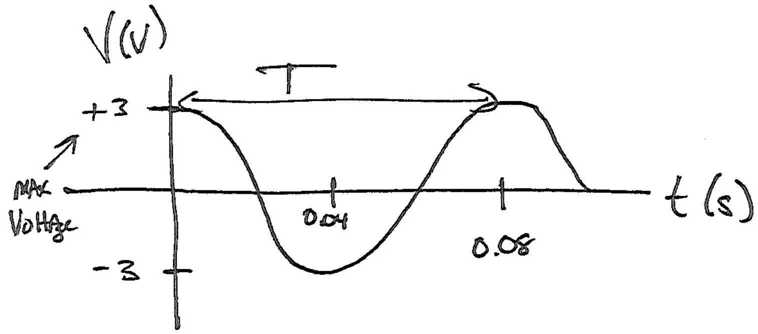
Physics 152, HW #8

Mastering: 10 problems from Chapters 26 and 25

Two written Questions

Graphical Analysis of AC Voltage Source



part a:
What is MAX Voltage? → just READ it off graph! $V_{MAX} = 3V$

b: Average Voltage? Like any AC source like this one, the graph is equally positive and negative ⇒ $V_{AVG} = 0$

c: V_{RMS}? Since $V_{AVG} = 0$, we need an RMS value. By definition,

$$V_{RMS} = \frac{1}{\sqrt{2}} V_{MAX} \Rightarrow V_{RMS} = \frac{1}{\sqrt{2}}(3V) = 2.12V$$

d: Period? Period is from peak to peak on graph ⇒ $T = 0.08s - 0 = 0.08s$

e) Frequency? $f = \frac{1}{T} = \frac{1}{0.08s} \Rightarrow f = 12.5Hz$

26.5 Toaster Oven: $P_{AV} = 1600\,\text{watt}$

$V_{RMS} = 120\,V$

$f = 60\,Hz$

a) $P_{AV} = \frac{V_{RMS}^2}{R} \Rightarrow R = \frac{V_{RMS}^2}{P_{AV}} = \frac{(120V)^2}{1600\,\text{watt}} = 9\Omega$

b) Peak Current $\Rightarrow I_0 = ?$

$V_{RMS} = I_{RMS} R \Rightarrow I_{RMS} = \frac{V_{RMS}}{R} = \frac{120V}{9\Omega} = 13.33\,A$

$I_{RMS} = \frac{1}{\sqrt{2}} I_0 \Rightarrow I_0 = \sqrt{2}\, I_{RMS} = \sqrt{2}\,(13.33A)$

$= 18.856\,A = 19\,A$

c) Peak Power? $\Rightarrow P_0 = ?$

$P_{AV} = I_{RMS} V_{RMS} = \left(\frac{I_0}{\sqrt{2}}\right)\left(\frac{V_0}{\sqrt{2}}\right) = \frac{1}{2} I_0 V_0 = \frac{1}{2} P_0$

$\Rightarrow P_0 = 2P_{AV} = 2(1600\,\text{watt}) = 3200\,\text{watt}$

SECONDARY Voltage & Current

A: which are step up? which are step Down?

$(V_2)_{rms} = \left(\frac{N_2}{N_1}\right)(V_1)_{rms}$ ⇒ If # in SECONDARY is LARGER than primary it's A step-up transformer. If # in secondary is smaller, it's a step-down transformer.

(Voltage in Primary doesn't matter.)

B: Rank based on $(V_2)_{rms}$.

