Sl.: 02DLSK_EC_IJKLM_131126

MADE EASY
Leading Institute for IES, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

ELECTROMAGNETICS THEORY

ELECTRONICS ENGINEERING

Date of Test : 13/11/2026

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (d)

Given

$$\vec{E}(z,t) = 3\sin(\omega t - kz + 30°)\hat{a}_y - 4\cos(\omega t - kz + 45°)\hat{a}_x \text{ V/m}$$

As the magnitude of orthogonal components are not equal and

$$\phi_x - \phi_y = 15°, \text{ so it is elliptically polarised.}$$

Since, the wave is travelling in +z-direction and the locus of the electric field on x-y plane with advancing time is counter-clockwise, hence as per the right hand rule, the wave is right circularly polarized.

2. (d)

For homogeneous dielectric material, $D = \in E$ and $J = \sigma E$.

3. (a)

1. When $Z_L = Z_0$, the reflection coefficient $\Gamma = 0$, hence the reflected wave does not exist.
2. We have, $Z_0 = \sqrt{Z_{SC}\, Z_{OC}}$; Z_O is the geometric mean of extreme case input impedances. For maximum power transfer $Z_L = Z_0 = \sqrt{(Z_{SC}Z_{OC})}$, i.e. somewhere in between Z_{SC} and Z_{OC}.
3. $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}}$, hence Z_0 is frequency dependent.

4. (d)

- If two or more modes have same cutoff frequency, they are said to be degenerate modes. e.g. – TE_{11} and TM_{11} are degenerate modes.
- If more than one mode is propagating, the waveguide is said to be overmoded. e.g., A discontinuity in the waveguide, like a bend or slot in the guide wall, will always produce multitude of modes.

5. (b)

$$f_{TE_{20}} = 15 \text{ GHz} = \frac{c}{a} = \frac{3\times10^8}{a}$$

$$a = \frac{3\times10^8}{15\times10^9}\times100 = 2 \text{ cm}$$

$$\Rightarrow \quad b = 1 \text{ cm}$$

$$f_{TE_{02}} = \frac{c}{b} = \frac{3\times10^8\times100}{1} = 30 \text{ GHz}$$

6. (d)

(i) $$Z_0 = \sqrt{Z_{OC}Z_{SC}} = \sqrt{50k}$$

If $k > 50$

$$Z_0 > k$$

$k \le Z_0 \le 50$ is possible

(ii) $Z_0 = \sqrt{50k}$

If $k < 50$

$Z_0 < k$

$50 \le Z_0 \le k$ is possible

7. (b)

Given, $Z_0 = 70\ \Omega$

$S = 1.6$

$\theta_\Gamma = 300° = -60°$

$l = 0.6\lambda$

For voltage minima,

$$2\beta x_{min} = (2n+1)\pi + \theta$$

$$2 \times \frac{2\pi}{\lambda} x_{min} = (2n+1)\pi + 300°$$

Considering $n = 0$ for the first minima,

$$\frac{4\pi}{\lambda} x_{min} = \pi - \frac{\pi}{3}$$

$$\frac{4}{\lambda} x_{min} = \frac{2}{3}$$

$$x_{min} = \frac{\lambda}{6}$$

8. (a)

For propagation inside a waveguide, $f > f_c$ i.e. $\lambda < \lambda_c$. Further, the guide wavelength λ_g is greater than the free space wavelength λ. We have,

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

9. (d)

Given: $H_z = 6x \cos\beta + 12\, y \sin\gamma\ \text{A/m}$

We know from Maxwell's equation,

$$\nabla \times H = \vec{J}$$

$$\nabla \times H = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 0 & 0 & 6x\cos\beta + 12y\sin\gamma \end{vmatrix}$$

$$= \hat{a}_x \left[\frac{\partial}{\partial y}(6x\cos\beta + 12y\sin\gamma) \right] + \hat{a}_y \left[0 - \frac{\partial}{\partial x}(6x\cos\beta + 12y\sin\gamma) \right]$$

$$\nabla \times H = \vec{J} = (12\sin\gamma\ \hat{a}_x - 6\cos\beta\ \hat{a}_y)\ \text{A/m}^2$$

