Announcements

- Homework
  - Webwork 19 due tonight
  - You'll have a video homework due on Monday
- Physics Tea talk today at 3:30!
  - Meeting info is posted on Campuswire!
- Test 3 two weeks from today (yikes)
- I actually got some updated grade reports posted! (gasp!) I'm still a bit behind, but progress is attempting to be made...
- Polling: `rembold-class.ddns.net`

Review Question

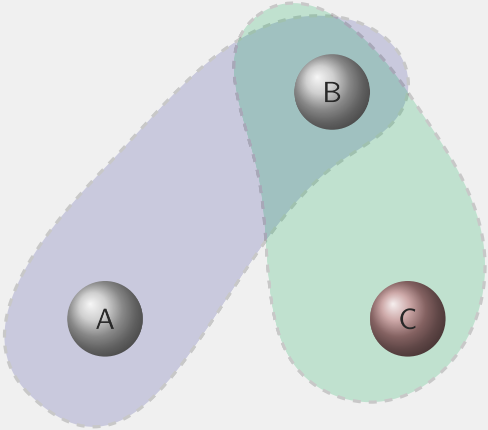
Suppose you have three charges, of which you know the charge of C is 2 C. You also have two Gaussian surfaces which you happen to know the total flux through. The blue surface has a total flux of $\frac{5}{\epsilon_0}$ V m passing through it, while green surface has a total flux of $-\frac{4}{\epsilon_0}$ V m passing through it. What is the charge of charge A?

A. -1 C

B. 3 C

C. 7 C

D. 11 C



Solution: 11 C

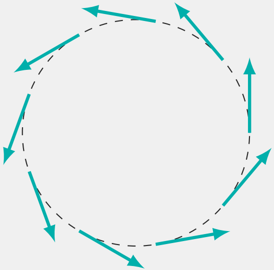
Magnetic Gauss's Law

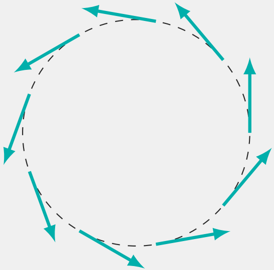
- Gauss's law can relate the flux of any field to the amount of field causing "stuff" on the interior
- Can talk about magnetic flux just as easily as electric flux
- One huge difference though:
  - Magnetic poles *always* come in pairs
  - Impossible to separate a north or south
  - Will *always* have both a source and a sink of magnetic fields in your Gaussian surface
- Thus, for magnets, Gauss's law says:

$$\oint \vec{\mathbf{B}} \cdot \hat{\mathbf{n}} dA = 0$$

A New Law of the Land

- How do we work with magnetic fields then?
  - Gauss's law doesn't tell us anything useful
  - Still want a method to predict the "source" of some particular magnetic field
- Sources for magnetic fields are moving charges or currents
  - We'll focus mostly on currents
- How to judge the direction and strength of the current that causes a particular magnetic field?

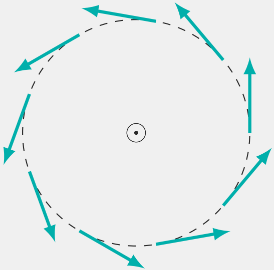




- Right-hand-rule tells us that current must be coming out of the board here
- Can integrate around the loop:

$$
\begin{aligned}
\oint \vec{\mathbf{B}} \cdot d\vec{\ell} &= B \oint d\ell \\
&= \frac{\mu_0}{4\pi} \frac{2\mathrm{I}}{r} \cdot 2\pi r \\
&= \mu_0 \mathrm{I}
\end{aligned}
$$

Enter Ampere's Law



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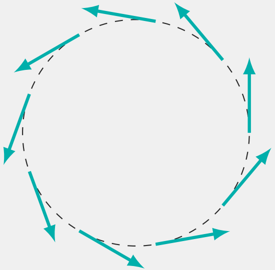

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$$= \mu_0 \mathrm{I}$$

Ampere's Law

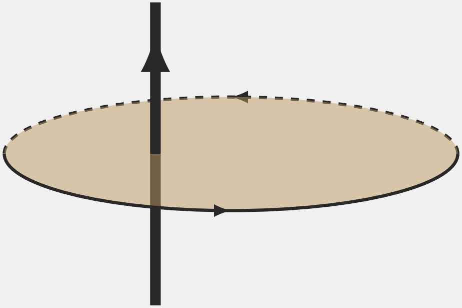
Around any closed loop

$$\oint \vec{\mathbf{B}} \cdot d\vec{\ell} = \mu_0 \mathrm{I}_{enc}$$

where positive or negative currents are determined by right hand rule.