Just Calculate EACH ONE:

$V_p = (V_1)_{rms}$	$N_p = N_1$	$N_s = N_2$	$(V_2)_{rms}$	
240V	1000	500	120V	← $\frac{500}{1000}(240V) = \frac{1}{2}(240V)$
480V	2000	1000	240V	etc.
240V	1000	2000	480V	
480V	4000	2000	240V	
120V	500	2000	480V	

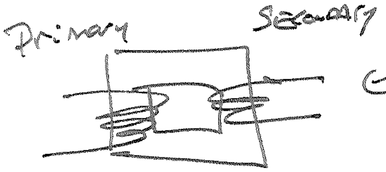
C: $(I_1)_{RMS} = 100A$ for each $\Rightarrow$ V_p doesn't matter

Calculate $(I_2)_{RMS}$ from $(I_2)_{RMS} = \left(\frac{N_1}{N_2}\right)(I_1)_{RMS}$

$$\Rightarrow (I_2)_{RMS} = \left(\frac{N_1}{N_2}\right)(100A)$$

V_p	N_p	N_s	I_2	
240V	1000	500	200A	← $\frac{1000}{500}(100) = 2(100) = 200A$
120V	500	2000	25A	etc.
480V	2000	1000	200 A	
480V	4000	2000	200 A	
240V	1000	2000	50A	

26.12



Output Power = 350 Watt

$(V_2)_{RMS} = 13kV = 13000V$

$N_1 = 500$

Normal Household Outlet $\Rightarrow (V_1)_{RMS} = 120V$

a.) $N_2 = ?$ $\quad (V_2)_{RMS} = (V_1)_{RMS} \frac{N_2}{N_1} \Rightarrow 13000V = 120V\left(\frac{N_2}{500}\right)$

$\Rightarrow N_2 = \left(\frac{13000V}{120V}\right)500 = 54166.6.. = 54200$

b.) $I_2 = ?$ $\leftarrow$ MEANS $(I_2)_{RMS}$

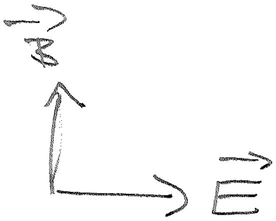
$P = I_{RMS}V_{RMS} \Rightarrow 350Watt = (I_2)_{RMS}(13000V) \Rightarrow (I_2)_{RMS} = \frac{350Watt}{13000V}$

$\Rightarrow (I_2)_{RMS} = 0.027A$

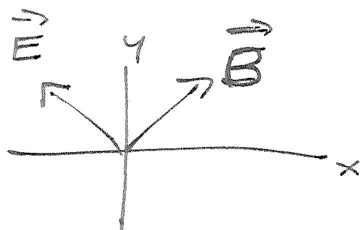
c.) $(I_1)_{RMS} = ?$ $\quad (I_2)_{RMS} = (I_1)_{RMS}\left(\frac{N_1}{N_2}\right) \Rightarrow 0.027A = (I_1)_{RMS}\left(\frac{500}{54200}\right)$

$\Rightarrow (I_1)_{RMS} = 2.9A$

Electric & Magnetic

a) 

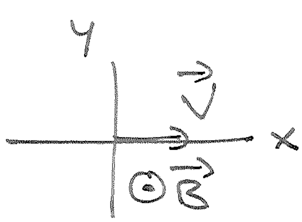
By RHR, $\vec{V}_{em}$ must be $\odot$. Given 3D picture ⇒ +Z

b) 

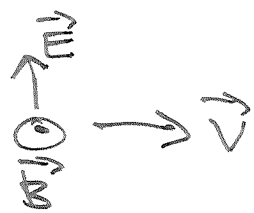
Both $\vec{E}$ & $\vec{B}$ in xy plane.

RHR ⇒ $\vec{V}_{em}$ is $\otimes$ ⇒ −Z

c) If we again draw xy plane

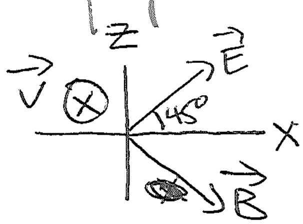


RHR tells use $\vec{E}$ has to be up



So +y

d) $\vec{V}$ along y tells us $\vec{B}$ must be in plane. $\vec{E}$ & $\vec{B}$ have to be perpendicular ⇒ has to be at 45° like this



in this picture, the y-axis is into the page.