10. (b)

Given: $\vec{B} = 6x\,\hat{a}_x + 3ky\,\hat{a}_y + 6\hat{a}_z$

From Maxwell's equation, $\vec{\nabla} \cdot \vec{B} = 0$

© Copyright: MADE EASY

$$\frac{\partial}{\partial x}(6x)+\frac{\partial}{\partial y}(3ky)+\frac{\partial}{\partial z}(6) = 0$$
$$6 + 3k = 0$$
$$k = -2$$

11. (d)

Given: $\in = 81\in_0$, $\sigma = 5$ S/m, $\mu = 4\pi \times 10^{-7}$ H/m

Since sea water is a poor conductor skin depth, $\left(\because \frac{\sigma}{\omega \in} << 1\right)$

$$\delta = \frac{2}{\sigma}\sqrt{\frac{\in}{\mu}} = \frac{2}{\sigma}\frac{\sqrt{\in_r}}{\eta_0}$$
$$\delta = \frac{2}{5}\times\frac{\sqrt{81}}{377}$$

attenuation, $\alpha = \frac{1}{\delta} = \frac{377\times 5}{9\times 2}$

$$\alpha = 104.722 \text{ Np/m}$$

12. (d)

Given: Endfire antenna, i.e., $\alpha = \pi$

$$\psi = \beta d \cos\phi + \alpha$$
$$\psi = \frac{2\pi}{\lambda}\times\frac{\lambda}{2}\cos\phi + \pi$$
$$\psi = \pi + \pi\cos\phi$$
$$\cos\psi = \cos(\pi + \pi\cos\phi)$$
$$= -\cos(\pi\cos\phi)$$

13. (a)

Given: $P_{avg} = 2.5$ mW, $P_{Loss} = 18.5$ mW per unit length

For energy to be conserved, the rate of decrease in P_{avg} must be equal to the time average power loss per unit length.

$$P_L = \frac{-d P_{avg}}{dz} = 2\alpha P_{avg} \qquad \{P_{avg} = P_0 e^{-2\alpha z}\}$$
$$\alpha = \frac{P_L}{2P_{avg}} = \frac{18.5}{2\times 2.5} = 3.7$$
$$\alpha = 3.7 \text{ Np/m}$$

14. (d)

Given; $\eta = 95\%$, $U_{max} = 0.5$ W/Sr

$$P_{in} = 0.4$$

Directivity, $D = \frac{4\pi U_{max}}{P_{rad}}$

$$D = \frac{4\pi\times 0.5}{0.95\times 0.4} = 16.53$$
$$D = 16.53$$

15. (b)

The array has largest HPBW when it is in the end fire direction. So we get,

$$20^\circ = \frac{20\times\pi}{180^\circ} = \frac{\pi}{9} = \sqrt{\frac{2\lambda}{(N-1)d}}$$

$$N >> 1$$

$$\sqrt{\frac{2\lambda}{Nd}} = \frac{\pi}{9}$$

$$\frac{2\lambda}{Nd} = \frac{\pi^2}{81}$$

$$Nd = \frac{2\times 81}{\pi^2}\times\lambda$$

For array spacing $d = \lambda/2$,

$$N = \frac{2\times 81}{\pi^2}\times\frac{\lambda\times 2}{\lambda} = \frac{4\times 81}{\pi^2} = 32$$

16. (c)

Comparing magnetic field intensity vector with standard form, we get,

$$\omega = 40000 \text{ rad/sec}, \quad \beta = 0.004 \text{ rad/m}$$

$$\therefore \quad \text{Phase velocity, } v_p = \frac{\omega}{\beta} = \frac{40000}{0.004} = 10^7 \text{ m/sec}$$

17. (a)

Length of the dipole is $\frac{\lambda}{2}$

$$l = \frac{\lambda}{2} = \frac{c}{2f} = \frac{3\times 10^8}{2\times 50\times 10^6} = 3 \text{ m}$$

18. (b)

