KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

SECOND SEMESTER 2008/2009

EE 340 (03) FINAL EXAM

LOCATION: 59-1001

TIME: 7:300 -10:00 A.M.

DATE: THURSDAY 4-FEBRUARY-2010

Student’s Name:…………………………………………….

Student’s I.D. Number: ………………….

Section Number: ………………………..

	Maximum Score	**Score**
Problem 1	**20**	
Problem 2	**20**	
Problem 3	**20**	
Problem 4	**20**	
Problem 5	**20**	
Total	**100**	

Problem 1 [20 points]

Answer the following multiple choice problems:

a) Consider a uniform plane electromagnetic wave which propagates in a lossy medium. The electric field amplitude of the wave is found to drop from 3V/m to 0.5V/m within a distance of 15m along the wave direction of propagation. Using the given information, it can be conclude that the depth of penetration equals:

1) 15.00m   2) 0.119m   3) 4.10m   4) 8.37m   5) 2.18m   6) 2.50m

b) Consider two semi-infinite media, which are separated by the xz plane. Medium 1 ($y > 0$) has a relative permeability of 3 and medium 2 ($y < 0$) has a relative permeability of 15. The magnetic field intensity vector in medium 1, at the boundary, is given by $\vec{H}_1 = -2\vec{a}_x + 5\vec{a}_y + 11\vec{a}_z \quad A/m$. Now consider a square area of dimension $2m \times 2m$ which lies entirely at the boundary between the two media (i.e. the xz plane). The boundary has no surface current. From the given information, it can be conclude that the magnetic flux (in Wb) through the given area equals:

1) $88\mu_o$ 2) $20\mu_o$ 3) $8\mu_o$ 4) $60\mu_o$ 5) $15\mu_o$ 6) $30\mu_o$

c) A conductor occupies the cylindrical volume ($\rho < a$) while the outside volume ($\rho > a$) is occupied by air. The electrostatic field $\vec{E} = \frac{A}{\rho}\vec{a}_\rho$ V/m exists in the volume occupied by air, where A is some constant. Using the given information, it can be concluded that the surface charge density (in C/m^2) on the conductor/air boundary is given by:

1) $\frac{A}{a}\varepsilon_o$ 2) $\frac{A}{\rho}$ 3) $-\frac{A}{a}\varepsilon_o$ 4) $\frac{A}{\rho}\varepsilon_o$ 5) $-\frac{A}{\rho}\varepsilon_o$ 6) $\frac{A}{a}\varepsilon_o\vec{a}_\rho$

d) Which one of the following expressions represents the 3D wave equation for the electric field in a source free region?

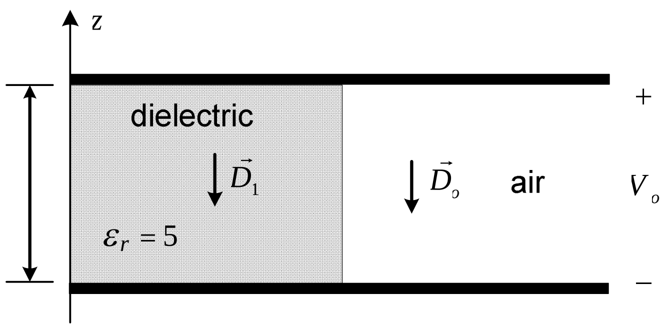
1) $\nabla^2\vec{E} = \mu\varepsilon\vec{E}$ 2) $\nabla^2\vec{E} = \mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2}$ 3) $\nabla^2\vec{E} = \frac{1}{\mu\varepsilon}\frac{\partial^2\vec{E}}{\partial t^2}$

4) $\frac{\partial^2\vec{E}}{\partial z^2} = \mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2}$ 5) $\nabla^2\vec{E} = \frac{\mu}{\varepsilon}\frac{\partial^2\vec{E}}{\partial t^2}$ 6) $\nabla^2\vec{E} = \frac{\partial^2\vec{E}}{\partial t^2}$

e) The figure shows a partially-filled parallel-plate capacitor with a plate separation $d = 0.5cm$. The relative permittivity of the dielectric filling is $\varepsilon_r = 5$. The electric flux density vector in the dielectric region is given by:

