Your Comments

Prof, before you get too disappointed by the number of people who, "didn't think about this," understand that I don't find value in completing the prelecture pre-lecture. It's much more useful for me to go to class, listen to you and my buddies explain some of the concepts, then watch the prelectures/read the book the weekend after that week of class. I find my ability to follow along with the videos is significantly better after I've got a decent foundation of knowledge from class. My process is a combination of procrastination and habit, but it works for me.

So unofficial....not as epic as I thought it was going to be.

Can you go over the presence (or absence) of a magnetic field inside a tube? I do not remember the prelecture explaining this and for some reason I feel like it is similar to the electric field in which it is zero inside the tube.

I cried when I heard the words Amperes Law is Gauss Law for Magnetism. Why god why?!?!? Could you also please go over an infinite sheet of current. i didnt understand what was happening during the prelecture.

I think you should change the "Sorry prof. but I didn't think about this" option to "Really sorry prof, but I would think about it if I could, but I don't have the time because I'm studying for my multitude of midterms and finishing homework that I unfortunately procrastinated on until now." Of course, this isn't for me...This is purely hypothetical and only a suggestion....

Could you please stop moving the infinite current carrying sheets that you keep in your office? The magnetic fields that are the same magnitude throughout space keep knocking down the hard drives at SmartPhysics and WebAssign. On second thought...

Dear Professor, This seems easy and I like this. Please don't ruin this by making this seemly simple concept overly complicated. Sincerely, Your Student

Physics 212
Lecture 15

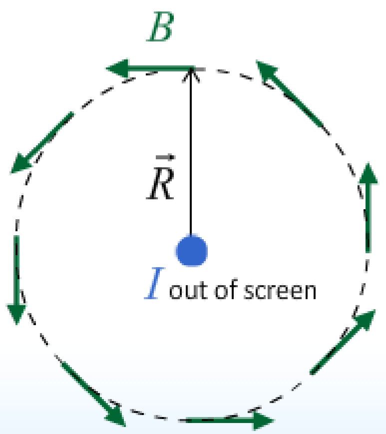
Today's Concept:

Ampere's Law

$$\oint \vec{B} \bullet d\vec{\ell} = \mu_o I_{enclosed}$$

Ampere's Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_o I$$



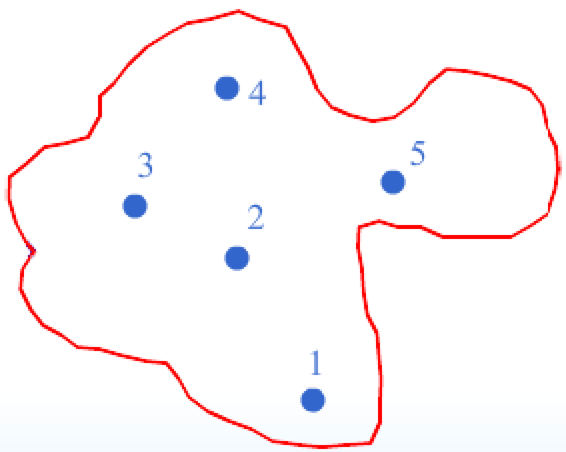
Infinite current-carrying wire

LHS: $\oint \vec{B} \bullet d\vec{\ell} = \oint B d\ell = B \oint d\ell = B \cdot 2\pi R$

RHS: $I_{enclosed} = I$

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

General Case

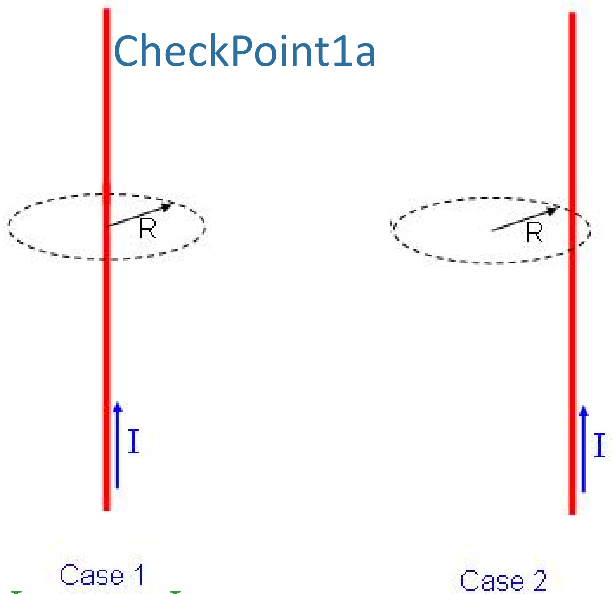


Ampere's Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_o I_{enclosed}$$

Practice on Enclosed Currents

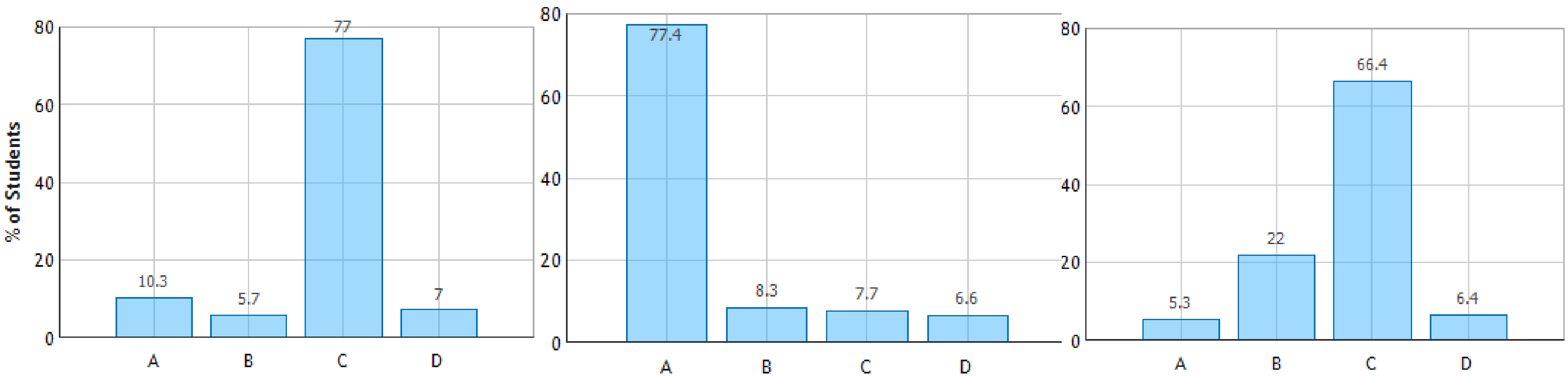
$$\oint \vec{B} \cdot d\vec{l} = \mu_o I_{enclosed}$$



$I_{enclosed} = I$ $\quad$ $I_{enclosed} = I$

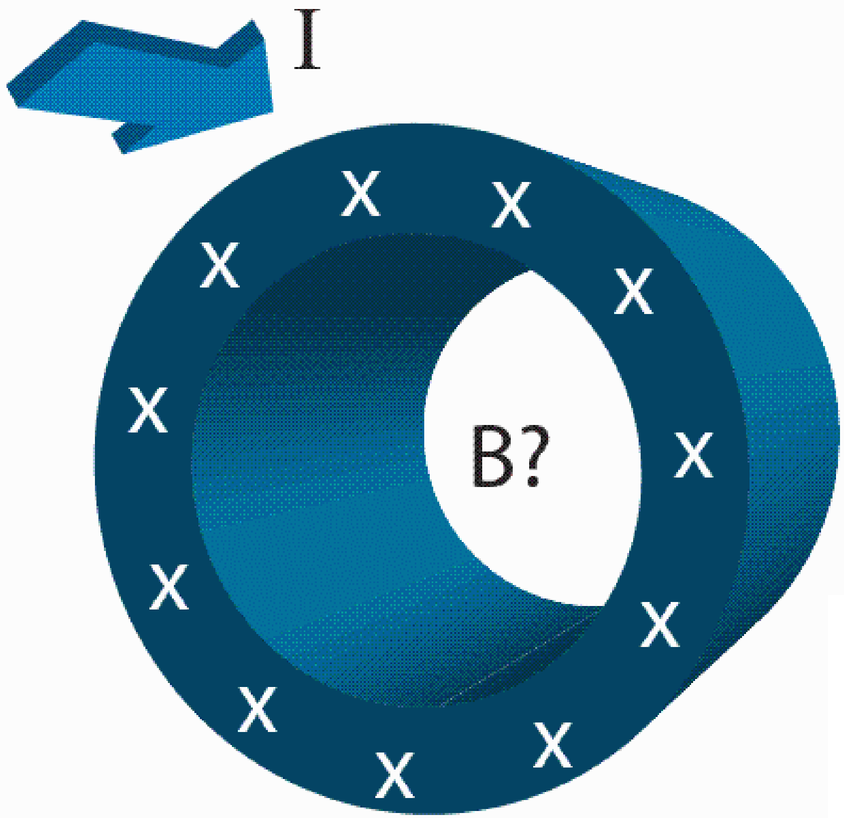
For which loop is ∫**B**·d**l** the greatest?

A. Case 1 ***B.*** Case 2 ***C.*** Same



CheckPoint 2a

An infinitely long hollow conducting tube carries current I in the direction shown.



What is the direction of the magnetic field inside the tube?