$x = 0$

Region (1)	Region (2)
$x < 0$	$x > 0$
$\vec{H}_1 = 2\hat{a}_x + \hat{a}_y - 4\hat{a}_z$ A/m	$\mu_{r2} = 4$
$\mu_{r1} = 6$	

Using Boundary conditions

$$\vec{H}_{t1} = \vec{H}_{t2} \qquad \text{(As no current at interface)}$$

$$\therefore \quad \vec{H}_{t2} = \hat{a}_y - 4\hat{a}_z = \vec{H}_{t1} \qquad \ldots(1)$$

Also,

$$\vec{B}_{n1} = \vec{B}_{n2}$$

$$\mu_0\mu_{r1}\vec{H}_{n1} = \mu_0\mu_{r_2}\vec{H}_{n2}$$

$$6\times 2\hat{a}_x = 4\vec{H}_{n2}$$

$$\vec{H}_{n2} = 3\hat{a}_x \qquad \ldots(2)$$

© Copyright: MADE EASY

$$\therefore \quad \vec{H}_2 = \vec{H}_{t2} + \vec{H}_{n2}$$

$$\vec{H}_2 = 3\hat{a}_x + \hat{a}_y - 4\hat{a}_z$$

$$\therefore \quad \text{Magnetic flux density, } \vec{B}_2 = \mu_0\mu_r\vec{H}_2$$

$$\vec{B}_2 = 4\left[\vec{H}_2\right]\mu_0$$

$$\vec{B}_2 = \left[12\hat{a}_x + 4\hat{a}_y - 16\hat{a}_z\right]\mu_0 \text{ Tesla}$$

19. (c)

$$\text{Poynting vector, } \vec{P} = \vec{E}\times\vec{H} = \frac{E_0^2}{2\eta}\hat{a}_x \qquad (\because \text{Wave propagating in +ve } x \text{ direction})$$

$$\eta = \frac{120\pi}{\sqrt{\epsilon_r}}$$

Given, $\omega = 10^8, \beta = 1$

$$V_P = \frac{\omega}{\beta} = \frac{c}{\sqrt{\epsilon_r}}$$

$$\frac{10^8}{1} = \frac{3\times10^8}{\sqrt{\epsilon_r}}$$

$$\epsilon_r = 9$$

$$\therefore \quad \eta = \frac{120\pi}{\sqrt{9}} = 40\pi\ \Omega$$

$$\therefore \quad \vec{P} = \left[\frac{4^2}{2\times40\pi}\right]\hat{a}_x$$

$$\vec{P} = \left[63.66\hat{a}_x\right]\text{mW/m}^2$$

20. (d)

Using Maxwell's equation $\quad \nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$

$$\nabla\times\nabla\times\vec{E} = \nabla\times\left(\frac{-\partial\vec{B}}{\partial t}\right)$$

$$\therefore \quad \nabla\times\nabla\times\vec{E} = \frac{-\partial}{\partial t}\left[\nabla\times\vec{B}\right]$$

Using Maxwell's equation

$$\nabla\times\vec{H} = \frac{\partial\vec{D}}{\partial t} = \epsilon_0\frac{\partial\vec{E}}{\partial t} \qquad (\because \text{Free space } \epsilon = \epsilon_0, \sigma = 0)$$

$$\nabla\times\vec{B} = \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t} \qquad (\because \text{Free space } \therefore \mu = \mu_0)$$

$$\therefore \quad \nabla\times\nabla\times\vec{E} = \frac{-\partial}{\partial t}\left[\mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}\right]$$

$$\nabla\times\nabla\times\vec{E} = -\mu_0\epsilon_0\frac{\partial^2\vec{E}}{\partial t^2}$$

21. (d)

