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University of Jordan
Elect. Eng. Dept.

Mid Exam. **Electromagnetics 0903351** **2/7/2017**

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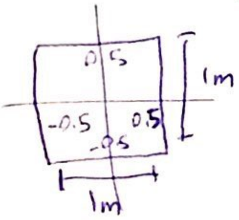
Q.1 **(5 Points)**

Find the emf voltage generated at the terminals of a 50 turns square coil of area $1m^2$ centered at the origin in x-y plane if the magnetic flux density is given by:



$$B = 4|x||y|\cos(2\pi 10^3 t)\,az$$

$V_{emf} = -N \int_s \frac{\partial B}{\partial t} \cdot ds$

$= -50 \times -8\pi \times 10^3 \sin(2\pi \times 10^3 t) \int_{-0.5}^{0.5}\int_{-0.5}^{0.5} |x||y| \, dx\, dy$

$= 1.256M \int_{-0.5}^{0.5} \left(2\int_0^{0.5} x\, dx\right) |y| dy \sin(2\pi \times 10^3 t)$ 0.25

$= 0.25 \times 1.256M \, 2\int_0^{0.5} y \, dy = 0.25 \times 0.25 \times 1.256M$

$= 78539 \sin(2\pi \times 10^3 t)$

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$\cos(2\pi \times 10^3 t)$

$\frac{\partial B}{\partial t} = \frac{\partial\, 4|x||y|\cos}{\partial t}$

$= 4|x||y|(-2\pi \times 10^3) \cdot \sin(2\pi \times 10^3 t)$

$= -8\pi \times 10^3 \sin(2\pi \times 10^3 t)\, |x||y|$

$\cancel{2}\, \frac{x^2}{\cancel{2}}\Big|_0^{0.5} = 0.25$

$\cancel{2}\, \frac{y^2}{\cancel{2}}\Big|_0^{0.5} = 0.25$

Q.2 **(5 Points)**

In free space at 6GHz the direction of propagation is in (0.6**ax** -0.8**ay**) if the power density is $100mW/m^2$ and the electric field is in the +**z** direction, Find E and H.

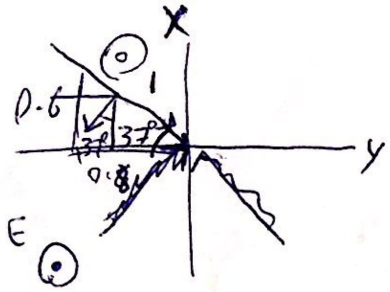
$f = 6GHz$ $\quad \eta = 120\pi$

$p = 100mW/m^2 = 0.1$ $\quad \beta = \frac{w}{c} = \frac{2\pi \times 6 \times 10^9}{3 \times 10^8}$

$= 40\pi$

$p = \frac{|E_o|^2}{2\eta}$

$0.1 = \frac{|E_o|^2}{2 \times 120\pi} \rightarrow E_o = 8.68 \; V/m$



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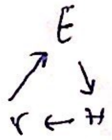

$E = E_o \cos(wt - \beta r)\, \vec{a}_z$

$= 8.68 \cos\left(2\pi \times 6 \times 10^9 t - 40\pi\,(0.6x - 0.8y)\right) \vec{a}_z$

$(0.6ax - 0.8ay) \times a_z$

$= -0.6\vec{a}_y - 0.8\vec{a}_x$

$H = \frac{E_o}{\eta} \cos(wt - \beta r)(-0.6\vec{a}_y - 0.8\vec{a}_x)$

$= \frac{8.68}{120\pi} \cos\left(2\pi \times 6 \times 10^9 t - 40\pi(0.6x - 0.8y)\right)(-0.6\vec{a}_y - 0.8\vec{a}_x)$