$\vec{D}_1 = -\vec{a}_z 0.707 \mu C/m^2$

The resulting potential difference V_o across the capacitor equals:

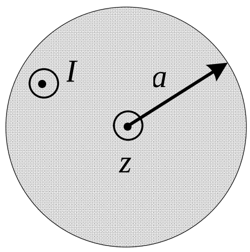


1) $16V$ 2) $2000V$ 3) $60V$ 4) $30V$ 5) $80V$ 6) $400V$

Problem 2 [20 Points]

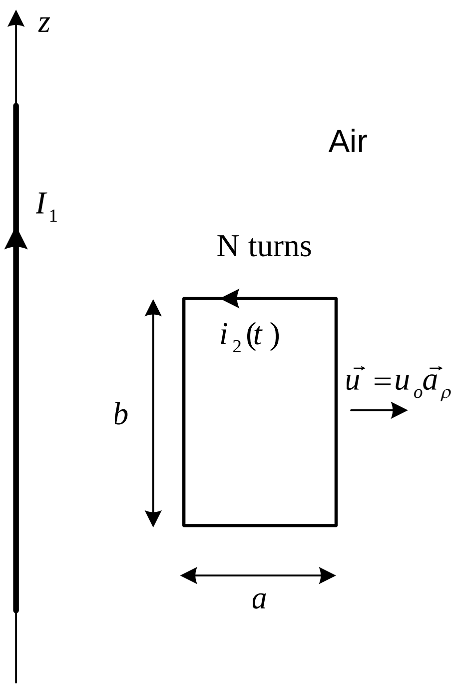
a) Consider the infinitely long cylindrical conductor shown in the figure. The conductor has radius a and it carries D.C. current I in the $+z$ direction. The axis of the conductor coincides with the z axis. The conductor is made of a nonmagnetic material.

Derive an expression for the magnetostatic energy stored in 1m length of the conductor.



b) Consider the infinitely long straight filamentary conductor which is placed along the entire $z-$axis. The conductor carries DC current I_1. As shown in the figure, the coplanar N-turn closed rectangular circuit recedes from the straight conductor with the constant velocity $\vec{u} = u_o \vec{a}_\rho$. At $t = 0$ the left hand side of the rectangular loop coincides with the straight conductor.

Assuming that the rectangular circuit has total resistance R, derive an expression (valid for $t > 0$) for the induced current $i_2(t)$.



Problem 3 [20 Points]

a) A uniform plane EM propagates in a lossless nonmagnetic medium. The wavelength of the wave equals $0.75cm$. The magnetic flux density vector associated with the wave is given by:

$$\vec{B} = \vec{a}_z\, 20\times10^{-6} \cos(10^{11}t - \beta y\,)\quad Wb\,/m^2$$

Find an expression for the $\vec{D}$ field associated with the wave. The required expression must not contain any unknown quantities.

b) The electric field of a 50MHz uniform plane EM wave propagating in a lossless medium is given by:

$$\vec{E}_s = \vec{a}_y\,(1+j\,)e^{j\,2x} + \vec{a}_z\,\sqrt{2}e^{j\,2x - j\pi/4}$$

1) What is the direction of wave propagation?
2) Calculate the phase velocity.
3) What is the wave polarization?

Problem 4 [20 Points]

a) A uniform plane TEM wave propagates in a lossy nonmagnetic medium. The intrinsic impedance of the wave equals $110e^{j37^o}\ \Omega$. Calculate the phase velocity of the wave.

b) Consider a uniform EM wave propagating in free space. The wave has the following instantaneous Poynting's vector:

$$\vec{a}_y\, 20\cos^2(1.5\times10^8 t - 0.5y)\quad W/m^2$$

Assuming the electric is linearly polarized in the x direction, find an expression for the magnetic field intensity vector of the wave.

