

DIVERGENCE & CURL OF B; STOKES THEOREM

Class Activities: Stokes' Thm, Div, Curl. Ampere. (1)

Visualization

Stokes' Theorem

<http://www.math.umn.edu/~nykamp/m2374/readings/stokesidea/>

Demonstration

Loop and arrow

Also brought a small "loop with arrow" which turned out to be a useful prop throughout class. One thing I did near the end was hold the compass near the loop, and pointed out B is NOT zero, and $B \cdot d\mathbf{l}$ is NOT zero, at various points around the loop... so, what if we integrate? Got the class to discuss that it must be zero ("backside of loop" cancelling with front) and that this was correct, since there's no current in the room...

Demonstration

Ampere's Law loop

I had a prop (a strip of paper, white on one side, yellow on the other) which I could twist to show the concept test idea about "direction/sign of current through a loop"

Tutorial

Current-carrying wire

Paul van Kampen – Dublin University (Tutorials 9-16, page 21)

Use Biot-Savart and Ampere's Law near current carrying wire. Calculate force. Then do force on square loop.

Tutorials

Ampere's Law activity

Oregon State University

Students working in small groups practice using Ampere's Law to determine the electric field due to several current distributions. Students practice using the symmetry arguments necessary to use Ampere's Law.

Informal interviews have shown that students will mimic the words "by symmetry" without really knowing what they mean. Also, they tend not to realize that the magnetic field can vary in both magnitude and direction-independently. This is a really valuable place to slowdown the pace and get students thinking about the geometry of what is going on.

Class Activities: Stokes' Thm, Div, Curl, Ampere (2)

Whiteboards

Boundary conditions on \mathbf{B}

One persistent difficulty that students have is an inability to recreate the mathematical steps to determine the boundary conditions on the parallel and perpendicular components of \mathbf{B} . After watching 3 continuous semesters of this course, I strongly recommend having a whiteboard or worksheet activity where students are asked to derive those boundary conditions given a surface current.

Whiteboard

Griffiths " \mathbf{B} " Triangle

Had them write out the triangle, took ~5 minutes. (There's still one "leg" they haven't gotten, some figured it out on the fly, it's a homework problem due Wed)

Computer Visualizations

\mathbf{B} fields, circulation, flux

Java applets allowing you to see 3D magnetic fields, and do surface and line integrals to determine circulation and flux.

<http://www.falstad.com/vector3dm/>

Computer Animation

Cycloid

I Googled "cycloid" and pull up Mathematica's webpage, it has a very nice animation of the cycloid.

Context rich problems

<http://groups.physics.umn.edu/physed/Research/CRP/on-lineArchive/crmff.html>

Tutorial

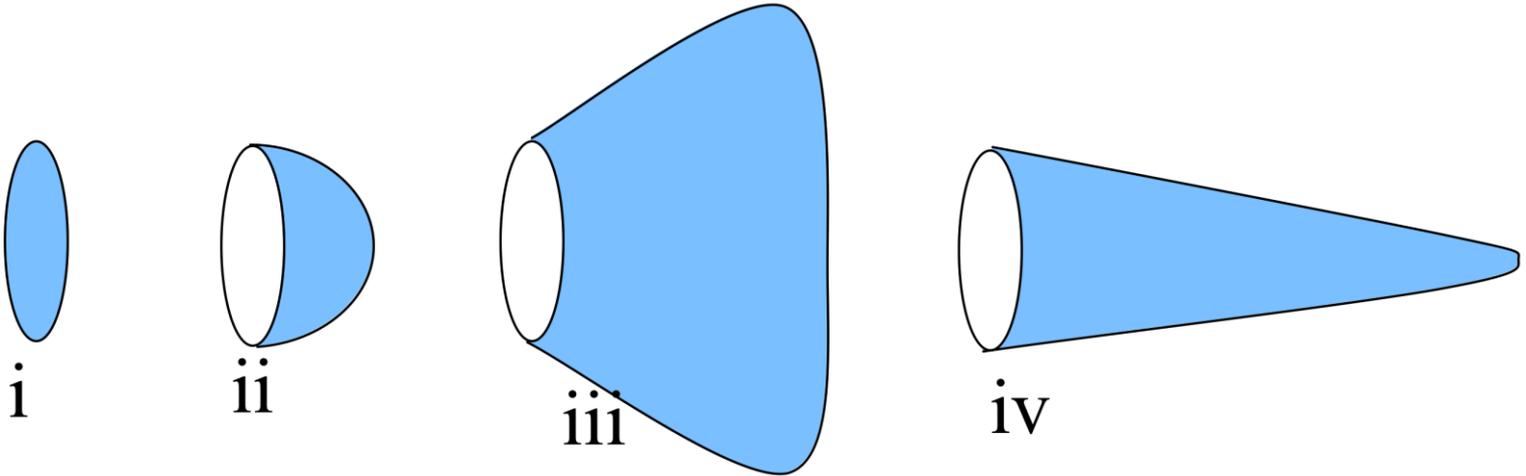
Magnetic Field Continuity across a Boundary

