

Magnetism II

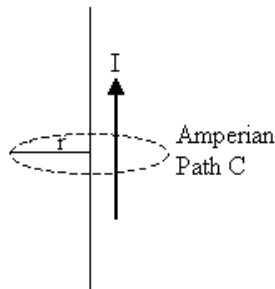
Name:

PES 216 Prelab Questions

Lab Station:

Prelab 1: Using Ampere's Law:

$$\oint_C \vec{B} \cdot d\vec{\ell} = \mu_0 I_{IN}$$



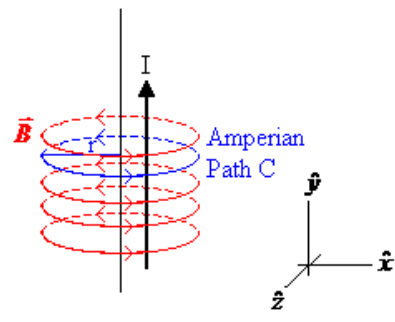
find the magnetic field of a long, straight current-carrying wire. What direction does the field point? (You must use Ampere's Law here. Using Biot-Savart earns zero points!)

Notice that the magnetic field direction is given by the right hand rule, by putting your thumb in the direction of the current and curling your finger (which are in turn pointing in the same direction as the generated magnetic field).



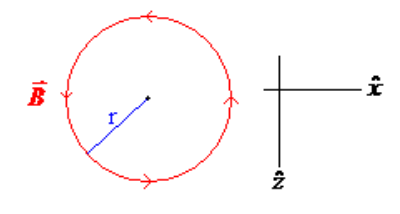
This means that the magnetic field is coming out of the page on the left side of the figure and going into the page on the right side of the figure. Notice that we “conveniently” chose the direction of the Amperian Path to also be in the same direction.

If we draw in the Amperian Path (in blue), the wire and current (in black) and a coordinate axis frame, we can start to describe the magnetic field (in red) being generated.



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If we take a “top down” view of this, it is very easy to see that the magnetic field sits in the X-Z plane and moves in the counter-clockwise direction (this is given the direction $+\hat{\theta}$).



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Using Ampere’s Law:

$$\oint_C \vec{B} \cdot d\vec{\ell} = \mu_0 I_{IN}$$

First, let’s consider the Right Hand Side (RHS) of Ampere’s Law:

$$\mu_0 I_{IN} = \mu_0 I$$

In this case, I is just the total current flowing through the wire.

Next, let's consider the Left Hand Side (LHS) of Ampere's Law:

$$\oint_C \vec{B} \cdot d\vec{\ell}$$

Notice that the Amperian Loop we selected, the distance segment is always pointing in the same direction as the magnetic field. This means that the angle between the distance segment and the magnetic field will always be zero.

$$\oint_C \vec{B} \cdot d\vec{\ell} = \int_0^{2\pi} \vec{B} \cdot d\vec{\ell} = \int_0^{2\pi} B d\ell \cos(\phi) = \int_0^{2\pi} B d\ell \cos(0) = \int_0^{2\pi} B d\ell$$

$$\oint_C \vec{B} \cdot d\vec{\ell} = B \ell \Big|_0^{2\pi} = B(2\pi - 0) = 2\pi B$$

Now, setting the LHS equal to the RHS:

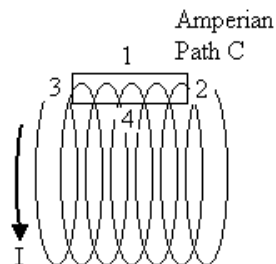
$$\underline{2\pi B = \mu_o I}$$

Thus putting everything together and solving for the Magnetic Field:

$$\underline{\vec{B} = \frac{\mu_o I}{2\pi} \hat{\theta}}$$

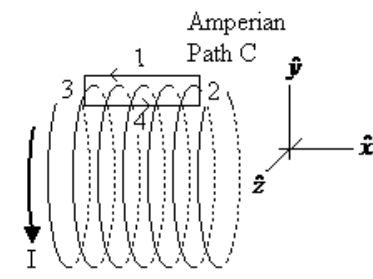
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Prelab 2: Using Ampere's Law, find the magnetic field inside a solenoid. What direction does the field point?



Actually, I find the image above a little ambiguous. It's hard for me to tell which way the current is actually going (with respect to what is out of the page and what is into the page). For my response to this question, I'm going to modify the image slightly to help explain this a little better (since the magnetic field direction will be determined by the current's direction).

