CHAPTER 6

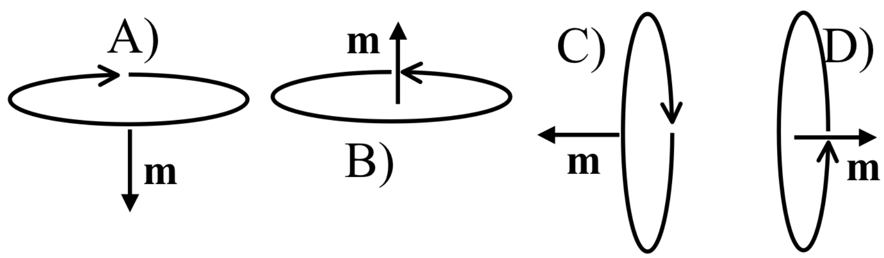
MAGNETIZATION

6.1

Griffiths argues that the torque *on* a magnetic dipole in a B field is:

$$\vec{\tau} = \vec{\mathbf{m}} \times \vec{\mathbf{B}}$$

How will a small current loop line up if the B field points uniformly up the page?



6.2

Griffiths argues that the force *on* a magnetic dipole in a B field is: $\vec{\mathbf{F}} = \vec{\nabla}(\vec{\mathbf{m}} \bullet \vec{\mathbf{B}})$

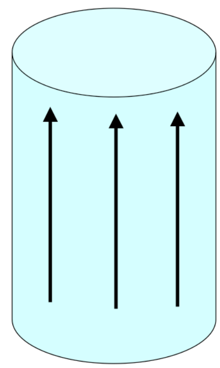
If the dipole **m** points in the z direction, what can you say about **B** if I tell you the force is in the x direction?

A) **B** simply points in the x direction
B) Bz must depend on x
C) Bz must depend on z
D) Bx must depend on x
E) Bx must depend on z

6.3

A solid cylinder has uniform magnetization **M** throughout the volume in the z direction as shown. Where do bound currents show up?

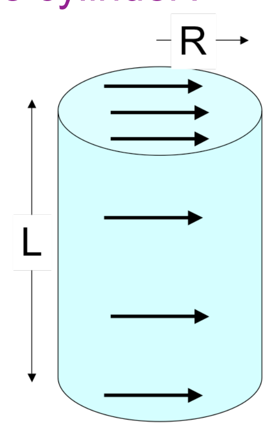
A) Everywhere: throughout the volume and on all surfaces
B) Volume only, not surface
C) Top/bottom surface only
D) Side (rounded) surface only
E) All surfaces, but not volume



6.4

A solid cylinder has uniform magnetization **M** throughout the volume in the x direction as shown. What's the magnitude of the total magnetic dipole moment of the cylinder?

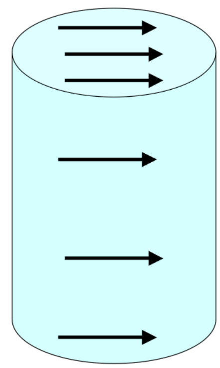
A) $\pi R^2 L M$
B) $2\pi R L M$
C) $2\pi R M$
D) $\pi R^2 M$
E) Something else, it's more complicated



6.5

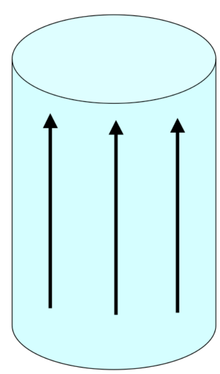
A solid cylinder has uniform magnetization **M** throughout the volume in the x direction as shown. Where do bound currents show up?

A) Top/bottom surface only
B) Side (rounded) surface only
C) Everywhere
D) Top/bottom, and parts of (but not all of) side surface (but not in the volume)
E) Something different/other combination!



To discuss:

A solid cylinder has uniform magnetization **M** throughout the volume in the z direction as shown. What will the B field look like? (Consider if the cylinder is tall and thin, or short and fat, separately)



6.6

A sphere has uniform magnetization M in the z direction.

Which formula is correct for this surface current?

A) $\mathrm{M}\ \sin\theta\ \hat{\theta}$

B) $\mathrm{M}\ \sin\theta\ \hat{\varphi}$

C) $\mathrm{M}\ \cos\theta\ \hat{\theta}$

D) $\mathrm{M}\cos\theta\ \hat{\varphi}$

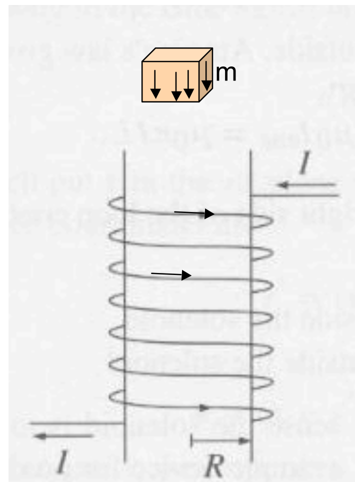
E) None of these!

