B\, 2\pi r$$

(same steps)

But, what is i_{enc}?

not all of it.

$$i_{enc} = i_{Tot} \frac{\text{current in}}{\text{vs. current out}}$$

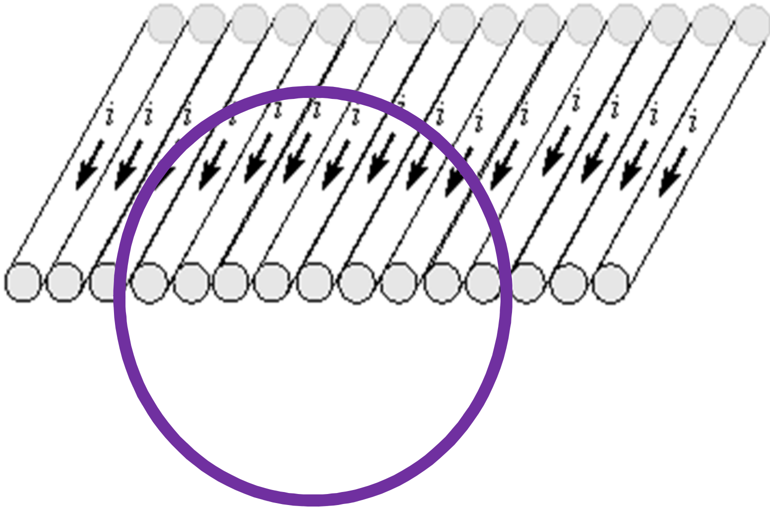
$$= i \frac{\pi r^2}{\pi R^2}$$

so, $B\, 2\pi r = \dfrac{i\, \pi r^2}{\pi R^2}$

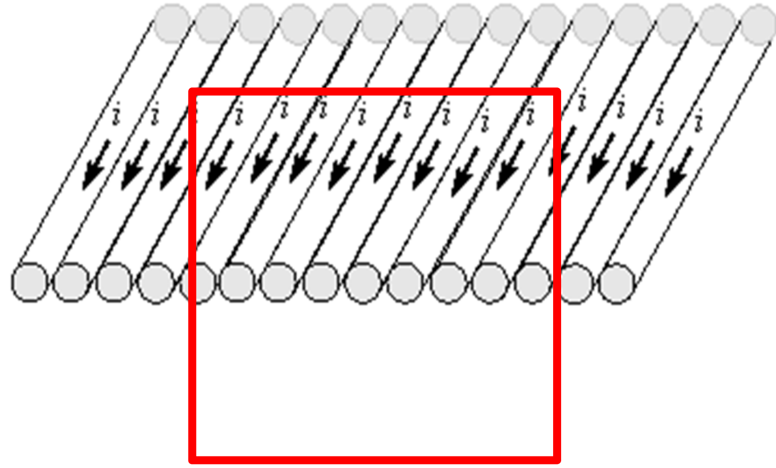
$$B = \frac{\mu_0 i}{2\pi R^2}\, r$$

Which Amperian shape should we use to find the B-field a distance z above the sheet?

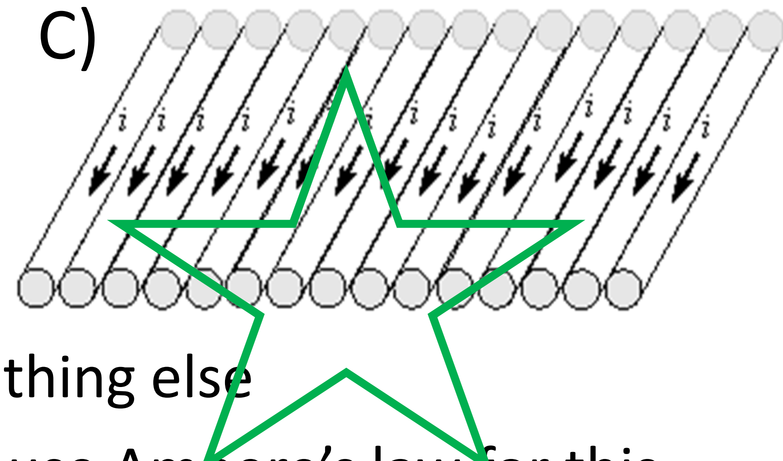
A)



B)



C)