A. clockwise

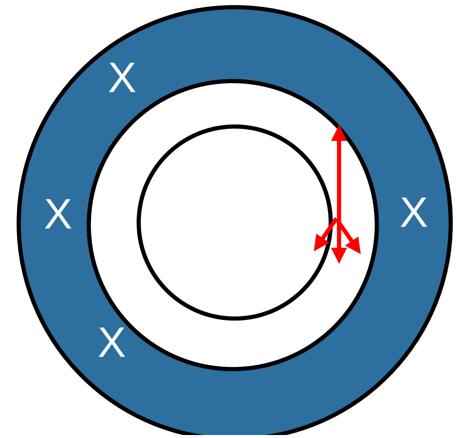
B. counterclockwise

C. radially inward to the center

D. radially outward from the ce

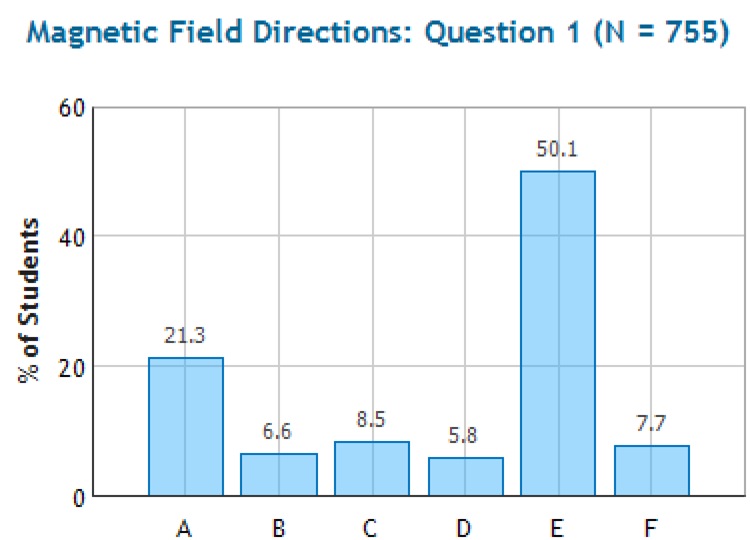
E. the magnetic field is zero

Cylindrical Symmetry



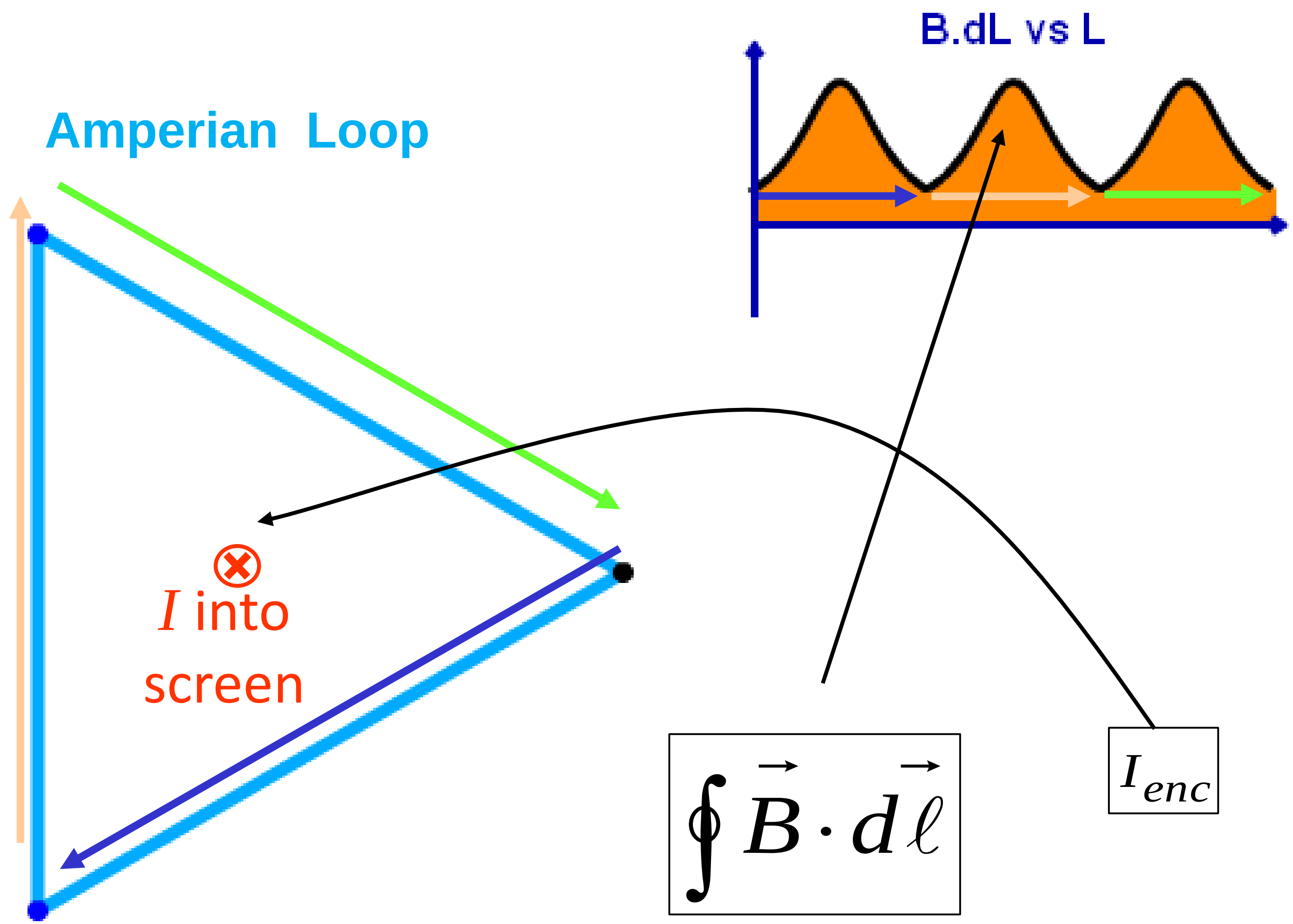
Enclosed Current = 0

Check cancellations



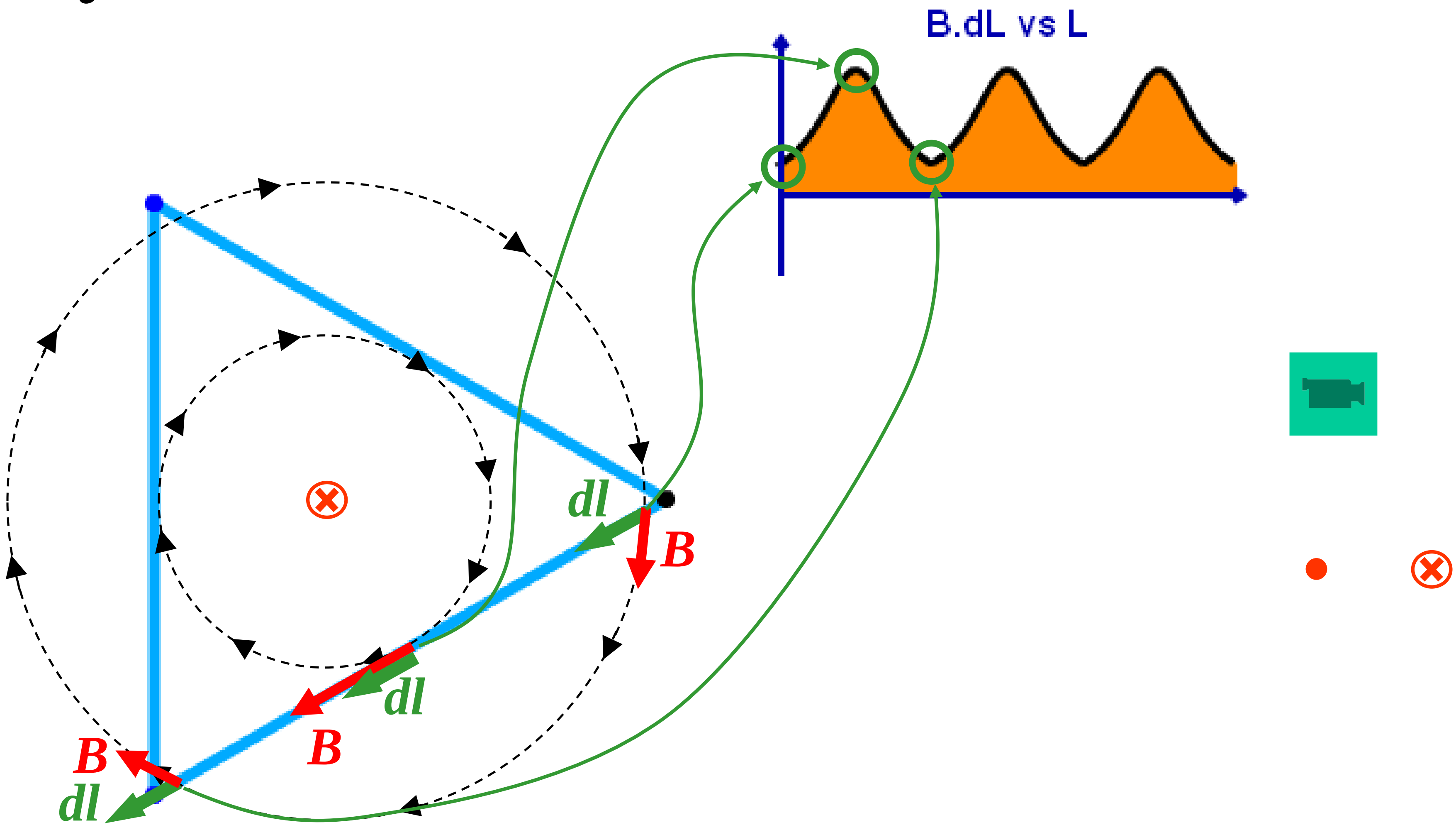
Ampere's Law

+integrals + magnetic field directinos



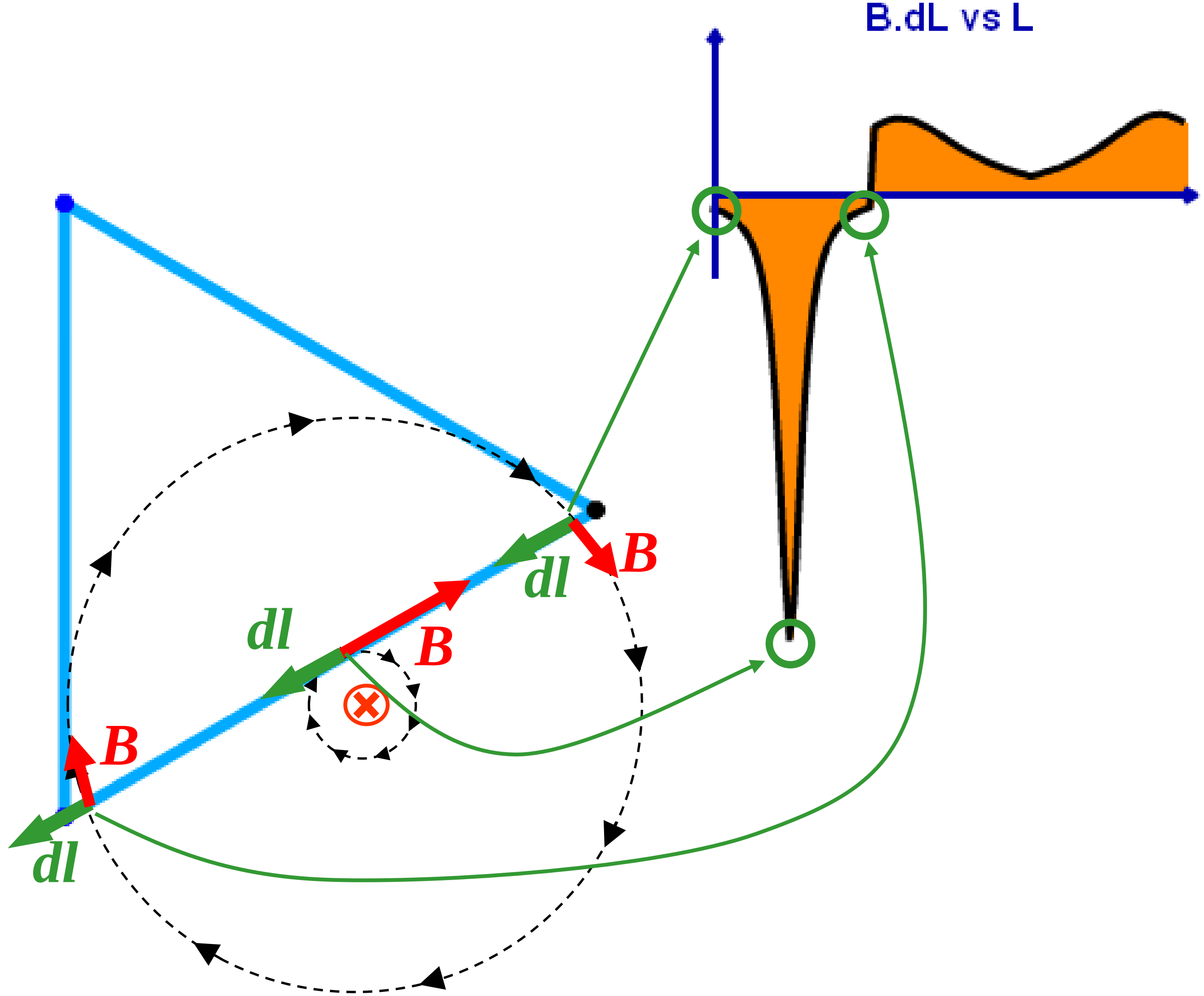
Ampere's Law

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