Oregon State University

Students working in small groups use Maxwell's equations to determine the continuity of the magnetic field across a charged surface

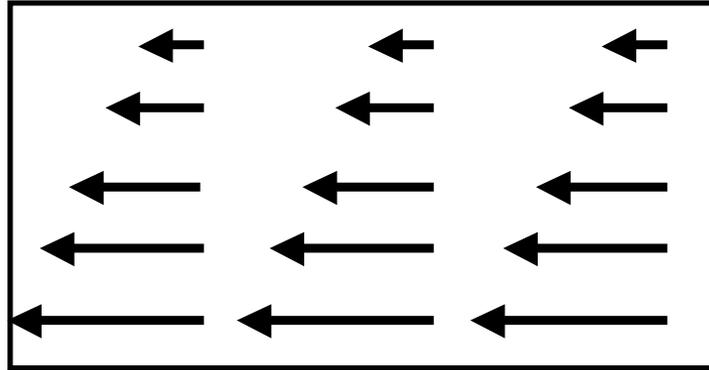
5.16

Rank order $\left| \iint \vec{J} \cdot d\vec{A} \right|$ (over blue surfaces)
 where \mathbf{J} is uniform, going left to right:



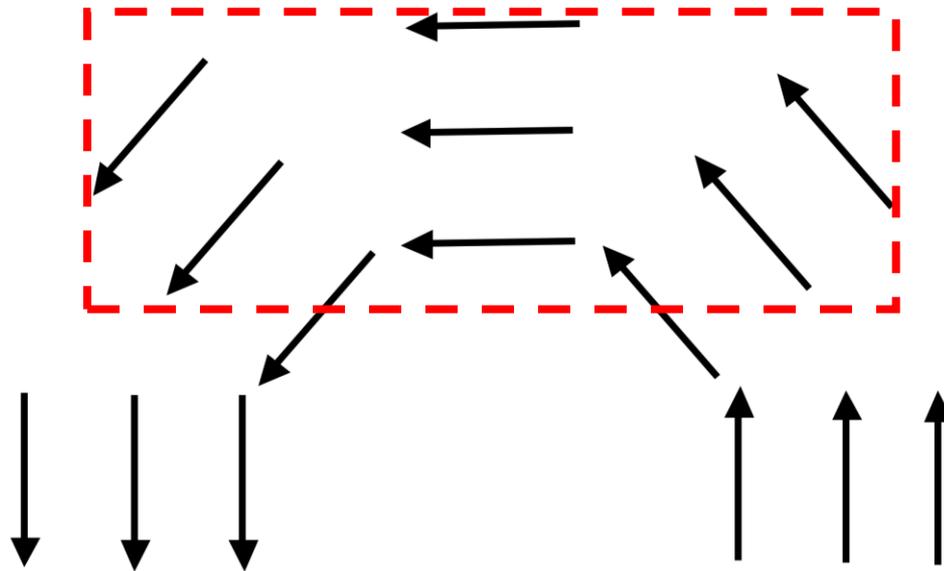
- A) $\text{iii} > \text{iv} > \text{ii} > \text{i}$
 B) $\text{iii} > \text{i} > \text{ii} > \text{iv}$
 C) $\text{i} > \text{ii} > \text{iii} > \text{iv}$
 D) Something else!!
 E) Not enough info given!!

The figure shows a static magnetic field in a region of space. Could this region of space be “empty”?



- A) Yes, it could be empty space (with currents somewhere off to the sides creating it)
- B) No, there must be static charges (ρ) in there.
- C) No, there must be a current density (J) in the plane of the page in this (boxed) region
- D) No, there must be a current density (J) perpendicular to the plane of the page in this region.
- E) Other/???

- 5.17
a **ONLY CLICK AFTER YOU FINISH p.2, part iib:**
If the arrows represent a B field (note that $|B|$ is the same everywhere), is there a nonzero \mathbf{J} (perpendicular to the page) in the dashed region?