1. A
2. B
3. C
4. Something else
5. Can’t use Ampere’s law for this

Response Counter

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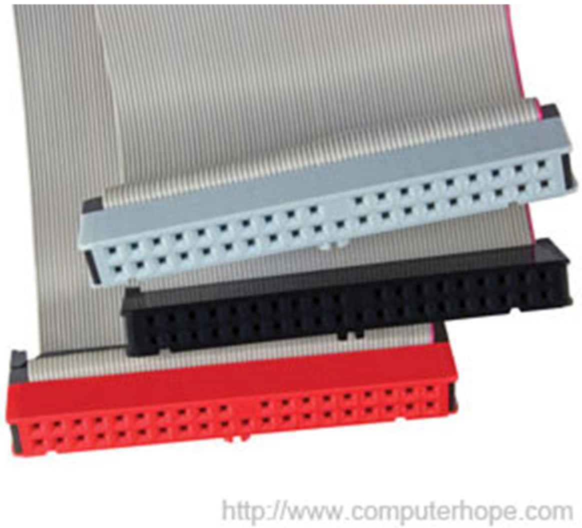
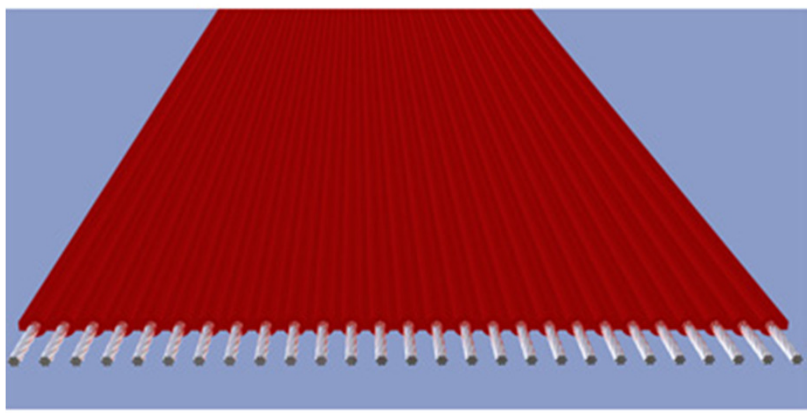
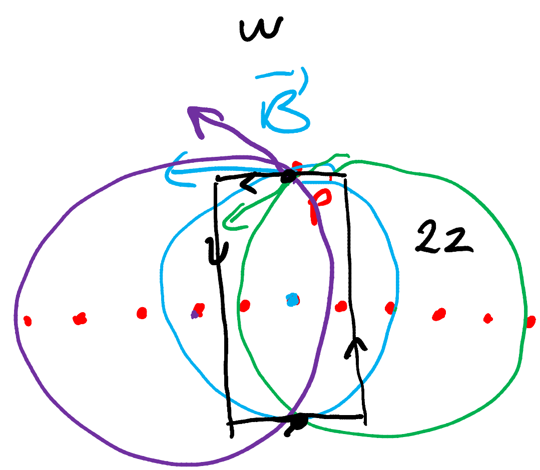




Work out #1 on worksheet, “Ribbon Cable”