How to "enclose" a current...

- A loop is 2d, so how can we define the current enclosed?
- Imagine a membrane or soap bubble stretched across the loop
  - Anything that would "pop" or piece that bubble in considered "enclosed"
  - Means the bubble can actually deform and you'll get the exact same results!



$I_{enc} > 0$

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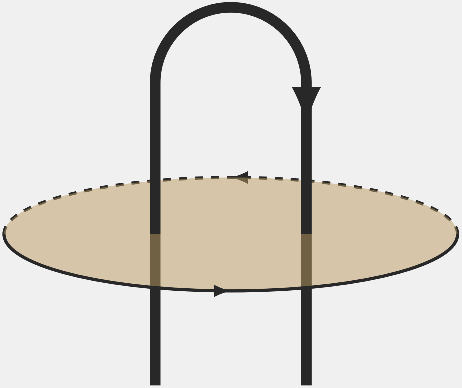

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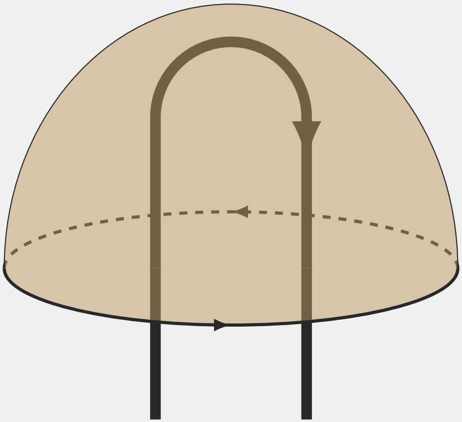


$I_{enc} = 0$

Usage Guidelines

- Like Gauss's law, Ampere's law is most advantageous and easy to use when we choose our loops wisely
  - If you choose your loop so that $\vec{\mathbf{B}}$ is always in the direction of $d\vec{\ell}$ and $\vec{\mathbf{B}}B$ is constant

$$\Rightarrow \oint \vec{\mathbf{B}} \cdot d\vec{\ell} = BL$$

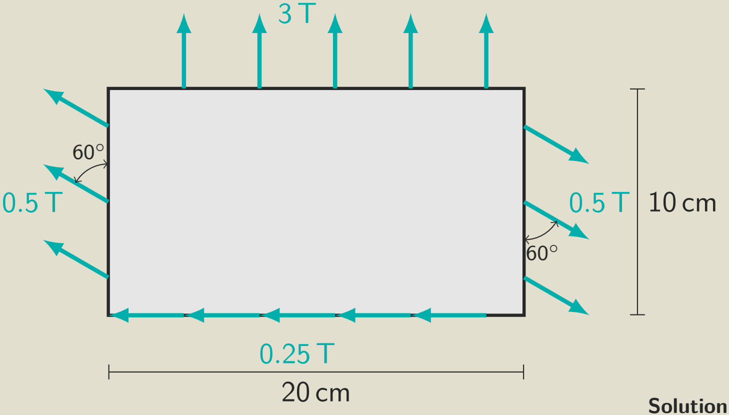
- Make sure you count currents as positive or negative according to your right hand rule
  - Loop curving in direction of fingers $\Rightarrow$ thumb direction is positive current contribution

Magnetic Field inside a Wire

Suppose you have a thick cable 1 cm in diameter which is carrying a current of 10 A. What is the magnitude of the magnetic field 2 mm from the center of the cable?

Solution: $1.6 \times 10^{-4}\,\mathrm{T}$

The figure below shows measured values and directions of the magnetic field around a piece of metal. What is the net current flowing through the metal and in what direction is it flowing?



Solution: 79.6 kA, Into the page