MAGNETIZATION+DIPOLES

Class Activities: Magnetization (1)

Discussion
Magz toys
I also brought some strong magnets and Magz toys - the magz are dipoles, and I used them to engage in a class discussion of "how do you know this is NOT just electrostatics". They would come up with solutions ("you can't ground it, if it was electric you could") which I tried to counter ("it's coated in a thin plastic film") ("So scrape off the plastic"-> "Maybe it's an electret") ("If you cut it in half, you get two smaller magnets" -> "As I said, maybe it's an electret"...)

Group Activity
Polarization and Magnetization
Start of class, asked them to write down (on paper) everything they could remember about P (electric polarization). ~3 minutes for that. Then, got in groups of three (new groups, this time!) and went to *boards* (so we had 6 groups, each group got one "board section") and they had to write down what their group came up with. ~5 minutes for that. Then the "scribes" sat down, we picked the nicest handwriting to go first, and they read/explained what they had done. Other groups erased what they had that was duplicated, and we argued when groups had disagreements (e.g. if there is an epsilon_0 in the formula P = xi*E*epsilon0, if if there is a minus sign in rho_bound = -? del.P, etc.) until all groups had presented. In the end, we had reviewed much of Chapter 4, and the analogies to Ch 5 (magnetization) were on everyone's fingertips. Took a little long (~20 minutes) but was fun, seemed pretty worthwhile. Many old formulas and ideas got "dredged up", they hit almost everything except the integral formulas for potential.

Simulations
B field and magnets
Activities: Had several MIT sim/quicktimes, showing B field for falling superconducting ring onto a magnet (or vice versa, or with finite resistance) See http://web.mit.edu/8.02t/www/802TEAL3D/visualizations/faraday/index.htm and "Activity Resources" folder.

Demo
Floating Magnet above another magnet
"Magnet floating above another magnet" demo (which provoked some questions and discussion - what determines the height, how does it scale, what happens if you let TWO strong magnets "stick" and then try to float them...)

Class Activities: Magnetization (2)

Demo
Solenoid
Also brought in a solenoidal electromagnet and nails, to introduce ferromagnets.

Demo
Barkhausen Effect
(CU Demo # 5G20.10)
Hear the sound of magnetic domains aligning themselves.

Demo
Permalloy Bar and Tape
(CU Demo # 5G20.55)
A bar will attract wire when aligned with the earth's magnetic field, and not when it is not. The effect is possible due to the high permeability of the alloy.

Demo
Diamagnetism and paramagnetism
(CU Demo # 5G30.11)
See how diamagnetic and paramagnet align in different directions with B field.

Dipoles

Whiteboard/paper
Dipoles
I put up the FORMULA for the B field from an ideal magnetic dipole (from Griffiths), and asked them to sketch it, as well as sketching the field for a *real* current loop of finite radius, and think about the differences. Gave about 5 minutes for this, they did it on paper but talked to each other. It was a very useful exercise - we'd done this before for the electric dipole (same thing!) but they STILL struggled in a variety of ways. Some (most) "knew the answer" either from memory or their heuristics about fields around rings, but they were not good about seeing the connection to the formula. I poked some groups with questions like "on the x axis, at very small x, what is the direction of B for the two cases (ideal and real), and can you reconcile these"?)

5.30

The leading term in the vector potential multipole expansion involves $\oint d\vec{\mathbf{l}}'$

What is the magnitude of this integral?

A) R

B) 2π R

C) 0

D) Something entirely different/it depends!

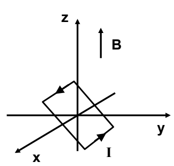
MD12-7

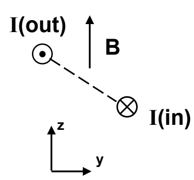
The force on a segment of wire L is $\vec{F} = I\,\vec{L}\times\vec{B}$

A current-carrying wire loop is in a constant magnetic field **B** = B **z_hat** as shown. What is the direction of the torque on the loop?

