

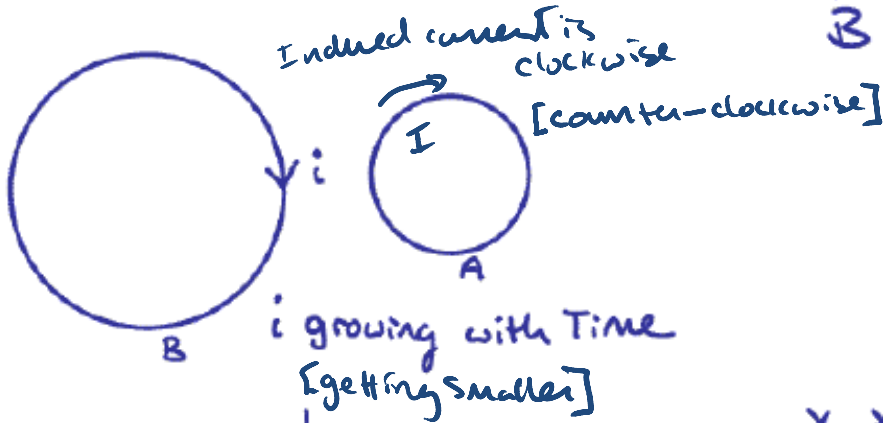
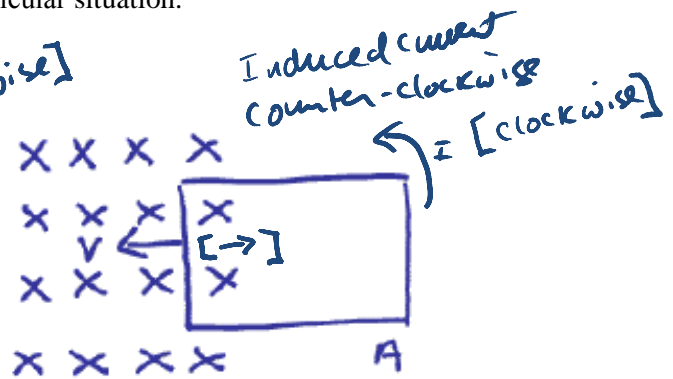
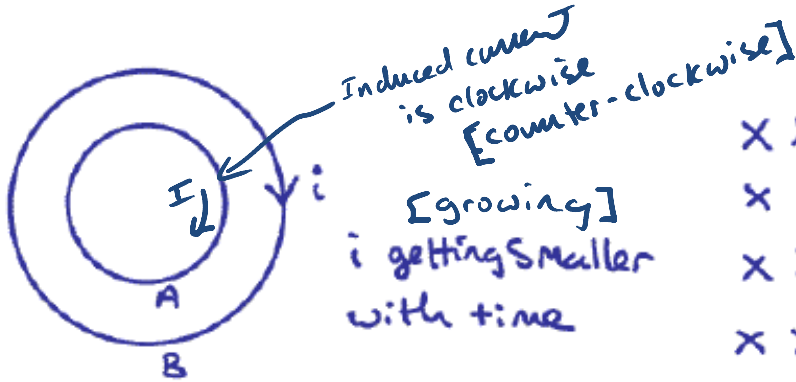
Exam 3 (April 15, 2010)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where indicated.