25.29 LASER with $\lambda = 633nm$, 1.4mm diameter, $P = 1mwatt = 1\times10^{-3}watt$

→ radius $r = 0.7mm$

$= 7\times10^{-4}m$

a) Intensity? Circular Dot (Not A sphere!) ⇒

$$I = \frac{P}{\pi r^2} = \frac{1\times10^{-3}\,watt}{\pi(7\times10^{-4}m)^2} = 649.612\,watt/m^2 = 650\,watt/m^2$$

b) Damage to eye caused by $10J/m^2$ (for red light). How long can you be exposed to red laser light of this intensity before damage caused?

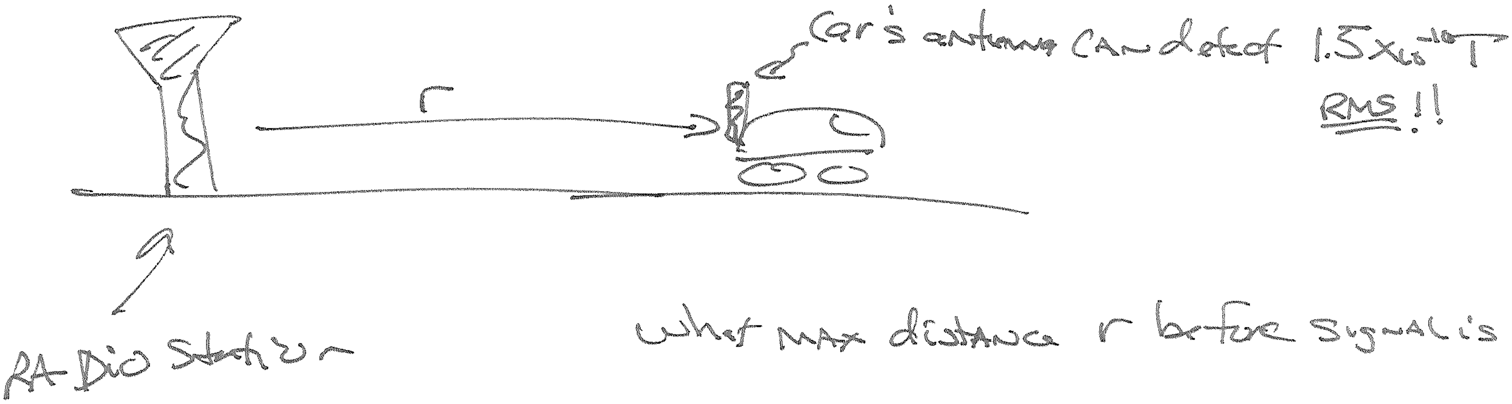
$$I = \frac{P}{A} \qquad \text{Power, } P = \frac{\text{energy}}{\text{time}} = \frac{\Delta E}{\Delta t}$$

$$\Rightarrow I = \frac{\Delta E/\Delta t}{A} = \left(\frac{\Delta E}{A}\right)\cdot\frac{1}{\Delta t} \Rightarrow \Delta t = \frac{\Delta E/A}{I} = \frac{10J/m^2}{650\,watt/m^2} =$$

($\frac{\Delta E}{A}$ = $10J/m^2$)

0.0154s !!

25.33 Radio station transmits radio wave with power of 23 kwatt = 23,000 watt.



what max distance r before signal is lost?

Radio station broadcasting in all directions $\Rightarrow I = \frac{P}{4\pi r^2} \Rightarrow r^2 = \frac{P}{4\pi I}$

$P = 23000$ watt, $r = ?$ $\Rightarrow$ Need Intensity

In terms of peak magnetic field $I = \frac{c}{2\mu_0} B_0^2$

For any sinusoidal, $B_{rms} = \frac{1}{\sqrt{2}} B_0 \Rightarrow B_0 = \sqrt{2} B_{rms}$

$\Rightarrow B_0 = \sqrt{2}(1.5\times10^{-10}T) = 2.121\times10^{-10}T$

$\Rightarrow I = \frac{3\times10^8 m/s}{2(4\pi\times10^{-7} T\cdot m/A)}(2.121\times10^{-10}T)^2 = 5.37\times10^{-6}$ watt/m^2 (somehow units work!)

