Part 1 – Magnetic field of a current carrying wire

A thin wire carries a uniform current I. This current produces a magnetic field, **B**. Up until now, you've always been told that magnetic fields loop around a current-carrying wire (figure a. below), but how do you know that there are not other components to the magnetic field? Perhaps the magnetic field has a z-component (figure b.) or a radial component (figure c.).

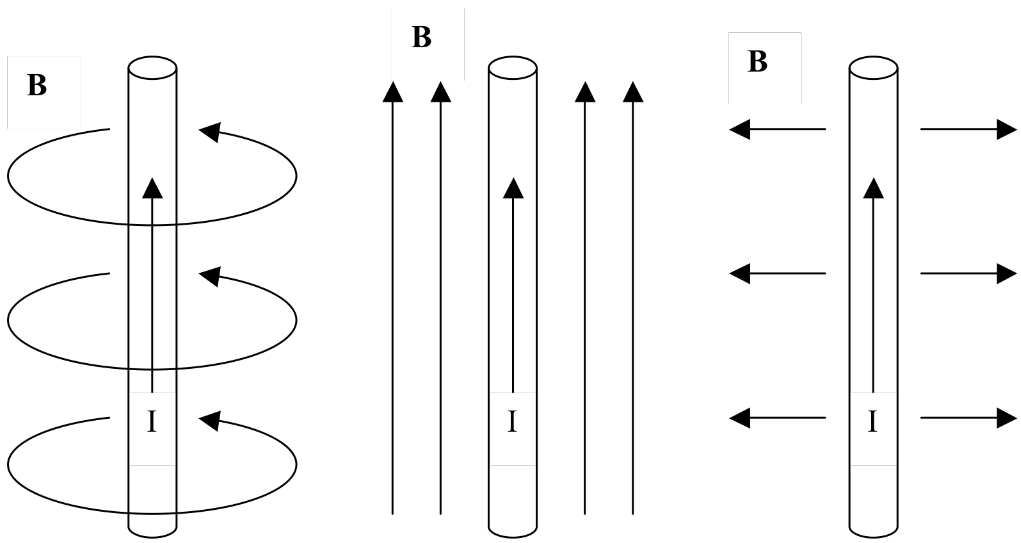

Figure a. Figure b. Figure c.

i. Can you think of any convincing arguments for why there shouldn't be a z- or s-component? It might be useful to consider symmetry, Maxwell's equations, and any laws that have recently been covered in class.

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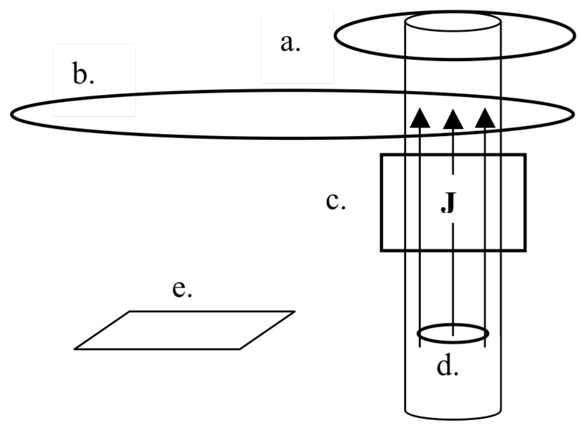
ii. Write down Ampere's Law in integral form:

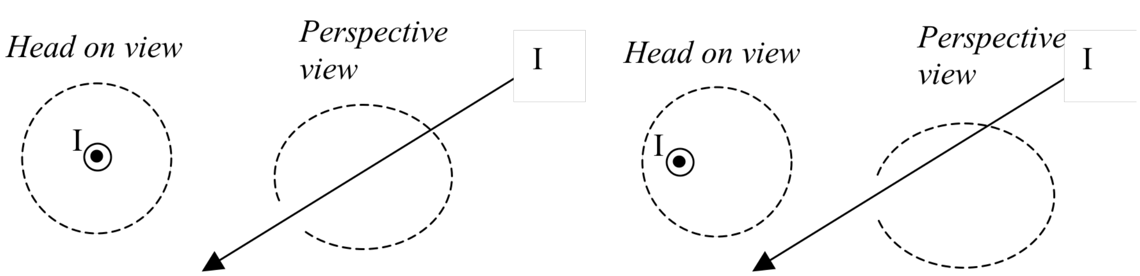
iii. When using Ampere's Law, you must choose an Amperian loop.
Consider a fat cylindrical wire with a known current density **J** flowing up it.
Consider the various loops shown in the figure, and decide what information, if any, Ampere's law applied to each loop might provide about **B.**
Is Ampere's law invalid for any of them?
Can you think of any OTHER Amperian loops that might be useful in this situation?



iv. Compare $\oint \vec{B} \bullet d\vec{\ell}$ for the two Amperian loops below. Which has a larger magnitude?)