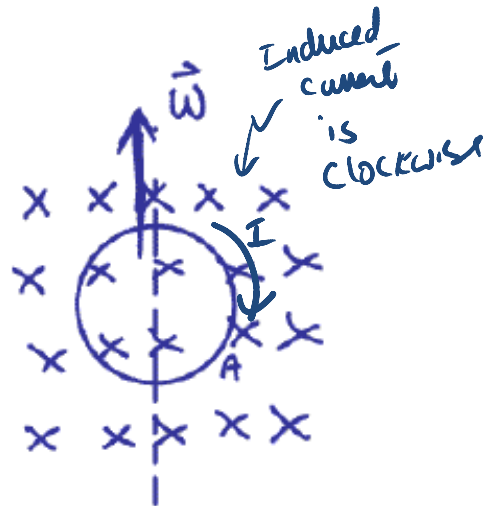
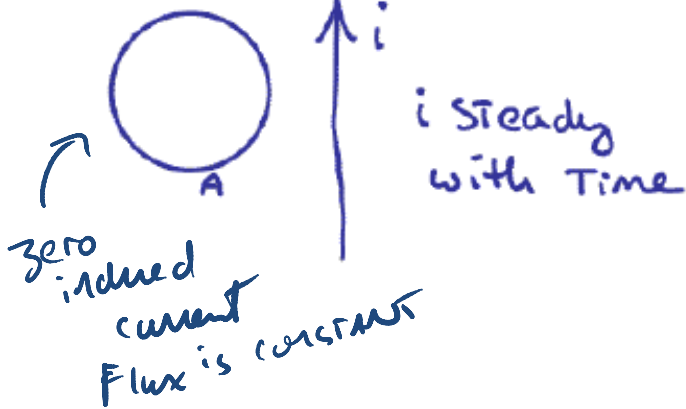
Problem 1 (18 pts):

Below are six separate figures. In each figure there is a rigid loop of conducting wire labeled "A". Beside each figure, specify clearly the direction of the induced current in loop A or state "zero current" if there is no current in loop A in that particular situation.

Two versions of this page used
Other version specified by []



loop A Moving to left with \vec{v} [Right]



loop A in plane of Paper but rotating about axis with Angular velocity $\vec{\omega}$

Problem 2 (12 pts):

The sketch to the right shows a graphical representation of the electric field of a short length of a long electromagnetic plane wave. Also given is the mathematical equation describing the electric component of this electromagnetic wave.

a) In what direction is this wave traveling?

+z direction (from $kz - \omega t$ Argument)



b) Write the equation for the magnetic component of this electromagnetic wave.

$\vec{E} \times \vec{B}$ must be in +z

$B = E/c$

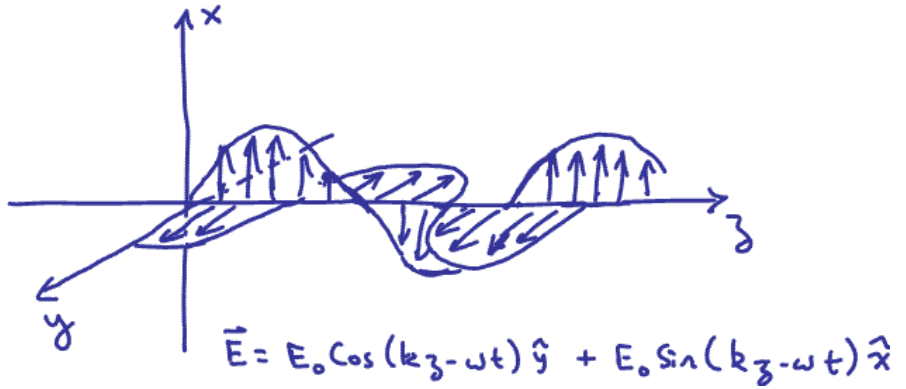
$\vec{B} = \frac{E_0}{c} \cos(kz - \omega t) (-\hat{x})$

in phase

c) Describe the polarization of this wave.

Problem 3 (9 pts):

The sketch to the right shows a graphical representation of the electric field of (short lengths of) two electromagnetic plane waves. Also given is the mathematical equation that describes these two electric field components. You can think of these two waves being orthogonal components of a single wave. Describe the polarization of that wave.