$\Rightarrow r = \sqrt{\frac{P}{4\pi I}} = \sqrt{\frac{23000 \text{ watt}}{4\pi \cdot 5.37\times10^{-6} \text{ watt/m}^2}} = 18459 m = 18.5 Km$

25.67 LASIK $10\,ns = 10(1\times10^{-9})s = 1\times10^{-8}s$

$Energy = 2.5\,mJ = 2.5\times10^{-3}\,J$

Circle of diameter $0.9\,mm$ ∴ $r = 0.45\,mm = 0.45(1\times10^{-3})m$

$= 4.5\times10^{-4}\,m$

a) Average Power? $P = \frac{Energy}{time} = \frac{2.5\times10^{-3}\,J}{1\times10^{-8}\,s} = 250000\,watt$

b) E_0 at focus point ∴ on circle so $A = \pi r^2$

↳ not sphere!

$\therefore\ I = \frac{P}{A} = \frac{250000\,watt}{\pi(4.5\times10^{-4}m)^2} = 3.93\times10^{11}\,Watt/m^2$

$I = \frac{1}{2}c\epsilon_0 E_0^2 \Rightarrow E_0 = \sqrt{\frac{2I}{c\epsilon_0}} = \sqrt{\frac{2(3.93\times10^{11}\,watt/m^2)}{(3\times10^8\,m/s)(8.85\times10^{-12}\,C^2/N\cdot m^2)}}$

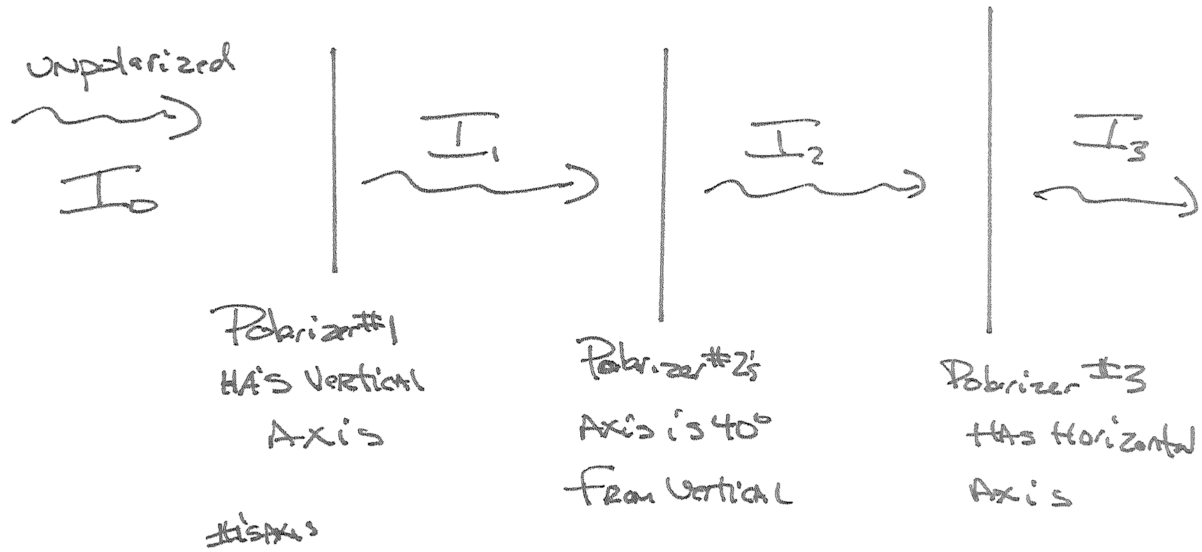
$\Rightarrow E_0 = \sqrt{2.92\times10^{14}\,V^2/m^2} = 1.72\times10^{7}\,V/m$

c) peak magnetic? $E_0 = B_0 c$ ∴ $B_0 = \frac{E_0}{c} = \frac{1.72\times10^7\,V/m}{3\times10^8\,m/s} = \underline{0.0573\,T}$