Ampere's Law

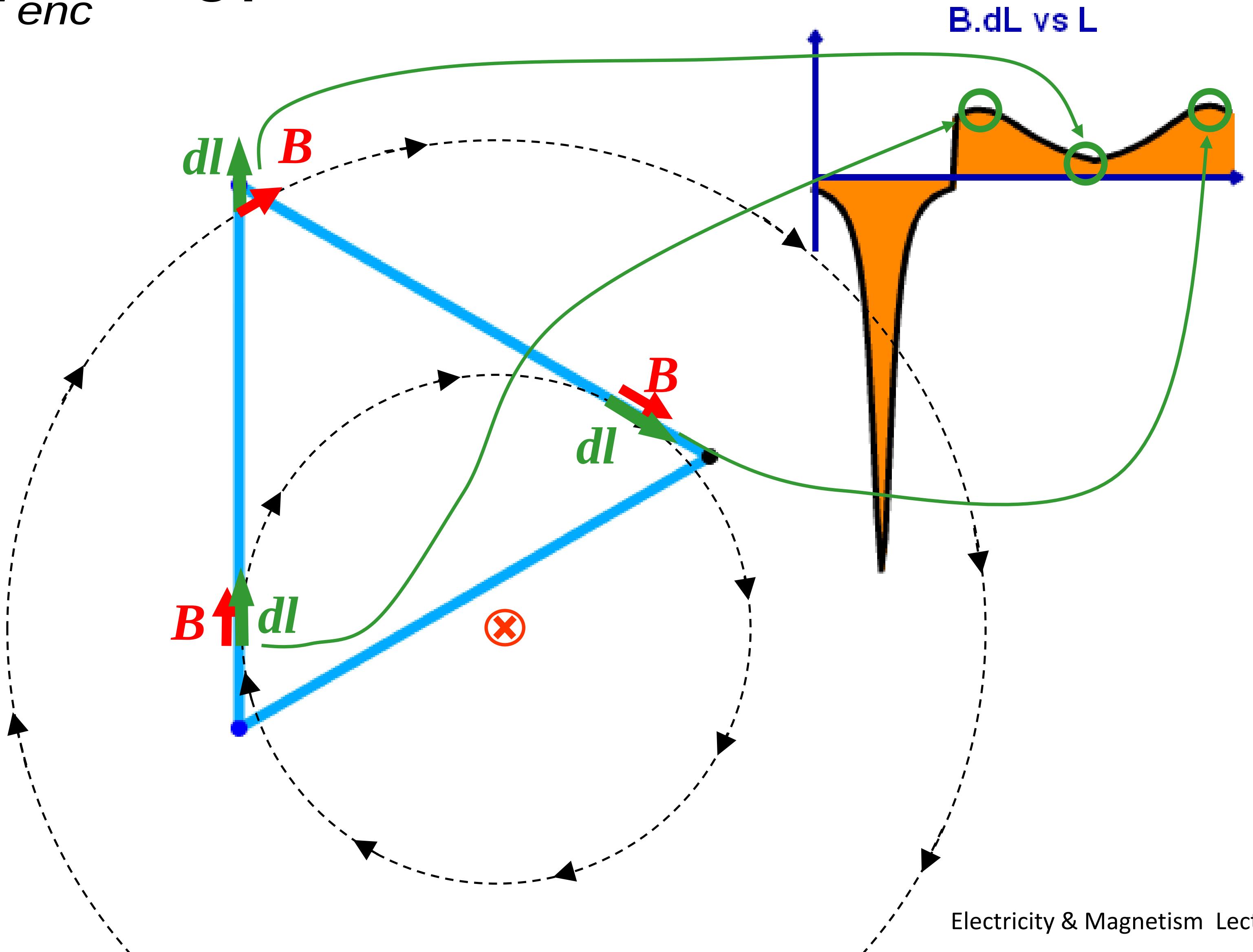
$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I_{enc}$$



Ampere's Law

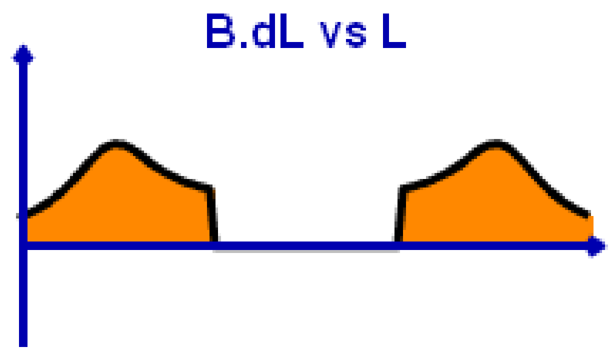
$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I_{enc}$$

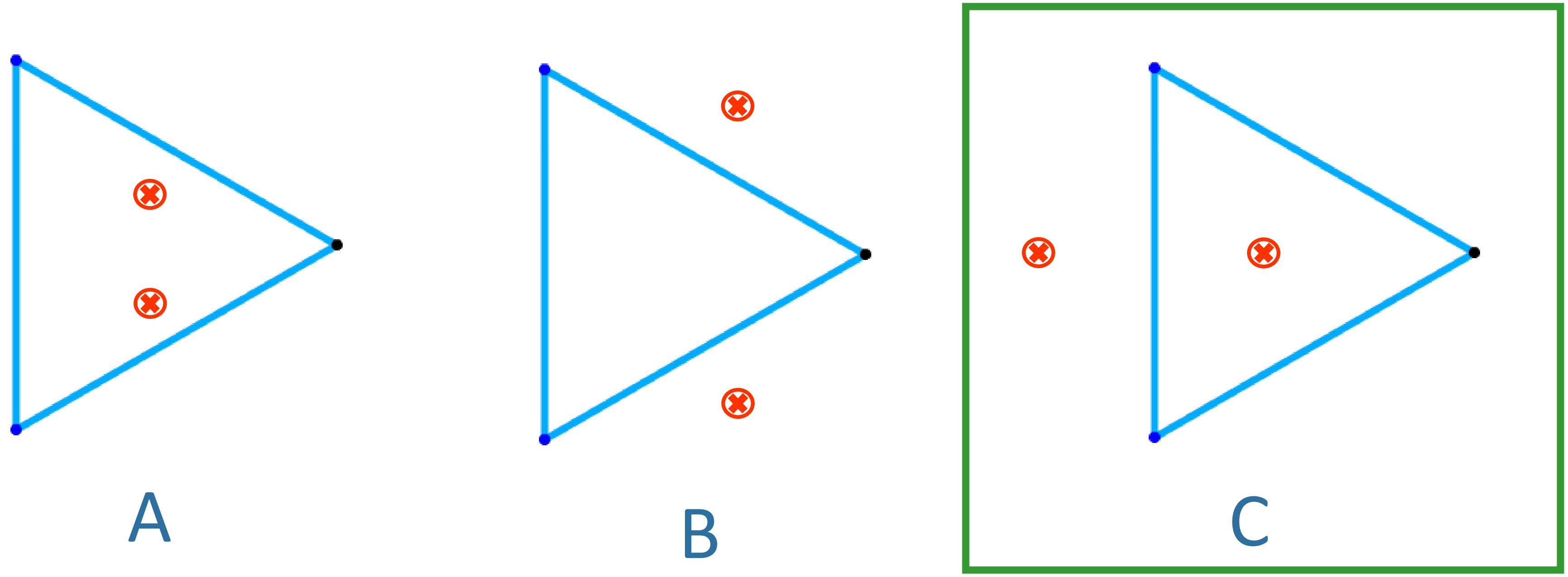
$I_{enc} = 0!$



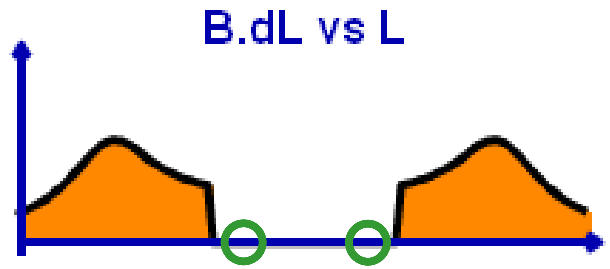
Ampere's Law Clicker Question

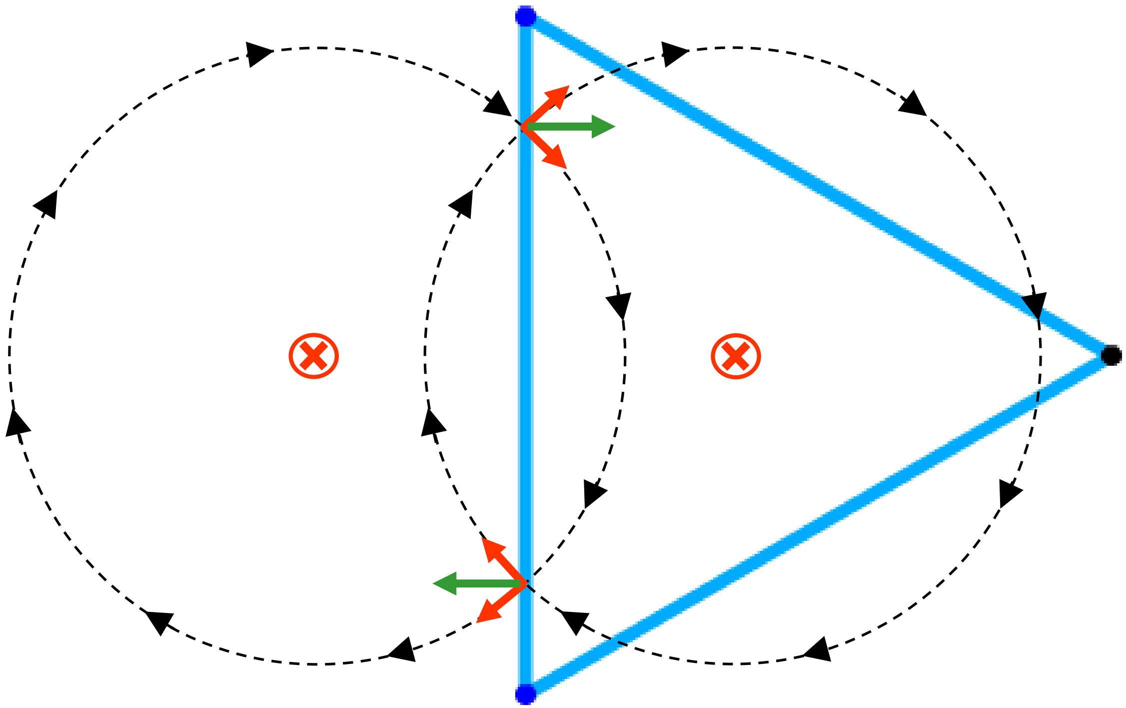
Which of the following current distributions would give rise to the $B \cdot dL$ distribution at the right?