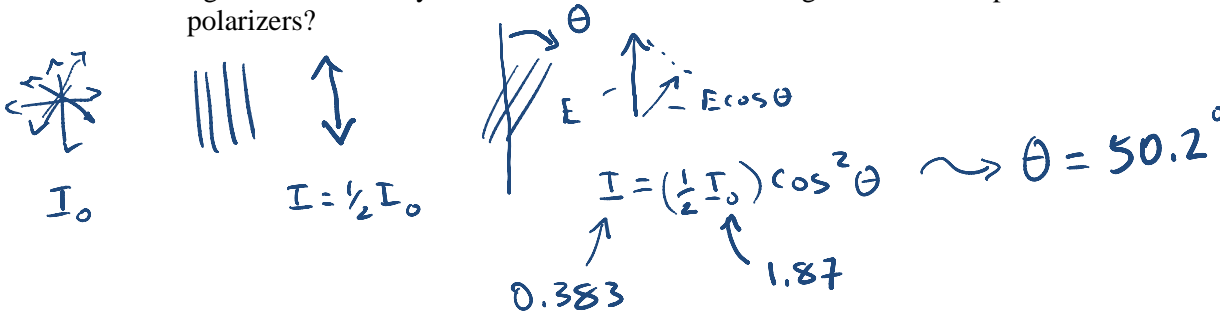


This EM wave has circular polarization

More specifically it is left-handed circular polarization

Problem 4 (9 pts):

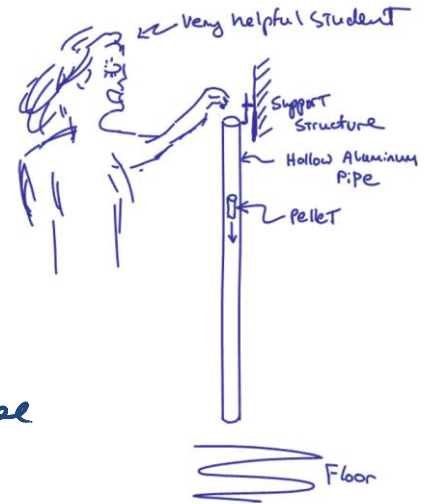
Unpolarized light with an intensity of 1.87 W/m^2 passes through two polarizers. The emerging light has an intensity of 0.383 W/m^2 . What is the angle between the polarization axes of the two polarizers?



1)	18	/18
2)	12	/12
3)	9	/9
4)	9	/9
5)	12	/12
6)	10	/10
7)	12	/12
8)	18	/18
tot		100 /100
Awesome!		

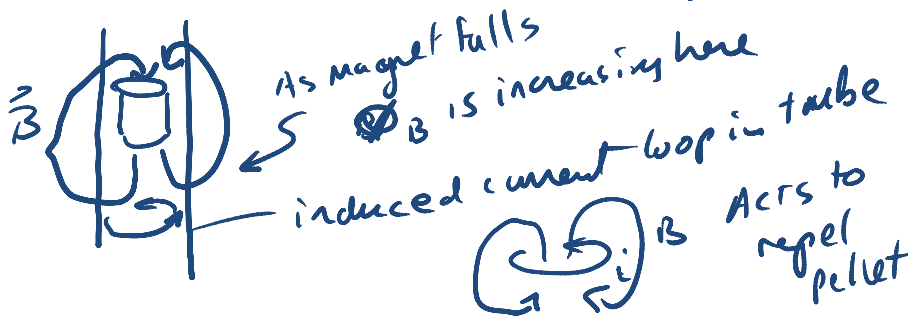
Problem 5 (12 pts):

In lecture one day this semester we did a demonstration. I brought in a rigid aluminum pipe about 0.75 inches in diameter and perhaps a meter and a half long. The pipe was hung in a vertical orientation as shown in the sketch. Two of your classmates volunteered to help. I handed each of the volunteers a cylindrical pellet that was sized such that it would fit easily in the hollow aluminum pipe. Each of the pellets was identical in size, shape and weight. However, one pellet was made of a nonmagnetic metal and one pellet was magnetized (think of it as a bar magnet). Each student then, in turn, dropped their pellet down the pipe. The nonmagnetic pellet fell quickly to the floor as if it were in free fall. The magnetized pellet took a long time to fall down the pipe, perhaps as much as 7 or 8 seconds. When we did the demo, it was my intent to capture your interest and discuss the physical phenomenon responsible for the odd behavior of the pellets. As it turns out, I forgot to explain the demo. So, let's turn the tables. Briefly explain, using your knowledge of the topics we have covered in class recently, why the nonmagnetic pellet falls through the pipe unperturbed and the magnetic pellet takes a long time to traverse the pipe. Please note that you cannot pick up an aluminum object with a magnet; so it is not reasonable to say the magnet sticks to the side of the pipe.



