

Problem 3: (30 pts.) You are given a hollow copper cylinder with inner radius a and outer radius $3a$. The cylinder's length is $200a$ and its electrical resistance to current flowing down its length is R . To test its suitability for use in a circuit, you connect the ends of the cylinder to a voltage source, causing a current I to flow down the length of the cylinder. The current is spread uniformly over the cylinder's cross section. You are interested in knowing the strength of the magnetic field that the current produces within the solid part of the cylinder, at a radius of $2a$ from the cylinder axis. But since it's not easy to insert a magnetic field probe into the solid metal, you decide instead to measure the field at a point outside the cylinder where the field should be as strong as at radius $2a$. At what distance from the axis of the cylinder should you place the probe?

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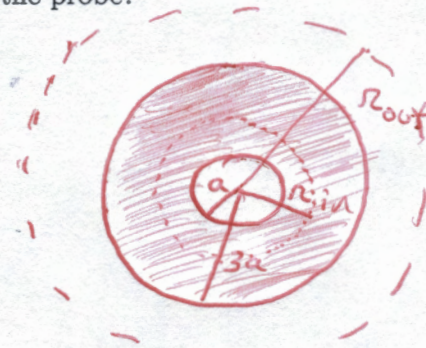
inside: $r_{in} = 2a$

$$\oint \vec{B}_{in} \cdot d\vec{s} = \mu_0 I_{net}$$

$$B_{in}(2\pi r_{in}) = \frac{\mu_0 I_{net} \cdot \pi(r_{in}^2 - a^2)}{\pi[(3a)^2 - a^2]}$$

Plug in $r_{in} = 2a$.

$$B_{in} = \frac{\mu_0 I (4a^2 - a^2)}{2\pi(2a)(9a^2 - a^2)} = \frac{\mu_0 I (3)}{4\pi a (8)}$$



Outside: $r_{out} = ?$

$$\oint B_{out} \cdot d\vec{s} = \mu_0 I$$

$$B_{out} 2\pi r_{out} = \mu_0 I$$

$$B_{out} = \frac{\mu_0 I}{2\pi r_{out}}$$

Set $B_{out} = B_{in}$

$$\frac{\mu_0 I}{2\pi r_{out}} = \frac{\mu_0 I (3)}{4\pi a (8)}$$

$$\boxed{\frac{16}{3} a = r_{out}}$$