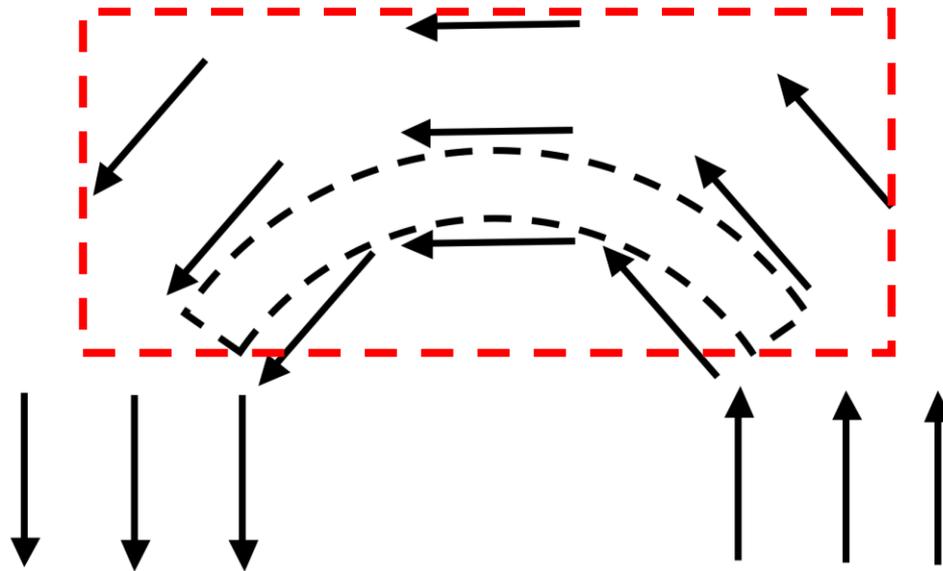


- A. Yes
B. No
C. Need more information to decide

5.17

b

If the arrows represent a B field (note that $|B|$ is the same everywhere), is there a nonzero \mathbf{J} (perpendicular to the page) in the dashed region?



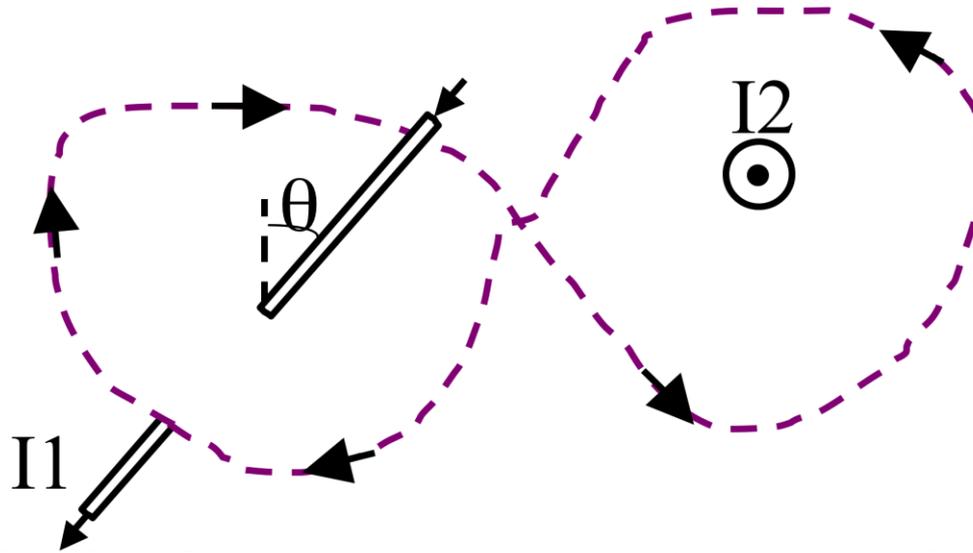
$$\vec{B} = B_0 \hat{j}$$

A. Yes

B. No

C. Need more information to decide

What is $\oint \vec{B} \cdot d\vec{l}$ around this purple (dashed) Amperian loop?