As the magnet falls down the conducting tube

It induces eddy currents above and below its position that act (via Lenz's law) to slow the fall via the induced magnetic fields (from the Eddy currents)



Above the pellet the induced current loop ATTRACTS the magnet



Problem 6 (10 pts):

You measure the self-inductance of a coil of wire to be L . Then you unwind the coil, cut the wire in half and rewind one of the half lengths into a coil with the same diameter but half the number of turns as the original coil. How does the self-inductance of the new coil compare to the self-inductance of the original coil?

Φ_B is proportional to # turns and current in the coil
 $\Phi_B = L i$ so L is proportional to # turns in the coil
 IF Area of new coil same as old coil and the only difference is that the # turns is halved —
 Then $L_{\text{New coil}} = \frac{1}{2} L_{\text{original coil}}$

Problem 7 (12 pts):

A 3 kilowatt carbon dioxide laser used for welding produces a beam of infrared light that is one mm in diameter. The light has a wavelength of 1×10^{-5} m. Use 3×10^8 m/s for c . *

a) What is the frequency of this light?

$$c = \lambda \nu \quad \frac{3 \times 10^8}{1 \times 10^{-5}} = 3 \times 10^{13} \text{ s}^{-1}$$

b) What is the amplitude of the electric field in this beam?

3 kW
1 mm diam

$$\text{Intensity} = \frac{E^2}{2\epsilon_0} = \frac{\text{Watts}}{\text{m}^2} = \frac{3000}{\pi (.0005)^2}$$

$$E^2 = \frac{2(3 \times 10^8)(4\pi \times 10^{-7}) 3000}{\pi (5 \times 10^{-4})^2}$$

$E = 1.7 \text{ NT/Coul}$

c) If this beam is fully absorbed by the surface it hits, what is the force it exerts on that surface?

Pressure = $\frac{\langle S \rangle}{c}$ for absorbed radiation

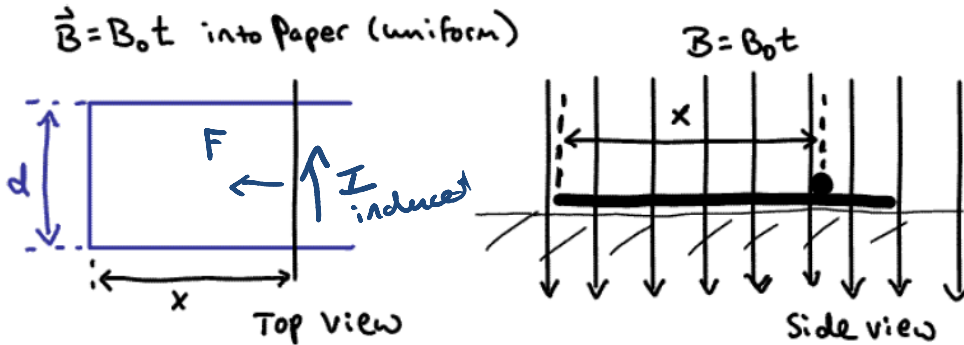
Area $\rightarrow \frac{3000}{[\pi (.0005)^2] 3 \times 10^8} = \text{Pressure}$

Force = Pressure (Area) = $\frac{3000}{3 \times 10^8}$

$F = 1 \times 10^{-5} \text{ N}$

Problem 8 (18 pts):

A rectangular piece of conducting metal with one open end is placed on the (level, horizontal) ground as shown in the sketch below. This metal has negligible resistance. The view in the sketch to the left is from above. The view in the sketch to the right is from the side. A conducting metal bar of mass m and resistance R is placed on two sides of the metal "U" forming a closed rectangle of sides x and d as shown in the sketch. A uniform magnetic field with strength varying with time as $B=B_0t$ points directly into the ground (into the paper in the sketch). The B field strength is zero for $t < 0$. The coefficient of static friction between the rod and the metal "U" is μ_s .