We know, $\nabla \times \vec{H} = \vec{J}$

$$\therefore \quad \nabla \times \vec{H} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \frac{1}{2}y & 3z & 2x \end{vmatrix}$$

$$= \hat{a}_x[0-3] - \hat{a}_y[2] + \hat{a}_z\left[0 - \frac{1}{2}\right]$$

$$\nabla \times \vec{H} = -3\hat{a}_x - 2\hat{a}_y - 0.5\hat{a}_z$$

i.e., $\vec{J} = -3\hat{a}_x - 2\hat{a}_y - 0.5\hat{a}_z$

$$\left|\vec{J}\right| = \sqrt{9+4+0.25} = 3.64 \text{ A/m}^2$$

22. (b)

$$\text{loss tangent; } \tan\theta = \frac{\sigma}{\omega\varepsilon} \quad \text{i.e., } \frac{\sigma}{\omega\varepsilon} \ll 1$$

$\therefore$ It is a lossy dielectric medium:

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+\frac{\sigma^2}{\omega^2\varepsilon^2}}-1\right)}$$

$$\alpha \cong \omega\sqrt{\frac{\mu\varepsilon}{2}\left(1+\frac{\sigma^2}{2\omega^2\varepsilon^2}-1\right)} = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}}$$

$$\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} = \frac{\sigma}{2}\sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{1}{\sqrt{\varepsilon_r}}$$

$$\alpha = \frac{\sigma}{2} \times \eta_0 \times \frac{1}{\sqrt{\varepsilon_r}}$$

$$\alpha = \frac{\tan\theta \times \omega\varepsilon \times \eta_0}{2\sqrt{\varepsilon_r}}$$

$$\alpha = \frac{\tan\theta \times \omega\varepsilon_0 \times \sqrt{\varepsilon_r} \times 120\pi}{2}$$

$$= \frac{0.002 \times 2\pi \times 5 \times 10^9 \times \sqrt{1.3} \times 120\pi \times 8.854 \times 10^{-12}}{2}$$

$$= 0.119 \text{ Np/m}$$

23. (d)

From wave equation:

$$\beta = \frac{\omega}{V_p}; \quad V_p = \frac{c}{\sqrt{\varepsilon_r}}$$

© Copyright: MADE EASY

here, $\beta = \frac{2\pi}{3}\text{ rad/m}$

$c = 3 \times 10^8\text{ m/s}$

$\beta = \frac{\omega}{c}\sqrt{\varepsilon_r}$

$\therefore \quad \sqrt{\varepsilon_r} = \frac{\beta \cdot c}{\omega} = \frac{\frac{2\pi}{3} \times 3 \times 10^8}{2\pi \times 125 \times 10^6} = 0.8$

$\varepsilon_r = 0.64$

$\therefore \quad \text{Intrinsic impedance } (\eta) = \frac{\eta_0}{\sqrt{\varepsilon_r}} = \frac{377}{\sqrt{0.64}} = 471.25\ \Omega$

24. (b)

For free space: $\eta_1 = \eta_0 = 377\ \Omega$

For lossless non-magnetic medium ($\mu_r = 1$)

$\eta_2 = \frac{\eta_0}{\sqrt{\varepsilon_r}} = \frac{377}{\sqrt{3.25}} = 209.12\ \Omega$

$\therefore \quad \text{Transmission coefficient } (T) = \frac{2\eta_2}{\eta_1 + \eta_2}$

$= \frac{2 \times 209.12}{377 + 209.12} = 0.713$

25. (c)

We have;

$|\text{Conduction current density}| = |\text{Displacement current density}|$

$\sigma E = \omega \varepsilon E$

$\omega = \frac{\sigma}{\varepsilon}$

$f = \frac{\sigma}{2\pi \cdot \varepsilon} = \frac{10^{-4}}{2\pi \times 8.854 \times 10^{-12} \times 9}$

$f \cong 0.2\text{ MHz}$

26. (a)

Intrinsic impedance, $\eta = 200 \angle 30°\ \Omega$

$\theta_\eta = 30°$

$\theta_\eta = \frac{1}{2}\tan^{-1}\left(\frac{\sigma}{\omega\varepsilon}\right)$