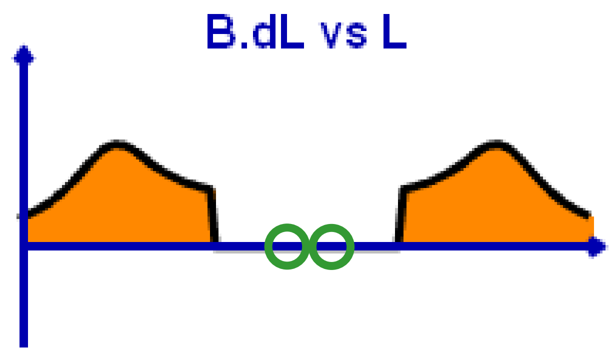


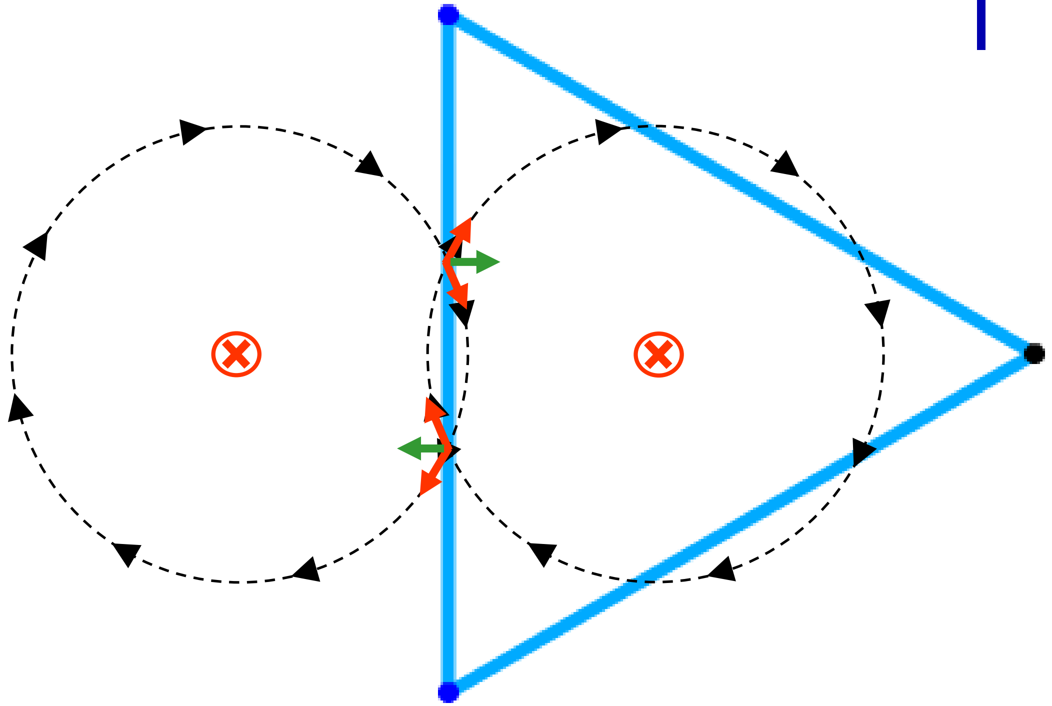
Ampere's Law Clicker Question



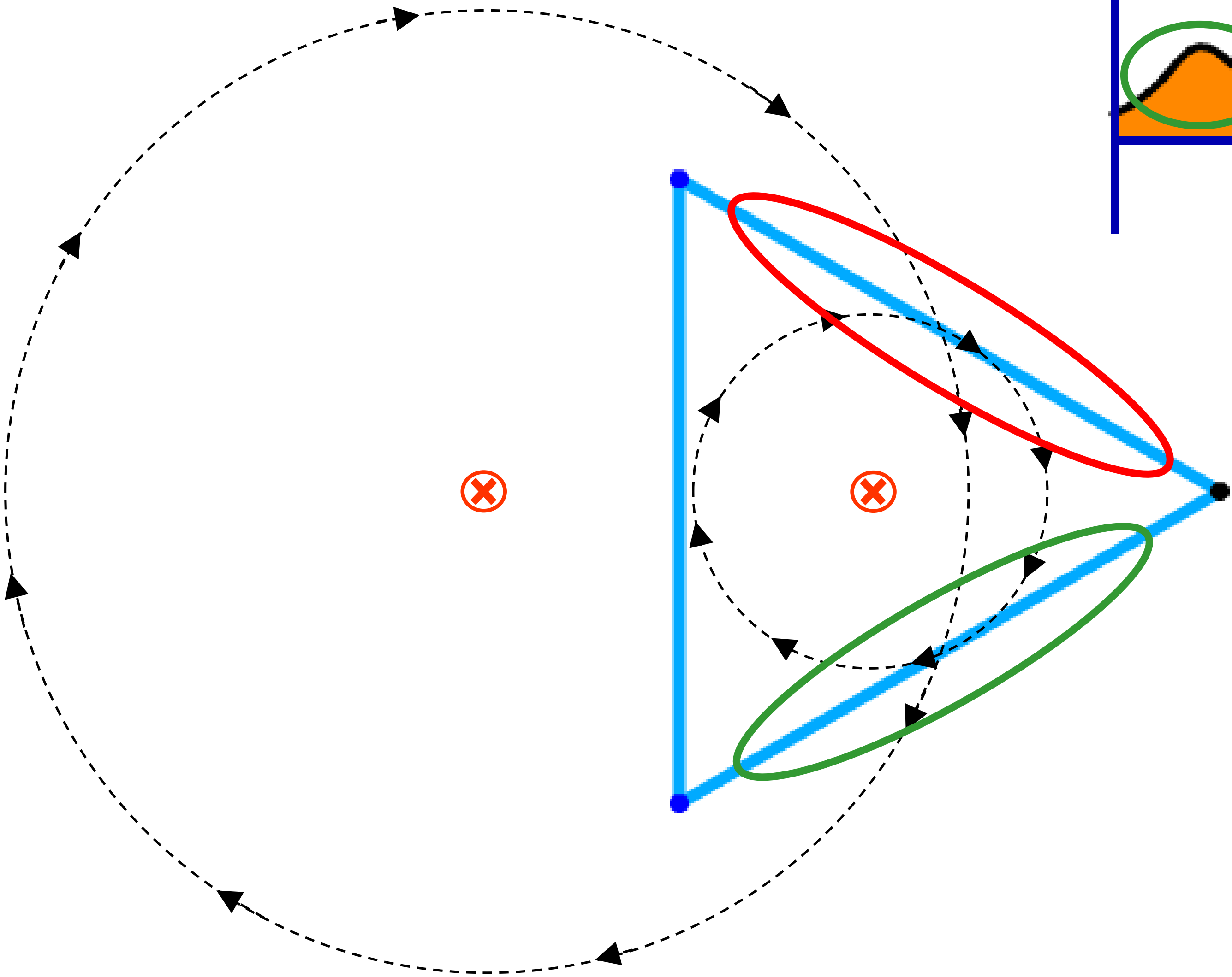


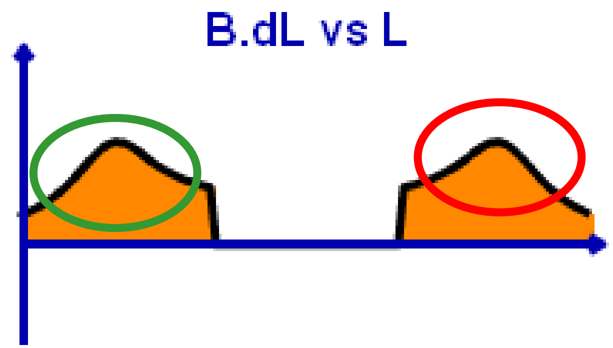
Ampere's Law Clicker Question



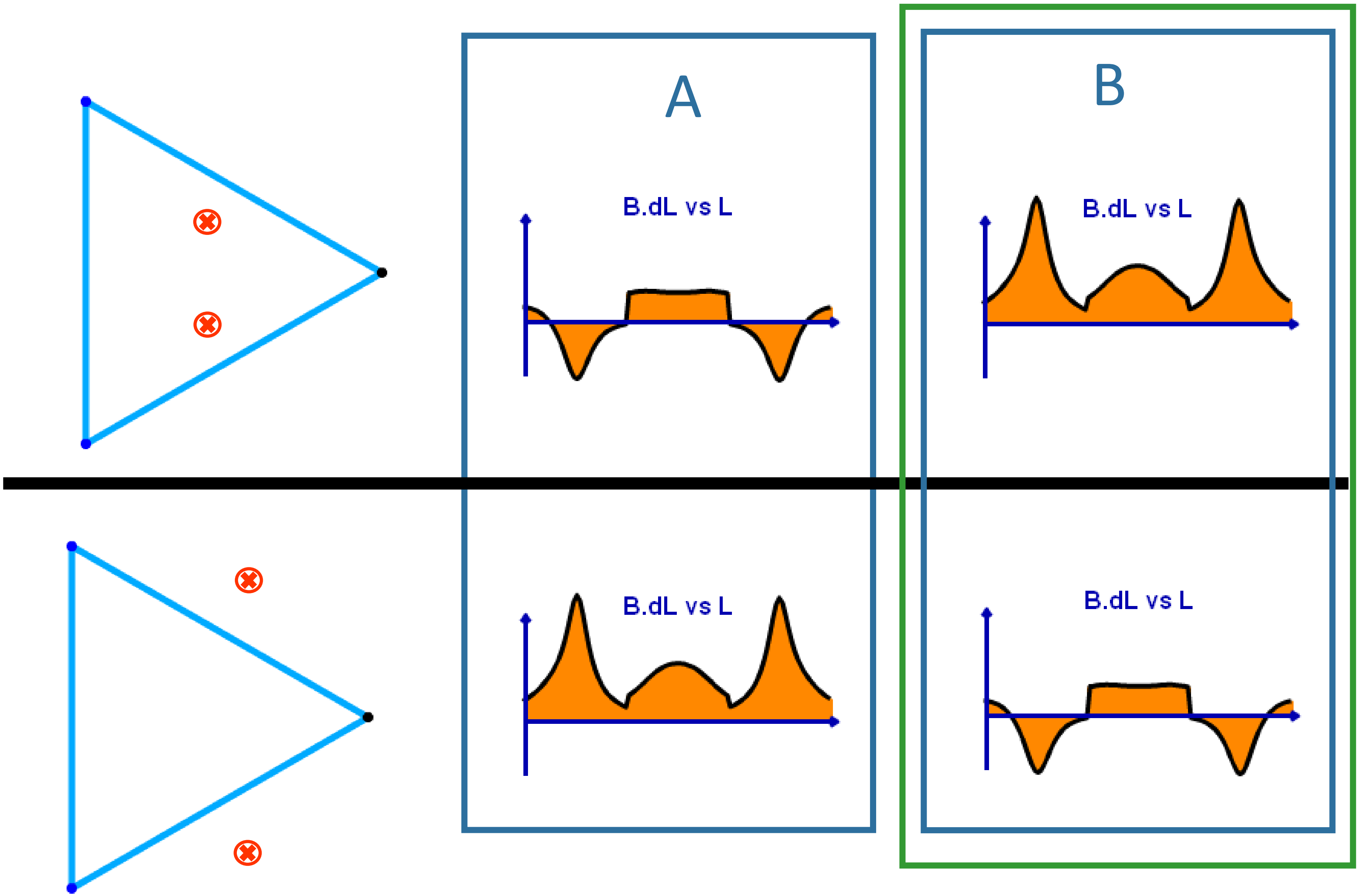


Ampere's Law Clicker Question



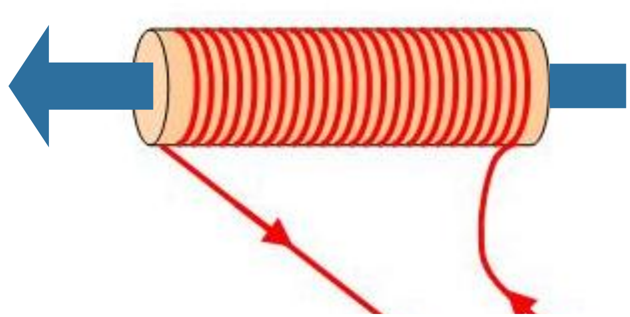


Match the other two:



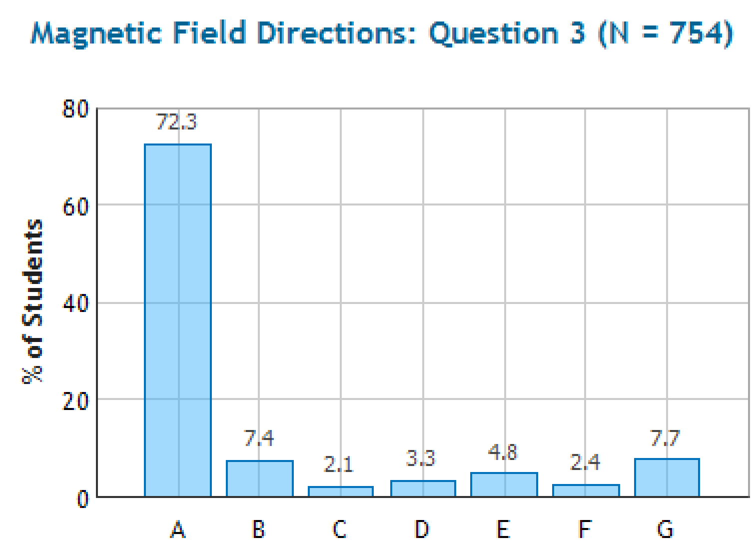
CheckPoint 2b

A current carrying wire is wrapped around cardboard tube as shown below.



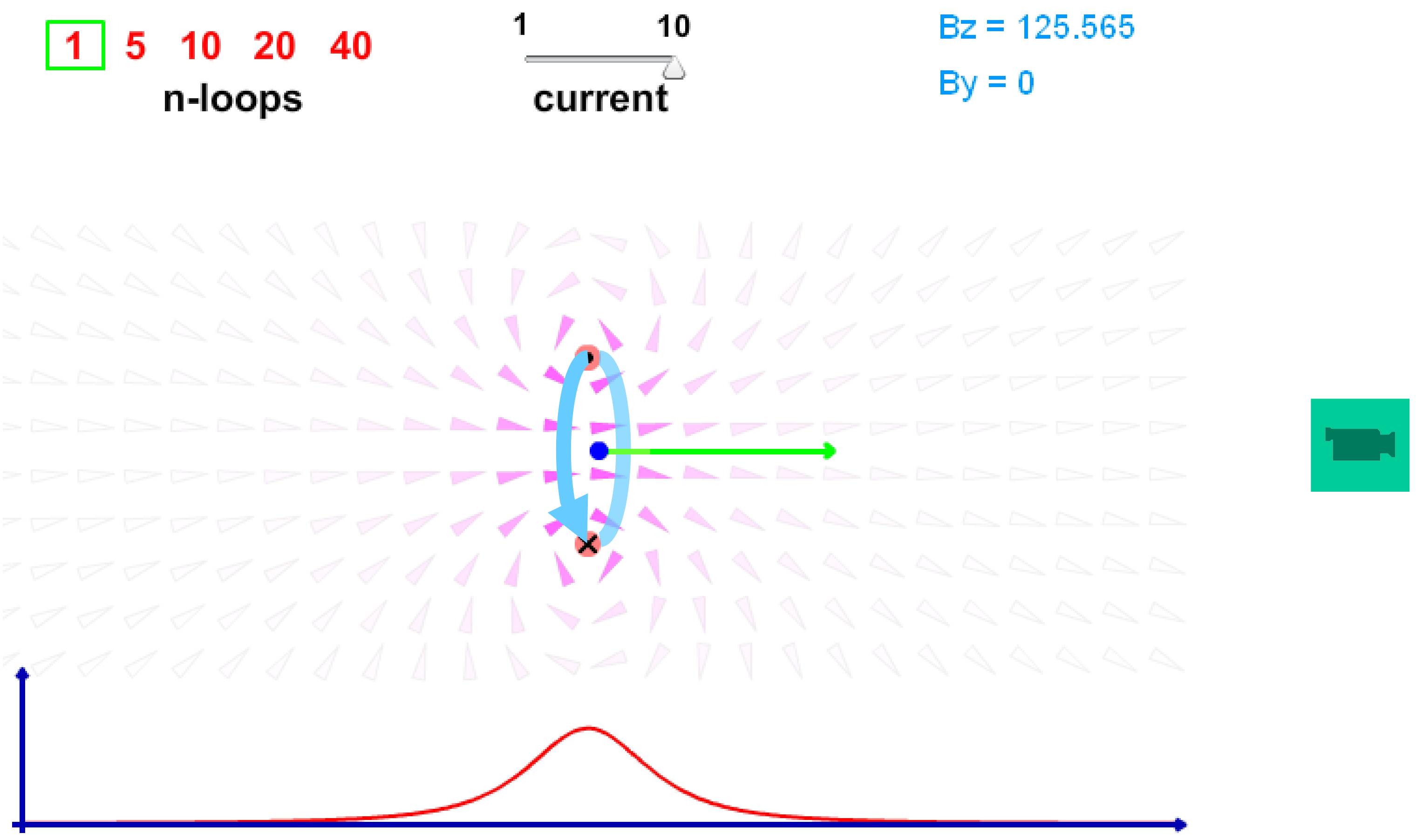
In which direction does the magnetic field point inside the tube?

A. Left　　***B.*** Right　　***C.*** Up　　***D.*** Down　　***E.*** Out of screen



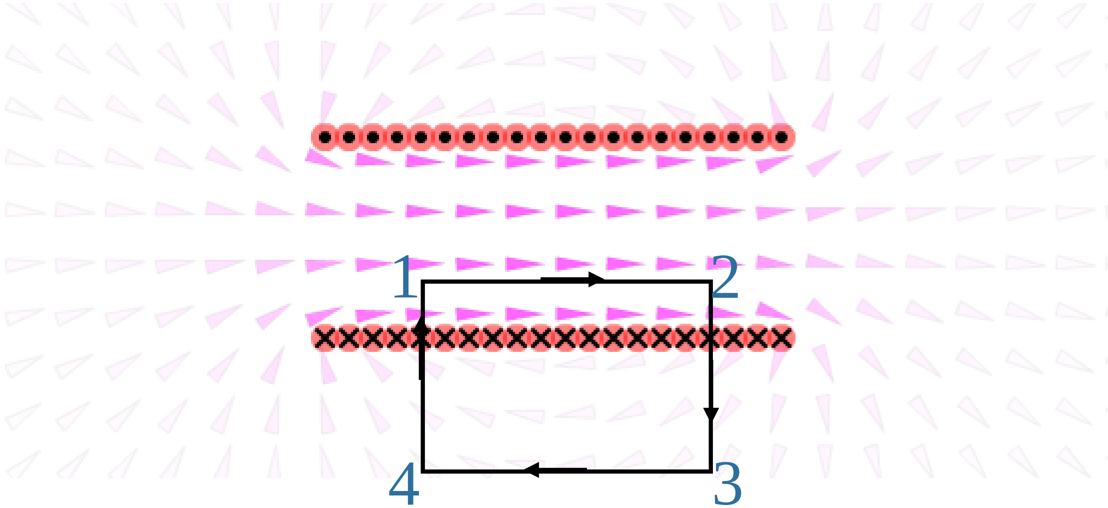
Use the right hand rule and curl your fingers along the direction of the curre

Simulation



Solenoid

Several loops packed tightly together form a uniform magnetic field inside, and nearly zero magnetic field outside.



From this simulation, we can assume a constant field inside the solenoid and zero field outside the solenoid, and apply Ampere's law to find the magnitude of the constant field inside the solenoid!

$$\oint \vec{B} \bullet d\vec{\ell} = \mu_o I_{enc} \rightarrow \int_1^2 \vec{B} \bullet d\vec{\ell} + \int_2^3 \vec{B} \bullet d\vec{\ell} + \int_3^4 \vec{B} \bullet d\vec{\ell} + \int_4^1 \vec{B} \bullet d\vec{\ell} = \mu_o I_{enc}$$

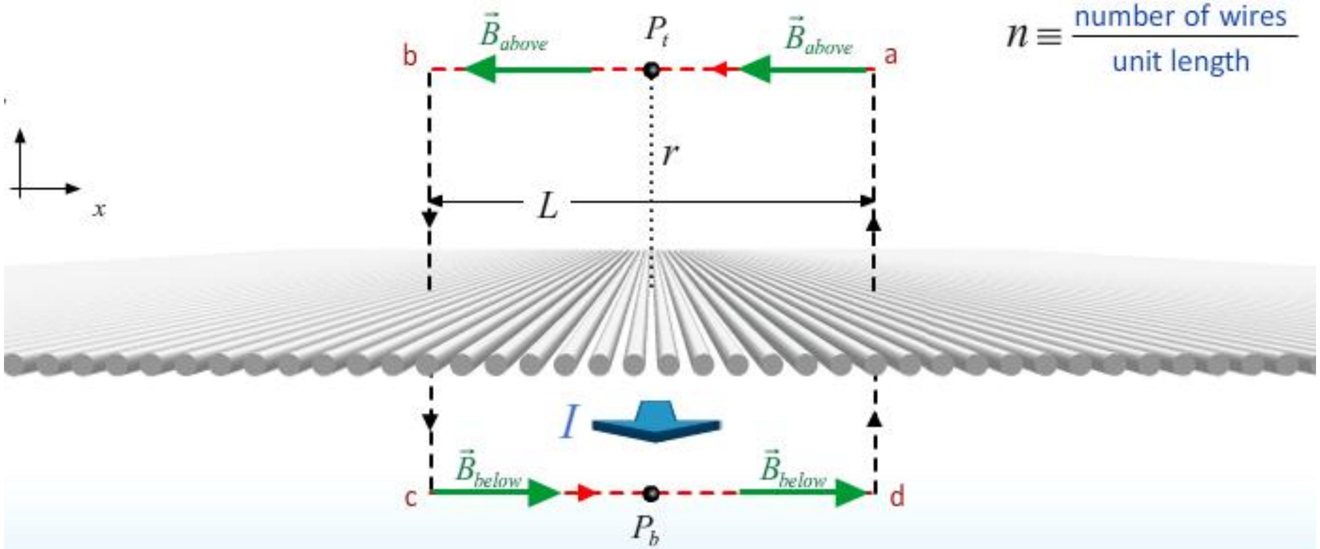
$$BL + 0 + 0 + 0 = \mu_o I_{enc} \rightarrow BL = \mu_o nLI \rightarrow B = \mu_o nI$$

n = # turns/length

Similar to the Current Sheet

Wire Density

$$n \equiv \frac{\text{number of wires}}{\text{unit length}}$$



$$\oint_{loop} \vec{B}\cdot d\vec{l} = \int_a^b \vec{B}\cdot d\vec{l} + \int_c^d \vec{B}\cdot d\vec{l}$$

$$= \quad BL \quad + \quad BL$$

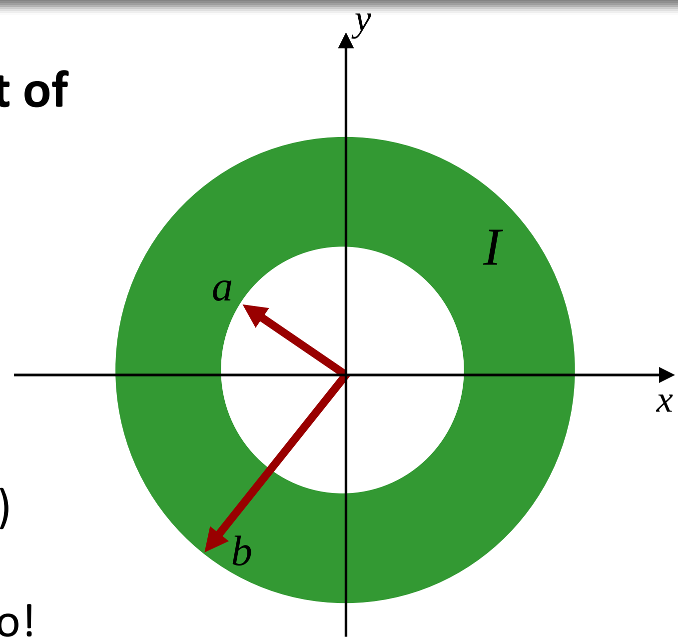
Total integral around the loop

$$\oint_{loop} \vec{B}\cdot d\vec{\ell} = 2BL = \mu_0 I_{enclosed}$$

$$\therefore B = \frac{\mu_0 N I}{2L} = \frac{\mu_0 n I}{2}$$

Example Problem

An infinitely long cylindrical shell with inner radius a and outer radius b carries a uniformly distributed current I **out of the screen.**



Sketch $|B|$ as a function of r.

Conceptual Analysis

Complete cylindrical symmetry (can only depend on r)

$\Rightarrow$ can use Ampere's law to calculate B

B field can only be clockwise, counterclockwise or zero!

$$\oint \vec{B} \bullet d\vec{\ell} = \mu_o I_{enc}$$

$$B\oint d\ell = \mu_o I_{enc}$$ For circular path concentric with shell.

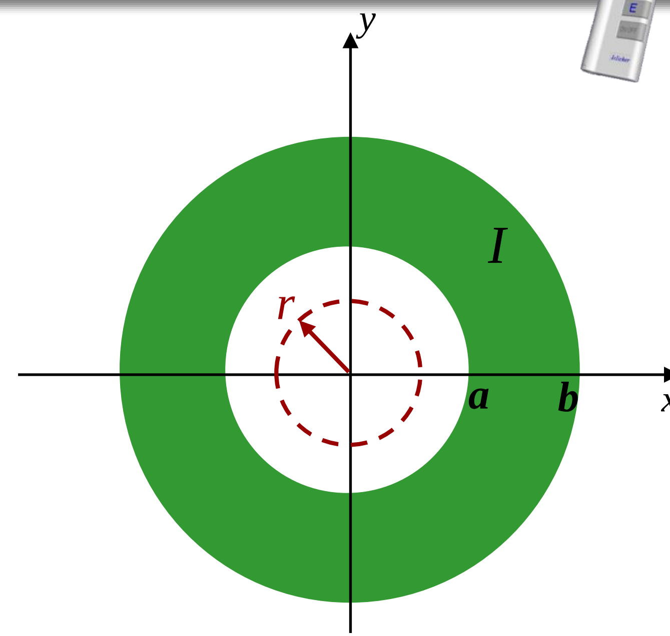
Strategic Analysis

Calculate B for the three regions separately:

1) $r < a$
2) $a < r < b$
3) $r > b$

Example Problem

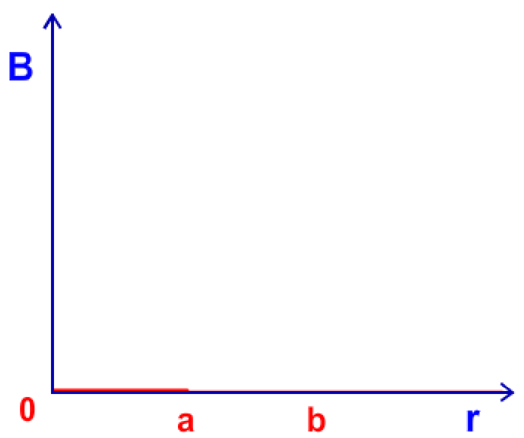
What does $|B|$ look like for $r < a$?



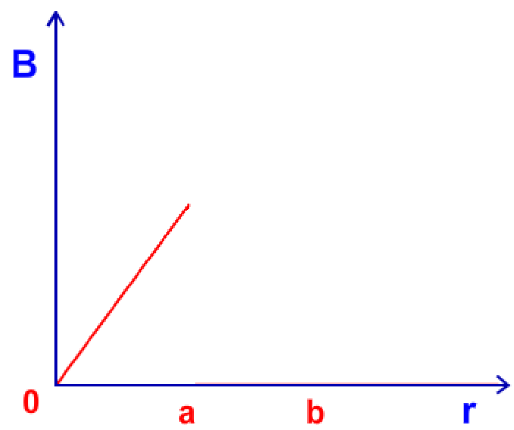
$$\oint \vec{B}\bullet d\vec{\ell} = \mu_o I_{inc}$$

I_{inc} → 0

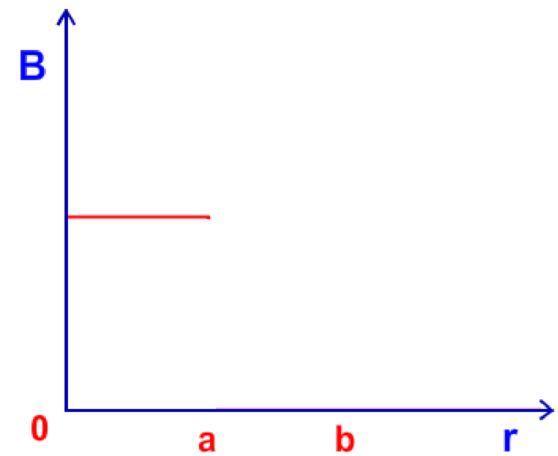
so $\vec{B} = 0$



A



B

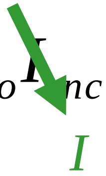


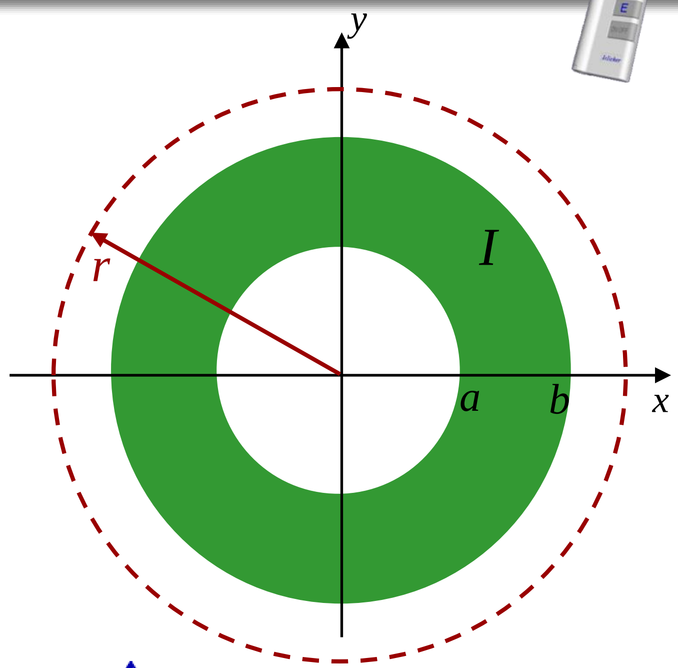
C

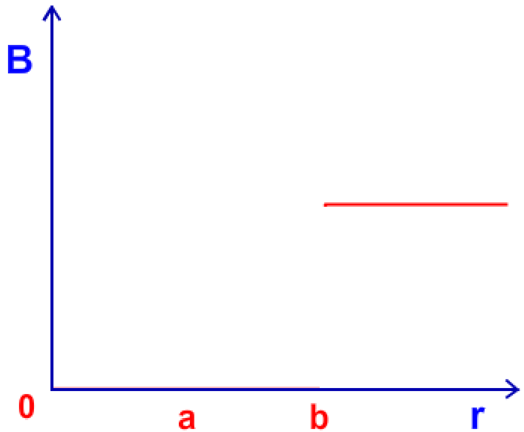
Example Problem

What does $|B|$ look like for $r > b$?