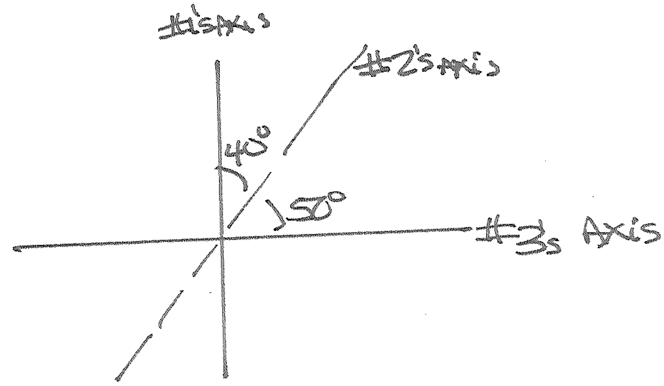
25.71 3 polarizers in a row. $I_0 = 1\,\text{watt/m}^2$

Light changes intensity each time it passes through a polarizer. Label

From the side:



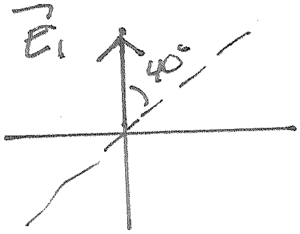
From the front:



So #3 is $90° - 40° = 50°$ from #2's axis

Light is initially unpolarized $\Rightarrow I_1 = \frac{1}{2} I_0 = \frac{1}{2}(1\,\text{watt/m}^2) = 0.5\,\text{watt/m}^2$

After leaving #1, light is vertically polarized!



Light striking polarizer #2 still has same intensity as when it left #1

Law of Malus $\Rightarrow I_2 = I_1 (\cos 40°)^2$

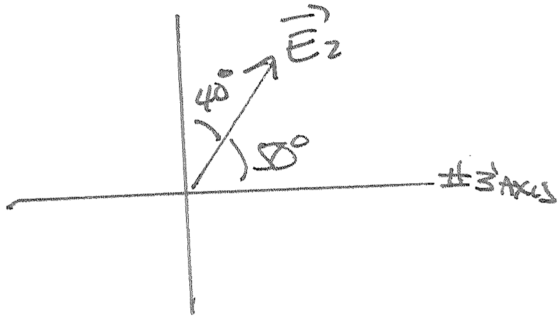
$\Rightarrow I_2 = 0.5\,\text{watt/m}^2 (\cos 40°)^2 = 0.5\,\text{watt/m}^2 (0.5868)$

