

**Problem 2:** (30 pts.) A long cylindrical wire is known to have a radius  $R$  greater than 4.00 mm but less than 10.0 mm. It carries a current  $I$  that is uniformly distributed over its cross section.

- a. (15 pts.) Use Ampere's Law to find a symbolic equation for the magnetic field a distance of 4.00 mm from the central axis. (Since you don't know  $I$  and  $R$ , you can't get a numerical answer.) Show your work clearly. Draw the Amperian loop you are using for your calculation, and show the directions of the current and  $\vec{B}$  clearly on your diagram. You must start from Ampere's Law to get credit for this part of the problem.
- b. (10 pts.) Use Ampere's Law again to find a symbolic equation for the magnetic field a distance of 10.0 mm from the central axis. You don't need to repeat work you've already done in part (a).
- c. (5 pts.) The magnitude of the magnetic field due to that current is 0.28 mT at a point 4.00 mm from the axis of the wire, and 0.20 mT at a point 10 mm from the axis of the wire. What is the radius of the wire?

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a)



$$\oint \vec{B}_1 \cdot d\vec{s} = \mu_0 I_{enc} = \mu_0 I \left( \frac{\pi r_1^2}{\pi R^2} \right)$$

← only this fraction of the total current passes through the loop.

$$B_1 (2\pi r_1) = \mu_0 I \frac{\pi r_1^2}{\pi R^2}$$

$$B_1 = \frac{\mu_0 I r_1}{2\pi R^2}$$

where  $r_1 = 4.00 \text{ mm}$

b)

$$\oint \vec{B}_2 \cdot d\vec{s} = \mu_0 I \Rightarrow B_2 (2\pi r_2) = \mu_0 I$$

$$B_2 = \frac{\mu_0 I}{2\pi r_2}$$

where  $r_2 = 10.0 \text{ mm}$ .

c)  $I = \frac{2\pi r_2 B_2}{\mu_0}$  plug in to (a)

$$B_1 = \frac{(2\pi r_2 B_2) r_1}{2\pi R^2} = \frac{r_1 r_2 B_2}{R^2}$$

$$R^2 = r_1 r_2 \frac{B_2}{B_1} \quad R = \sqrt{r_1 r_2 \frac{B_2}{B_1}} = \sqrt{(4.0)(10.0) \left( \frac{0.20}{0.28} \right)}$$

$$R = 5.35 \text{ mm}$$