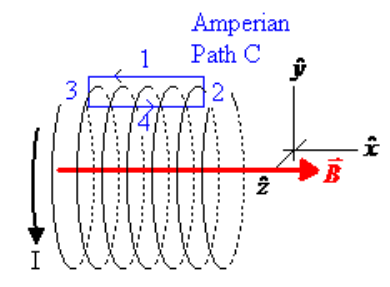
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This makes it easier to see that the current is coming out of the page on the left side (solid line) and then back into the page (dashed line). Likewise, we give a 3D orientation to use for directions, and finally – we specify the direction the path is going to follow around the Amperian Path. With these modifications, then by using the right hand rule we can determine the direction the magnetic field will point:



Similar to above, if we draw in the Amperian Path (in blue), the wire and current (in black) and a coordinate axis frame, we can start to describe the magnetic field (in red) being generated. Hence, the magnetic field is pointing to the right ($+\hat{x}$ direction).



Using Ampere's Law:

$$\oint_C \vec{B} \cdot d\vec{\ell} = \mu_0 I_{IN}$$

First, let's consider the Right Hand Side (RHS) of Ampere's Law:

$$\mu_0 I_{IN} = \mu_0 NI$$

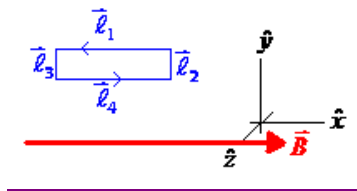
(Where N is the number of loops contained within the amperian path, C).

Next, let's consider the Left Hand Side (LHS) of Ampere's Law:

$$\oint_C \vec{B} \cdot d\vec{\ell}$$

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We need to consider the angle between the magnetic field and the line element so we can evaluate the dot product for each line element.



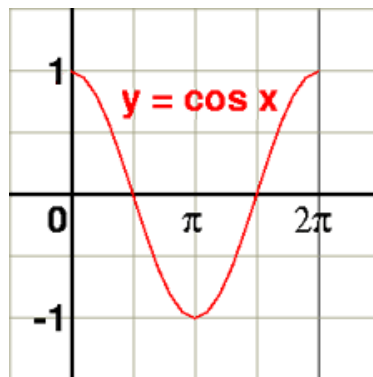
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For the Amperian Loop we have defined, we know the LHS is thus:

$$\oint_C \vec{B} \cdot d\vec{\ell} = \oint_C \vec{B} \cdot d\vec{\ell}_1 + \oint_C \vec{B} \cdot d\vec{\ell}_2 + \oint_C \vec{B} \cdot d\vec{\ell}_3 + \oint_C \vec{B} \cdot d\vec{\ell}_4$$

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Since there are multiple dot products to evaluate here, we will need to remember the value of the cosine function at various angles:



Angle	0°	90°	180°	270°	360°
Cosine (Angle)	+1	0	-1	0	+1

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We need to consider each of the 4 integrals separately:

$$\oint_C \vec{B} \cdot d\vec{\ell}_1 = B \ell_1 \cos(\theta)(\hat{x} \bullet -\hat{x}) = 0 \ell_1 \cos(180^\circ)(-1) = 0$$

$$\oint_C \vec{B} \cdot d\vec{\ell}_2 = B \ell_2 \cos(\theta)(\hat{x} \bullet \hat{y}) = B \ell_2 \cos(90^\circ)(0) = B \ell_2 (0)(0) = 0$$

$$\oint_C \vec{B} \cdot d\vec{\ell}_3 = B \ell_3 \cos(\theta)(\hat{x} \bullet -\hat{y}) = B \ell_3 \cos(270^\circ)(0) = B \ell_3 (0)(0) = 0$$

$$\oint_C \vec{B} \cdot d\vec{\ell}_4 = B \ell_4 \cos(\theta)(\hat{x} \bullet \hat{x}) = B \ell_4 \cos(0^\circ)(1) = B \ell_4 (1)(1) = B \ell_4$$

Hence:

$$\oint_C \vec{B} \cdot d\vec{\ell} = 0 + 0 + B \ell_4 + 0 = B \ell_4 = B \ell$$

Now, setting the LHS equal to the RHS:

$$B \ell = \mu_o N I$$

Thus putting everything together and solving for the Magnetic Field:

$$\vec{B} = \frac{\mu_o N I}{\ell} \hat{x}$$

If we let “n” be the number of loops per unit length, this simplifies to:

$$\vec{B} = \mu_o n I \hat{x}$$

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Prelab 3: This lab uses high currents of a few amps. You need to worry about safety in this lab. High electric currents cause the circuit to heat up dramatically, and they also pose an electric shock hazard. What precautions do you need to take when doing this lab? (Hint: Read *The Lab* section of the manual.)

As mentioned in the Lab Manual, here are several precautions we should take:

- Make adjustments only when the power supply is turned off.
- Don't touch any uninsulated portions of the wires.
- Don't disconnect or move any wires while the power supply is turned on.
- Only have the switch closed when actually taking measurements.

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