A) Zero B) +x C) +y D) +z

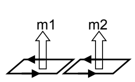
E) None of these

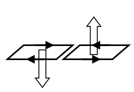


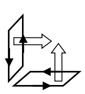


MD12-5

Two magnetic dipoles **m**1 and **m**2 are oriented in three different ways.

1. 

2. 

3. 

Which ways produce a dipole field at large distances?

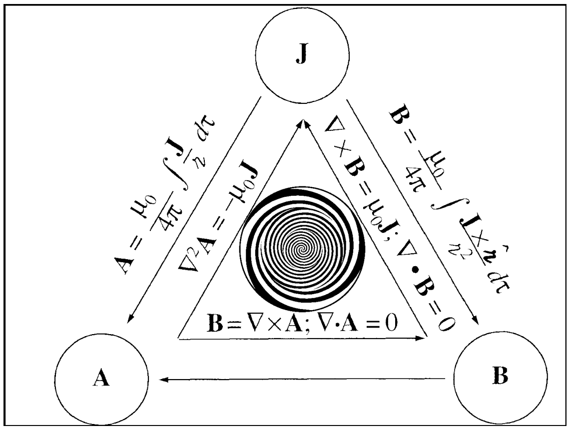
A) None of these

B) All three

C) 1 only

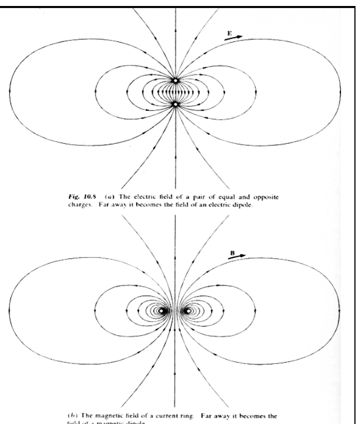
D) 1 and 2 only

E) 1 and 3 only



E-field around electric dipole

B-field around magnetic dipole (current loop)



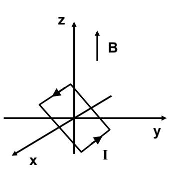
From Purcell, Electricity and Magnetism

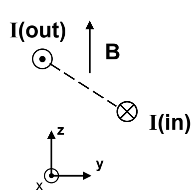
MD12-7

The force on a segment of wire L is $\vec{F} = I\,\vec{L}\times\vec{B}$

A current-carrying wire loop is in a constant external magnetic field **B** = B **z_hat** as shown. What is the direction of the torque on the loop?

A) Zero B) +x C) +y D) +z
E) None of these



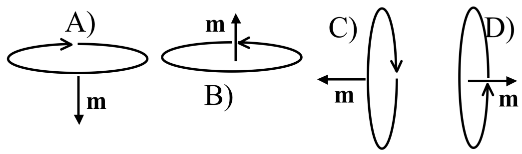


6.1

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

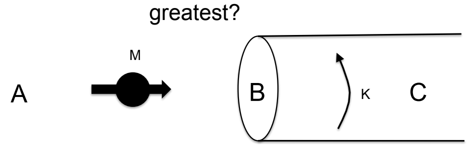
Griffiths argues that the force *on* a magnetic dipole in a B field is: $\vec{\mathbf{F}} = \vec{\nabla}(\vec{\mathbf{m}} \bullet \vec{\mathbf{B}})$

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

6.2x

Suppose I place a small dipole M at various locations near the end of a large solenoid. At which point is the magnitude of the force on the dipole greatest?



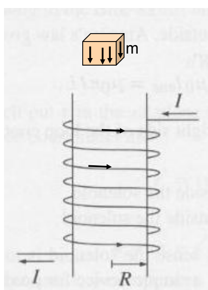
D) Not enough information to answer
E) There is no net force on a dipole

Writing assignment

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!