Problem 5 [20 Points]

Consider two semi-infinite media. Medium 1 $(x < 0)$ is a *lossless nonmagnetic* dielectric and medium 2 $(x > 0)$ is air. A 5GHz uniform plane EM wave is normally incident from medium 1 onto medium 2. The incident and reflected electric fields are respectively given by:

$$\vec{E}_{is} = 30e^{-j\beta_1 x}\vec{a}_z \qquad \text{V/m}$$
$$\vec{E}_{rs} = 10e^{j\beta_1 x}\vec{a}_z \qquad \text{V/m}$$

Where the subscript s indicates the phasor form of the field. Find:

a) β_1

b) $\vec{E}_{ts}$

c) An expression for the reflected instantaneous magnetic field $\vec{H}_r$.

d) The numerical value of the reflected electric field $\vec{E}_r$, $5cm$ from the boundary at $t = 1\mu s$.

Electrostatics:

$$\vec{E} = \sum_{i=1}^{N} \frac{Q_i \vec{R}_i}{4\pi\varepsilon R_i^3} + \int_l \frac{\rho_L \vec{R}}{4\pi\varepsilon R^3} + \int_s \frac{\rho_s \vec{R}}{4\pi\varepsilon R^3} + \int_v \frac{\rho_v \vec{R}}{4\pi\varepsilon R^3} \quad , \quad V = \sum_{i=1}^{N} \frac{Q_i}{4\pi\varepsilon R_i} + \int_l \frac{\rho_L}{4\pi\varepsilon R} + \int_s \frac{\rho_s}{4\pi\varepsilon R} + \int_v \frac{\rho_v}{4\pi\varepsilon R}$$

$$\oint_s \vec{D}.d\vec{s} = Q \ , \quad \oint_l \vec{E}.d\vec{l} = 0 \ , \quad \nabla\vec{D} = \rho_v \ , \quad \nabla \times \vec{E} = 0 \ , \quad \vec{D} = \varepsilon \vec{E} \ , \quad V_P = -\int_{\infty}^{P} \vec{E}.d\vec{l} \ ,$$

$$V_{AB} = V_B - V_A = -\int_A^B \vec{E}.d\vec{l} \ , \quad \vec{E} = -\nabla V \ , \quad w_e = \frac{1}{2}\varepsilon E^2 \ , \quad \vec{E} = \frac{\rho_L}{2\pi\varepsilon\rho}\vec{a}_\rho \ , \quad \vec{E} = \frac{\rho_s}{2\varepsilon}\vec{a}_N \ , \quad D_{1n} - D_{2n} = \rho_s \ ,$$

$$E_{1t} = E_{2t} \ , \quad C = \frac{Q}{V_o} \ , \quad \nabla^2 V = -\frac{\rho_v}{\varepsilon}$$

Magnetostatics:

$$\oint_s \vec{B}.d\vec{s} = 0 \ , \quad \oint_l \vec{H}.d\vec{l} = I \ , \quad \nabla\vec{B} = 0, \quad \nabla \times \vec{H} = \vec{J} \ , \quad \vec{B} = \mu\vec{H} \ , \quad \vec{B} = \nabla \times \vec{A} \ , \quad \vec{A} = \frac{I}{4\pi}\int_l \frac{d\vec{l} \times \vec{R}}{R} \ , \quad \nabla\vec{A} = 0 \ ,$$

$$\nabla^2\vec{A} = -\mu\vec{J} \ , \quad \psi_m = \int_s \vec{B}.d\vec{s} = \oint_l \vec{A}.d\vec{l} \ , \quad M_{21} = \frac{\Lambda_{21}}{I_1} = \frac{N_2\psi_{21}}{I_1} \ , \quad L = \frac{\Lambda}{I} \ , \quad d\vec{H} = \frac{I}{4\pi}\frac{d\vec{l} \times \vec{R}}{R^3} \ ,$$

