NAME_____ **PHY424/ELE 324**
Date_____ **Fall 2005 – FINAL EXAM**

Info: There are 7 problems. Point values are indicated. You must do the first 5 problems. Do EITHER problem 6 or 7, NOT BOTH. Clearly XXX out the one you don't want to count.

Work expeditiously. Don't spend too much time on any one problem. If you have questions, please ask.
Rules:

(A) You must show your work or explain your answer to receive full credit.
(B) Your final answer MUST be put in a BOX to ensure you receive full credit.

Some formulas, etc you may find useful:

Legendre Polynomials:
$x=\cos(\theta)$

$P_0(x) = 1$
$P_1(x) = x$
$P_2(x) = (3/2x^2-1/2)$
$P_2(x) = ((5/2)x^3-(3/2)x)$

Half-angle formula
$c^2 = a^2 + b^2 - 2ab\cos\theta$

$$\vec{N} = \vec{r} \times \vec{F}$$

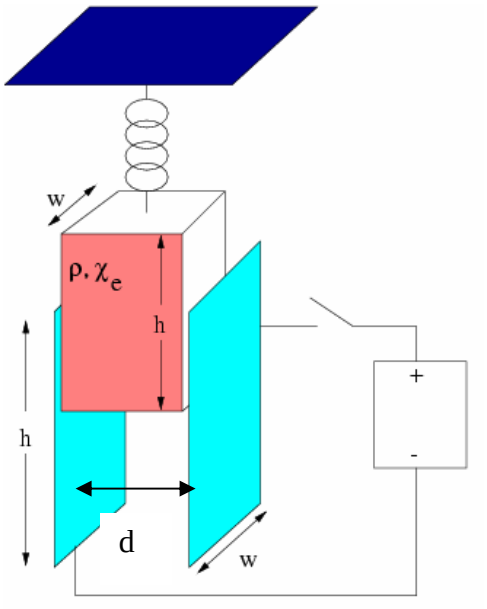
$$\vec{F} = m\vec{a}$$

$$L = mvr$$

$$v = \omega r$$

1) A dielectric having susceptibility χ_e is suspended by a spring and hanging between the plates of a parallel-plate capacitor as shown. The plates are connected to a voltage source of voltage V_0. Initially the switch is open, but at some later time, the switch is closed.

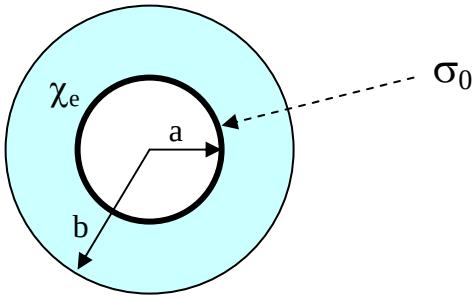
a. Determine the displacement of the dielectric after the switch is closed (15 pts).



b. If the polarity of the plates was swapped, how would the displacement of the dielectric compare to that found in (a), explain. (5 points)

2) A sphere of radius R has a potential along its surface of, $V = V_0\cos^2(\theta)$ over its surface.
   a. Find the potential for all *r*. (20 points)

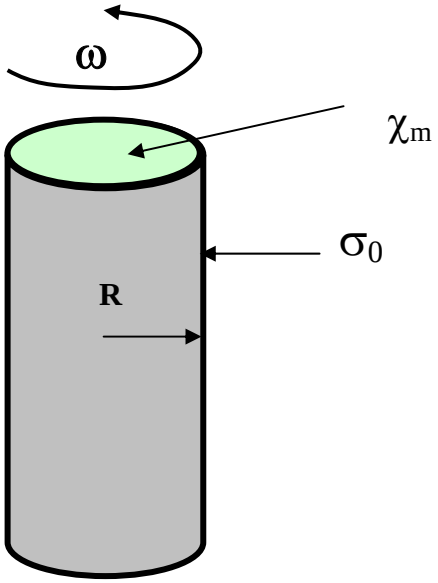
3) A spherical conductor of radius *a* carries a uniform surface charge σ_0 and is surrounded by a linear dielectric of susceptibility χ_e out to radius *b*.



a. Compute the energy stored in this system. (12 points)

b. Determine the capacitance of this sphere (10 points)

4) A long conducting cylindrical shell of radius R and surface charge σ_0 is rotating with an angular velocity ω. It is filled with a linear medium which has magnetic susceptibility χ_m. Note: The material in the cylinder is not rotating, only the outer shell is.