$= 0.2934\,\text{watt/m}^2$

Light Leaving #2 is polarized at 40°, still has intensity I_2 when it hits #3

$\Rightarrow I_3 = I_2(\cos\theta)^2$

so $\theta = 50°$



$\Rightarrow I_3 = 0.2934\ \text{watt/m}^2\ (\cos 50°)^2$

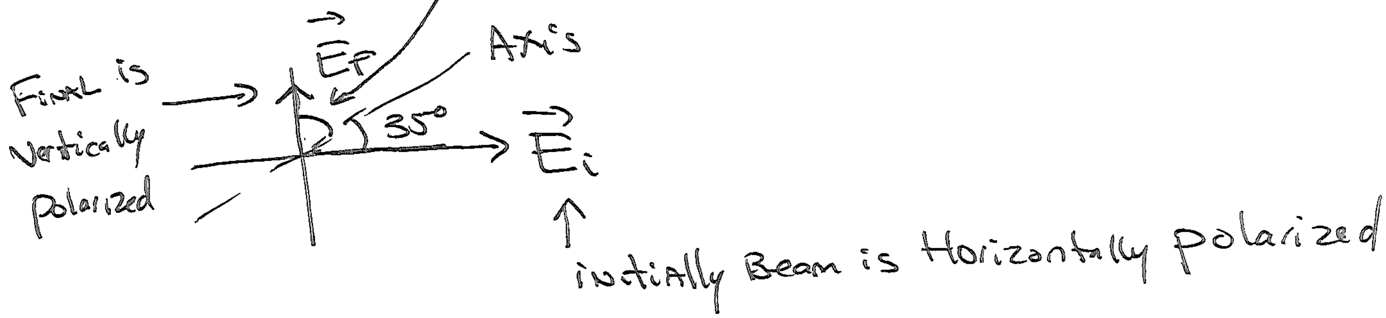
$= 0.2934\ \text{watt/m}^2\ (0.4132)$

$= \underline{0.121\ \text{watt/m}^2}$

25. 39

1.5 mW = Power

$90° - 35° = 55°$



If you prefer: $\vec{E}_i = \vec{E}_{cold}$, $\vec{E}_f = \vec{E}_{warm}$

Law of Malus: $I_t = I_0 (\cos\theta)^2$

Same I_0 for warm and cold since $I_0 = \frac{\text{Power}}{\text{Area}}$

and I assume the laser's dot isn't changing size.

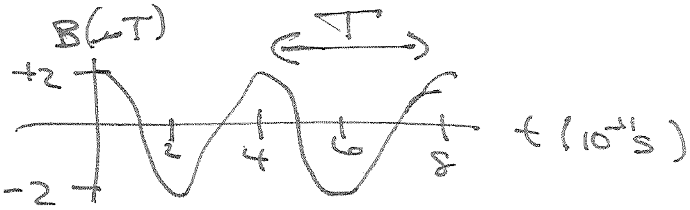
So $I_{cold} = I_0(\cos 35°)^2$ but $I_{warm} = I_0(\cos 55°)^2$

$$\therefore \frac{I_{warm} - I_{cold}}{I_{cold}} = \frac{I_{warm}}{I_{cold}} - \frac{I_{cold}}{I_{cold}} = \frac{I_0(\cos 55°)^2}{I_0(\cos 35°)^2} - 1$$

$$= \left(\frac{\cos 55°}{\cos 35°}\right)^2 - 1 = (0.700)^2 - 1 = -0.5097 = -0.51 = -51\%$$

Decreases by 51%

Written Question #1



a) What is frequency?

The field-versus-time graph gives us the period. The peak-to-peak time interval is $8\times10^{-11}s - 4\times10^{-11}s = 4\times10^{-11}s$

$$f = \frac{1}{T} = \frac{1}{4\times10^{-11}s} \Rightarrow f = 2.5\times10^{10}Hz$$

Either tells us that this is a microwave

b.) What is wavelength?

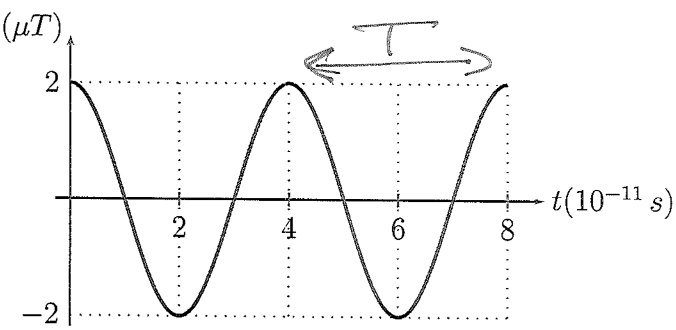
$$\lambda f = c \Rightarrow \lambda = \frac{c}{f} = \frac{3\times10^{8}m/s}{2.5\times10^{10}Hz} = 0.012m$$

c.) What is field-versus-position graph? We know that $\lambda = 0.012m \Rightarrow$ peak-to-peak distance. We're supposed to show two wavelengths and there are a total of 8 tick marks $\Rightarrow$ Distance between tick marks is $\frac{0.012m}{4} = 0.003m$.

To make the graph look the best, plot z in milimeters $\Rightarrow$ Each tick mark is 3mm.

