Key Concepts

Chapter 7

Magnetic field

Right-hand rule

Vector addition

$B = \frac{\mu_0 I}{2\pi r}$ (T) (long straight wire)

$B = \frac{\mu_0 I}{2r}$ (T) (center of wire loop)

Takeaways

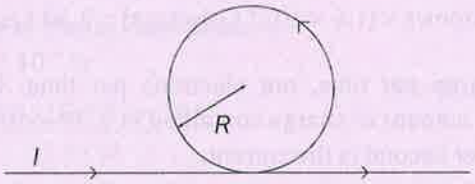
This problem is another example of considering the sources of a field separately and then adding their effects. This is the same process you use to find the net electric field due to multiple charges.

Things to Watch Out For

Many students confuse the right-hand rule, but the rule is essential to getting the correct answer on any magnetic field problem.

Magnetic Field

A current of 2 A flows down a long wire with a loop of radius 50 cm in it. The current flows around the loop counterclockwise, as shown in the diagram below. What is the magnitude and direction of the of the magnetic field at the center of the loop?
($\mu_0 = 4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}$.)



1) Find the magnetic field due to the straight section.

$$B_{\text{straight}} = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi\times10^{-7})(2)}{2(0.5)} = 8 \times 10^{-7}\ \text{T}$$

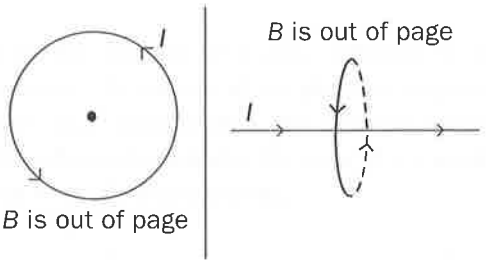
The magnetic field due to the straight section is given by the formula $B = \frac{\mu_0 I}{2\pi r}$.

2) Find the magnetic field due to the circular section.

$$B_{\text{circular}} = \frac{\mu_0 I}{2r} = \frac{(4\pi\times10^{-7})(2)}{2(0.5)} = 2.5 \times 10^{-6}\ \text{T}$$

The magnetic field due to the circular section is given by the formula $B = \frac{\mu_0 I}{2r}$.

3) Determine the direction of each of the magnetic fields.



Determine the direction of the magnetic field produced by each source separately. To determine the direction of a magnetic field, we use a right-hand rule—essentially the same right-hand rule for a long straight wire as for a circular loop: (i) Grasp a section of the wire, with your thumb pointing in the direction of the current through that section. (ii) Your fingers will now curl in the direction of the magnetic field. To find the direction of the magnetic field at a

particular location, position your fingertips at that location (while still gripping the wire with your thumb pointing in the direction from step (i)); your fingertips will now point in the direction of the magnetic field at that location.

MCAT Pitfall: There are two different right-hand rules, one for finding the direction of a magnetic field and one for finding the direction of a magnetic force. Don't confuse them!

To determine the direction of the field generated by the loop: (i) Let's say you grasp the bottom of the loop. Then you should point your thumb to the right. (ii) Your fingers will now curl in the direction of the magnetic field around the bottom of the loop. We want to know the direction of the field inside the loop; therefore, position your fingertips inside the loop. Your fingertips will now be pointing out of the page; therefore, the direction of the magnetic field inside the loop is out of the page.

To determine the direction of the field generated by the straight wire: (i) Grasp the wire, pointing your thumb to the right. (ii) Your fingers will now curl in the direction of the magnetic field. We want to know the direction of the field above the wire; therefore, position your fingertips above the loop. Your fingertips will now be pointing out of the page; therefore, the direction of the magnetic field above the wire is out of the page.

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4) Find the net magnetic field.

$$B_{net} = B_{straight} + B_{circular} = 8 \times 10^{-7} + 2.5 \times 10^{-6}$$
$$= 3.3 \times 10^{-6}\ \text{T}$$

Because the magnetic fields are pointed in the same direction, simply add their magnitudes to find the net field. If they were pointed in opposite directions, you would need to subtract one from the other.

Similar Questions

1) For a long wire with a loop in it as in the previous problem, at what point(s) is there no net magnetic field?
2) Two parallel, straight wires, each carrying a current of 10 mA in the same direction, are located 10 cm apart. What is the net magnetic field halfway between the two wires?
3) Two circular loops of wire are concentric. They both carry a current of 50 mA but in opposite directions. If the radii of the loops are 10 cm and 30 cm, and the inner loop carries a clockwise current, what is the magnitude and direction of the magnetic field at the center of the loops?