6.7a 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



ERK6.1

Which type of magnetic material has the following properties:

1) The atoms of the material have an odd number of electrons
2) The induced atomic magnetic dipoles align in the same direction as an applied magnetic field
3) Thermal energy tends to randomize the induced dipoles

A. Ferromagnetic
B. Diamagnetic
C. Paramagnetic

6.7 b

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

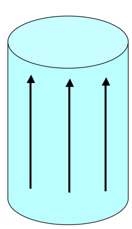
a) The paramagnet is pushed out, the diamagnet is sucked in
b) The diamagnet is pushed out, the paramagnet is sucked in
c) Both are sucked in, but with different force
d) Both are pushed out, but with different force

FIELDS FROM MAGNETIZED OBJECTS + BOUND CURRENTS

6.3

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

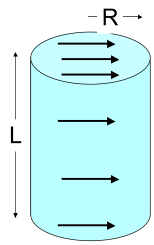
A) Everywhere: throughout tl volume and on all surfaces
B) Volume only, not surface
C) Top/bottom surface only
Δ) Side (rounded) surface or
E) All surfaces, but not volun



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?

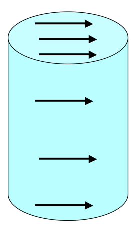
A) $\pi R^2 L M$
B) $2\pi R L M$
C) $2\pi R M$
Δ) $\pi R^2 M$
E) Something else, it's more complicated



6.5

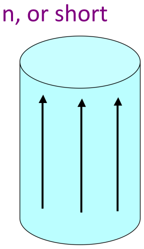
A solid cylinder has uniform magnetization **M** throughout the volume in the x direction as shown. Where do bound currents show up?

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:

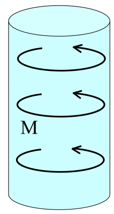
A solid cylinder has uniform magnetization **M** throughout the volume in the z direction as shown. What will the B field look like?
(Consider if the cylinder is tall and thin, or short and fat, separately)



6.21

A solid cylinder has uniform magnetization **M** throughout the volume in the φ direction as shown. In which direction does the bound surface current flow on the (curved) sides?

A. There is no bound surface current.
B. The current flows in the ±φ direction.
C. The current flows in the ±*s* direction.
D. The current flows in the ±*z* direction.
E. The direction is more complicated than the answers B, C, or D.

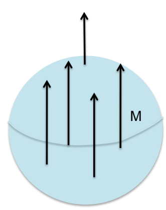


6.6

A sphere has uniform magnetization M in the z direction.

Which formula is correct for this surface current?

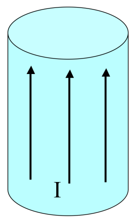
A) $M \sin\theta\ \hat{\theta}$
B) $M \sin\theta\ \hat{\varphi}$
C) $M \cos\theta\ \hat{\theta}$
D) $M \cos\theta\ \hat{\varphi}$
E) None of these!



BOUND CURRENT PROBLEMS WITH REFERENCE TO "H"

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



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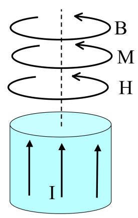
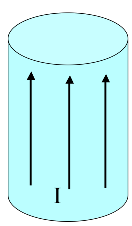


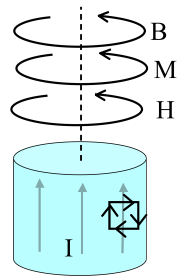
6.9 b A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction.
What is the direction of the bound surface current?

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?

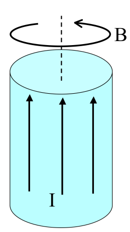
$\mathbf{K_B}$ points anti-parallel to I



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) ???