Coming up first today: Write down (by yourself, *without* book or notes or collaboration, yet!) what you remember about electric Polarization P, and all related concepts and formulas we've worked with!

6.7 a

A small chunk of material (the "tan cube") is placed above a solenoid. It magnetizes, weakly, as shown by small arrows inside. What kind of material must the cube be?

A) Dielectric
B) Conductor
C) Diamagnetic
D) Paramagnetic
E) Ferromagnetic



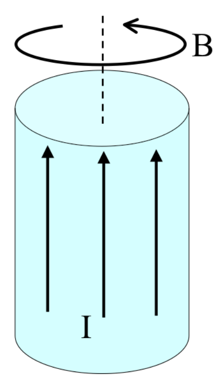
6.7 b

Predict the results of the following experiment: a paramagnetic bar and a diamagnetic bar are pushed inside of a solenoid.

a) The paramagnet is pushed out, the diamagnet is sucked in
b) The diamagnet is pushed out, the paramagnet is sucked in
c) Both are sucked in, but with different force
d) Both are pushed out, but with different force

AUXILIARY FIELD H

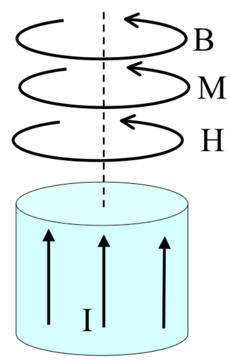
6.8 A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction. We know **B** will be CCW as viewed from above. (Right?)
What about **H** and **M** inside the cylinder?



A) Both are CCW
B) Both are CW
C) **H** is CCW, but **M** is CW
D) **H** is CW, **M** is CCW
E) ???

A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction. We know **B** will be CCW as viewed from above. (Right?)

What about **H** and **M** inside the cylinder?

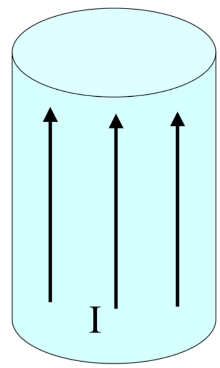


LINEAR AND NONLINEAR MEDIA

6.9

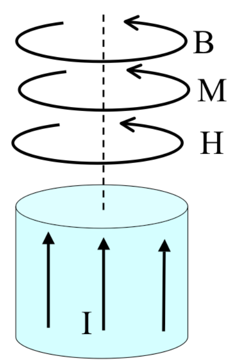
A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction. What is the direction of the bound volume current?

A) $\mathbf{J}_B$ points parallel to I
B) $\mathbf{J}_B$ points anti-parallel to I
C) Other/not sure



A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction. What is the direction of the bound volume current?

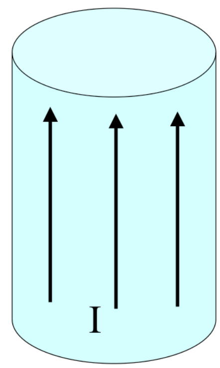
A) $\mathbf{J}_B$ points parallel to I



6.9 b

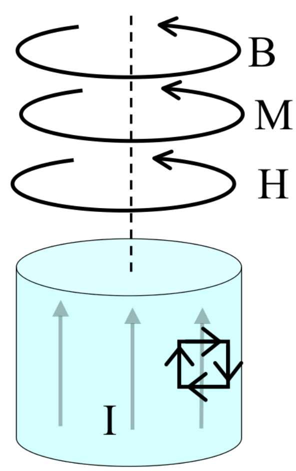
A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction.
What is the direction of the bound surface current?

A) $\mathbf{K}_B$ points parallel to I
B) $\mathbf{K}_B$ points anti-parallel to I
C) Other/not sure



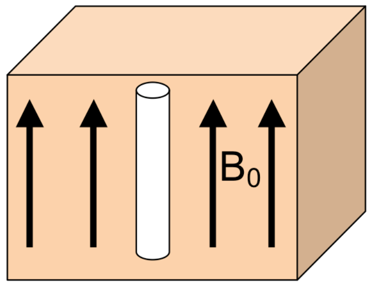
A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction.
What is the direction of the bound volume current?