$$w_m = \frac{1}{2}\mu H^2 \quad \vec{H} = \vec{a}_\phi \frac{I}{4\pi\rho}[\cos\alpha_2 - \cos\alpha_1], \ \vec{H} = \vec{a}_\phi \frac{I}{2\pi\rho} \ , \quad \vec{F}_m = I\int_l d\vec{l} \times \vec{B} \ , \quad B_{1n} = B_{2n} \ ,$$

$$(\vec{H}_1 - \vec{H}_2) \times \vec{a}_{n12} = \vec{K}$$

EMF: $emf = -\int_s \frac{\partial \vec{B}}{\partial t} d\vec{s} + \oint_l (\vec{u} \times \vec{B}) d\vec{l} = -\frac{d\psi_m}{dt}$

Maxwell's Equations (General Form):

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \ , \quad \nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \ , \quad \nabla\vec{D} = \rho_v \ , \quad \nabla\vec{B} = 0$$

Plane TEM Waves:

$$u_p = \frac{\omega}{\beta} \ , \quad u_g = \frac{d\omega}{d\beta} \ , \quad u_p = \frac{c}{\sqrt{\mu_r\varepsilon_r}} \ , \quad \eta = \sqrt{\frac{\mu}{\varepsilon}} \ , \quad \lambda = \frac{2\pi}{\beta} \ , \quad \eta = \frac{\sqrt{\mu/\varepsilon}}{[1+(\sigma/\omega\varepsilon)^2]^{1/4}}\exp[j\ \frac{1}{2}\tan^{-1}(\sigma/\omega\varepsilon)] \ ,$$

$$\gamma = \alpha + j\beta = j\omega\sqrt{\mu\varepsilon(1 - j\sigma/\omega\varepsilon)} \ , \quad \alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+(\sigma/\omega\varepsilon)^2} - 1]} \ , \quad \beta = \omega\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+(\sigma/\omega\varepsilon)^2} + 1]} \ ,$$

$$\delta = 1/\alpha \ ,$$

$$\Gamma_\perp = \frac{\eta_2\cos\theta_i - \eta_1\cos\theta_t}{\eta_2\cos\theta_i + \eta_1\cos\theta_t} \ , \quad \tau_\perp = \frac{2\eta_2\cos\theta_i}{\eta_2\cos\theta_i + \eta_1\cos\theta_t} \ , \quad 1 + \Gamma_\perp = \tau_\perp$$

$$\Gamma_{//} = \frac{\eta_2\cos\theta_t - \eta_1\cos\theta_i}{\eta_2\cos\theta_t + \eta_1\cos\theta_i} \ , \quad \tau_{//} = \frac{2\eta_2\cos\theta_i}{\eta_2\cos\theta_t + \eta_1\cos\theta_i} \ , \quad 1 + \Gamma_{//} = \tau_{//}\left(\frac{\cos\theta_t}{\cos\theta_i}\right) \ , \quad \beta_1\sin\theta_i = \beta_2\sin\theta_t \ ,$$

$$\theta_r = \theta_i$$

For normal incidence, $\theta_i = 0$

Poynting's Vector = $\vec{E} \times \vec{H}$, Average Poynting's Vector = $\frac{1}{2}\mathrm{Re}(\vec{E}_s \times \vec{H}_s^*)$

Differentials:

$$d\vec{l} = \vec{a}_\rho d\rho + \vec{a}_\phi \rho d\phi + \vec{a}_z dz \ , \quad d\vec{s} = \vec{a}_\rho \rho d\phi dz + \vec{a}_\phi d\rho dz + \vec{a}_z \rho d\rho d\phi \ , \quad dv = \rho d\rho d\phi dz$$

$$d\vec{l} = \vec{a}_r dr + \vec{a}_\theta r d\theta + \vec{a}_\phi r\sin\theta d\phi \ , \quad d\vec{s} = \vec{a}_r r^2\sin\theta d\theta d\phi + \vec{a}_\theta r\sin\theta dr d\phi + \vec{a}_\phi r dr d\theta \ , \quad dv = r^2\sin\theta dr d\theta d\phi$$