A) $\mu_0 (|I_2| + |I_1|)$

B) $\mu_0 (|I_2| - |I_1|)$

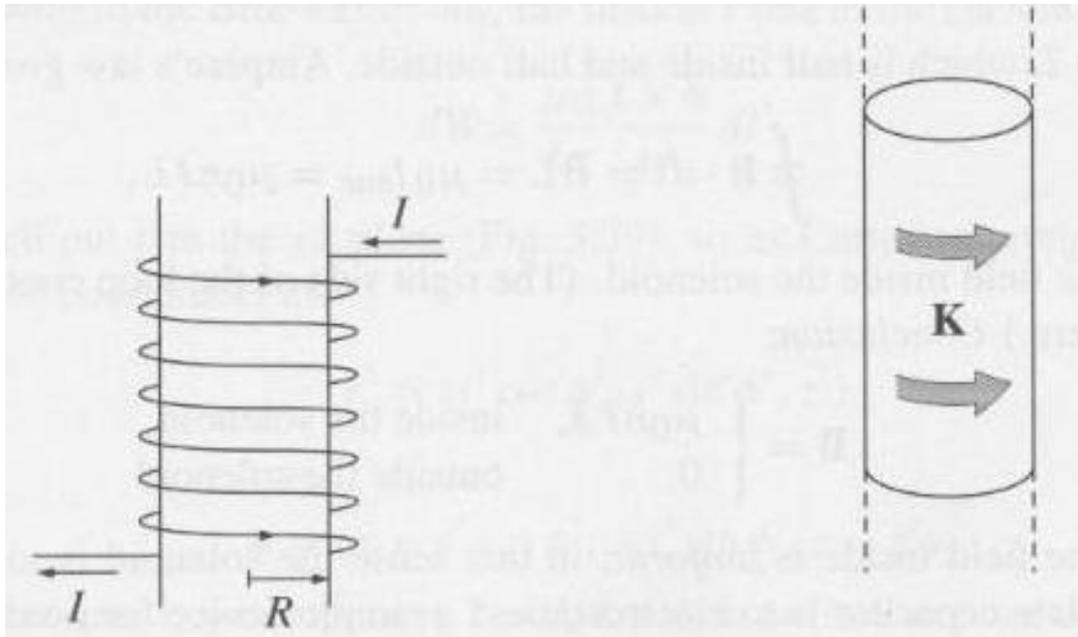
C) $\mu_0 (|I_2| + |I_1| \sin\theta)$

D) $\mu_0 (|I_2| - |I_1| \sin\theta)$

E) $\mu_0 (|I_2| + |I_1| \cos\theta)$

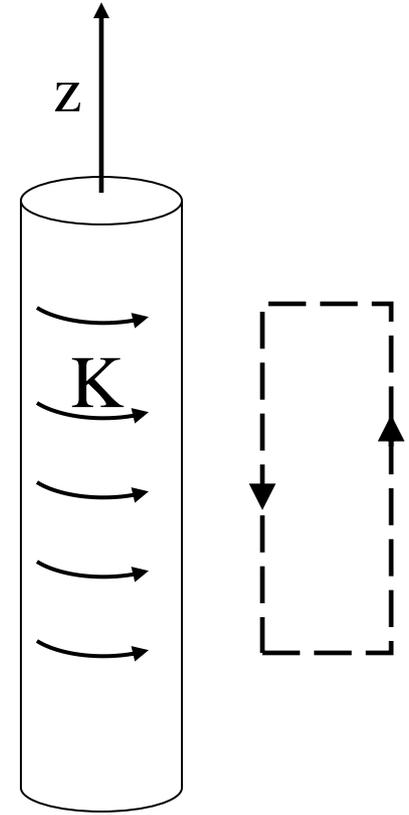
A solenoid has a total of N windings over a distance of L meters. We "idealize" by treating this as a surface current running around the surface.

What is K ?



- A) I B) NI C) I/L D) $I N/L$
E) Something else...

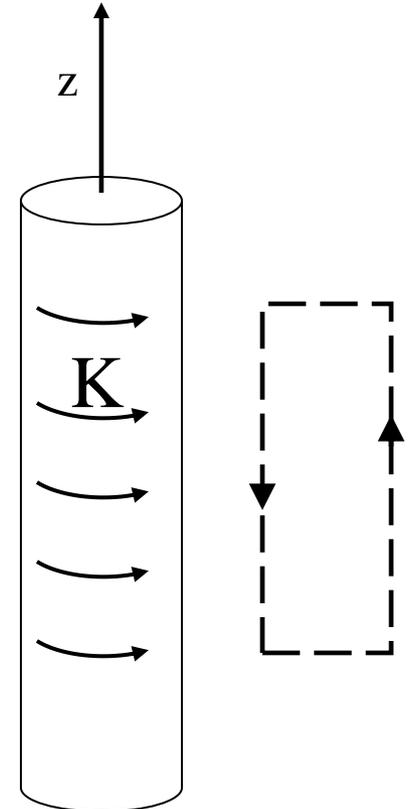
An infinite solenoid with surface current density K is oriented along the z -axis. Apply Ampere's Law to the rectangular imaginary loop in the yz plane shown. What does this tell you about B_z , the z -component of the \mathbf{B} -field outside the solenoid?