$\left(\frac{\sigma}{\omega\varepsilon}\right) = \tan(60°) = \sqrt{3}$

$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1 + \left(\frac{\sigma}{\omega\varepsilon}\right)^2} - 1\right]}$

$$\beta = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}+1\right]}$$

$$\frac{\alpha}{\beta} = \frac{\sqrt{\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}-1}}{\sqrt{\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}+1}} = \frac{\sqrt{\sqrt{1+3}-1}}{\sqrt{\sqrt{1+3}+1}}$$

$$\frac{\alpha}{\beta} = \frac{\sqrt{2-1}}{\sqrt{2+1}} = \frac{1}{\sqrt{3}}$$

$$\alpha = \frac{1}{\sqrt{3}}\beta = \frac{1}{\sqrt{3}}\times\frac{1}{2} = 0.2887 \text{ Np/m}$$

27. (b)

$a = 5$ cm, $b = 2$ cm

$$f_c = \frac{c}{2a} = \frac{3\times10^8}{2\times5\times10^{-2}}$$

$f_c = 3$ GHz

The propagation constant is given as,

$$\gamma = \sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2-\omega^2\mu\varepsilon}$$

For TE_{10} mode, $m = 1$, $n = 0$

The operating frequency is

$f = 0.95\, f_c$

$= 0.95 \times 3 = 2.85$ GHz

$$\gamma = \sqrt{\left(\frac{\pi}{5\times10^{-2}}\right)^2-\left(\frac{2\pi\times2.85\times10^9}{3\times10^8}\right)^2}$$

$\gamma = 19.62$

As propagation constant is real value.

$\therefore$ Attenuation constant = 19.62 Np/m.

28. (d)

If the electric field vector of the incident wave lies in the plane of incidence, the wave incident at the Brewster Angle will be completely transmitted and there is no reflected wave. The Brewster angle is given as

$$\tan\theta_B = \frac{\eta_2}{\eta_1}$$

Brewster's angle does not exist for perpendicular polarization.

© Copyright: MADE EASY

29. (c)

Given, $Z_0 = 50\ \Omega$

$f = 300$ MHz

$l = 2.5$ m

$Z_L = (40 + j20)\ \Omega$

For lossless transmission line, $Z_{in} = Z_0\left[\dfrac{Z_L + jZ_0\tan\beta l}{Z_0 + jZ_L\tan\beta l}\right]$

$$\beta l = \frac{2\pi}{\lambda}\times 2.5 = \frac{5\pi}{\lambda}$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{3\times10^8} = 1\text{ m}$$

$\therefore$ $\beta l = \dfrac{5\pi}{\lambda} = 5\pi$ rad/m

$\therefore$ $Z_{in} = 50\left[\dfrac{(40 + j20) + j50\tan(2\pi\times 2.5)}{50 + j(40 + j20)\tan(2\pi\times 2.5)}\right]$

$= 50[(40 + j20) + j50 \times 0]/[50 + j(40 + 20) \times 0]$

$Z_{in} = (40 + j20)\ \Omega$

30. (c)

Given, $I = 0.25\sin 10^8 t$ A

For a Hertzian dipole antenna,

$$H_{\phi s} = j\frac{I\beta l\sin\theta}{4\pi r}\cdot e^{-j\beta r}\hat{a}_\phi$$

$$H_{\phi s} = j\frac{I\times\frac{2\pi}{\lambda}\cdot\frac{\lambda}{100}\sin 30^\circ}{4\pi\times\frac{\lambda}{5}}\cdot e^{-j\frac{2\pi}{\lambda}\cdot\frac{\lambda}{5}}\hat{a}_\phi$$

where, $\lambda = \dfrac{c}{f} = \dfrac{3\times10^8}{10^8/2\pi} = 6\pi$ m

$$H_{\phi s} = j\frac{I}{80\lambda}\cdot e^{-j\frac{2\pi}{5}}\hat{a}_\phi$$

$$= j\frac{I}{480\pi}e^{-j\frac{2\pi}{5}}\hat{a}_\phi$$

$$= \frac{1}{480\pi}je^{-j\frac{2\pi}{5}}\left[0.25\cos 10^8 t\right]\hat{a}_\phi$$

$$H_{\phi s} = 0.1658\cos(10^8 t + 18^\circ)\hat{a}_\phi\ \text{mA/m}$$

$$|H_{\phi s}| = 0.1658\ \text{mA/m}$$

■■■■