5 Points Each, <u>*Circle the best answer*</u>

1. Assuming a 200 ohm voltage source, the reflection coefficient of a 100 ohm load is Γ=

   a) -1/2 b) -1/3 c) 1/4 d) 1/3 e) none above

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S} = \frac{100-200}{100+200} = \frac{-1}{3}$$

2. In a <u>30 ohm system</u>, the return loss of a 50 ohm load is

   a) -3 dB b) 3 dB c) 6 dB d) 12 dB e) none above

$$-10\log_{10}\left(|\Gamma|^2\right) = -10\log_{10}\left(\left|\frac{50-30}{50+30}\right|^2\right) = -10\log_{10}\left(\left|\frac{20}{80}\right|^2\right) = -10\log_{10}\left(\frac{1}{16}\right) = 12dB$$

3. If propagation constant $\gamma = 2 + j\pi/2$ in a transmission line, the wavelength λ=

   $= \alpha + j\beta$

   a) $1/\pi$ m b) 2 m c) 4 m d) 8 m e) none above

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\pi/2} = 4$$

4. If propagation constant $\gamma = j2\pi$ in a transmission line, the line is lossless.

   $= \alpha + j\beta \Rightarrow \alpha = 0$

   a) True b) False

5. In a right-handed LC transmission line with L_R=300 nH/m and C_R=2000 pF/m, the wave equation would be

   a) $\frac{\partial^2 v(x,t)}{\partial x^2} = 150\ \frac{\partial^2 v(x,t)}{\partial t^2}$ b)) $\frac{\partial^2 v(x,t)}{\partial x^2} = \frac{6}{10^{16}}\ \frac{\partial^2 v(x,t)}{\partial t^2}$

   c) $\frac{\partial^2 v(x,t)}{\partial x^2} = \frac{10^{16}}{6}\ \frac{\partial^2 v(x,t)}{\partial t^2}$ d) none above

$$\frac{\partial^2 v}{\partial x^2} = L_R C_R \frac{\partial^2 v}{\partial t^2} \Rightarrow \frac{300}{10^9}\cdot\frac{2000}{10^{12}} = \frac{6}{10^{16}}.$$

5 Points Each, <u>*Circle the best answer*</u>

6. A coaxial line with 5.4 mm outer radius and 2 mm inner radius with ε_r=16, μ_r=1 has an impedance in ohms of Z_0=

a) 15 b) 30 c) 60 d) 90 e) none above

$$Z_0 = \sqrt{\frac{\mu}{\epsilon}}\,\frac{\ln(b/a)}{2\pi} = \sqrt{\frac{\mu_0}{16\epsilon_0}}\,\frac{\ln(5.4/2)}{2\pi} = 94\cdot\frac{1}{2\pi} = 15$$

7. In a transmission line with propagation constant $\gamma = 2 + j\omega^3/6$, the group velocity is v_g=

$= \alpha + j\beta$

a) $2/\omega^2$ m/s b) $4/\omega^2$ m/s c) $2\omega^2$ m/s d) $j4\omega^2/3$ m/s e) none above

$$v_g = \frac{d\omega}{d\beta} = \frac{1}{d\beta/d\omega} = \frac{1}{d(\omega^3/6)/d\omega} = \frac{1}{3\omega^2/6} = 2/\omega^2$$

8. For a system with 50-ohm S-parameters $S = \begin{bmatrix} 0.5 & -0.25 \\ -1.5 & 0.5 \end{bmatrix}$ and a 150 ohm load, the input reflection coefficient is Γ_{in} =

$\Gamma_L = \frac{150-50}{150+50} = 1/2$

a) 0.2 b) 0.33 c) 0.75 d) 0.9 e) none above

$$\Gamma_{in} = S_{11} + \frac{S_{21}S_{12}\Gamma_L}{1+S_{22}\Gamma_L} = \frac{1}{2} + \frac{\left(\frac{-3}{2}\right)\left(\frac{-1}{4}\right)\left(\frac{1}{2}\right)}{1-\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)} = \frac{1}{2} + \frac{3/16}{3/4} = \frac{3}{4}$$

9. For a system with 50-ohm S-parameters $S = \begin{bmatrix} 0.5 & 0 \\ 8 & 0 \end{bmatrix}$ with a 50-ohm source and a 150 ohm load, the magnitude of the transducer gain is $|g_T|$=