$\mathbf{K}_B$ points anti-parallel to I



6.10

A large chunk of paramagnetic material ($\chi_m > 0$) has a uniform field B0 throughout its interior. We cut out a cylindrical hole (very skinny, very tall!)



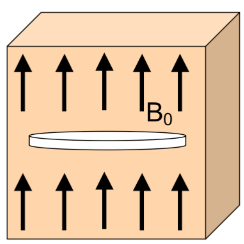
What is B at the center of that hole?

A) B_0 B) more than B_0 C) less than B_0

D) ??

6.10 b

A large chunk of paramagnetic material ($\chi_m > 0$) has a uniform field B0 throughout its interior. We cut out a wafer-like hole (very wide, very short!)



What is B at the center of that hole?

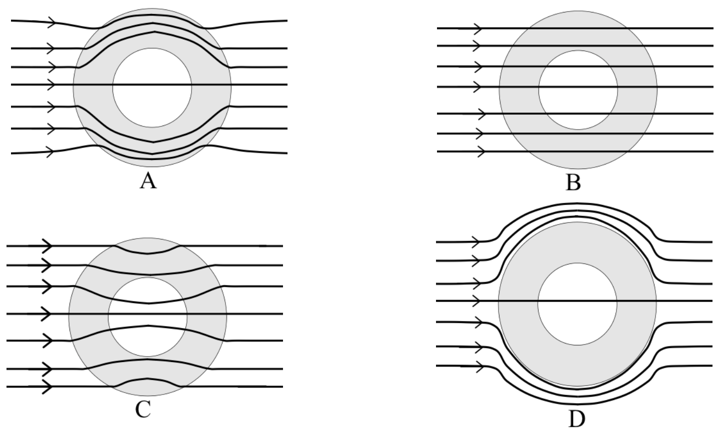
A) B_0

B) more than B_0

C) less than B_0

D) ??

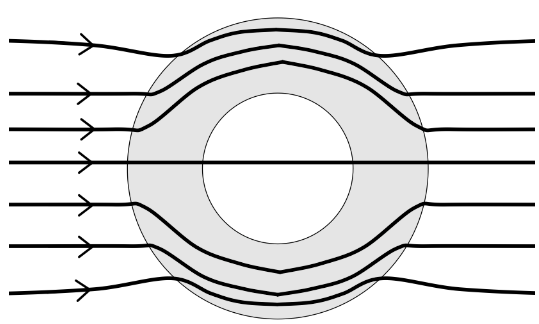
6.11 A sphere (with a spherical cavity inside it) is made of a material with *very* large positive χ_{m}.
It is placed in a region of uniform B field.
Which figure best shows the resulting B field lines?



E) None of these can be even remotely correct

6.11 b

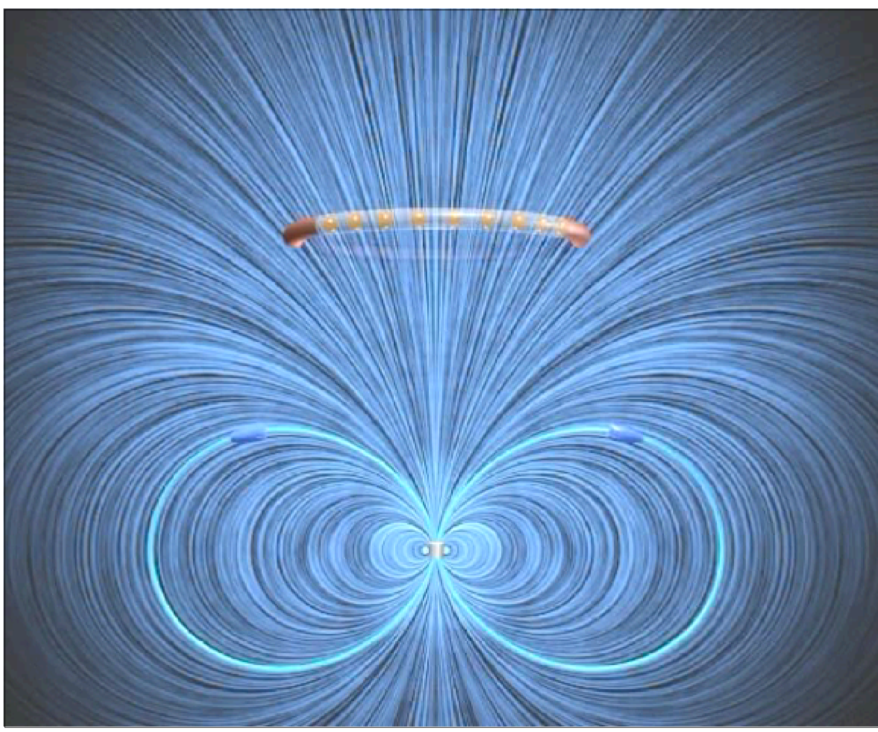
Mu-metal (75% nickel, 15% iron, plus copper and molybdenum) acts as a *sort* of “magnetic shield”...
(there is no perfect “Faraday cage” effect for magnetism - why not)



6.12 A superconducting ring sits above a strong permanent magnet (N side up). If you drop the ring, which way will current flow (as viewed from above), and what kind of force will the ring feel?