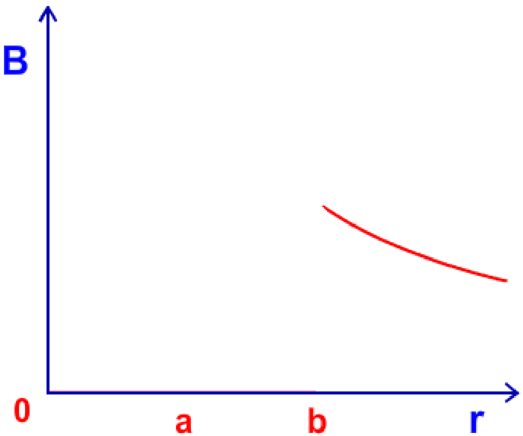
$$\oint \vec{B} \bullet d\vec{\ell} = \mu_o I_{inc}$$



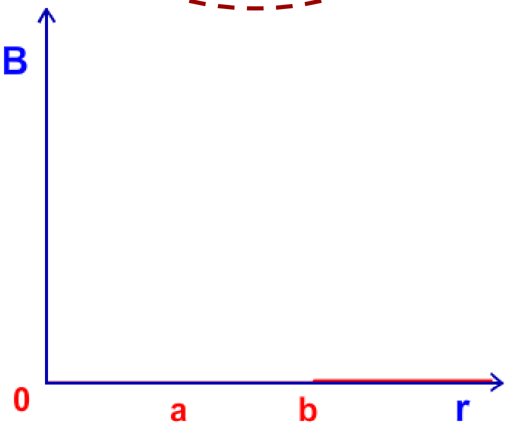




A



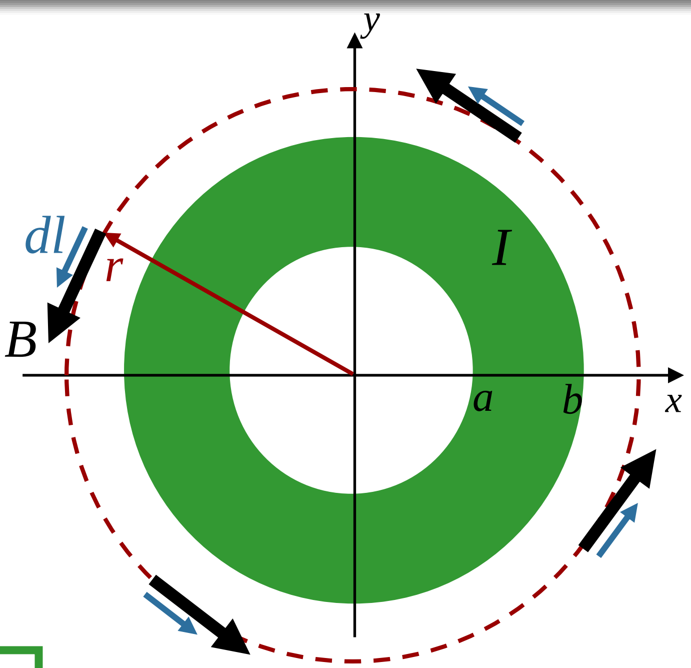
B



C

Example Problem

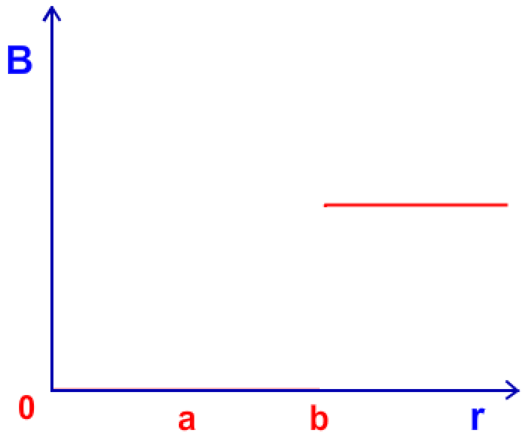
What does $|B|$ look like for $r > b$?



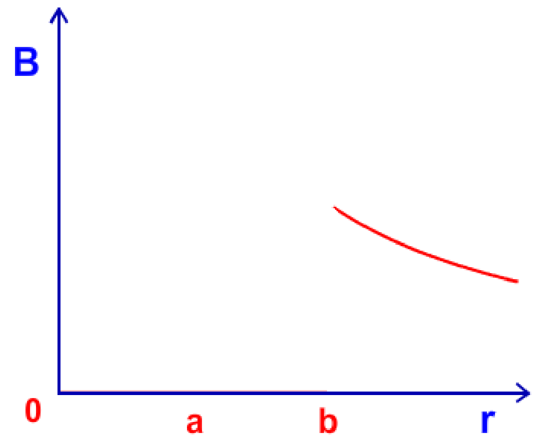
LHS: $\oint \vec{B} \bullet d\vec{\ell} = \oint B d\ell = B \oint d\ell = B \cdot 2\pi r$

RHS: $I_{enclosed} = I$

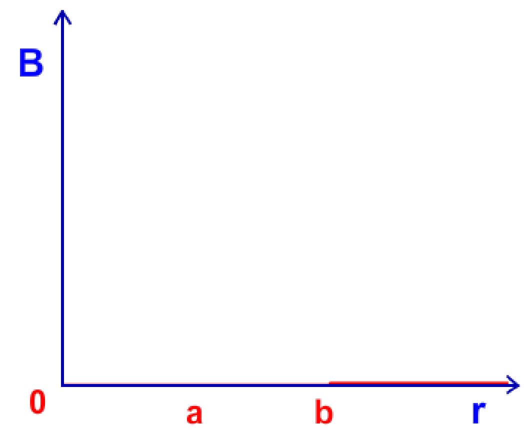
$$B = \frac{\mu_o I}{2\pi r}$$



A



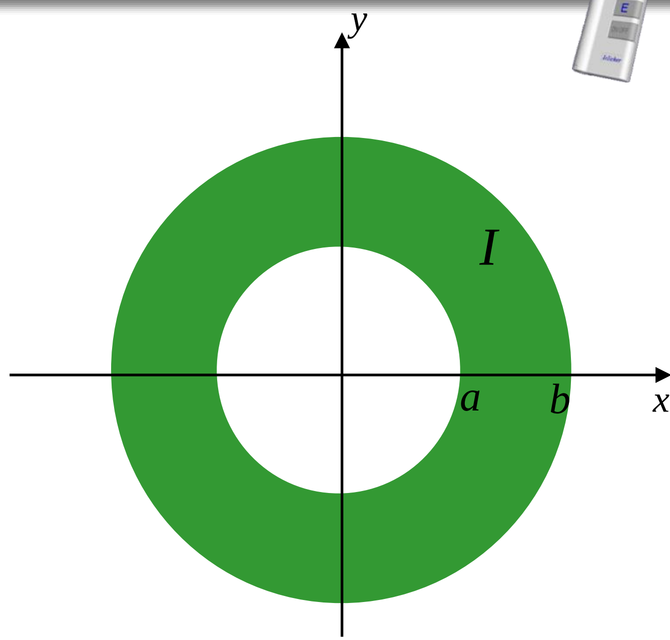
B



C

Example Problem

What is the current density j (Amp/m^2) in the conductor?



A) $j = \dfrac{I}{\pi b^2}$

B) $j = \dfrac{I}{\pi b^2 + \pi a^2}$

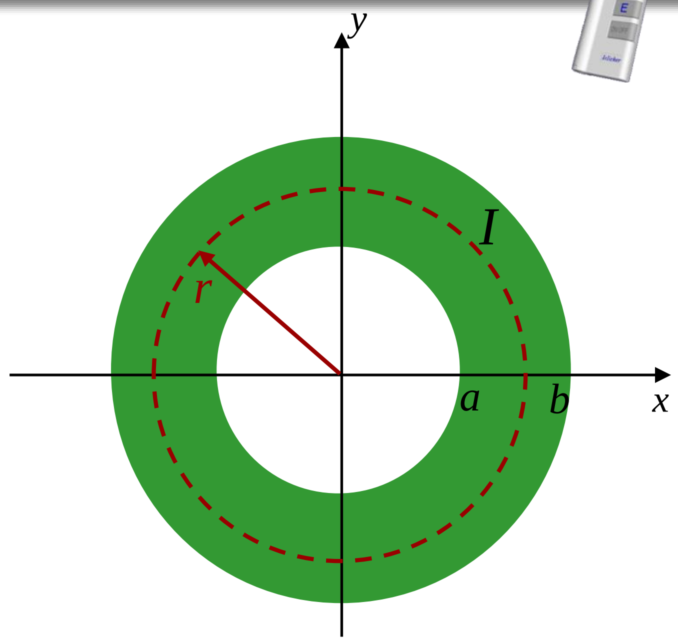
C) $j = \dfrac{I}{\pi b^2 - \pi a^2}$

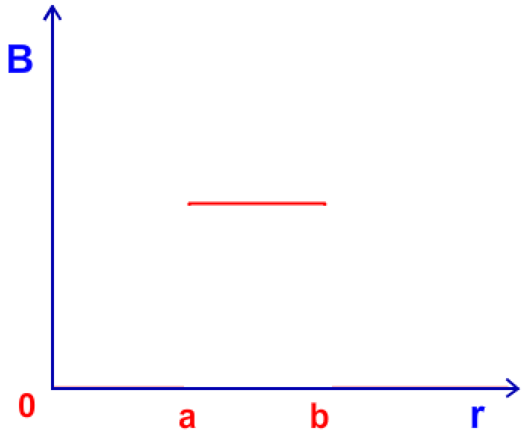
$j = I / area$ $\quad$ $area = \pi b^2 - \pi a^2$

$$j = \frac{I}{\pi b^2 - \pi a^2}$$

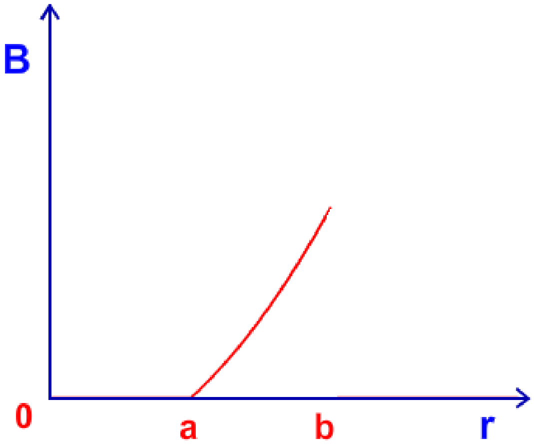
Example Problem

What does $|B|$ look like for $a < r < b$?