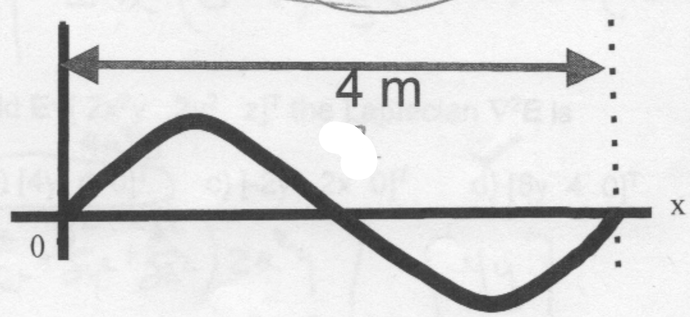
$\Gamma_L = \frac{150-50}{150+50} = \frac{1}{2}$

a) 12 b) 24 c) 48 d) 96 e) none above

$$g_T = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-S_{11}\Gamma_S)(1-S_{22}\Gamma_L)-S_{21}S_{12}\Gamma_S\Gamma_L|^2} = \frac{8^2(1-0)(1-\frac{1}{4})}{|(1-\frac{1}{2}\cdot 0)(1-0\cdot\frac{1}{2})-8\cdot 0\cdot 0\cdot\frac{1}{2}|^2} = \frac{64\cdot 3}{4} = 48$$

10. The following sinusoidal waveform is observed on a transmission line at time t=0, where the transmission line phase velocity is known to be $v_p=10^8$ m/s. The frequency of the sine wave is f =

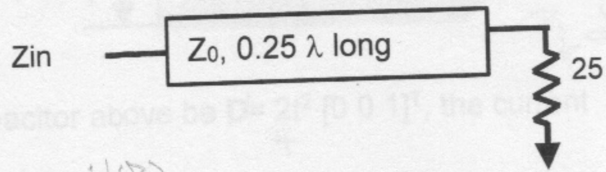
a) $20/\pi$ MHz b) $10\pi/4$ MHz c) 25 MHz d) 50 MHz e) none above



$v_p = \lambda f$

$\Rightarrow f = v_p/\lambda = \frac{10^8}{4}$

5 Points Each, <u>*Circle the best answer*</u>



$\left(\frac{Z_0}{25}\right)^2 25 = 100$

11. For the circuit above to have Zin=100 ohms, the line impedance in ohms must be Z_0=

a) 20 b) 40 c) 50 d) 75 e) none above

$Z_0 = \sqrt{\frac{100}{25}\cdot 25^2} = \sqrt{2500} = 50$

12. For the two electric fields $\mathbf{E}_1=[2\ 2\ 2]^T$ and $\mathbf{E}_2=[1\ 2\ 3]^T$ the cross product $\mathbf{E}_1\times\mathbf{E}_2$ is

a) $[2\ -4\ 6]^T$ b) $[4\ -2\ 2]^T$ c) $[2\ -4\ 2]^T$ d) $[-2\ 4\ -2]^T$ e) none above

$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 2 & 2 & 2 \\ 1 & 2 & 3 \end{vmatrix} = \underbrace{\hat{x}(2\cdot 3-2\cdot 2)}_{2\hat{x}} - \underbrace{\hat{y}(2\cdot 3-2\cdot 1)}_{-4\hat{y}} + \underbrace{\hat{z}(2\cdot 2-2\cdot 1)}_{2\hat{z}}$

13. For the voltage potential scalar field $V=x^3z$ the gradient ∇V is

a) $[3x^2z\ \ 0\ \ x^3]^T$ b) $[3x^2y\ \ x^3\ \ 0]^T$ c) $[x^3z\ \ x^2\ \ y]^T$ d) $[z\ \ 0\ \ x^3z]^T$ e) none above

$\begin{bmatrix} \partial/\partial x \\ \partial/\partial y \\ \partial/\partial z \end{bmatrix} x^3 z = \begin{bmatrix} 3x^2 z \\ 0 \\ x^3 \end{bmatrix}$

14. For the electric field $\mathbf{E}=[\ 2x^2y^2\ \ 0\ 0]^T$ the curl $\nabla\times\mathbf{E}$ is

a) $[4xy\ 0\ 0]^T$ b) $[0\ 0\ -4x^2y]^T$ c) $[0\ 0\ \ -8x^2y]^T$ d) $[8xy\ \ 0\ \ 0]^T$ e) none above

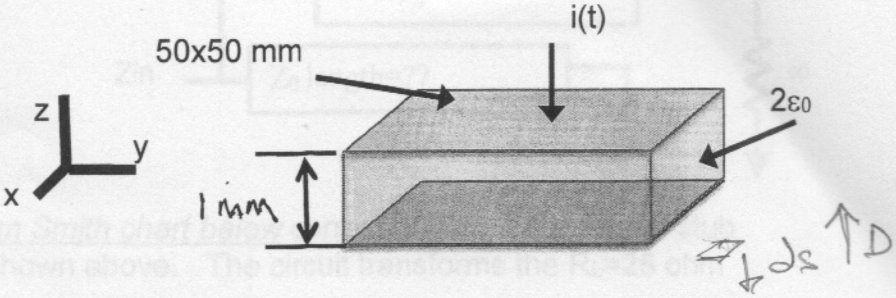
$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 2x^2y^2 & 0 & 0 \end{vmatrix} = \hat{x}(0-0) - \hat{y}(0-0) + \hat{z}(0-4x^2y)$

15. For the electric field $\mathbf{E}=[\ 2x^2y\ \ \ 2y^2\ \ \ z]^T$ the Laplacian $\nabla^2\mathbf{E}$ is

a) $[2xy\ \ x\ \ 0]^T$ b) $[4y\ \ 4\ \ 0]^T$ c) $[-2y\ \ \ 2x\ \ 0]^T$ d) $[8y\ \ 4\ \ 0]^T$ e) none above

$\begin{bmatrix} \nabla^2 2x^2y \\ \nabla^2 2y^2 \\ \nabla^2 z \end{bmatrix} = \begin{bmatrix} \left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right) 2x^2y \\ (\quad '' \quad) 2y^2 \\ (\quad '' \quad) z \end{bmatrix} = \begin{bmatrix} 4y \\ 4 \\ 0 \end{bmatrix}$

5 Points Each, *Circle the best answer*



16. Let the D-field between the two plates of the capacitor above be **D**= $2t^2\,[0\ 0\ 1]^T$, the current **in mA** as shown into the top plate is i(t)=

a) -10 t b) -20 t c) 10 t d) 20 t e) none above

$$I = \int \frac{\partial D}{\partial t}\cdot ds = -\frac{d}{dt}(2t^2)\cdot\left(\frac{50}{1000}\right)^2 = -4t\left(\frac{2500}{1000^2}\right) = \frac{-10t}{1000}$$

17. Let a 2-turn rectangular loop of 3 m^2 area in the x-y plane have a B-field along the z-axis of B= $2t^2\,[0\ 0\ 1]^T$, the magnitude of the emf in volts is |emf|=

a) 12 t b) 24 t c) 36 t d) 48 t e) none above

$$|emf| = \left|-N\frac{d\phi}{dt}\right| = \frac{2d}{dt}2t^2\cdot 3 = 24t$$

18. The capacitance of two 5x5 mm square metal plates separated by a 1 mm thick dielectric with ε = 9 ε0 is

a) 1 pF b) 1.5 pF c) 2 pF d) 2.5 pF e) none above

$$C = \frac{\epsilon A}{d} = \frac{9\epsilon_0\left(\frac{5}{1000}\right)^2}{1/1000} = \frac{225}{1000}\cdot 8.85\,pF/m = 1.991\,pF$$

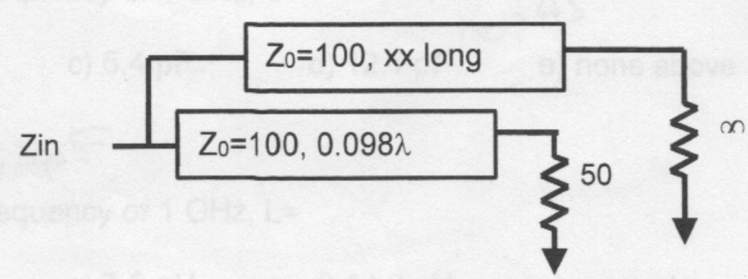
19. The inductance of a 5-turn inductor in vacuum with radius 2 mm and length 10 mm is

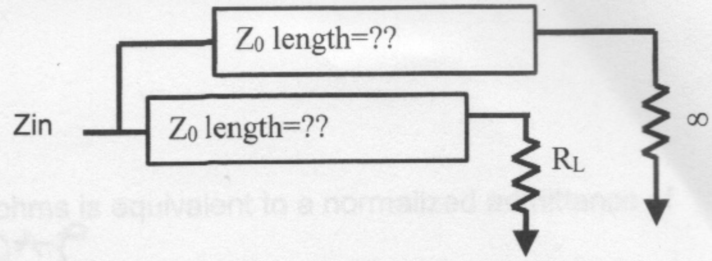
a) 20 nH b) 40 nH c) 80 nH d) 160 nH e) none above

$$L = \frac{N^2\pi r^2\mu_r\mu_0}{d} = \frac{25\pi\left(\frac{2}{1000}\right)^2 1257\,nH/m}{10/1000} = 39.5\,nH$$

20. In the single-stub match below, for Zin=100 ohms, the length of the open-circuit stub is xx=

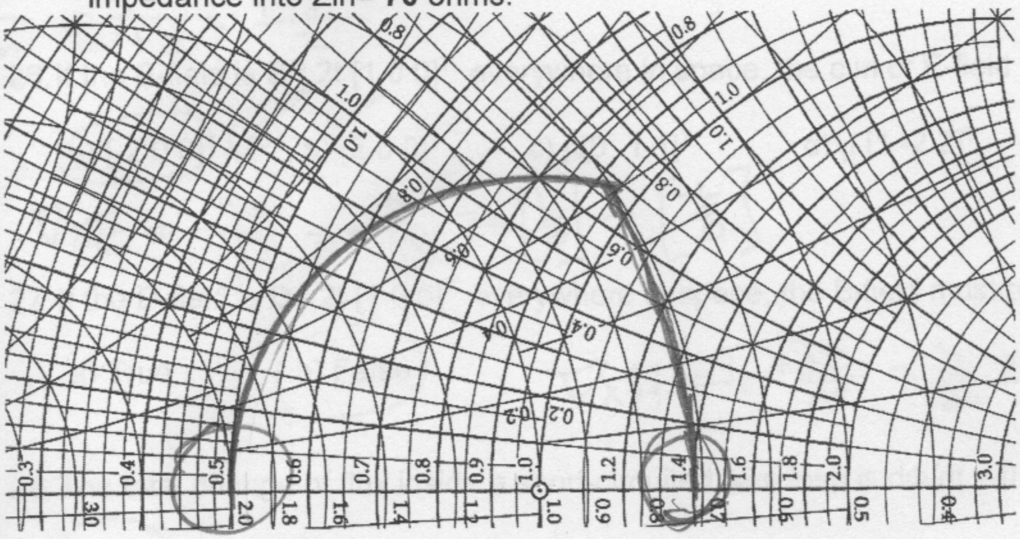
a) 0.055 λ b) 0.096 λ c) 0.125 λ d) 0.22 λ



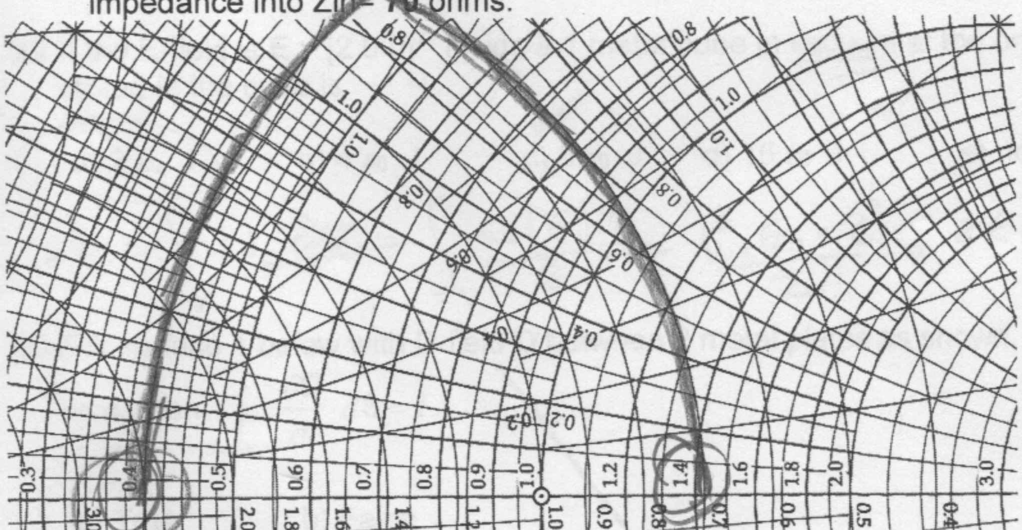


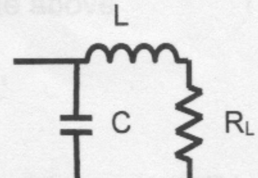
5 Points Each, <u>Circle the best answer</u>

21. *Draw the paths on the* ***Z₀=50*** *ohm Smith chart below* corresponding to the single-stub matching network of the circuit shown above. The circuit transforms the R_L=**25** ohm impedance into Zin= **70** ohms.



22. *Draw the paths on the* ***Z₀=50*** *ohm Smith chart below* (for L and C) corresponding to the matching network of the circuit shown below. The circuit transforms the R_L=**20** ohm impedance into Zin= **70** ohms.





$\frac{X_L}{50} \approx 0.65$

$X_L = 32.5$

$Y_B = 1.1$

$\frac{X_C}{50} = 0.91$

$X_C = 45$

23. For the above impedance match at a frequency of 1 GHz, C=

a) 1.2 pF b) 3.6 pF c) 5.4 pF d) 12.1 pF e) none above

$C = \frac{1}{\omega \cdot X_C} = \frac{1}{2\pi \cdot 10^9 \cdot 45} = 3.5pF$

24. For the above impedance match at a frequency of 1 GHz, L=

a) 3.9 nH b) 5.0 nH c) 7.6 nH d) 14.3 nH e) none above

$L = \frac{X_L}{\omega} = \frac{32.5}{2\pi \cdot 10^9} = 5.2nH$

5 Points Each, <u>*Circle the best answer*</u>

25. An normalized impedance $Z_n = 1.0 + j\,1.0$ ohms is equivalent to a normalized admittance of $Y_n =$

SWAP

a) 2 - j2 b) 0.5 + j 0.5 c) 0.5 - j 0.5 d) -2 - j d) none above

$Y_n = \frac{1}{x_n} = \frac{1}{1+j} = \frac{1-j}{2}$

26. If the B-field is **B**= 2t [1 0 0]^T everywhere in space, the curl of E-field is $\nabla\times\mathbf{E}$ =

a) [-2 0 0]^T b) [2 0 0]^T c) μ[0 -1 1]^T d) μ [1 -2 2]^T d) none above

$\nabla\times E = -\frac{\partial B}{\partial t} = -\frac{\partial}{\partial t} 2t\begin{bmatrix}1\\0\\0\end{bmatrix} = \begin{bmatrix}-2\\0\\0\end{bmatrix}$

27. If the D-field is **D**= 2t [1 0 0]^T everywhere in space, the B-field must be zero.

a) True b) False

$\nabla\times H = J_e + \frac{\partial D}{\partial t} = \frac{\partial}{\partial t} 2t\begin{bmatrix}1\\0\\0\end{bmatrix} = \begin{bmatrix}2\\0\\0\end{bmatrix}$

28. The total change of flux inside a short-circuited wire loop is dΦ/dt = 0.

a) True b) False

29. If the E-field is **E** = [2 0 0]^T inside a 1 meter cube in vacuum at the origin, the total energy stored in the cube is

a) 2 ε_0 J b) 4 ε_0 J c) 8 ε_0 J d) 16 ε_0 J e) none above

$W_E = \int_V w_E \, dv = \int_V \frac{\epsilon_0 |E|^2}{2} = \frac{1^3 \cdot \epsilon_0 \cdot 2^2}{2} = 2\epsilon_0.$

30. For surface 1 below with D-field **D** between 2 metal plates as shown, and for current "I" in the wire, then $\int_{Surface1} \frac{\partial \mathbf{D}}{\partial t}\cdot d\mathbf{S} = I$.

a) True b) False