Assuming the bar does not move, determine the force on the bar in terms of the variables in this problem.

$\phi_B = x d B_0 t$
 $\frac{d\phi_B}{dt} = x d B_0$
 $|\mathcal{E}| = x d B_0$

induced I is
 counterclockwise
 F is to left = $I d B_0 t = \frac{x d B_0 d B_0 t}{R}$
 (would act to reduce Area of loop)
 $\mathcal{E} = I R \rightarrow I = \mathcal{E} / R$

$F = \frac{x d^2 B_0^2 t}{R}$

At what time t will the bar begin to move?

Give answer in terms of variables in the problem *

will move at the instant after

$$F_{\text{friction}} = F_{\text{bar}}$$

$$\mu_s m g = \frac{x d^2 B_0^2 t}{R}$$

$$t = \frac{R \mu_s m g}{x d^2 B_0^2}$$

Exam 3 Formulas

$$\vec{F} = q\vec{E}$$

$$\vec{F} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}$$

$$\phi_E = \oint \vec{E} \cdot d\vec{A}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

$$\vec{E} = \int_{\text{vol}} k \frac{dQ}{r^2} \hat{r}$$

V = work/charge

$$V_{\text{point charge}} = \frac{kQ}{r}$$

$$V = \int_{\text{vol}} \frac{k dQ}{r}$$

$$E_s = -dV/ds$$

$$V = IR$$

$$Q = CV$$

$$U = \frac{1}{2} CV^2$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

$$|e| = 1.6 \times 10^{-19} \text{ coulombs}$$

$$k = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} C^2 / Nm^2$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{T \cdot m}{A}$$

$$E = E_0 / \kappa$$

$$C = \kappa C_0$$

$$Q(t) = CE(1 - e^{-t/RC})$$

$$Q(t) = Q_0 e^{-t/RC}$$

$$\left. \begin{aligned} R_{\text{eq}} &= \sum R_i \\ 1/C_{\text{eq}} &= \sum 1/C_i \end{aligned} \right\} \text{For series geometry}$$

$$\vec{F} = q \vec{v} \times \vec{B} = q \vec{i} \times \vec{B}$$

$$\vec{\mu} = nIA$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

$$B_{\text{solenoid}} = \mu_0 n I$$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{i d\vec{l} \times \hat{r}}{r^2}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{encl}} \text{ (Amperes)}$$

$$\mathcal{E} = -d\phi_B/dt$$

$$\phi_B = \oint \vec{B} \cdot d\vec{a}$$

$$\phi_B = LI$$

$$\mathcal{E} = -L di/dt$$

$$U_B = B^2 / 2\mu_0$$

$$B = E/c$$

For plane wave

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

$$\langle S \rangle = \frac{EB}{2\mu_0}$$

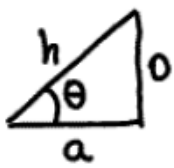
$$P_{\text{radiation (Absorbed)}} = \frac{S}{c}$$

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$v = \lambda \nu$$

$$\vec{B} = \mu_0 (1 + \chi_M) \vec{B}_{\text{ext}}$$

$$\mu_0 \chi_M = \mu$$



$$\sin \theta = \frac{h}{r} \quad \cos \theta = \frac{a}{r}$$

$$\tan \theta = \frac{h}{a}$$

$$\text{Sphere: } A = 4\pi r^2 \quad V = \frac{4}{3}\pi r^3$$

$$\text{cylinder: } A = 2\pi rL + 2\pi r^2$$
$$V = \pi r^2 L$$

$$\int u^n du = \frac{u^{n+1}}{n+1}$$

$$\int \frac{du}{u} = \ln|u|$$

$$\int e^u du = e^u$$

$$\int \frac{x dx}{(x^2+a^2)^{3/2}} = \frac{1}{\sqrt{x^2+a^2}}$$

$$a_c = \frac{mv^2}{r}$$

$$s = r\theta$$

$$KE = \frac{1}{2}mv^2$$

$$PE_{\text{spring}} = \frac{1}{2}kx^2$$

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x = x_0 + \frac{1}{2}(v + v_0)t$$