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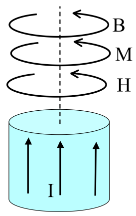
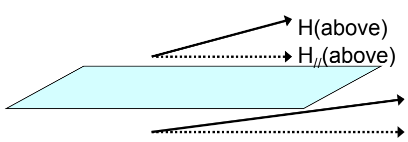


BOUNDARY VALUE PROBLEMS

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

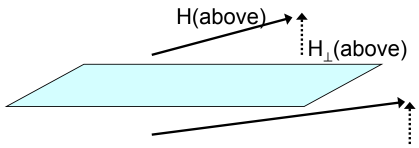
A) $\nabla \times \mathbf{H}$

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

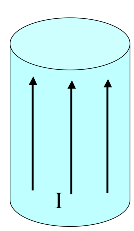
A) $\nabla \times \mathbf{H}$
B) $\nabla \bullet \mathbf{H}$
C) ???

LINEAR AND NONLINEAR MEDIA

6.9

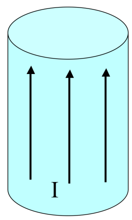
A very long aluminum (paramagnetic!) rod carries a uniformly distributed current I along the +z direction.
What is the direction of the bound volume current?

A) $\mathbf{J_B}$ points parallel to I
B) $\mathbf{J_B}$ points anti-parallel to I
C) $\mathbf{J_B}$ curls around I (RHR)
D) $\mathbf{J_B}$ curls around I (LHR)
E) Other/not sure



6.9b 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



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
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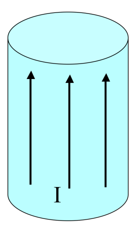
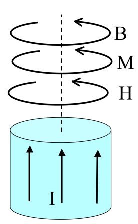
C) Other/not sure



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?

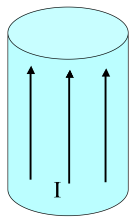
A) $\mathbf{J_B}$ points parallel to I



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



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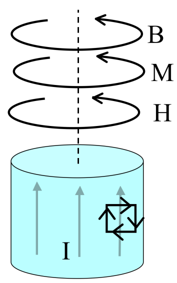
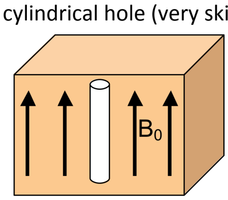
What is the direction of the bound volume current?

$\mathbf{K_B}$ points anti-parallel to I



6.10

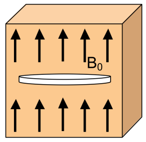
A large chunk of paramagnetic material (χ_m>0) has a uniform field B0 throughout its interior.
We cut out a cylindrical hole (very skinny, very tall!)



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

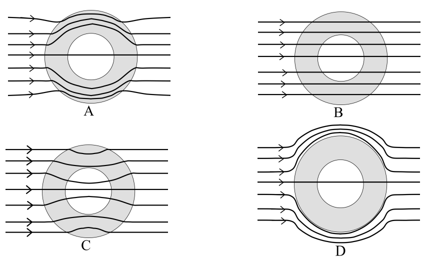
A large chunk of paramagnetic material (χ_m>0) has a uniform field B0 throughout its interior.
We cut out a wafer-like hole (very wide, very short!)



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

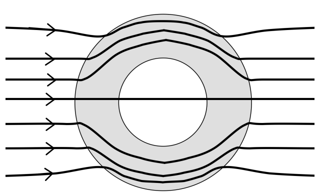
A sphere (with a spherical cavity inside it) is made of a material with *very* large positive χ_m.
It is placed in a region of uniform B field.
Which figure best shows the resulting B field lines?



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?

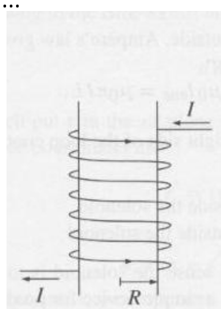
A superconducting ring sits above a strong permanent magnet (N side up). If you drop the ring, which way will current flow (as viewed from above), and what kind of force will the ring feel?

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

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

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 very long 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