CLASS TEST

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ELECTROMAGNETICS

ELECTRONICS ENGINEERING

Date of Test : 22/04/2022

ANSWER KEY

1.	(a)	7.	(a)	13.	(a)	19.	(a)	25.	(c)
2.	(a)	8.	(a)	14.	(d)	20.	(b)	26.	(a)
3.	(a)	9.	(b)	15.	(b)	21.	(c)	27.	(b)
4.	(a)	10.	(c)	16.	(c)	22.	(d)	28.	(b)
5.	(b)	11.	(c)	17.	(d)	23.	(b)	29.	(a)
6.	(d)	12.	(a)	18.	(a)	24.	(d)	30.	(c)

Detailed Explanations

1. (a)

$$\eta_{TE} = \frac{120\pi}{\cos\theta} > 120\pi$$

$$\eta_{TM} = 120\pi \times \cos\theta < 120\pi$$

$$\eta_{TEM} = 120\pi$$

3. (a)

Skin depth is given by

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

$$\therefore \quad \frac{\delta_1}{\delta_2} = \sqrt{\frac{f_2}{f_1}}$$

$$\therefore \quad \frac{\delta}{\delta_2} = \sqrt{\frac{4}{1}}$$

$$\therefore \quad \delta_2 = \frac{6}{7} = 3\ \mu\text{m}$$

4. (a)

$$\nabla \times \vec{A} = \vec{B}$$

$$\nabla \times \vec{A} = \mu \vec{H}$$

$$\Rightarrow \quad \vec{H} = \frac{1}{\mu}\left(\nabla \times \vec{A}\right)$$

5. (b)

$$\hat{a}_E \times \hat{a}_H = \hat{a}_k$$

Given that, $\hat{a}_E = \hat{a}_y$ and $\hat{a}_k = \hat{a}_z$

$$\Rightarrow \quad \hat{a}_y \times \hat{a}_H = \hat{a}_z$$

$$\Rightarrow \quad \hat{a}_H = -\hat{a}_x$$

6. (d)

$$v_p \times v_g = c^2$$

$$3.5 \times 10^8 \times v_g = (3 \times 10^8)^2$$

$$v_g = \frac{9 \times 10^{16}}{3.5 \times 10^8} = 2.57 \times 10^8\ \text{m/s}$$

7. (a)

$$Z_{in} = Z_0 \left.\frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}\right|_{l = \frac{\lambda}{8},\ Z_0 = 50,\ Z_L = 0}$$

$$= 50 \frac{j50 \tan 45°}{50} = j50\ \Omega$$

8. (a)

$$\frac{\sin\theta_i}{\sin\theta_t} = \sqrt{\frac{\varepsilon_{r_2}}{\varepsilon_{r_1}}}$$

$$\frac{\sin 30^\circ}{\sin\theta_t} = \sqrt{3}$$

$$\Rightarrow \quad \sin\theta_t = \frac{1}{2\sqrt{3}}$$

$$\Rightarrow \quad \theta_t = \sin^{-1}\left(\frac{1}{2\sqrt{3}}\right) = 16.78^\circ$$

9. (b)

Electrical length of the line, $\theta = \beta l$

$$v_p = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10\times10^{-6}\times0.1\times10^{-12}}} = 10^9 \text{ m/s}$$

$$\lambda = \frac{v_p}{f} = \frac{10^9}{10^6} = 1000 \text{ m}$$

$$\theta = \frac{2\pi}{\lambda}\times l = \frac{2\pi}{1000}\times250 = \frac{\pi}{2} = 90^\circ$$

10. (c)

Given,

$$\left|\frac{J_C}{J_D}\right| = \left|\frac{\sigma E}{\omega\varepsilon E}\right| = \frac{\sigma}{\omega\varepsilon} = 10$$

or, $$\omega = \frac{\sigma}{10\varepsilon}$$

$\therefore$ $$2\pi f = \frac{\sigma}{10\varepsilon} \Rightarrow f = \frac{\sigma}{20\pi\varepsilon} = \frac{20}{20\pi\times81\times8.854\times10^{-12}}$$

$$f = 443.84 \text{ MHz}$$

11. (c)

We have, $$\frac{m\pi x}{a} = \frac{2\pi x}{a}, \quad m = 2$$

$$\frac{n\pi x}{b} = \frac{3\pi y}{b}, \quad n = 3$$

$\therefore$ it is TE_{23} node

Cut off frequency, $$f_c = \frac{u}{2}\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{2}\right)^2} = \frac{3\times10^8}{2}\sqrt{\left(\frac{2}{286}\right)^2+\left(\frac{3}{1.016}\right)^2}\times100$$

$$= 46.19 \text{ GHz}$$

$\omega = 10\pi\times10^{10}$, $\quad f = 50$ GHz

$$\beta = \frac{2\pi f}{c}\sqrt{1-\left(\frac{f_c}{f}\right)^2} = \frac{2\pi\times50\times10^9}{3\times10^8}\sqrt{1-\left(\frac{46.19}{50}\right)^2} = 400.68 \text{ rad/m}$$

$\because f > f_c$ $\quad \alpha = 0$

$\gamma = \alpha + j\beta = j400.7$ rad/m

12. (a)

Propagation constant given by

$$\tau = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$= \sqrt{(0.03 + j2\pi \times 10^3 \times 10^{-4})(0 + j2\pi \times 10^3 \times 20 \times 10^{-9})}$$

$$= 2.121 \times 10^{-4} + j8.88 \times 10^{-3} \text{ /m}$$

$$\therefore \quad r = \alpha + j\beta$$

$$\therefore \quad \alpha = 2.121 \times 10^{-4} \text{ Np/m} = 0.21 \times 10^{-3} \text{ Np/m}$$

A distortion less line operating at 120 MHz has $R = 20\ \Omega$/m, $L = 0.3\ \mu$H/m, $C = 63$ pF/m

13. (a)

Wave travels along $-x$ direction

$\beta = 6$ rad/m, $\quad \omega = 2 \times 10^8$ rad/c

$$\text{Phase velocity, } u = \frac{\omega}{\beta} = \frac{2 \times 10^8}{6} = \frac{c}{\sqrt{u_r \varepsilon_r}}$$

$$\therefore \quad \frac{3 \times 10^8}{\sqrt{\varepsilon_r}} = \frac{2 \times 10^8}{6}$$

$$\sqrt{\varepsilon_r} = 9, \quad \varepsilon_r = 81$$

$$\eta' = \frac{\eta_0}{\sqrt{\varepsilon_r}} = \frac{120\pi}{9} = 41.88\ \Omega$$

$$\eta' = \frac{E_0}{H_0}$$

$$\therefore \quad E_0 = 41.88 \times 25 \times 10^{-3} = 1.047 \text{ V/m}$$

$$\therefore \quad \bar{E} = E_0 \sin(\omega t + \beta x)\hat{a}_E$$

Also, $\hat{a}_E \times \hat{a}_H = \hat{a}_p$, $\quad \hat{a}_E \times a\hat{y} = -\hat{a}x$

$$a_E = a\hat{z}$$

$$\therefore \quad \bar{E} = 1.04 \sin(1 \times 10^8 t + 6x)a\hat{z}$$

14. (d)

$$\Gamma_A = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{150 - 100}{150 + 100} = 0.2$$

$$\therefore \quad S_A = \frac{1 + |\Gamma|}{1 - |\Gamma|} = 1.5$$

$$\Gamma_B = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{j150 - 100}{j150 + 100}$$

$$|\Gamma_B| = 1 = |\Gamma_C|$$

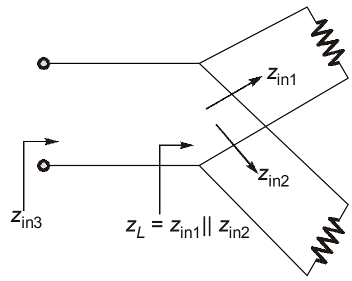
$$\therefore \quad S_B = S_C = \infty$$

15. (b)

For quarter wave transformer, $z_0^2 = z_{in} \cdot z_L$

$$z_{in1} = \frac{z_0^2}{200} = \frac{50^2}{200} = 12.5\,\Omega$$

$$z_{in2} = \frac{z_0^2}{0} = \infty$$



$$z_L = z_{in1} || z_{in2} = \infty || 12.5 = 12.5\ \Omega$$

$$z_{in3} = \frac{z_0^2}{z_L} = \frac{50^2}{12.5} = 200\ \ \Omega$$

16. (c)

Since wave is travelling along positive y-direction and E_z and E_x components are not equal

$\therefore$ $$E_z \neq E_x$$

Also, E_x leads by 90° it's left elliptical polarization

17. (d)

$$\beta = \frac{2\pi}{\lambda} = \frac{2\pi}{c} \times f = \frac{2\pi \times 2 \times 10^9}{3 \times 10^8} = \frac{40\pi}{3}$$

$$\beta l = \frac{40\pi}{3} \times 0.1 = \frac{4\pi}{3}$$

Input impedance of short circuited line's

$$z_{in} = jz_0 \tan\beta l = jz_0 \tan\frac{4\pi}{3} = j50 \times \sqrt{3}$$

$\therefore$ Hence inductive.

18. (a)

$$Z_{in_2} = Z_{02} \left.\frac{Z_L + jZ_{02}\tan\beta l}{Z_{02} + jZ_L \tan\beta l}\right|_{\substack{l = 5\lambda/2 \\ Z_{02} = 100\,\Omega \\ Z_L = 75\,\Omega}} = 100\frac{75 + j100\tan 5\pi}{100 + j75\tan 5\pi} = 75\ \Omega$$

$$Z_{in} = Z_{01} \left.\frac{Z_{in_2} + jZ_{01}\tan\beta l}{Z_{01} + jZ_{in_2}\tan\beta l}\right|_{\substack{l = 3\lambda/4 \\ Z_{in_2} = 75\,\Omega \\ Z_{01} = 50\,\Omega}} = 50\frac{75 + j50\tan\frac{3\pi}{2}}{50 + j75\tan\frac{3\pi}{2}}$$

$$= \frac{50^2}{75} = 33.33\,\Omega$$

19. (a)

- $$\nabla V = \frac{\partial V}{\partial x}\hat{a}_x + \frac{\partial V}{\partial y}\hat{a}_y + \frac{\partial V}{\partial z}\hat{a}_z$$
$$= (2xy - 2y^2)\hat{a}_x + (x^2 - 4xy)\hat{a}_y + (3z^2)\hat{a}_z$$
- At point (2, 4, –3), $$\nabla V = (16-32)\hat{a}_x + (4-32)\hat{a}_y + (27)\hat{a}_z$$
$$= -16\hat{a}_x - 28\hat{a}_y + 27\hat{a}_z$$
- Along the direction of $\hat{a}_x + 2\hat{a}_y - \hat{a}_z$,
- $$(\nabla V)\cdot\frac{(\hat{a}_x + 2\hat{a}_y - \hat{a}_z)}{\sqrt{1+4+1}} = \frac{-16-56-27}{\sqrt{6}} = -40.416$$

20. (b)

$$\vec{J_d} = \frac{\partial \vec{D}}{\partial t} = \varepsilon_0\frac{\partial \vec{E}}{\partial t} = \varepsilon_0\left(2\pi\times10^6\right)\cos\left(2\pi\times10^6 t + \beta z\right)\hat{a}_y$$
$$= \frac{10^{-9}}{36\pi}\times 2\pi\times10^6\cos\left(2\pi\times10^6 t + \beta z\right)\hat{a}_y \text{ A/m}^2$$
$$= 55.5\cos\left(2\pi\times10^6 + \beta z\right)\hat{a}_y\ \mu\text{A/m}^2$$

21. (c)
- Field contains orthogonal components with unequal amplitudes ⇒ Elliptical polarization
- y component leads x component by 90° and wave is travelling in positive-z direction ⇒ Left elliptically polarized.

22. (d)
For a distortionless line, $$RC = GL$$
$$G = \frac{RC}{L}$$
- $$Z_0 = \sqrt{\frac{L}{C}}$$
- $$\alpha = \sqrt{RG} = R\sqrt{\frac{C}{L}} = \frac{R}{Z_0}$$

⇒ $$R = \alpha Z_0 = 10\times10^{-3}\times 100 = 1\ \Omega/\text{m}$$
$$v = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{LC}}\times\sqrt{\frac{L}{L}} = \frac{1}{L}\sqrt{\frac{L}{C}} = \frac{1}{L}\times Z_0$$
⇒ $$L = \frac{Z_0}{v} = \frac{100}{2\times10^8} = 50\times10^{-8} = 0.5\ \mu\text{H/m}$$

23. (b)

- $$Z_{\text{in}_3} = \frac{Z_{03}^2}{Z_{L3}} = \frac{300^2}{200} = 450\ \Omega$$
- $$Z_{\text{in}_2} = \frac{Z_{02}^2}{Z_{L2}} = \frac{100^2}{0} = \infty\ \text{(open)}$$
- $$Z_{L(\text{eff})} = Z_{\text{in}_3} \,||\, Z_{\text{in}_2} = 450\ \Omega$$
- $$Z_{\text{in}} = Z_{\text{in}_1} = \frac{100^2}{450} = 22.22\ \Omega$$

24. (d)

$$U(\theta, \phi) = \frac{1}{2}\sin\phi\sin\theta$$

The directivity,

$$D = \frac{|U(\theta, \phi)|_{max}}{P_{rad}} \times 4\pi$$

$$|U(\theta, \phi)|_{max} = \frac{1}{2} \text{ for } \phi = \theta = \frac{\pi}{2}$$

$$P_{rad} = \int_{\theta=0}^{\pi}\int_{\phi=0}^{\pi} U(\theta, \phi)\sin\theta\, d\theta\, d\phi = \frac{1}{2}\int_{\theta=0}^{\pi}\int_{\phi=0}^{\pi} \sin^2\theta\sin\phi\, d\theta\, d\phi$$

$$= \frac{1}{2}\int_{\theta=0}^{\pi} \sin^2\theta\, d\theta \int_{\phi=0}^{\pi} \sin\phi\, d\phi = \frac{1}{2}\times\left(\frac{\pi}{2}\right)\times 2 = \frac{\pi}{2}$$

$\Rightarrow$

$$D = \frac{1/2}{\pi/2}\times 4\pi = 4$$

25. (c)

$$\theta_n = 36°$$

$$\text{Loss tangent} = \tan 2\theta_n$$

$$\tan 72° = 3.077$$

26. (a)

The time average power is given by,

$$P = \frac{E^2}{2\eta}$$

Where,

$$\eta = 120\pi\sqrt{\frac{\pi^2}{80}} = \frac{120\pi^2}{\sqrt{80}} = 132.414$$

$\therefore$

$$P = \frac{(15)^2}{2\times 132.414} = 0.849 \text{ W/m}^2 \approx 0.85 \text{ W/m}^2$$

27. (b)

The reflection coefficient $\Gamma = \dfrac{S-1}{S+1} = \dfrac{2.2-1}{2.2+1} = \dfrac{1.2}{3.2} = \dfrac{3}{8}$

$\therefore$ Transmission coefficient, $T = 1 + \Gamma = \dfrac{11}{8}$

As we know,

$$P_t = \frac{\eta_1}{\eta_2}\times T^2 \times P_i$$

Also,

$$\Gamma = \frac{1-\dfrac{\eta_1}{\eta_2}}{1+\dfrac{\eta_1}{\eta_2}} = \frac{3}{8}$$

or

$$\frac{\eta_1}{\eta_2} = \frac{5}{11}$$

$\therefore$

$$P_t = \frac{5}{11}\times\left(\frac{11}{8}\right)^2\times 3$$

$$P_t = 2.578 \text{ W/m}^2$$

28. (b)

For short circuited transmission line,

$$Z_{in} = jZ_0 \tan\beta l$$

$$j60 = j35 \tan\beta l$$

$$\tan\beta l = 1.714$$

or $$\beta l = (59.743)°$$

$\because$ $$\beta = \frac{2\pi}{\lambda} = \frac{2\pi \times 1 \times 10^6}{3 \times 10^8}$$

$$\frac{2\pi \times 1 \times 10^6}{3 \times 10^8} \times l = 59.743° \times \frac{\pi}{180°}$$

$$l = 49.785 \text{ m}$$

29. (a)

For dominant mode, $$f_c = \frac{c}{2a} = \frac{3 \times 10^{10}}{2 \times 4} = 3.75 \text{ GHz}$$

and $$\eta_{TE} = \frac{\eta_0}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} = \frac{377}{\sqrt{1 - \left(\frac{3.75}{10}\right)^2}} = 406.7\ \Omega$$

$\therefore$ $$P_{avg} = \frac{E_0^2 ab}{4\eta_{TE}} = \frac{(65)^2 \times 4 \times 2 \times 10^{-4}}{4 \times 406.7} = 2.078 \text{ mW}$$

30. (c)

$$\text{Electrical length} = \beta l = 2\pi f\sqrt{LC} \times l$$

$$92° \times \frac{\pi}{180°} = 2 \times 40 \times 10^6 \times 20 \times 10^{-2}\sqrt{L \times 20 \times 10^{-12}}$$

$$\sqrt{L \times 20 \times 10^{-12}} = \frac{92°}{16 \times 10^6 \times 180°} = 3.194 \times 10^{-8}$$

On solving the above equation, we get,

or, $$L = \frac{(3.194 \times 10^{-8})^2}{20 \times 10^{-12}}$$

$$L = 51.008\ \mu\text{H/m}$$

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