$$\oint \vec{B}\cdot\vec{d\ell} = \mu_0 I_{enc}$$

Sides: $\vec{B}\cdot\vec{d\ell}$ $\quad \vec{B}, \vec{d\ell} \perp$

dot product $= 0$

top: $\oint |B||d\ell|$

$B \oint d\ell$

Bw

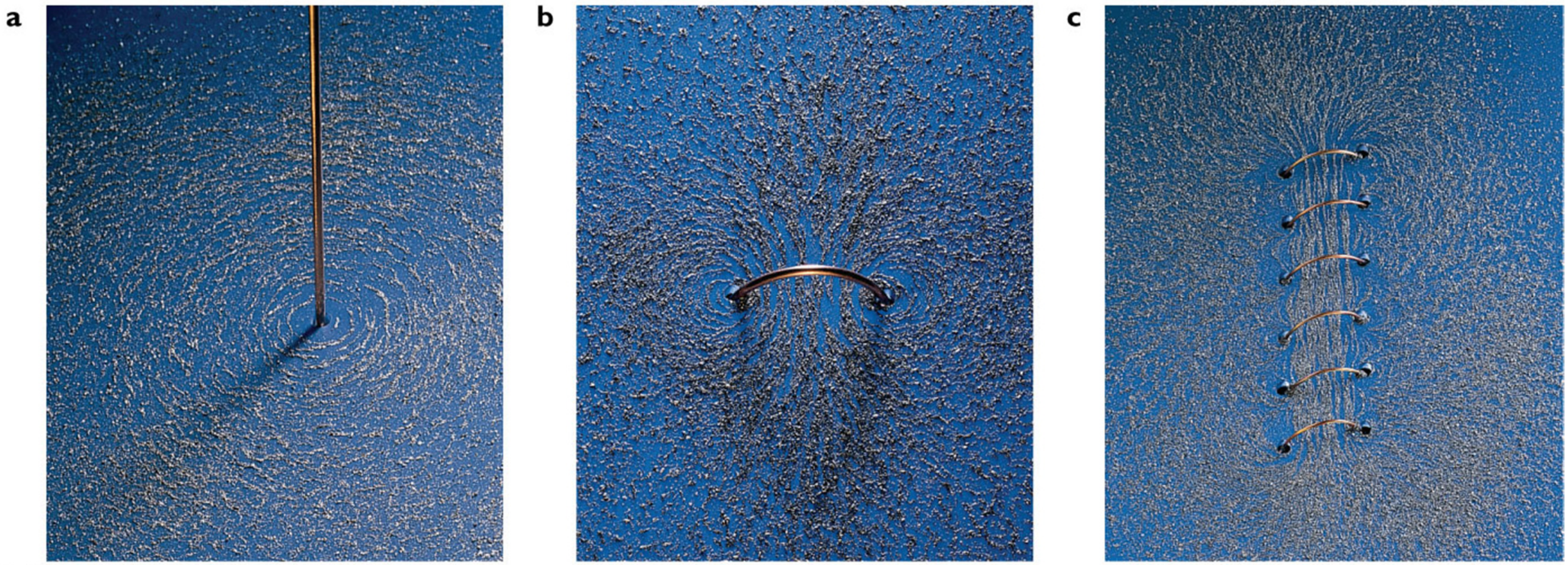
