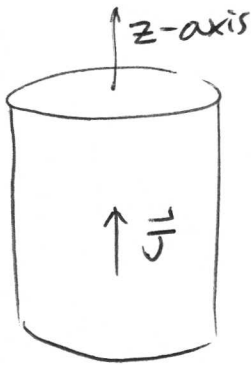


Last time we derived $\nabla \times \vec{H} = \vec{J}_{\text{free}}$ where $\vec{H} = \frac{\vec{B}}{\mu_0} - \vec{M}$



Inside a current carrying wire

$$\vec{H} = \frac{Jr}{2} \hat{\phi}$$

Now I want to know \vec{M} & \vec{B} .

Since the metal is a linear diamagnetic material I know that \vec{H} , \vec{B} and \vec{M} all point in the same direction (either parallel or antiparallel)

$$\vec{M} = (\text{const}) \vec{B}$$

what shall we call this constant?

$$\frac{1}{\mu_0} \frac{\chi_m}{1 + \chi_m} \text{ seems like a good idea !?!}$$

Note: χ_m is called magnetic susceptibility. χ_m is dimensionless, just like χ_e .

(2)

First find \vec{M}

$$\begin{aligned}
 H &= \frac{1}{\mu_0} B - M \\
 &= \frac{1}{\mu_0} \frac{\mu_0 (1 + \chi_m) M}{\chi_m} - M \\
 &= \frac{(1 + \chi_m) M - \chi_m M}{\chi_m} \\
 &= \frac{M}{\chi_m}
 \end{aligned}$$

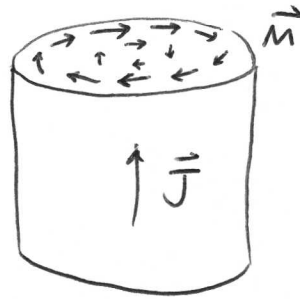
$$\vec{M} = \chi_m \vec{H}$$

True for all linear materials.

For the current carrying wire example, $\chi_m \approx -10^{-5}$

$$\vec{M} = \frac{\chi_m J r}{2} \hat{\phi}$$

inside the wire.

Now find \vec{B}

$$\begin{aligned}
 H &= \frac{1}{\mu_0} B - M \\
 &= \frac{1}{\mu_0} B - \frac{1}{\mu_0} \frac{\chi_m}{1 + \chi_m} B \\
 \mu_0 H &= \frac{(1 + \chi_m) B - \chi_m B}{1 + \chi_m} = \frac{B}{1 + \chi_m}
 \end{aligned}$$

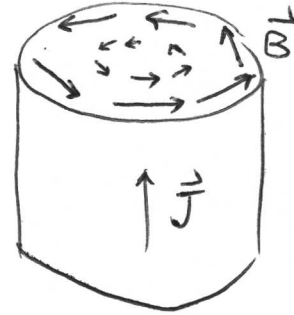
③

$$\vec{B} = \mu_0 (1 + \chi_m) \vec{H}$$

True for all linear materials

For the current carrying wire example, $\chi_m \approx -10^{-5}$

$$\vec{B} = \mu_0 (1 + \chi_m) \frac{Jr}{2} \hat{\phi}$$



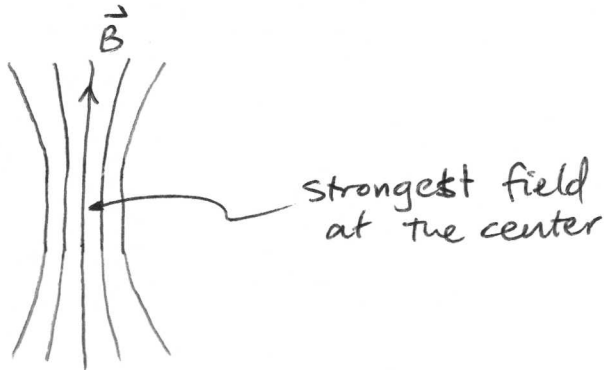
Note: \vec{B} is opposite direction as \vec{M} .

\vec{B} inside the wire is slightly less (1 part in 10^5) than you would guess if you didn't know about diamagnetism.

Pop Quiz

Pop Quiz ⁽⁴⁾
Day 10

A frog is placed near the center of a 20 Tesla magnet



Frogs, like people, are mostly water. $\chi_m \approx -10^{-5}$

- Estimate the net dipole moment of the frogs $\vec{M}V$, where \vec{M} is magnetization and V is volume.
- Is the frog attracted or repelled from the region of highest field?
- Consider a material with $\chi_m = -1$. How would it behave compared to the frog?