A) CW/repulsive
B) CW/attractive
C) CCW/repulsive
D) CCW/attractive
E) No net current will flow/no net force

To think about/discuss:
Remember Lenz' law? What does it say about this situation?
What will the resulting *motion* of the ring look like?
What if you dropped a magnet onto the ring, instead of dropping the ring onto the magnet?

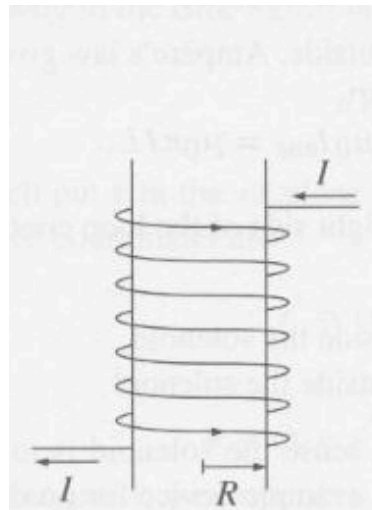


6.13 Inside a hollow solenoid,

$B=B_0=\mu_0 nI$, (so $H=H_0=nI$)

If the solenoid is filled with a paramagnetic material, what is B inside?...

A) B_0
B) a little more than B_0
C) a lot more than B_0
D) a little less than B_0
E) a lot less than B_0

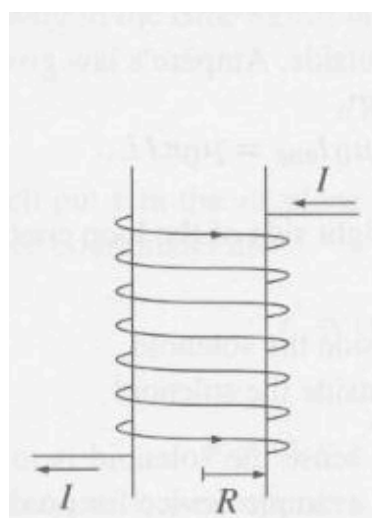


6.14 Inside a hollow solenoid,

$B=B_0=\mu_0 nI$, (so $H=H_0=nI$)

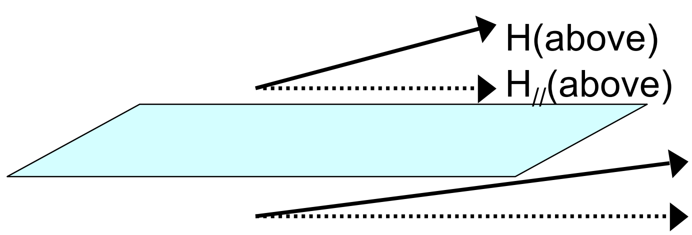
If the solenoid is filled with iron, what is H inside?...

A) H_0
B) a little more than H_0
C) a lot more than H_0
D) a little less than H_0
E) a lot less than H_0



BOUNDARY VALUE PROBLEMS

6.11 I have a boundary sheet, and would like to learn about the change (or continuity!) of H(parallel) across the boundary.



Am I going to need to know about

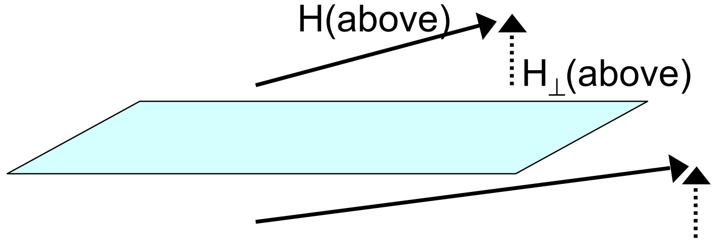
A) $\nabla \times \mathbf{H}$

B) $\nabla \bullet \mathbf{H}$

C) ???

6.11 b

I have a boundary sheet, and would like to learn about the change (or continuity!) of H(perp) across the boundary.



Am I going to need to know about

A) $\nabla \times \mathbf{H}$

B) $\nabla \bullet \mathbf{H}$

C) ???