sides: add 0

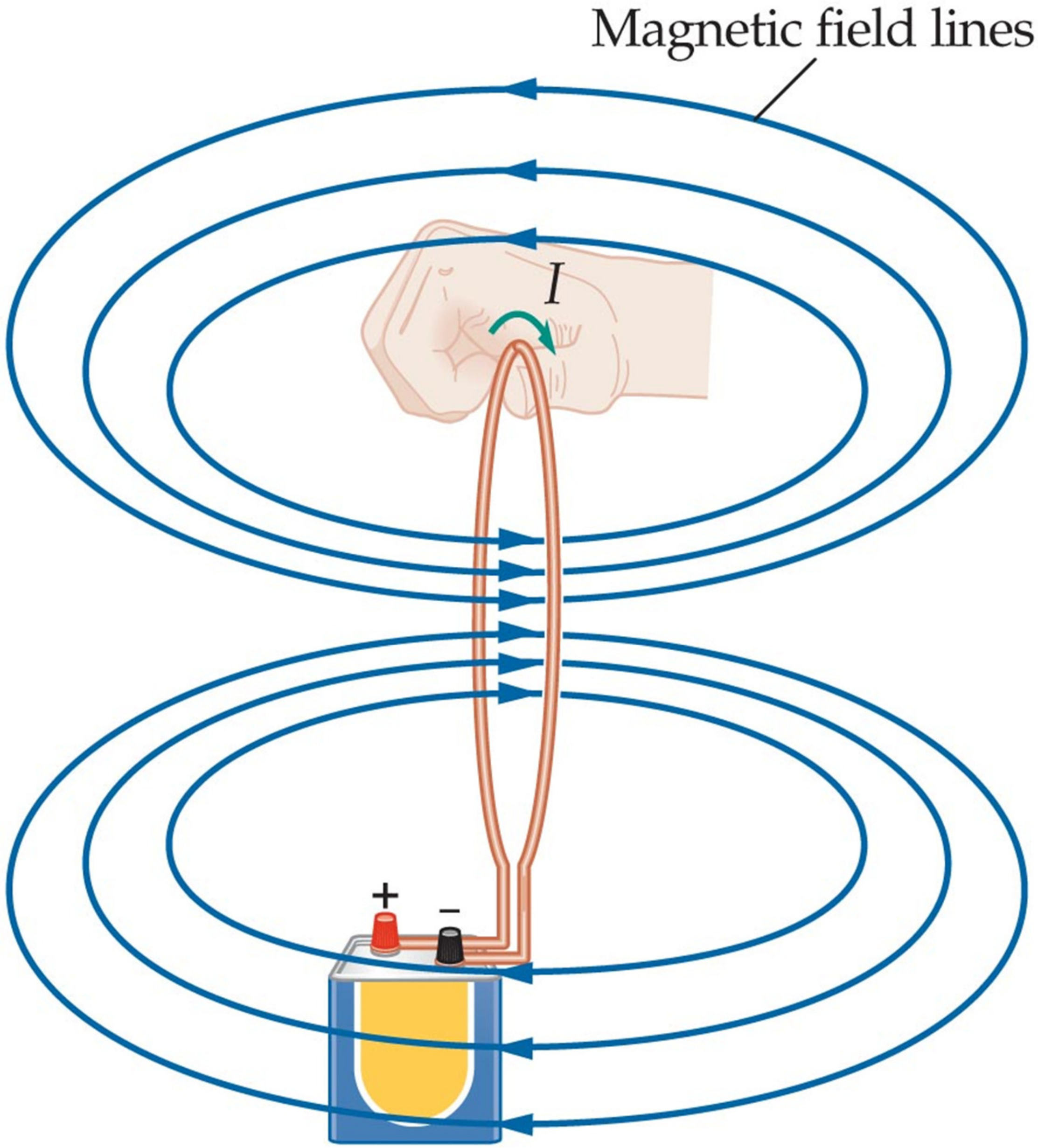
Bottom: same

$$\oint \vec{B}\cdot\vec{d\ell} = Bw + Bw + 0 + 0 = \mu_0 I_{enc}$$

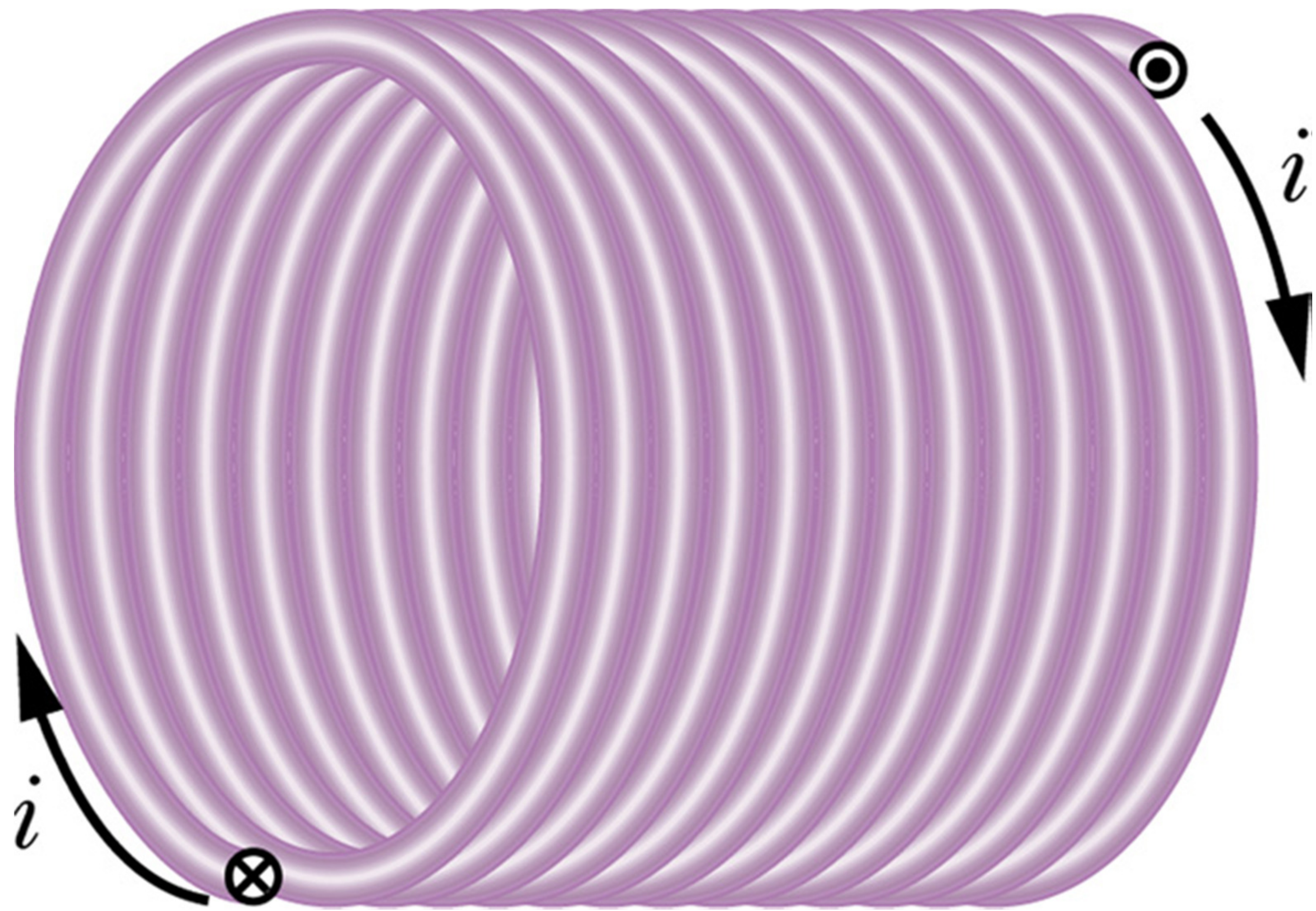
$$2Bw = \mu_0 I_{enc} = \mu_0 (n \cdot w\, I)$$

Solve for $B = \dfrac{\mu_0 n I}{2}$

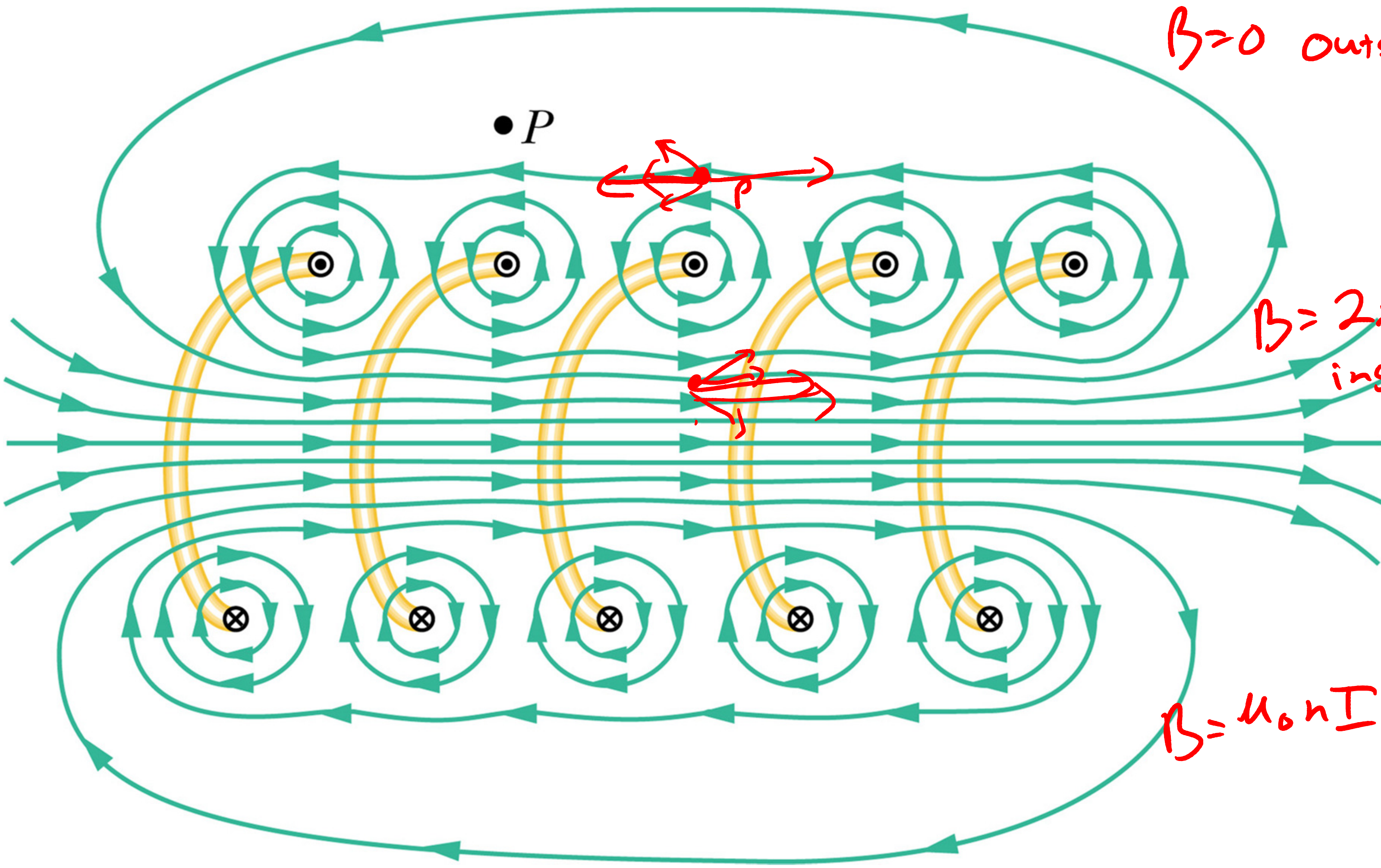

a
b
c



(a) Magnetic field of a current loop


i
i

From one row: $B = \frac{\mu_0 n I}{2}$ (left or right)