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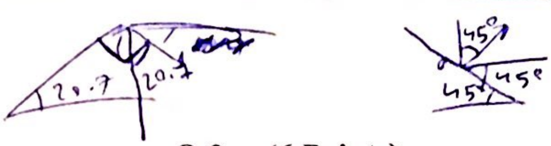


$$\beta_1 = \frac{w}{c} = \frac{2\pi \times 6\times 10^9}{3\times 10^8}$$

$$\theta_i \quad \beta_2 = \frac{w}{u} = \frac{2\pi\times 6\times 10^9 \times 2}{3\times 10^8}$$

Q.3 (6 Points)
A plane wave at 6GHz is incident at angle of 45 from normal from air into a dielectric with relative permittivity of 4. If the incident electric field amplitude is 10^{-6} V/m in +y direction. Find the reflected wave and transmitted wave(both E and H).

$f = 6\,GHz \quad \theta_i = 45°$

$|E_i| = 10^{-6}\ V/m\ \vec{a}_y$

$\eta_1 = 120\pi \quad \eta_2 = \frac{120\pi}{\sqrt{\epsilon_r}} = \frac{120\pi}{2} = 60\pi$

$\eta_1 \sin(\theta_i) = \eta_2 \sin(\theta_t)$

$\frac{\eta_1}{\eta_2}\sin(\theta_i) = \sin(\theta_t)$

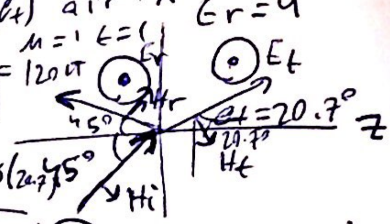
$\frac{\sqrt{\epsilon_1\mu_1}}{\sqrt{\epsilon_2\mu_2}}\sin(45) = \sin(\theta_t)$

$\boxed{\theta_t = 20.7}$

6

$$\Gamma_\perp = \frac{\eta_2\cos(\theta_i) - \eta_1\cos(\theta_t)}{\eta_2\cos(\theta_i) + \eta_1\cos(\theta_t)}$$

$$= \frac{60\pi\cos(45) - 120\pi\cos(20.7)}{60\pi\cos(45) + 120\pi\cos(20.7°)}$$



$\cos(20.7) = 0.93$

$\sin(20.7) = 0.35$

$\Gamma_\perp = -0.45$

$\tau_\perp = 0.55$

$E_r = \Gamma_\perp E_0 \cos(wt - \beta_1(\sin(45°)x - \cos(45°)z))\ \vec{a}_y$

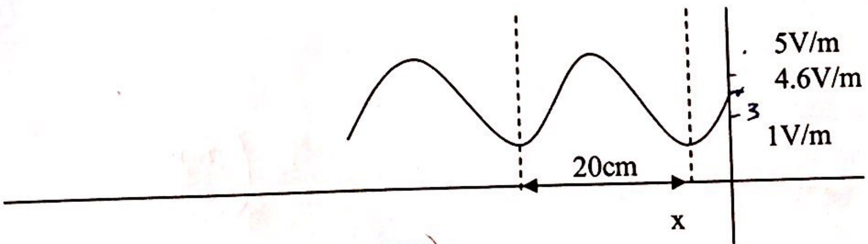
$= -0.45\times 10^{-6}\cos(2\pi\times 6\times 10^9 - 40\pi(\frac{1}{\sqrt2}x - \frac{1}{\sqrt2}z))$

$H_r = \frac{-0.45\times 10^{-6}}{120\pi}\cos(2\pi\times 6\times 10^9 - 40\pi(\frac{1}{\sqrt2}x - \frac{1}{\sqrt2}z))\ \vec{a}_y\ (\frac{1}{\sqrt2}\vec{a}_x + \frac{1}{\sqrt2}\vec{a}_z)$

$E_t = 0.55\times 10^{-6}\cos(2\pi\times 6\times 10^9 - 80\pi(\frac{1}{\sqrt2}x + \frac{1}{\sqrt2}z))\ \vec{a}_y$ (0.35, 0.93)

$H_t = \frac{0.55\times 10^{-6}}{60\pi}\cos(2\pi\times 6\times 10^9 - 80\pi(\frac{1}{\sqrt2}x + \frac{1}{\sqrt2}z))(-0.93\vec{a}_x + 0.35\vec{a}_z)$ (0.35, 0.93)

Q.4 (6 Points)
Given the following standing wave, find **x** and the characteristic impedance for the second media if the first media is free space.