Also notice that from 1st graph of B vs. t, at $t = 2\times10^{-11}$, $B = -2\mu T$ at $z=0 \Rightarrow$ B vs. z graph must start with negative value. (See graph on next page)

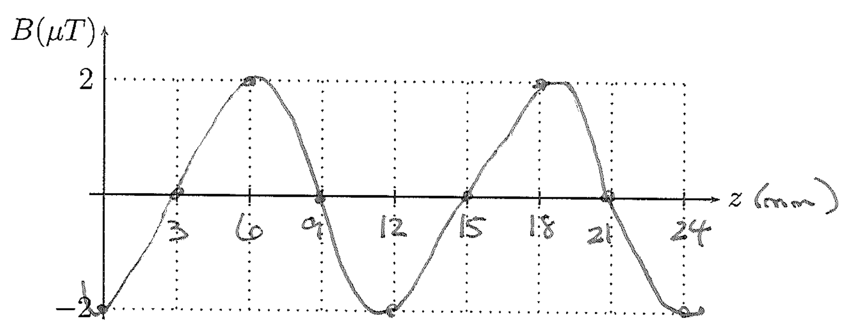
Written Question #1: An electromagnetic wave is propagating in the $+z$ direction. The magnetic-field-versus-time graph is shown for the location $z = 0$. (Please notice the use of $10^{-11}\,s$ as the unit for time.)



(a.) What is the frequency of this wave? Explain how you determined your answer.

(b.) What is the wavelength? Explain how you determined your answer.

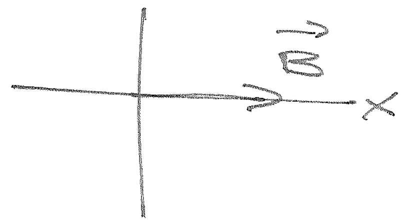
(c.) On the axes provided, sketch the magnetic-field-versus-position graph for this EM wave at the time $t = 2 \times 10^{-11}\,s$. For full points, your graph must show two wavelengths of distance and must use all of the tick marks given. Also, you must label each axis on the graph with the appropriate numerical values and explain how you determined those values.



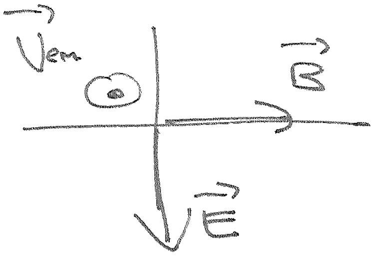
Written Question #2

at time $t = 0$

Assume $\vec{B}$ is along x-axis $\Rightarrow$



We're told wave is propagating in +z direction $\Rightarrow$ out of page



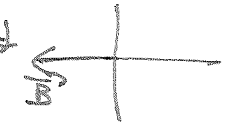
RHR $\Rightarrow$ initially $\vec{E}$ must point downward so that when we curl from $\vec{E}$ to $\vec{B}$, our thumb points out of page

$\Rightarrow$ $\vec{E}$ is along y-axis and begins pointing downward

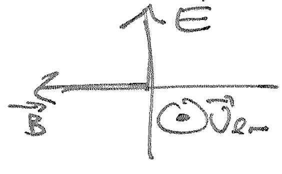
b.) Sketch $\vec{E}$ and $\vec{B}$ for the times given. From the original graph of B vs t we see that $B = 0$ at $t = T/4$ and $\frac{3T}{4}$ (Remember that $T = 4\times10^{-11}$s $\Rightarrow T/4 = 1\times10^{-11}$, $\frac{3T}{4} = 3\times10^{-11}$ and that's where graph crosses zero.) Electric field must be zero when magnetic field ~~also~~ zero.