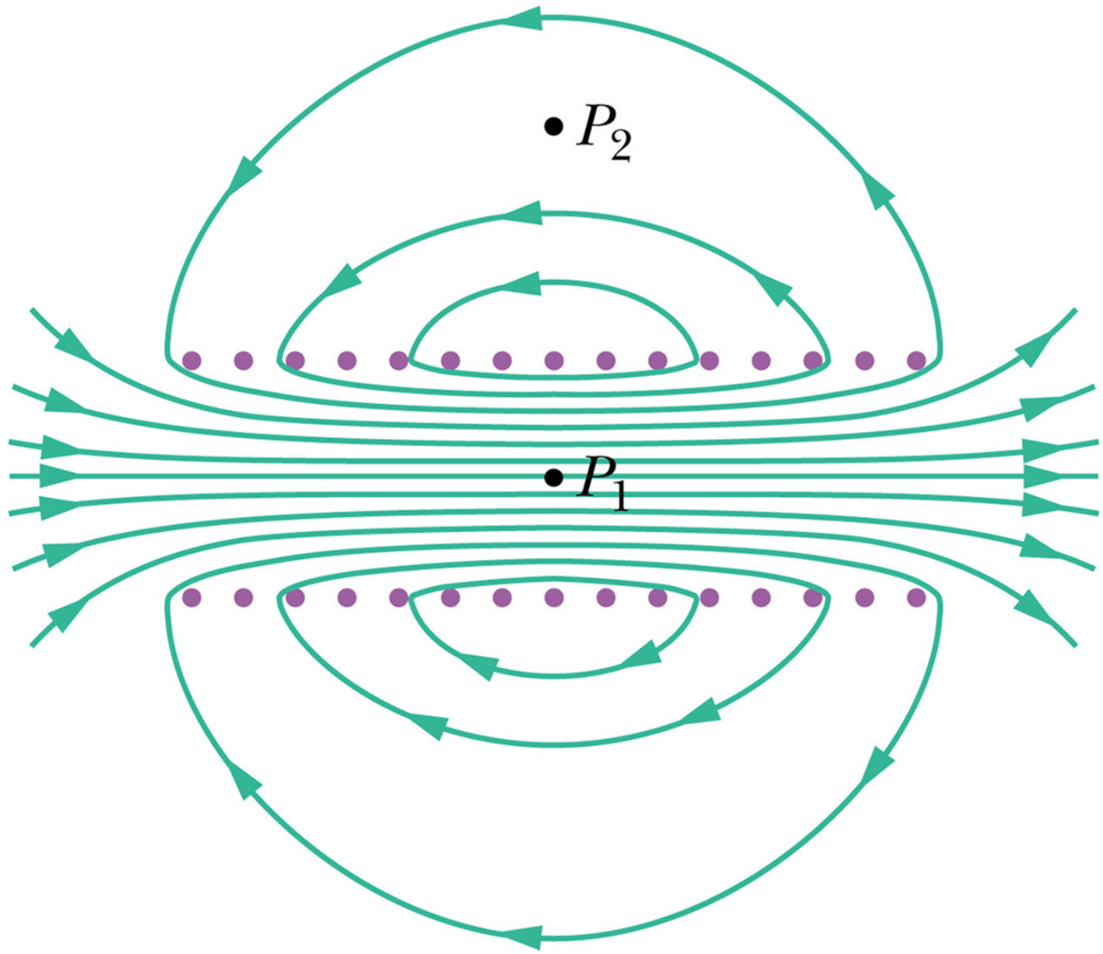


$B = 0$ outside

$B = 2\times$ inside

$B = \mu_0 n I$

Solenoids are a collection of loops…

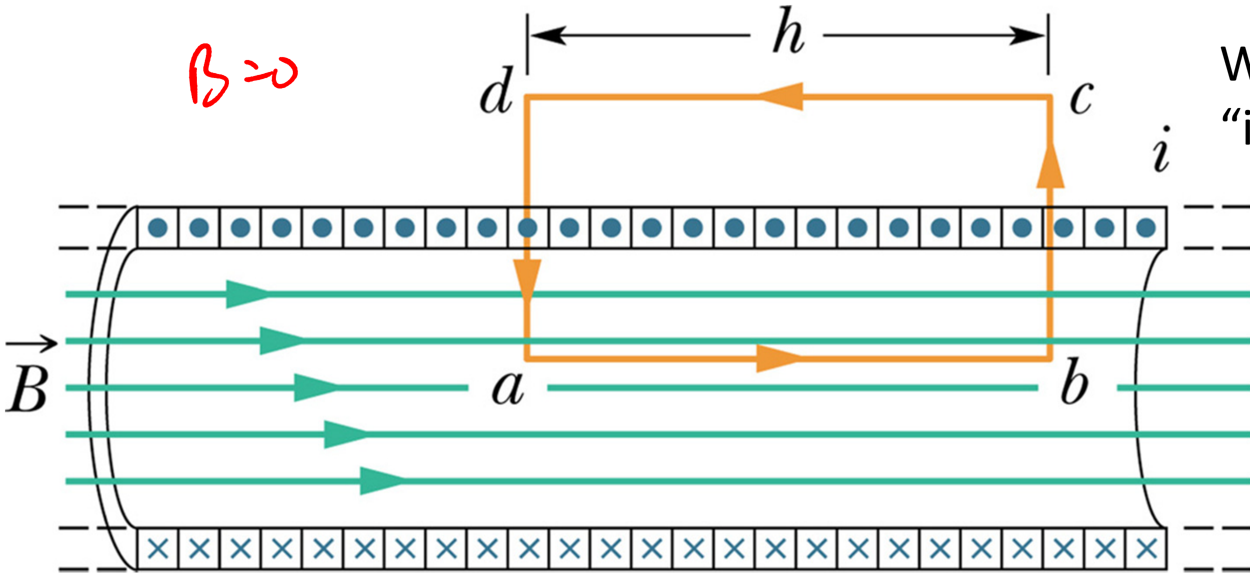


… that make a pretty uniform B down the bore.

An Ideal, tightly wound, really long solenoid:

- Exactly uniform in the bore, zero B outside

$B \approx 0$



Works out B using this "ideal" solenoid assumption

$$\oint \vec{B}\cdot d\vec{\ell} = \int_{ab} B\cdot d\ell \cdot \cos 0 = Bh$$

$$+ \int_{bc} B\cdot d\ell \cdot \cos 90 = 0$$

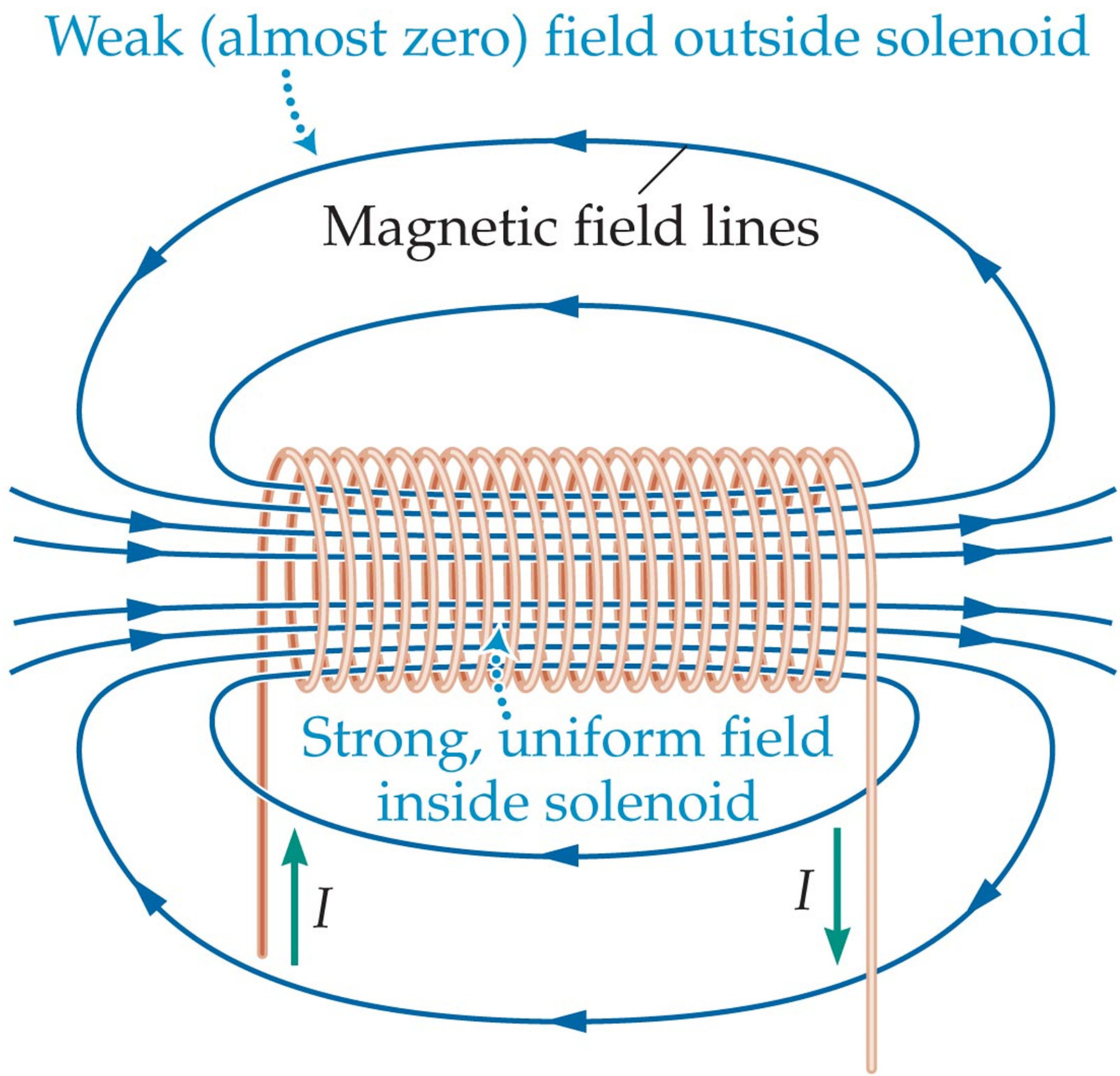
$$+ \int_{cd} B\cdot d\ell = 0$$

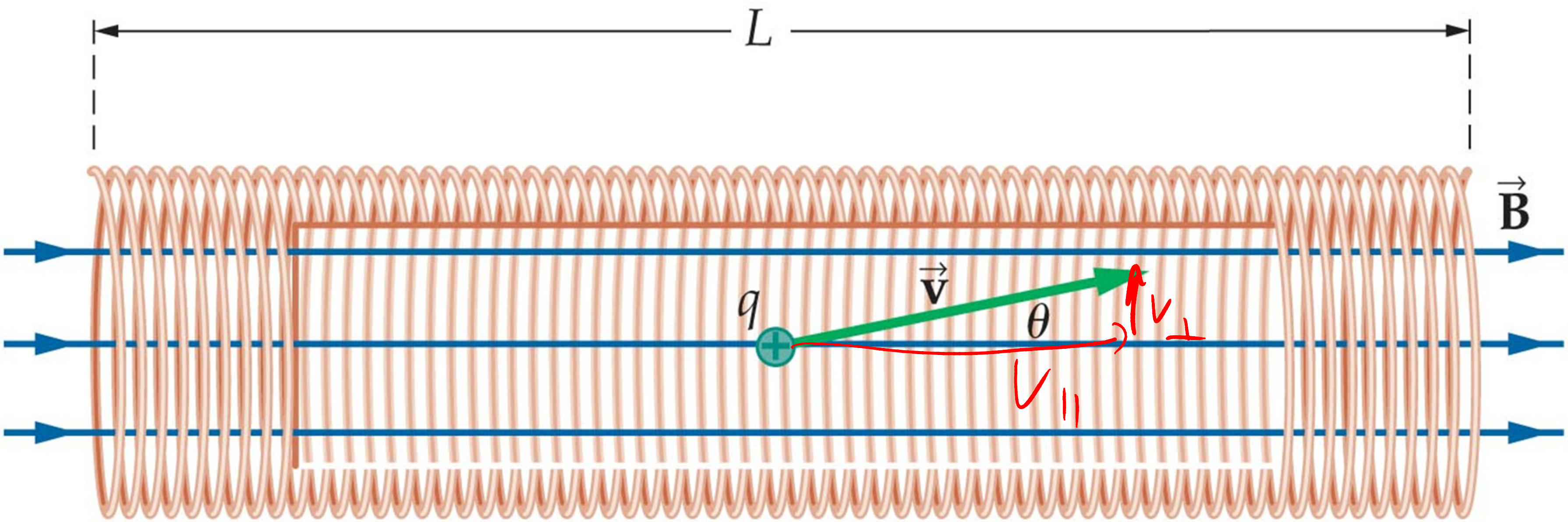
$$+ \int_{da} B\cdot d\ell \cdot \cos 90 = 0$$

$$= B\cdot h = \mu_0 I_{enc}$$

$$= \mu_0 (nh) I$$

$$B = \mu_0 n I$$

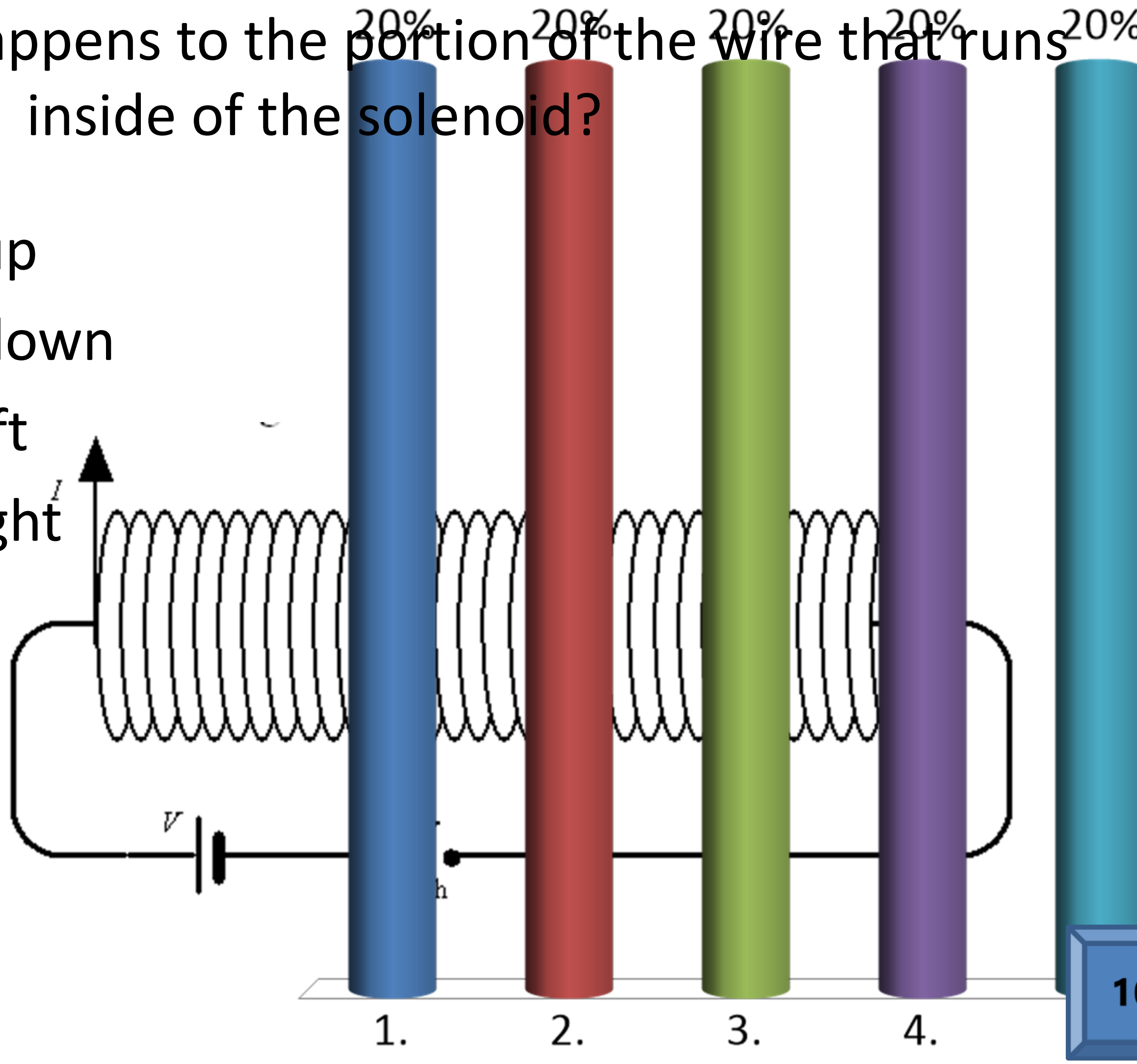

Weak (almost zero) field outside solenoid
Magnetic field lines
Strong, uniform field
inside solenoid
I
I



$$\vec{F_B} = q\vec{v} \times \vec{B}$$

A wire, connected to a battery and switch, passes through the center of a long current-carrying solenoid as shown in the drawing. When the switch is closed and there is a current in the wire, what happens to the portion of the wire that runs inside of the solenoid?

1. Nothing
2. The wire is pushed up
3. The wire is pushed down
4. The wire is pulled left
5. The wire is pulled right



Response Counter

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