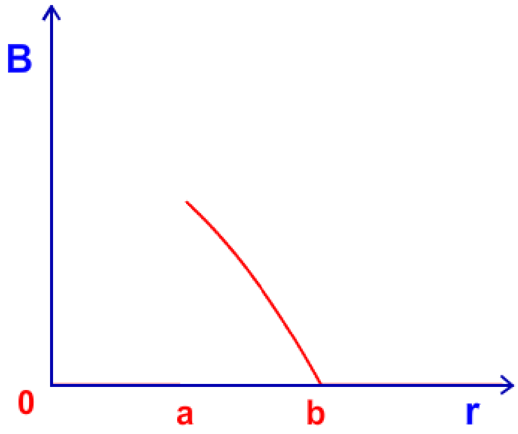




A



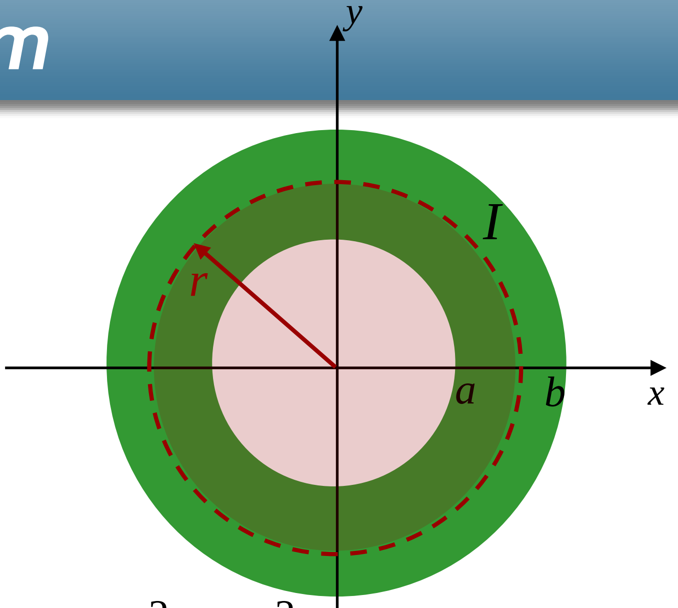
B



C

Example Problem

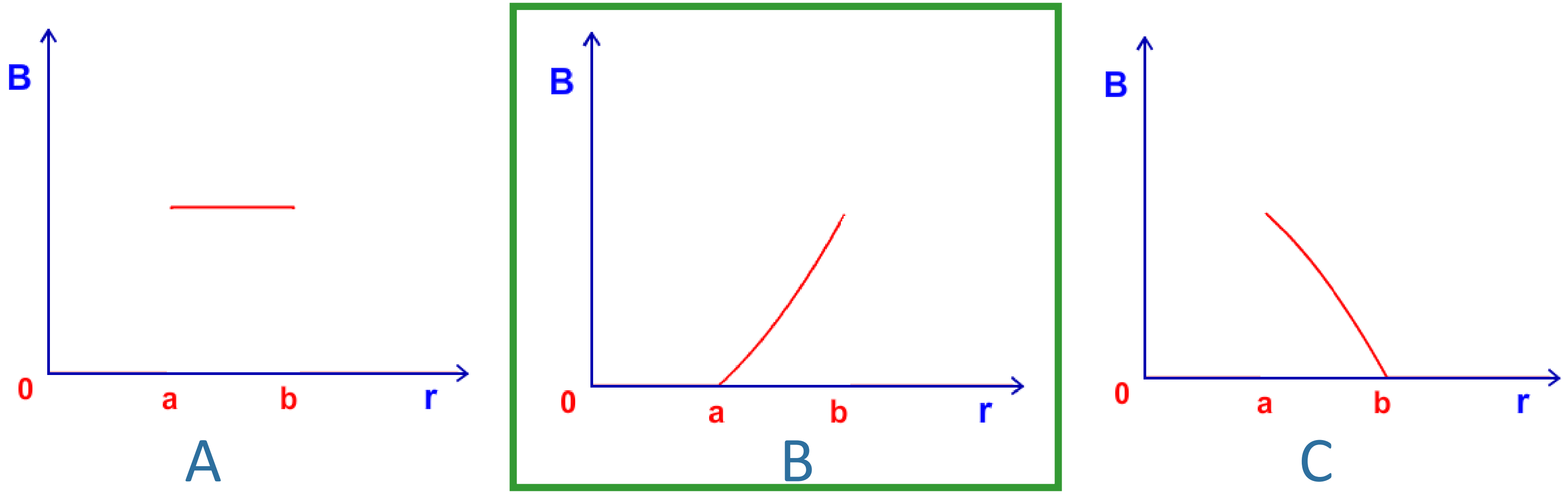
What does $|B|$ look like for $a < r < b$?



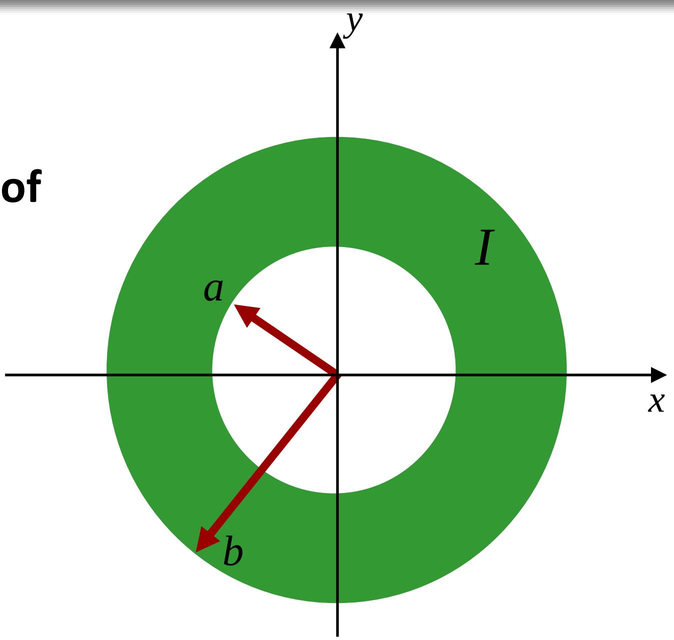
$$\oint \vec{B} \bullet d\vec{\ell} = \mu_o I_{enc} \quad \rightarrow \quad B \cdot 2\pi r = \mu_o \cdot j A_{enc}$$

$$B \cdot 2\pi r = \mu_o \cdot \frac{I}{\pi(b^2 - a^2)} \cdot \pi(r^2 - a^2) \quad \rightarrow \quad B = \frac{\mu_o I}{2\pi r} \cdot \frac{(r^2 - a^2)}{(b^2 - a^2)}$$

Starts at 0 and increases almost linearly

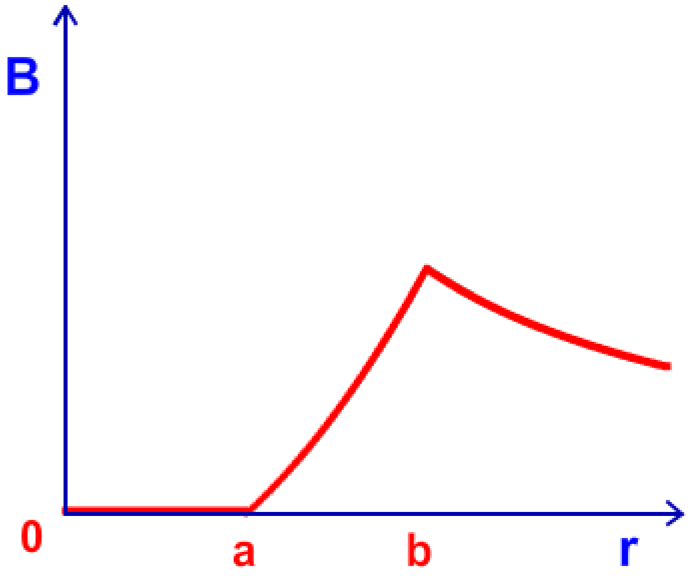


Example Problem



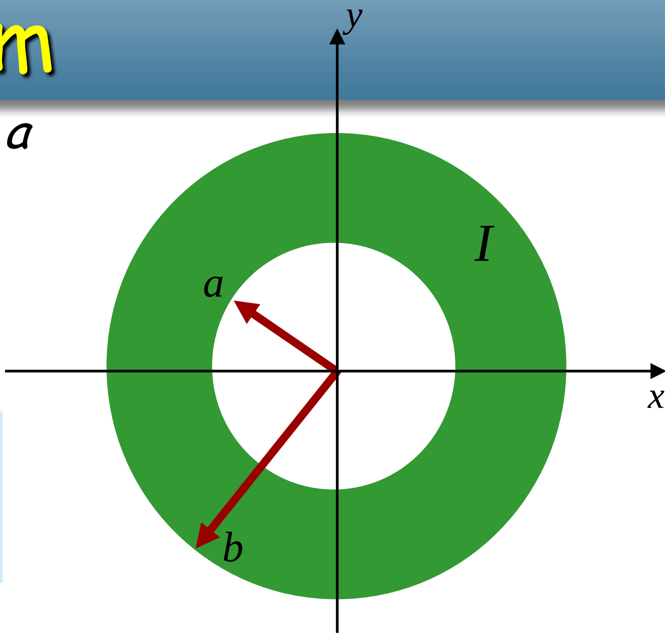
An infinitely long cylindrical shell with inner radius a and outer radius b carries a uniformly distributed current **I out of the screen.**

Sketch $|B|$ as a function of r.



Example Problem

An infinitely long cylindrical shell with inner radius *a* and outer radius *b* carries a uniformly distributed current I ***out of the screen***.

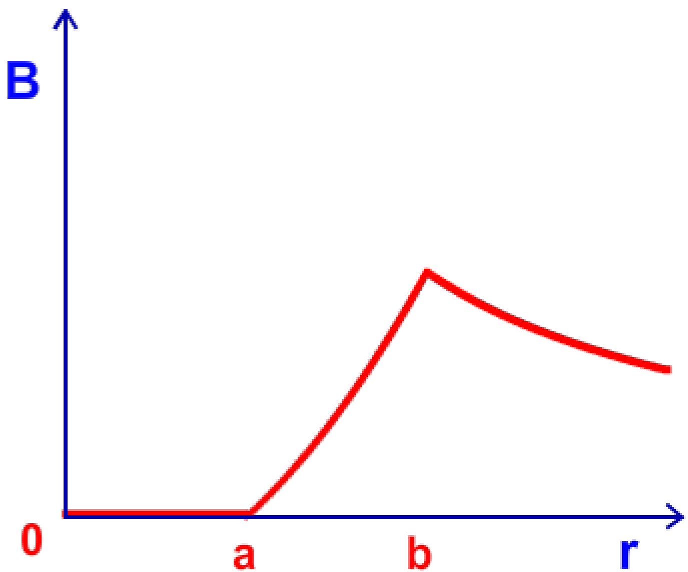


Sketch |B| as a function of *r*.

How big is B at *r* = *b*?

$$B = \frac{\mu_o I}{2\pi r} \cdot \frac{(r^2 - a^2)}{(b^2 - a^2)}$$

Let I = 10 A, b = 1 mm



$$B(b) = \frac{\mu_o I}{2\pi b}$$

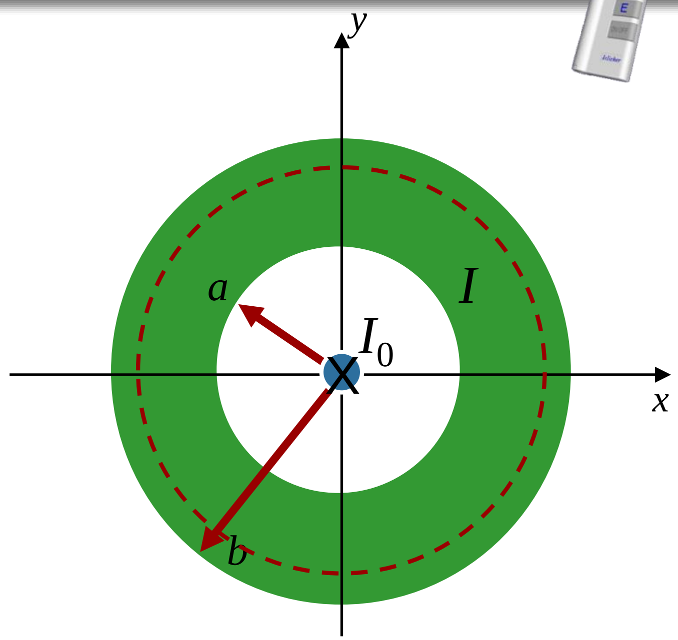
$$= \frac{4\pi x 10^{-7}\ \mathrm{Tm/A} \cdot 10\mathrm{A}}{2\pi \cdot 0.001\,\mathrm{m}}$$

$$= 2x10^{-3}\ \mathrm{T}$$

Follow-Up

Add an infinite wire along the z axis carrying current I_0.

What must be true about I_0 such that there is some value of r, $a < r < b$, such that $B(r) = 0$?



A) $|I_0| > |I|$ AND I_0 into screen

B) $|I_0| > |I|$ AND I_0 out of screen

C) $|I_0| < |I|$ AND I_0 into screen

D) $|I_0| < |I|$ AND I_0 out of screen

E) There is no current I_0 that can produce $B = 0$ there

B will be zero if total current enclosed $= 0$