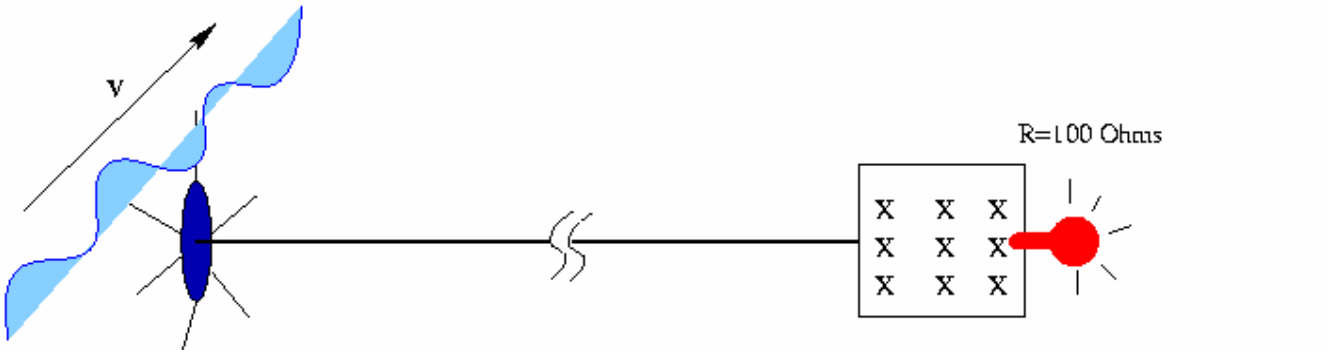
a) Determine the magnetic field inside the cylinder (12 pts)

b) Compute the bound volume current and bound surface current in the medium (5 pts ea.).

c) Consider the following four cases: (8 pts)
   i. No material inside the cylinder
   ii. A diamagnetic material inside the cylinder
   iii. A paramagnetic material inside the cylinder
   iv. A ferromagnetic material inside the cylinder

   Draw a single graph which shows the magnetic field strength **as a function of ω.** Label each of the four curves (i), (ii), (iii), and (iv) as defined from above.

5) A square with a length/side of ℓ_0 has a constant field $B=B_0$ passing through it. At t=0, the loop is aligned perpendicularly to the field as shown. The loop is attached to a wheel via a long shaft as shown. Water from a nearby river moving at speed *v* causes the wheel to rotate.



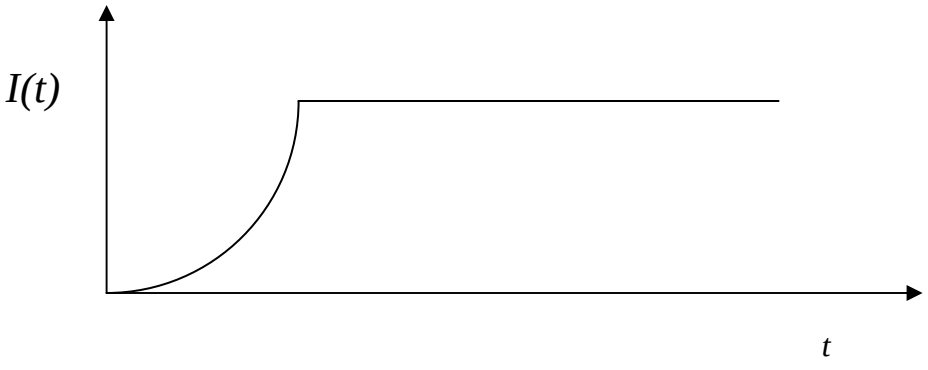
a. Determine the current flowing through the light bulb (assume R=100 Ohm resistance). (10 points)

b. Describe **three** things you could do to increase the current through the loop (6 pts).

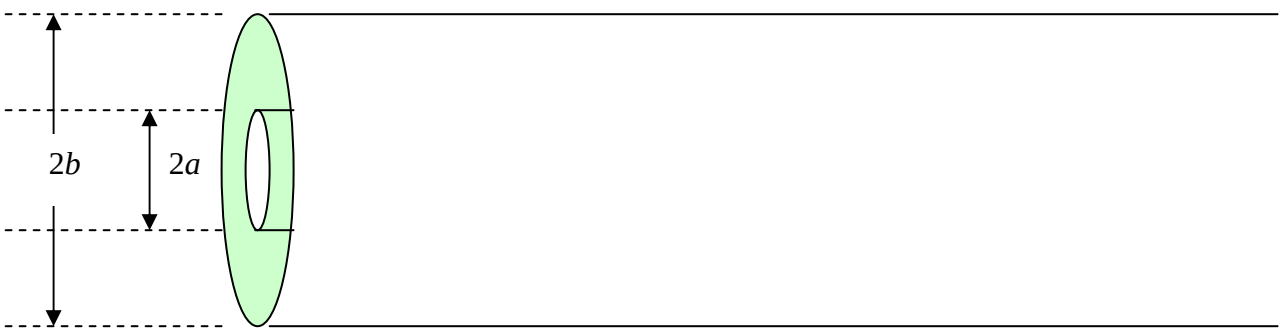
6) A long solenoid of length ℓ and radius R containing *n* turns per unit length is filled with a linear magnetic medium of susceptibility χ_m. It is connected to a current source.

a. Compute the self-inductance of the solenoid. (10 pts)

b. If the current increases with time as $I(t)=I_0 t^2$ as shown below, make a sketch of the back *EMF* as a function of time. Make the sketch on a separate graph just below the one provided. (6 pts).



7) A long coaxial cable filled with a linear medium of susceptibility χ_m, carries a current I along the surface of the inner conductor at radius a, and the current returns along the outer conductor at radius b as shown.



a. Determine the self-inductance of the cable (12 pts).

b. Determine the energy stored in the cable once the current reaches its steady state value. (4 pts)