$\frac{\lambda}{2} = 20\,cm$

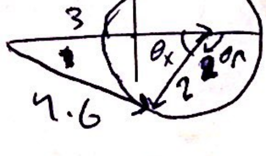
$\lambda = 40\,cm$

$E_{max} = 5$

$E_{min} = 1$

$|\Gamma| = \frac{5-1}{1+5} = \frac{4}{6} = \frac{2}{3}$

6



$\boxed{\eta_2 = 788.35\angle -60.4°}$

$\boxed{x = 7.4\,cm}$ 7.38 cm

$(4.6)^2 = 3^2 + 2^2 - 2\times 2\times 3\cos(\theta_x)$

$\theta_x = 132.8$

$\theta_\Gamma = 132.8 - 180° = -47.15°$

0.5 − 0.315
= 0.185 λ
= 7.4 cm

$\eta_2 = 120\pi + \eta_2(\frac{2}{3}\angle -47.15°) + 120\pi(\frac{2}{3}\angle -47.15°)$

$\eta_2 = 788.35\angle -60.4°$

$\frac{\eta_2 - 120\pi}{\eta_2 + 120\pi} = \Gamma = \frac{2}{3}\angle -47.15°$

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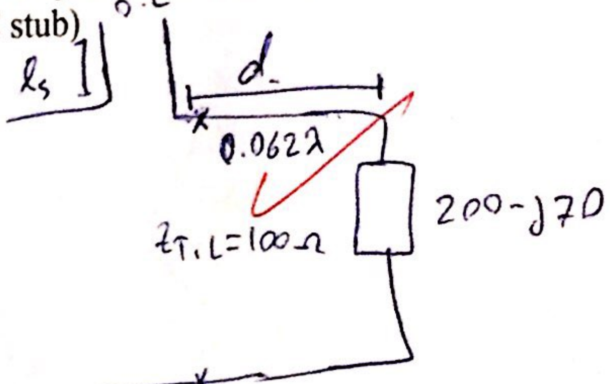
Q.5 (8 Points)

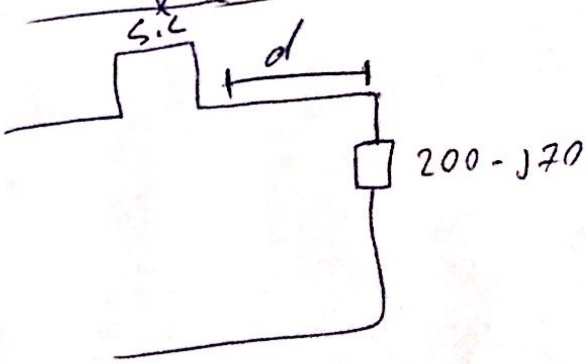
Use series stub matching to match a load of 200-j70 if the T.L impedance is 100Ω (solve using S.C stub and repeat for O.C stub)



$Z_L = 200 - j70$

$Z_{T.L} = 100\Omega$

$z_L = \dfrac{200 - j70}{100} = 2 - 0.7j$



0.342λ

$1 - 0.9j \rightarrow d = 0.342\lambda - 0.28\lambda$

$= 0.062\lambda$

$1 + 0.9j$

$+0.9j \rightarrow 0.117\lambda$

for short circuit stub

$l_s = 0.117$

for open circuit stub

$l_s = 0.25\lambda + 0.117\lambda = 0.367\lambda$

8

E

=

H.