- A) B_z is constant outside
- B) B_z is zero outside
- C) B_z is not constant outside
- D) It tells you nothing about B_z

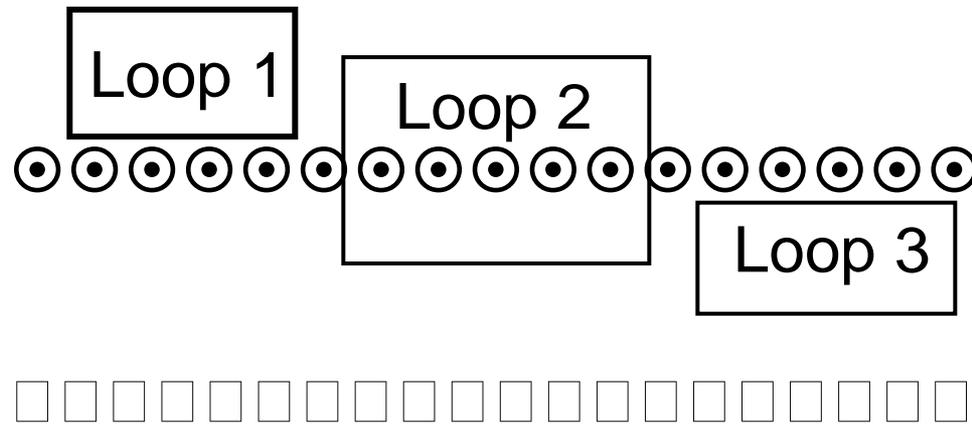
An infinite solenoid with surface current density K is oriented along the z -axis. Apply Ampere's Law to the rectangular imaginary loop in the yz plane shown.

We can safely assume that $B(s \rightarrow \infty) = 0$.
What does this tell you about the \mathbf{B} -field outside the solenoid?



- A) $|B|$ is a small non-zero constant outside
- B) $|B|$ is zero outside
- C) $|B|$ is not constant outside
- D) We still don't know anything about $|B|$

5.23



In the case of the infinite solenoid we used loop 1 to argue that the **B**-field outside is zero. Then we used loop 2 to find the **B**-field inside. **What would loop 3 show?**

- a) The **B**-field inside is zero
- b) It does not tell us anything about the **B**-field
- c) Something else

5.21

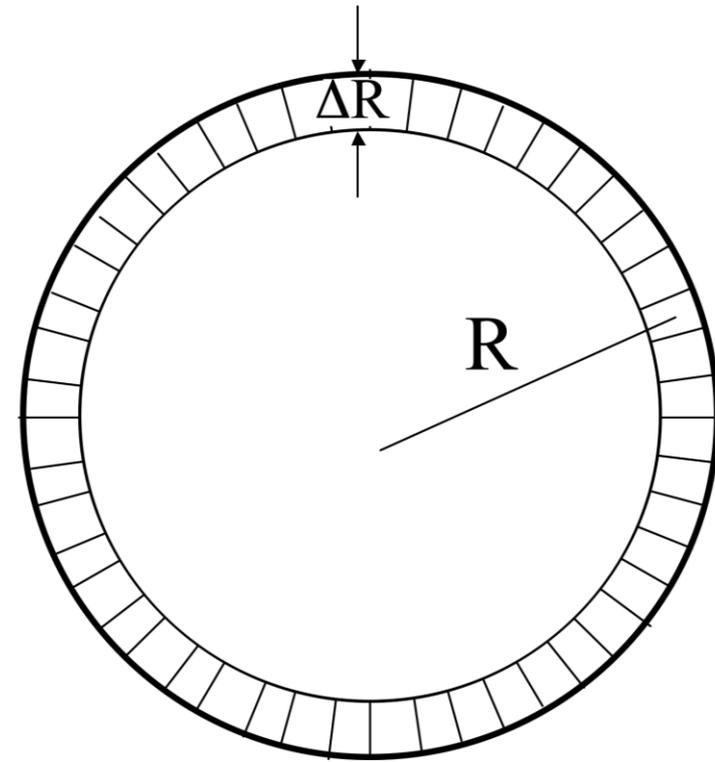
a

A thin toroid has (average) radius R and a total of N windings with current I .

We "idealize" this as a surface current running around the surface.

What is K , approximately?

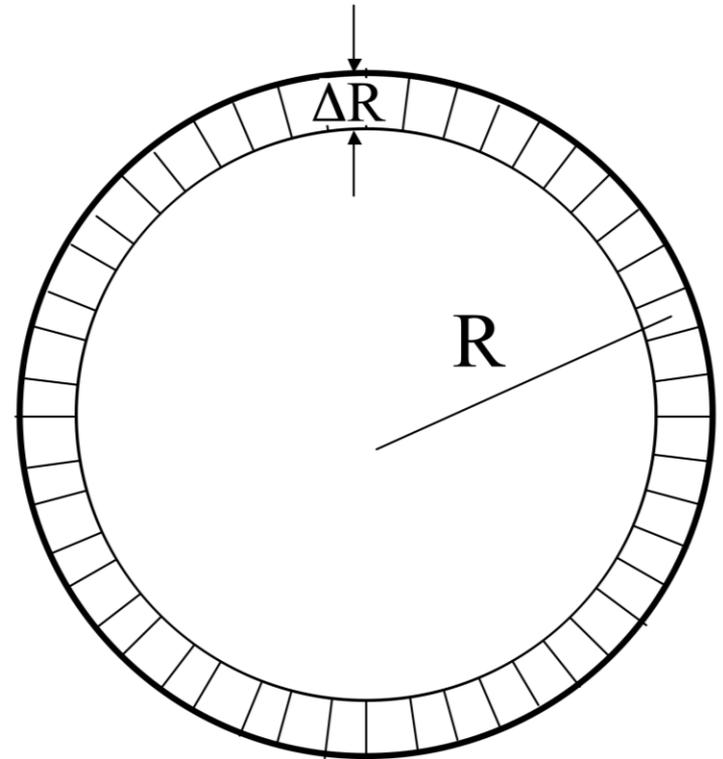
- A) I/R B) $I/(2\pi R)$
C) NI/R D) $NI/(2\pi R)$
E) Something else



5.21b

What direction do you expect the B field to point?

- A) Azimuthally
- B) Radially
- C) In the z direction
(perp. to page)
- D) Loops around the rim
- E) Mix of the above...

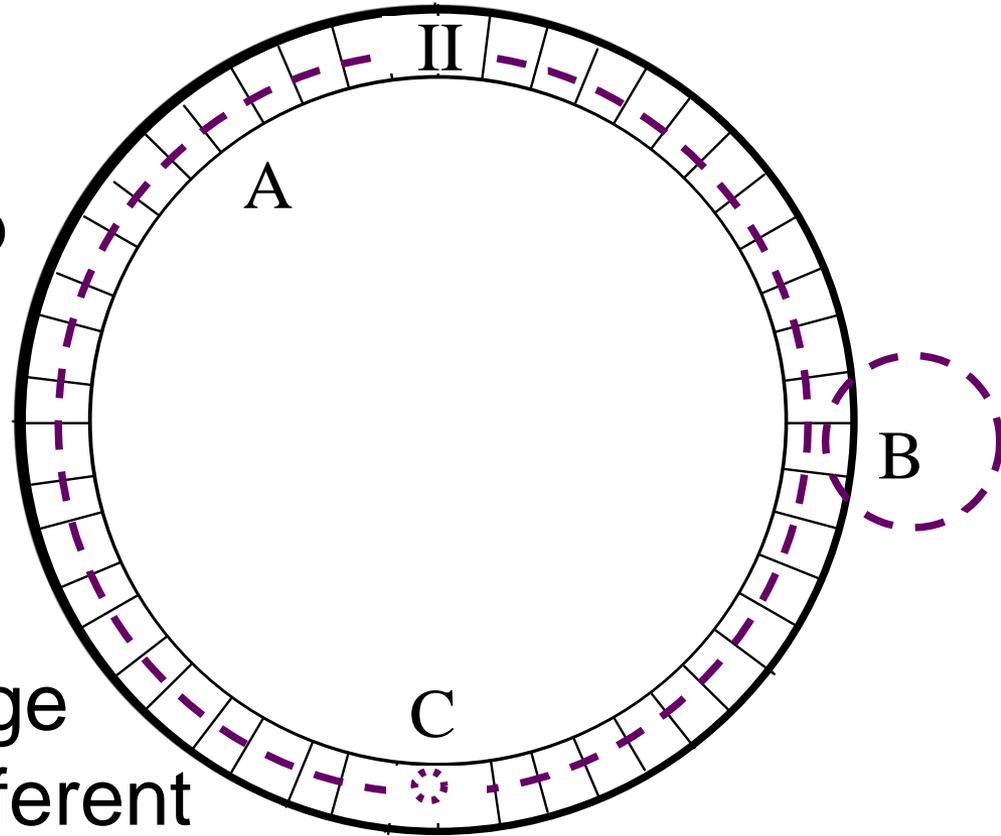


5.21

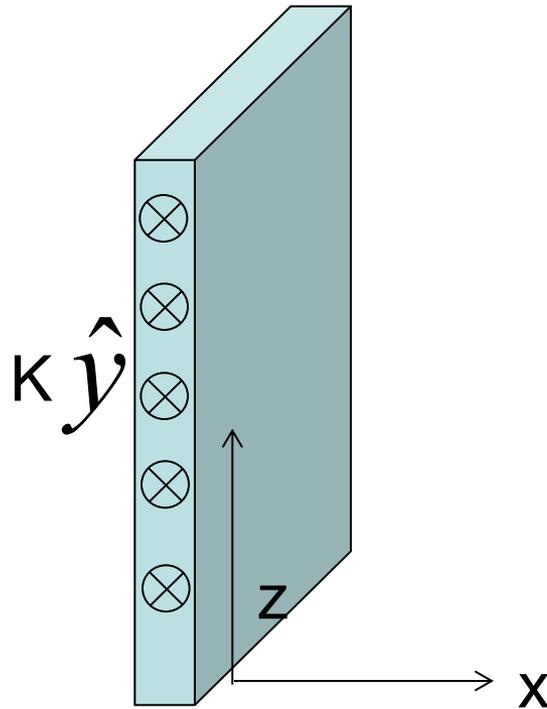
c

What Amperian loop would you draw to find B “inside” the Torus (region II)

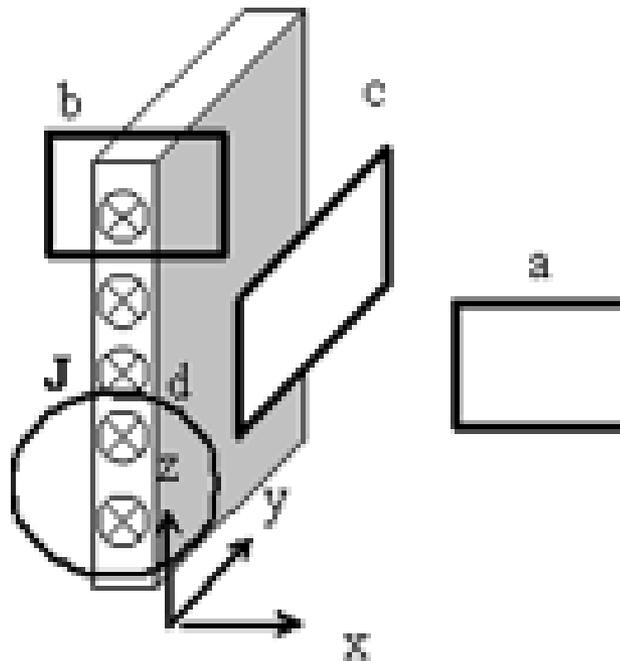
- A) Large “azimuthal” loop
- B) Smallish loop from region II to outside (where $B=0$)
- C) Small loop in region II
- D) Like A, but perp to page
- E) Something entirely different



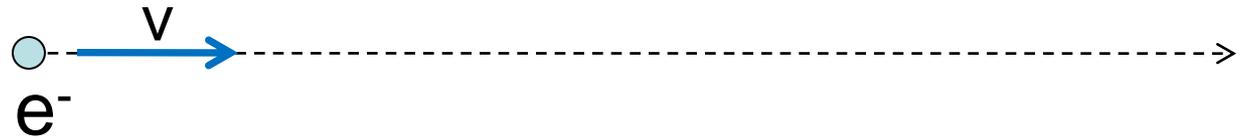
Which Amperian loop would you draw to learn *something* useful about \mathbf{B} anywhere?



Which Amperian loops are *useful* to learn about $B(x,y,z)$ somewhere?



An electron is moving in a straight line with constant speed v . What approach would you choose to calculate the B-field generated by this electron?



- A) Biot-Savart
- B) Ampere's law
- C) Either of the above.
- D) Neither of the above.

BOUNDARY CONDITIONS

5.28

When you are done with p. 1:

Choose all of the following statements that are implied if $\oiint \vec{B} \cdot d\vec{a} = 0$ for any/all closed surfaces

(I) $\vec{\nabla} \cdot \vec{B} = 0$

(II) $B_{above}^{//} = B_{below}^{//}$

(III) $B_{above}^{\perp} = B_{below}^{\perp}$

A) (I) only

B) (II) only

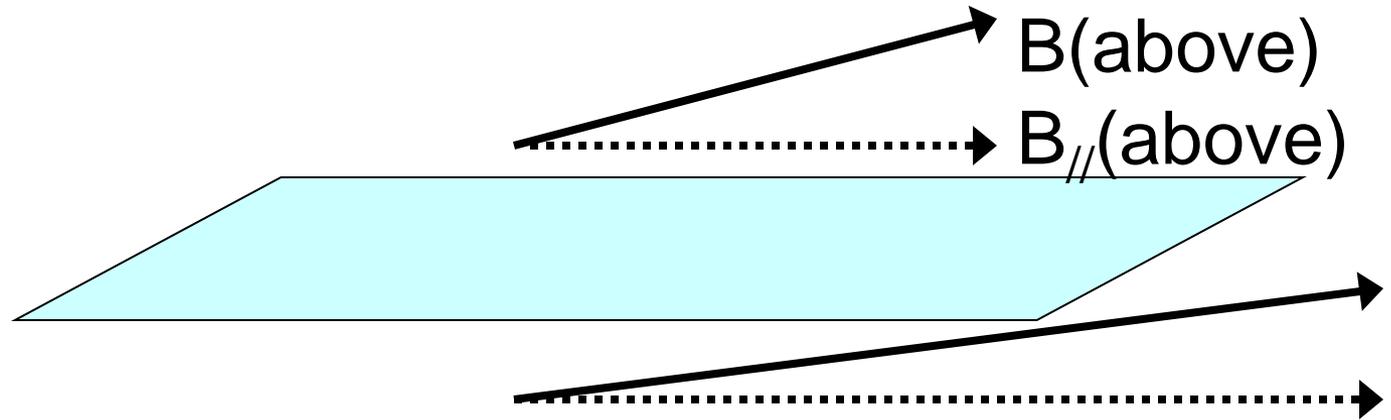
C) (III) only

D) (I) and (II) only

E) (I) and (III) only

6.11

I have a boundary sheet, and would like to learn about the change (or continuity!) of B (parallel) across the boundary.



Am I going to need to know about

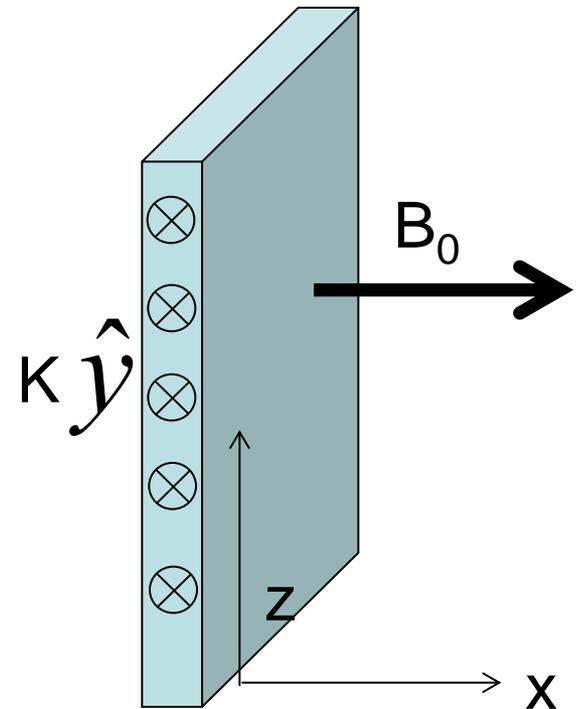
A) $\nabla \times B$

B) $\nabla \cdot B$

C) ???

If $B=B_0$ in the $+x$ direction just RIGHT of the sheet, what can you say about B just LEFT of the sheet?

- A) $+x$ direction
- B) $-x$ direction
- C) $+z$ direction
- D) $-z$ direction
- E) Something else!



5.28

b

In general, which of the following are continuous as you move past a boundary?



- A) \mathbf{A}
- B) Not all of \mathbf{A} , just A_{perp}
- C) Not all of \mathbf{A} , just $A_{//}$
- D) Nothing is guaranteed to be continuous regarding \mathbf{A}