Loop 1: wire runs through center of loop

Loop 2: wire is not centered in loop



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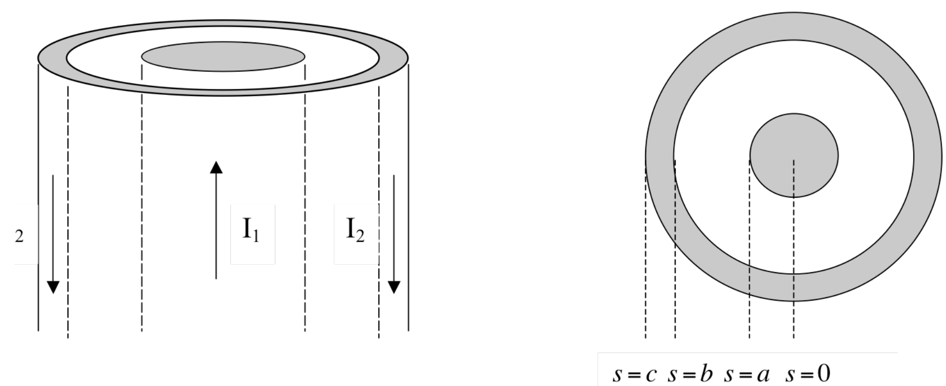
Part 2 – Application of Ampere's Law

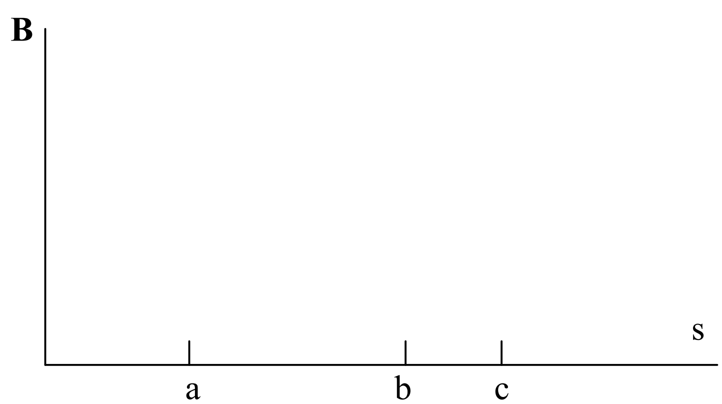
While studying intensely for your physics final, you decide to take a break and listen to your stereo. As you unwind to a little Hootie & the Blowfish, your thoughts drift to newspaper stories about the dangers of household magnetic fields on the body. You examine your stereo wires and find that most of them are coaxial cable: essentially one thin conducting cylinder surrounded by a conducting cylindrical shell (the shell has some thickness). Current travels up the inside conductor, and back down the conducting shell. As a way to practice for your physics final you decide to calculate the magnetic field at different radii.

Perspective view: *Top view:*



i. Before you begin calculating, think about what answers you expect. Sketch a qualitative graph of **B** in four regions: s < a; a < s < b; b < s < c; and s > c.

- Is there a magnetic field inside either of the two conductors?
- How should I_1 and I_2 compare so there is no magnetic field outside the coax?



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ii. Ohm's law for a wire says: Resistance ∝ Length/Area. Does this dependence imply anything about the current density **J** throughout the body of a conducting wire? (i.e. Is all the current concentrated right at the center of the wire? Does it only flow on the outer edges? Does it spread out uniformly across the cross-sectional area? Is it proportional to the radius?)

iii. Using your model for **J** from the previous part, calculate **B** in four regions:

1) $s < a$ 2) $a < s < b$ 3) $b < s < c$ 4) $s > c$

Does your guessed sketch above resemble your answers?

iv. If I is 1 Amp (not an unreasonable number), what is the maximum possible value of B anywhere in this problem? What is it at your location in the room? At either of these places, how does it compare with the earth's magnetic field (about 5E-4 T) What do you think about the newspaper's concerns?

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