at $t = T/2 = 2\times10^{-11}$s, $B = -B_0 = -2\,\mu T$. ~~when~~ $\Rightarrow$

$t = T/2$

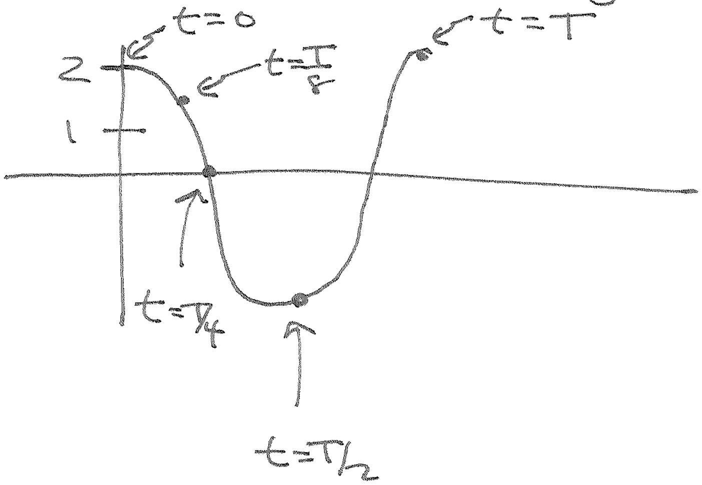


From RHR, we know that $\vec{E}$ must point upward at this time to make $\vec{V}_{em}$ be ⊙



Also when $B = B_0$, $E = E_0$ $\Rightarrow$ Both at max. ~~Amplitude~~ magnitude.

The tricky parts are the in-between times. You can kind of get it from the graph.



Given the shape of this graph, we see that at T/8 the value is <u>not</u> half of peak value. It's a little bit larger.

The math lover should be able to figure out that it's 0.707 of the peak value.

The basic equation for a cosine graph of period T is $\cos\left(\frac{2\pi t}{T}\right)$

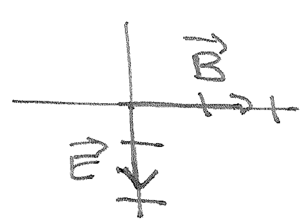
$\Rightarrow$ at $t = \frac{T}{8}$ $\quad \cos\left(\frac{2\pi \cdot T/8}{T}\right) = \cos(\pi/4)$ ← RADIANS!

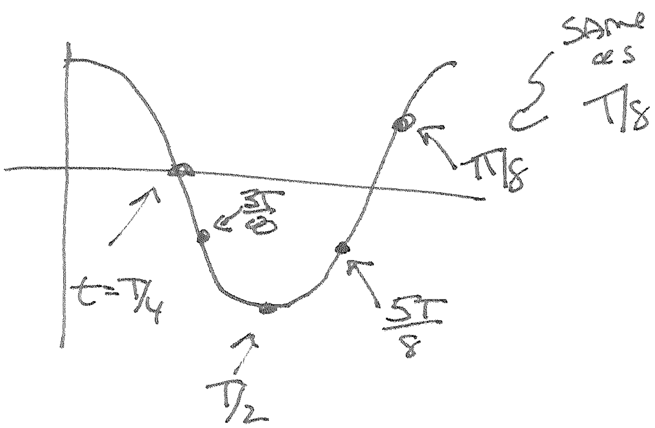
$= \cos 45^\circ = 0.707$

$B = 0.707 B_0$. To make $\vec{V}_{em}$ ⊙, E has to point down. It also has to be at same point in its cycle

$\Rightarrow E = -0.707 E_0$

$\Rightarrow$



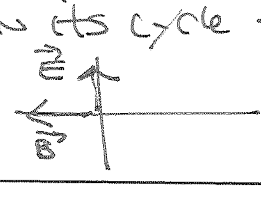


at $\frac{3T}{8}$ and $\frac{5T}{8}$ $\quad B = -.707 B_0$

$\Rightarrow$ opposite direction $\Rightarrow$ to left instead of right.

To make $\vec{V}_{em}$ out of page $\vec{E}$ has to be up at both of these times. It also has to be at same point in its cycle $\Rightarrow E = +0.707 E_0$

$\Rightarrow$



See next page for all of the vectors.

Written Question #2: For the electromagnetic wave propagating in the $+z$ direction from problem #1, assume that the magnetic fields' directions are along the x-axis (positive values of B are along the positive x-axis and vice versa).

(a.) What direction is the wave's electric fields? Explain how you determined your answer. **Hint:** For the typical x and y-axes shown, $+z$ is out of the page.

(b.) For the $z = 0$ location, sketch both the electric and magnetic field vectors for the indicated times. Draw the peak electric and magnetic field vectors to be two units long.