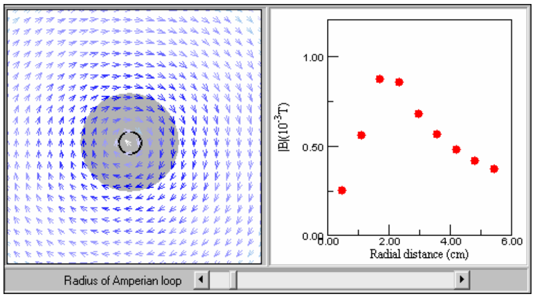
Worksheet for Exploration 28.1: A Long Wire with Uniform Current



The gray circle in the center represents a cross section of a wire carrying current coming out of the computer screen. The current is uniformly distributed throughout the wire **(position is given in centimeters and magnetic field strength is given in millitesla)**. The black circle is an Amperian loop with a radius you can change with the slider.

Begin with the Amperian loop with a radius larger than the radius of the wire.

a. What is the radius of the Amperian loop?
b. What is the magnetic field at this radius?
   i. Make careful measurements of B at the selected position.

r=________ B=________

You will use Ampere's law to find the total current in the wire:

$$\int \mathbf{B} \bullet d\mathbf{l} = \mu_0 I, \quad \mu_0 = 4\pi \times 10^{-7} \text{ Tm/A},$$

where the integration is over a closed loop (closed path), d**l** is an element of the path in the direction of the path, and I is the total current enclosed in the path. Pick a point on the Amperian loop and draw both the direction of the magnetic field at that point and the direction of dl (tangent to the path).

c. The magnetic field and d**l** should be parallel to each other. What is **B** • d**l**?

Pick another point on the Amperian loop.

d. What is the magnitude of the magnetic field at that point? At any point on the loop?
   i. Measure the magnitude of B at several locations on the same loop and verify your assertion.

B_1=________

B_2=________

B_3=________

e. This means you can write $\int \mathbf{B} \cdot d\mathbf{l} = B \int dl$. Why?

$\int dl$ is simply the length of the Amperian loop (in this case the circumference). Therefore, $B = \mu_0 I / 2\pi r$ outside the wire.

f. Calculate the current carried by the wire from your measurement of the magnetic field.

I=________

g. Change the radius of the loop (but leave it still bigger than the wire) and predict the magnetic field on that loop. Measure the value to verify your answer.
   i. Decide on an r first, then predict, then measure.

r=________

$B_{predicted}$=________

$B_{measured}$=________

Make the Amperian loop smaller so it fits inside the wire. This time, the current inside the loop is not equal to the total current, but instead it is equal to the total current times the fraction of the area inside the loop, Ir^2/a^2, where a is the radius of the wire.

h. Why?
   i. Make a careful sketch showing why, and discuss clearly but CONCISELY.

i. Use this fraction and Ampere's law to predict the magnetic field inside the loop.
   i. You are predicting B at a specific distance from the center of the loop.
   ii. The simulation places the “Amperian circular loop” at a position centered on the wire. What would happen to the current enclosed if the loop were shifted slightly?
   iii. Is Ampere’s law still valid for that shifted case?
   iv. Is that shifted loop useful to you for determining magnetic fields? Discuss why.
   v. Now predict the magnetic field.
   vi. You should examine your prediction for the magnetic field and check any limiting cases. Specific limits to check are at r=0 and r=the radius of the wire (2.0cm here). Does your expression do what you expect at the limits?

j. Measure the field to verify your answer.

k. Show that the general expression for the magnetic field inside the wire is $\mu_0 I\ r/2\pi a^2$. (If you have not already done this above).