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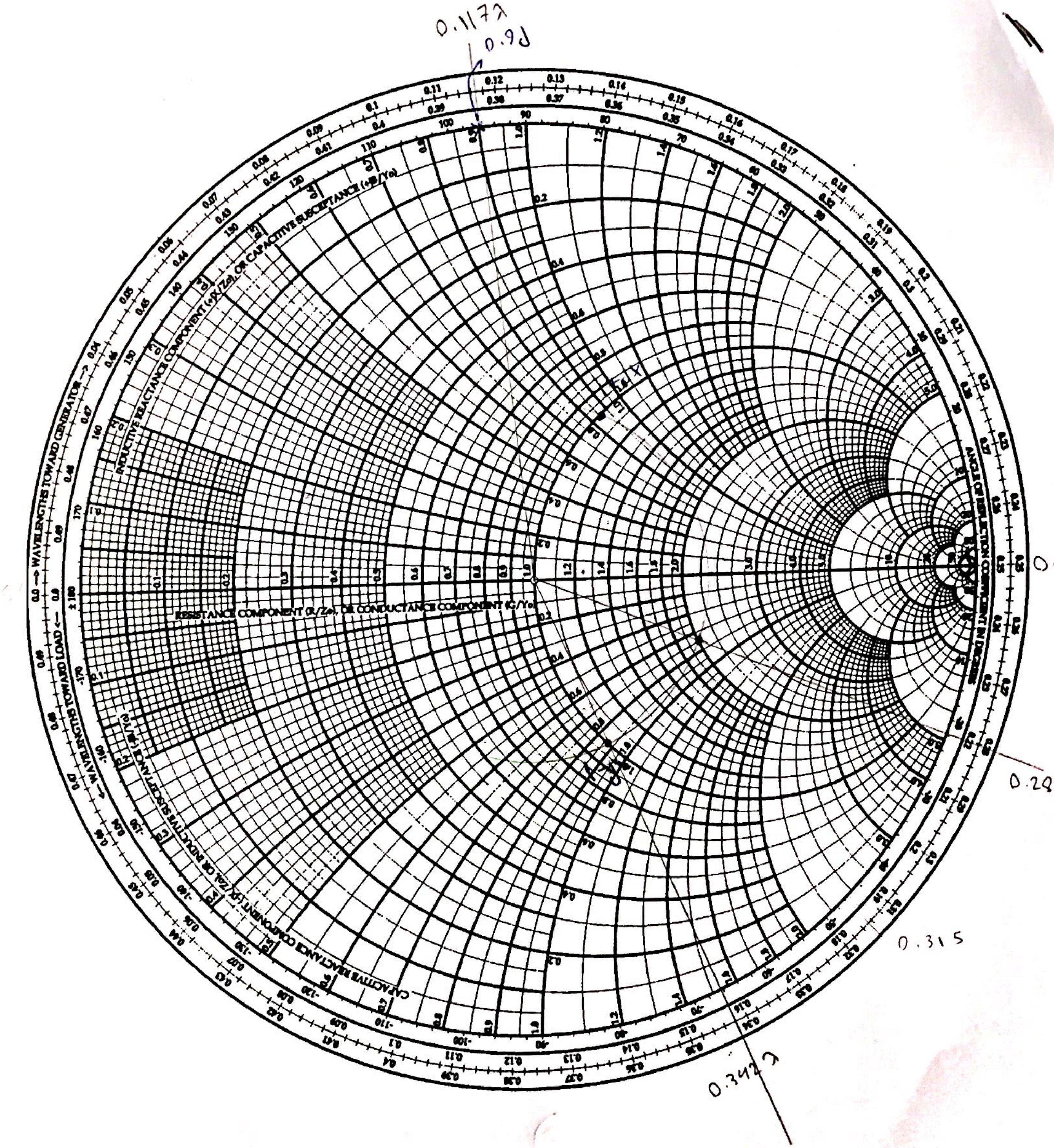
0.117λ
0.28
0.315
0.342λ
0.0 → WAVELENGTHS TOWARD GENERATOR →
← WAVELENGTHS TOWARD LOAD ←
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES