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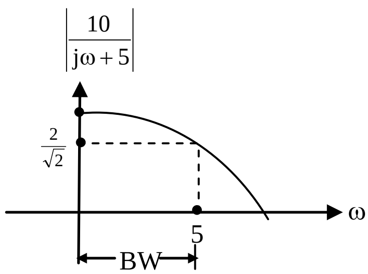
ESE- 2019 (Prelims) - Offline Test Series Test-5

ELECTRONICS & TELECOMMUNICATION ENGINEERING

SUBJECT: CONTROL SYSTEMS & ELECTROMAGNETICS
SOLUTIONS

01. Ans: (a)

Sol:



Bandwidth = 5 rad/sec

02. Ans: (d)

Sol: From option (d)
No poles and zeros lies in the right side of s-plane.

03. Ans: (c)

Sol: $\text{TF} = \dfrac{\frac{1}{s}}{1+\frac{1}{s}} = \dfrac{1}{s+1}$

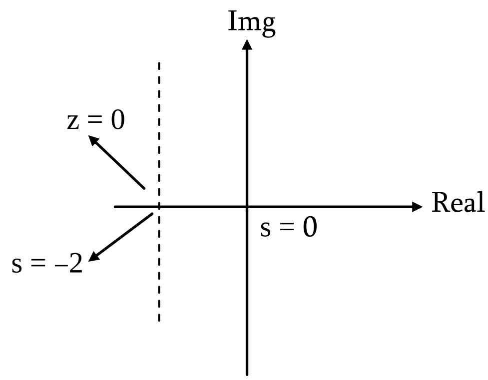
$$A = \left|\frac{1}{j\omega+1}\right| = \left.\frac{1}{\sqrt{\omega^2+1}}\right|_{\omega=1} = \frac{1}{\sqrt{2}}$$

$$\phi = \angle\frac{1}{j\omega+1} = -\tan^{-1}\omega\Big|_{\omega=1} = -45^\circ$$

$\therefore$ Output $\quad A\sin(t+\phi) \qquad = \dfrac{1}{\sqrt{2}}\sin(t-45^\circ)$

04. Ans: (c)

Sol: $CE = 1 + \frac{k(s+5)}{s(s+3)(s+7)} = 0$



$s(s^2 + 10s + 21) + k(s+5) = 0$

$s^3 + 10s^2 + (21+k)s + 5k = 0$

Substitute s = (z–2)

$(z-2)^3 + 10(z-2)^2 + (21+k)(z-2) + 5k = 0$

$z^3 - 6z^2 + 12z - 8 + 10z^2 - 40z + 40 + 21z + Kz - 42 - 2K + 5K = 0$

$z^3 + 4z^2 + (k-7)z + 3k - 10 = 0$

$$\begin{array}{c|cc} z^3 & 1 & k-7 \\ z^2 & 4 & 3k-10 \\ z^1 & \frac{4(K-7)-(3K-10)}{4} & \\ z^0 & 3k-10 & \end{array}$$

$\frac{4(K-7)-(3K-10)}{4} > 0 \Rightarrow k > 18$

And $(3K-10) > 0 \Rightarrow k > \frac{10}{3}$

$\therefore$ For k > 18 the closed loop poles lie left side of s = –2

05. Ans: (a)

Sol: $M_r = \frac{2}{2\zeta\sqrt{1-\zeta^2}} = 5 \;......0 \le \zeta \le 0.707$

Solve

$\zeta = 0.2$ and $\zeta = 0.97$

$\therefore \zeta = 0.2$ is valid

06. Ans: (b)

Sol: Routh Hurwitz $\rightarrow$ Stability
W.R.Evans $\rightarrow$ Root locus
Bode $\rightarrow$ Asymptotic
Nyquist $\rightarrow$ Polar plot

07. Ans: (b)

Sol: No. of forward paths = 1
No. of loops = 2
Two non touching loops =1

$$TF = \frac{G \times 4\left(\frac{1}{4}\right)}{1-(-H_1 - H_2) + H_1H_2} = \frac{G}{1 + H_1 + H_2 + H_1H_2}$$

08. Ans: (b)

Sol: As k increases, ζ decreases ($\because k \propto \frac{1}{\zeta^2}$)

If ζ decreases, rise time decreases. Hence bandwidth increases ($\because$ Bandwidth $\propto \frac{1}{\text{rise time}}$)

If ζ decreases, ω_d increases ($\because \omega_d = \omega_n\sqrt{1-\zeta^2}$)

$\therefore$ Oscillatory nature of response increases.

As k increases ζ decreases $\Rightarrow$ stability decreases.

09. Ans: (c)

Sol: $\frac{C(s)}{R(s)} = \frac{G_1G_2}{1-G_1G_2}(G_3 - X) = \frac{G_1G_2G_3}{1-G_1G_2} - \frac{XG_1G_2}{1-G_1G_2}$

$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3 - 1 + G_1G_2}{1-G_1G_2}$$

10. Ans: (c)

Sol: CLTF is

$$\frac{C(s)}{R(s)} = \frac{\frac{20}{s^2}}{1+\frac{20}{s^2}(s+5)} = \frac{20}{s^2+20s+100}$$

$$C(s) = \frac{20\,R(s)}{s^2+20s+100} = \frac{20}{s(s^2+20s+100)}$$

Steady state output $c(\infty) = \underset{s\to 0}{\text{Lt}}\ s\,C(s) = \underset{s\to 0}{\text{Lt}}\ s\frac{20}{s(s^2+20s+100)} = \frac{20}{100} = 0.2$

11. Ans: (c)

Sol: Output is more sensitive to feedback path parameter changes than the forward path parameter changes.

12. Ans: (a)

Sol: $\text{OLTF} = \frac{\text{CLTF}}{1-\text{CLTF}} = \frac{1}{10s}$

$$k_v = \underset{s\to 0}{\text{Lt}}\ sG(s) = \frac{1}{10}$$

Steady state error $e_{ss} = \frac{1}{k_v} = 10$

13. Ans: (b)

Sol: $M_p = \frac{11.63-10}{10}\times 100 = 16.3\%$

i.e $\zeta = 0.5$

settling time t_s ($\pm$ 2% tolerance) = $\frac{4}{\zeta\omega_n} = 4$

$\zeta\omega_n = 1$

$\omega_n = 2$

$\omega_d = \omega_n\sqrt{1-\zeta^2}$

$= 2\sqrt{1-0.5^2}$ = 1.73 rad/sec

14. Ans: (a)

Sol: G(s) is type-1 system

By introducing integral controller

It becomes type-2 system

And for the step input to type-2 system steady state error is zero.

15. Ans: (a)

Sol: C.E = $s^3 + 11s^2 + 10s + 2k = 0$

110 = 2k

$k_{marginal} = 55$

$11s^2 + 110 = 0$

$s = \pm j10$

$\omega_n = \sqrt{10}$ = 3.16 rad/sec

16. Ans: (c)

Sol: $G(s) = \frac{K(s+2)^3}{s^2}$

Two poles at the origin

$\therefore$ Type 2 system

CE = 1 + G(s) = 0

$s^2 + K(s+2)^3 = 0$, three roots

$\therefore$ order is '3'.

17. Ans: (d)

Sol: Ex: Consider 2nd order system $as^2 + bs + c = 0$

In R-H tabulation,

$$\begin{array}{c|cc} s^2 & a & c \\ s^1 & b & \\ s^0 & c & \end{array}$$

For all positive values of a, b, c system is stable

18. Ans: (b)

Sol: R-H tabulation

$$\begin{array}{c|lll} s^4 & 1 & 11 & 18 \\ s^3 & 2 & 18 & \\ s^2 & 2 & 18 & \\ s^1 & 0(2) & & \\ s^0 & 18 & & \end{array}$$

No sign changes
2- Imaginary poles
2-left side poles

19. Ans: (c)

Sol: $(TF)_{PD} = k_p\,(1+T_D s)$

One zero at $-\dfrac{1}{T_D}$

20. Ans: (a)

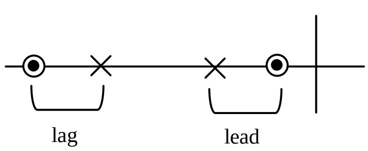
Sol: $(TF)_{PI} = k_p\left(1+\dfrac{1}{T_I s}\right) = \dfrac{k_p}{T_I}\left(\dfrac{1+T_I s}{s}\right)$

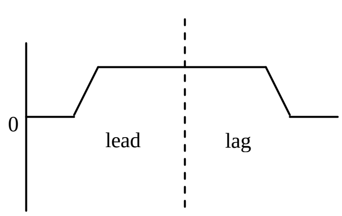
Pole: $s = 0$

Zero: $s = -\dfrac{1}{T_I}$

21. Ans: (c)

Sol: Pole zero plot of lead-lag compensator



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22. Ans: (c)

Sol: $K_p = \underset{s\to 0}{Lt}\dfrac{K}{s+A} = \dfrac{K}{A}$

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+\frac{K}{A}} = \frac{A}{K+A}$$

$$S_K^{e_{ss}} = \frac{\partial e_{ss}}{\partial K}\frac{K}{e_{ss}} = \frac{\partial}{\partial K}\left[\frac{A}{K+A}\right]\frac{K}{e_{ss}}$$

$$= \frac{A(-1)}{(K+A)^2}\frac{K}{\left(\frac{A}{K+A}\right)}$$

$$S_K^{e_{ss}} = \frac{-K}{(K+A)}$$

23. Ans: (a)

Sol: It is a lead compensator

Transfer function of lead compensator is

$G_C(s) = \dfrac{(1+aTs)}{(1+Ts)}$ where $(a > 1)$

Maximum phase angle lead provided by the compensator is

$$\phi_m = \sin^{-1}\left(\frac{a-1}{a+1}\right) \quad (a>1)$$

From above transfer function, T = 1, aT= 3, $\therefore$ a = 3

$$\phi_m = \sin^{-1}\left(\frac{3-1}{3+1}\right) = \sin^{-1}\left(\frac{1}{2}\right) = 30^0$$

24. Ans: (b)

Sol: By using Laplace Transform on both the sides

$$\left(s^3+4s^2+5s+2\right)Y(s) = (s+1)X(s)$$

$$\frac{Y(s)}{X(s)} = \frac{(s+1)}{s^3+4s^2+5s+2}$$

s^3	1	5
s^2	4	2
s^1	18/4	0
s^0	2	

Number of sign changes = 0

$\therefore$ All the three poles are in LHP.

25. Ans: (b)

Sol: System is critically damped at A and B

26. Ans: (a)

Sol: Number of forward paths = 2

Number of loops = 3

There is no two non touching loops

27. Ans: (b)

Sol: Two poles at origin and one pole at s = –T

$\therefore$ Loop transfer function = $\dfrac{k}{s^2(s+T)}$

28. Ans: (b)

Sol: System will not oscillations when $\zeta \geq 1$.

29. Ans: (d)

Sol: $\left|\dfrac{k}{s}\right|_{\omega=1} = 36\text{dB}$

$\dfrac{k}{\omega} = 2^6$

$k = 2^6\,(\omega)$

$k = 2^6 = 64$

$\therefore K_V = k = 64$

30. Ans: (c)

Sol: Given $A = 10^3$

$dA = 200$

$\beta = 0.4\%$

$$A_f = \frac{A}{1+\beta A} = \frac{1000}{1+\dfrac{4}{1000}\times 1000}$$

$$= \frac{1000}{5}$$

$A_f = 200$

% change in gain of feedback amplifier $A_f = \left(\dfrac{1}{1+A\beta}\right)$ (% change in A)

$$= \frac{1}{5}\times\frac{200}{10^3}\times 100$$

$= 4$

31. Ans: (c)

Sol: $2k > -1 \Rightarrow k > \frac{-1}{2}$

and $\frac{k}{5} < 1 \Rightarrow k < 5$

$\therefore$ Range $-\frac{1}{2} < k < 5$

32. Ans: (d)

Sol: CE = $s^2 + 0.5s + k = 0$

Compare with $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$

$2\zeta\omega_n = 0.5$

$\omega_n = \frac{1}{4}$

$k = \left(\frac{1}{4}\right)^2 = \frac{1}{16} = 0.0625$

33. Ans: (a)

Sol: $\frac{dk}{ds} = 0 \Rightarrow \frac{d}{ds}\left[s^2 + 2s\right] = 0$

$\Rightarrow 2s+2 = 0$

$\therefore s = -1$

Breakaway point is $s = -1$.

34. Ans: (b)

Sol: When $1 < \frac{a}{b} < 2$, dominant frequency range is

$f_{c_{10}} < f < f_{c_{01}} \Rightarrow f_{c_{10}} < f < f_{c_{10}}\left(\frac{a}{b}\right) \quad \left(\text{say}, f_{c_{10}} = f_1 \text{ and } f_{c_{10}}\left(\frac{a}{b}\right) = f_2\right)$

here $\left(\frac{f_2}{f_1}\right)_{max} < 2 \rightarrow (1)$

If $\frac{a}{b} \geq 2$ then dominant frequency range is

$f_{c_{10}} < f < f_{c_{20}} \Rightarrow f_{c_{10}} < f < 2f_{c_{10}}$

$\left(\text{say}, f_{c_{10}} = f_1 \text{ and } 2f_{c_{10}} = f_2\right)$

here $\left(\frac{f_2}{f_1}\right)_{max} = 2 \rightarrow (2)$

$\therefore$ from (1) and (2) we can conclude $\left(\frac{f_2}{f_1}\right)_{max} = 2$

35. Ans: (d)

Sol:

(1) $\eta_{TE_{10}} = \dfrac{\eta}{\sqrt{1-\left(\dfrac{f_{c_{10}}}{f}\right)^2}}$ $\qquad$ $\eta_{TM_{11}} = \eta\sqrt{1-\left(\dfrac{f_{c_{11}}}{f}\right)^2}$

$\therefore \eta_{TE_{10}} > \eta$ $\qquad$ $\therefore\ \eta_{TM_{11}} < \eta$

$\therefore \eta_{TE_{10}} > \eta_{TM_{11}}$

(2) $\nu_{g_{TE_{10}}} = \nu\sqrt{1-\left(\dfrac{f_{c_{10}}}{f}\right)^2}$, $\qquad$ $\nu_{g_{TM_{11}}} = \nu\sqrt{1-\left(\dfrac{f_{c_{11}}}{f}\right)^2}$

$\because \left(\dfrac{f_{c_{11}}}{f}\right)^2 > \left(\dfrac{f_{c_{10}}}{f}\right)^2 \Rightarrow \nu_{g_{TE_{10}}} > \nu_{g_{TM_{11}}}$

(3) $\nu_{p_{TE_{10}}} = \dfrac{\nu}{\sqrt{1-\left(\dfrac{f_{c_{10}}}{f}\right)^2}}$, $\nu_{p_{TM_{11}}} = \dfrac{\nu}{\sqrt{1-\left(\dfrac{f_{c_{11}}}{f}\right)^2}}$

$\left(\dfrac{f_{c_{11}}}{f}\right)^2 > \left(\dfrac{f_{c_{10}}}{f}\right)^2$ implies $\nu_{p_{TM_{11}}} > \nu_{p_{TE_{10}}}$

$\therefore$ (1), (2) and (3) all are correct

36. Ans: (b)

Sol: For TE_{03} mode ($E_z = 0$, $H_z \neq 0$)

$$H_z = H_0 \cos\left(\frac{3\pi}{b} y\right) e^{-j\beta_{mn} z}$$

$$E_x = \frac{-j\omega\mu}{h^2}\frac{\partial H_z}{\partial y} \neq 0$$

$$E_y = \frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial x} = 0$$

$$H_x = \frac{-j\beta_{mn}}{h^2}\frac{\partial H_z}{\partial x} = 0$$

$$H_y = \frac{-j\beta_{mn}}{h^2}\frac{\partial H_z}{\partial y} \neq 0$$

From the above we can conclude that E_x, H_y and H_z components exists

37. Ans: (a)

Sol: Given: $f = 2f_{c_{10}}$ (TE_{10} is the dominant mode.)

$$v_{p_{10}} = \frac{c}{\sqrt{1-\left(\frac{f_{c_{10}}}{f}\right)^2}} = \frac{c}{\sqrt{1-\left(\frac{1}{2}\right)^2}} = \frac{3\times10^8}{\sqrt{\frac{3}{4}}} = \frac{6\times10^8}{\sqrt{3}} = 2\sqrt{3}\times10^8\,\text{m/sec}$$

38. Ans: (c)

Sol: We know that $v_p\,v_g = c^2$

$$\Rightarrow v_p(0.8c) = c^2\{\because v_g = 0.8c\}$$

$$\therefore v_p = \frac{c}{0.8} = \frac{c}{\sqrt{1-\left(\frac{f_{c_{10}}}{f}\right)^2}}$$

$$\Rightarrow 1-\left(\frac{f_{c_{10}}}{f}\right)^2 = (0.8)^2$$

$$\Rightarrow \left(\frac{f_{c_{10}}}{f}\right)^2 = 1-0.64 = 0.36$$

$$\therefore f_{c_{10}} = (0.6)f = 0.6\times6\times10^9\{\because f = 6\text{GHz}\}$$

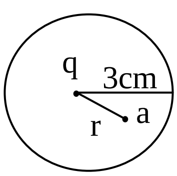
$$\therefore f_{c_{10}} = 3.6\text{GHz}$$

$$\because f_{c_{10}} = \frac{c}{2a} = 3.6\text{GHz}, a = \frac{c}{2\times3.6\times10^9} = \frac{3\times10^{10}}{2\times3.6\times10^9}$$

$= 4.167$cm

39. Ans: (b)

Sol:



Electric field intensity at point 'a' inside the cavity is given by

$$E = \frac{q}{4\pi\varepsilon_0 r^2} = \frac{9\times10^9\times2\times10^{-7}}{(1.5\times10^{-2})^2}$$

$$= \frac{9\times2\times10^2}{1.5\times1.5\times10^{-4}} = 8\times10^6 \text{ V/m (or) N/C}$$

Within a perfect conductor $\vec{E} = 0$ and hence electric field intensity at point 'b' is zero.

40. Ans: (c)

Sol: The energy stored in a capacitor, with spacing between plates is

$$E_0 = \frac{1}{2}CV^2$$

If spacing is doubled then $C' = \frac{\varepsilon A}{(2d)} = \frac{C}{2}$

The energy stored is given by

$$E_0' = \frac{1}{2}C'V^2 = \frac{1}{2}\frac{C}{2}V^2 = \frac{1}{2}\left\{\frac{1}{2}CV^2\right\} = \frac{E_0}{2}$$

$$\therefore E_0' = \frac{E_0}{2}$$

41. Ans: (c)

Sol: Given:

Electric flux density, $\vec{D} = 24\hat{i} + 30\hat{j} + 16\hat{k}\ \ C/m^2$

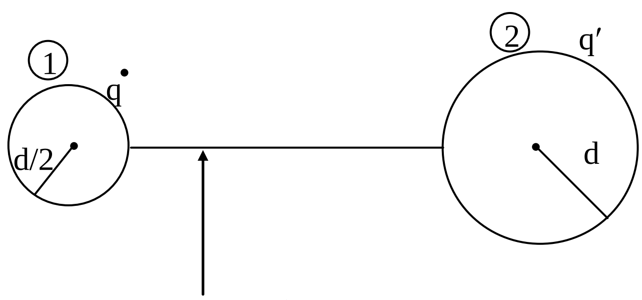
Displacement flux crossing the surface

x = constant (or) yz plane of area $2m^2$ is given by $\psi = \vec{D}.\vec{S}$

$\psi = D_x \times$ Area = 24×2 = 48C

42. Ans: (a)

Sol:



When the two spheres are connected by a conducting wire, charge will flow (transfer) from one to another until their potentials are equal. (they will become equipotential surfaces)

i.e. $V_1 = V_2$

$$\frac{1}{4\pi\varepsilon}\frac{q}{\left(\frac{d}{2}\right)} = \frac{1}{4\pi\varepsilon}\frac{q'}{(d)}$$

2q = q′

(or) q′ = 2q

q′: charge on larger sphere.

Therefore conducting spheres (1) & (2) can have the same potential, but they can not have the same charge.

43. Ans: (a)

Sol: (A) Ampere's law in current free region

$$\nabla \times \vec{H} = 0 \ \& \ \nabla \times \frac{\vec{B}}{\mu} = 0$$

If the medium is homogenous, then

$$\nabla \times \vec{H} = 0 \ \& \ \nabla \times \vec{B} = 0$$

(B) Gauss's law in source free ($\rho_V = 0$) region

$$\nabla . \vec{D} = 0 \ \& \ \nabla . \varepsilon \vec{E} = 0$$

If the medium is non-homogeneous, then $\nabla . \vec{D} = 0$

(C) At low frequency Kirchhoff's voltage law is given by

$$\nabla \times \vec{E} = 0$$

(D) Kirchhoff's current law is given by

$$\nabla . \vec{J} = 0$$

$\therefore$ Matching code: A-2, B-5, C-4, D-3

44. Ans: (b)

Sol: $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}}$

So, Z_0 is independent of length. So the characteristic impedance of new line is the same Z_0.

45. Ans: (c)

Sol: For loss less transmission line (R= G = 0), $Z_0 = \sqrt{\dfrac{L}{C}}$

46. Ans: (d)

Sol: $t_r = \dfrac{l}{v} = \dfrac{4}{2 \times 10^8} = 2 \times 10^{-8} = 20 \text{n sec}$

47. Ans: (d)

Sol: $\Gamma_L = \dfrac{Z_L - Z_0}{Z_L + Z_0} = \dfrac{100 - 75}{100 + 75} = \dfrac{1}{7}$

$$\Gamma_g = \frac{Z_g - Z_0}{Z_g + Z_0} = \frac{50 - 75}{50 + 75} = -\frac{1}{5}$$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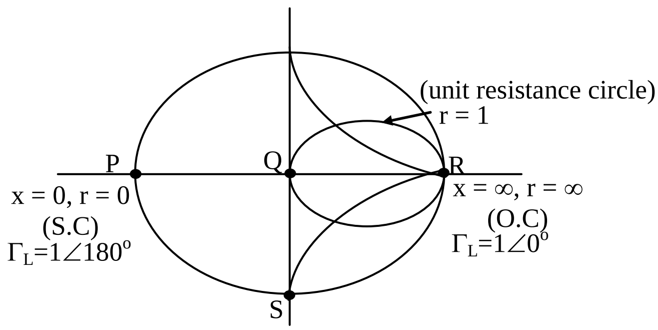
48. Ans: (b)

Sol: Statement (1), (2) and (4) are correct for a normalized impedance smith chart.

49. Ans: (c)

Sol:



(Normalized impedance $\left(\bar{z} = \frac{Z_L}{Z_0}\right)$ smith chart)

Point P: Indicates r = 0, x = 0 i.e., short circuit and with reflection co-efficient $\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = -1 = 1\angle 180^o$

Point Q: Indicates r = 1, x = 0

i.e., Normalized impedance $\bar{z} = \frac{Z_L}{Z_0} = 1$ and reflection co-efficient

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Z_L/Z_0 - 1}{Z_L/Z_0 + 1} = \frac{1-1}{1+1} = 0$$

i.e., transmission line is matched terminated ($Z_L = Z_0$)

Point R: Indicates r = ∞, x = ∞ i.e., open circuit and with reflection co-efficient

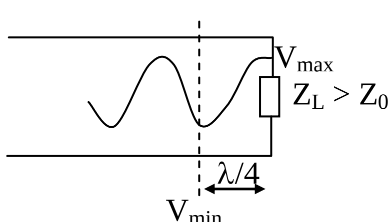
$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{1 - Z_0/Z_L}{1 + Z_0/Z_L} = 1 = 1\angle 0^o$$

Point S indicates pure capacitance load

So, 2 and 4 are correct.

50. Ans: (c)

Sol: $Z_L > Z_0$ (at load V_{max})



λ = 8cm

$$\frac{\lambda}{4} = 2\text{cm}$$

51. Ans: (d)

Sol: $V_L = |V^+|\,(1 + |\Gamma_L|\,e^{j\phi_L})$

$V_L = |V^+|\,[1 - |\Gamma_L|]$, $|\Gamma_L| = \left|\dfrac{50-100}{100+50}\right| = \dfrac{1}{3}$

$40 = |V^+|\,[1 - 1/3]$

$|V^+| = 60V$

$$P = \frac{|V^+|^2}{2Z_0}[1 - |\Gamma_L|^2] = \frac{60\times 60}{2\times 100}[1-(1/9)] = 16\text{Watts}$$

52. Ans: (b)

Sol: $$\bar{E}_s = \frac{\rho_S}{2\varepsilon_0}\hat{a}_n = \frac{20\times 10^{-9}}{2\times\frac{10^{-9}}{36\pi}}\times(-\hat{a}_z) = -360\pi\hat{a}_z\,V/m$$

53. Ans: (d)

Sol: $\bar{A} = 4x\hat{a}_x + 6y\hat{a}_y + 8z\hat{a}_z$

$$\oint_s \bar{A}.d\bar{s} = \int(\nabla.\bar{A})dV$$

$\nabla.\bar{A} = 4 + 6 + 8 = 18$

$$\oint_s \bar{A}.d\bar{s} = \int(\nabla.\bar{A})dV = \int 18\,dV$$

$$\oint_s \bar{A}.d\bar{s} = 18V$$

54. Ans: (d)

Sol: In a rectangular waveguide the longitudinal components will not contribute to the power transfer along the waveguide. Here in the above given rectangular waveguide the longitudinal components are E_z & H_z.

55. Ans: (b)

Sol: Cut-off frequency $f_0 = \dfrac{c}{2a} = \dfrac{3\times 10^{10}}{2\times 2.25} = 6.67\,\text{GHz}$

We introduce a dielectric medium of dielectric constant 'ε_r' then

Cut-off frequency $f_0' = \dfrac{f_0}{3} = \dfrac{c}{2a\sqrt{\varepsilon_r}} = \dfrac{f_0}{\sqrt{\varepsilon_r}}$

$$\therefore \frac{f_0}{3} = \frac{f_0}{\sqrt{\varepsilon_r}}$$

$$\varepsilon_r = 9$$

56. Ans: (a)

Sol: $P_r = G_{dr} G_{dt} \left[\frac{\lambda}{4\pi r}\right]^2 P_t$

$P_r = G_{dr} G_{dt} \frac{\lambda}{4\pi}^2 \times \frac{\lambda}{4\pi}^2 \times \frac{1}{r^2 \lambda^2} \times P_t$

$P_r = \frac{A_{er} \times A_{et}}{r^2 \lambda^2} P_t = \frac{A_{er} \times A_{et} \times P_t}{r^2 c^2} f^2$

$\therefore P_r = \frac{A_{er} \times A_{et} \times P_t}{r^2 c^2} f^2 \quad \left\{\because \lambda^2 = \frac{c^2}{f^2}\right\}$

$P_r \propto f^2$

$\therefore \frac{P_{r1}}{P_{r2}} = \frac{f_1^2}{f_2^2} = \left(\frac{12}{36}\right)^2 = \frac{1}{9}$

$\therefore P_{r2} = 9P_{r1}$

57. Ans: (a)

Sol:

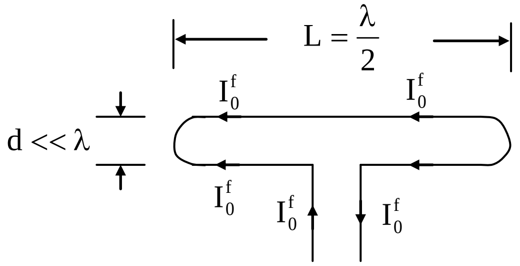


Figure: Geometry of folded dipole

The power radiated by the folded dipole is

$P_{rad}^f = \frac{1}{2} I_0^2 R_{rad}^f$

For the same input current power radiated by the single dipole is

$P_{rad}^d = \frac{1}{2} I_0^2 R_{rad}^f$

$\because$ The field of a folded dipole is twice that of a single dipole and the power radiated must be four times for the same input current I_0

$\therefore\ P_{rad}^f = 4P_{rad}^d$

$\frac{1}{2} I_0^2 R_{rad}^f = 4\frac{1}{2} I_0^2 R_{rad}^d$

$\therefore\ R_{rad}^f = 4 R_{rad}^d$

58. Ans: (c)

Sol: For q_3 to be in equilibrium, net force acting on q_3 is zero

$$F_{31} + F_{32} = 0$$

$$\frac{1}{4\pi\varepsilon}\left[\frac{q_1 q_3}{(2x)^2} + \frac{q_2 q_3}{x^2}\right] = 0$$

$$\frac{q_1}{4} = -q_2$$

$$q_1 = -4q_2$$

59. Ans: (b)

Sol: $f = \frac{\sigma}{2\pi\varepsilon_r\varepsilon_0} = \frac{5}{2\pi \times \frac{10^{-9}}{36\pi} \times 1}$

$$f = 9\times 10^{10}\,\text{Hz}$$

60. Ans: (d)

Sol: $\frac{\lambda}{2} \rightarrow \frac{T}{2}$

$$t_1 = \frac{T}{2} = \frac{1}{2}\left(\frac{2\pi}{\omega}\right) = \frac{\pi}{10^8}$$

$t_1 = 31.42$ ns

61. Ans: (b)

Sol: Given

$\alpha z = \pi$

$$\alpha = \frac{\pi}{2.5}$$

For good conductor $\alpha = \beta = \frac{\pi}{2.5}$

So, $d = \frac{2\pi}{\beta}$

$$d = \frac{2\pi}{\left(\frac{\pi}{2.5}\right)} = 5\text{m}$$

62. Ans: (a)

Sol: The mean/time average Poynting vector is given as,

$$P_{avg} = \frac{E_m}{\sqrt{2}} \times \frac{H_m}{\sqrt{2}} = \frac{1}{2} E_m . H_m$$

But, $\frac{E_m}{H_m} = \eta$ (intrinsic impedance)

$$P_{avg} = \frac{E_m^2}{2\eta} \quad \text{........... (1)}$$

$$\because \eta = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \sqrt{\frac{\mu_0^2}{\mu_0\varepsilon_0}} = \frac{\mu_0\omega}{\omega\sqrt{\mu_0\varepsilon_0}}$$

Again, $\because \beta = \omega\sqrt{\mu_0\varepsilon_0}$

{β is the phase constant in rad/m}

$$\Rightarrow \eta = \frac{\omega\mu_0}{\beta} \quad \text{............(2)}$$

Also, velocity of the EM wave in free space,

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow c^2 = \frac{1}{\mu_0\varepsilon_0}$$

$$\mu_0 = \frac{1}{c^2\varepsilon_0} \quad \text{...........(3)}$$

From equation (2)

$$\eta = \frac{\omega}{\beta c^2\varepsilon_0} \quad \text{...........(4)}$$

From equation (4) $\rightarrow$ (1)

$$P_{avg} = \frac{E_m^2}{2 \times \frac{\omega}{\beta c^2 \omega_0}} = \frac{\beta c^2 \varepsilon_0 E_m^2}{2\omega}$$

63. Ans: (b)

Sol: Given data,

$$E(t,z) = \hat{a}_x 2\cos\left[10^8 t - \frac{z}{\sqrt{3}}\right] - \hat{a}_y \sin\left[10^8 t - \frac{z}{\sqrt{3}}\right] (V/m)$$

On comparing the given electric field equation with the standard equation, one gets phase constant,

$$\beta = \frac{1}{\sqrt{3}} \text{ rad/m}$$

Angular frequency, $\omega = 10^8$ rad/sec

Now, velocity of the wave is given as,

$v = \frac{\lambda}{T}$ {where, λ is the wave length and T is the time period}

$$v = \frac{\lambda}{2\pi} \times \frac{2\pi}{T} = \frac{\omega}{\beta} \quad \left\{\because \omega = \frac{2\pi}{T} \text{ and } \beta = \frac{2\pi}{\lambda}\right\}$$

$$v = \frac{10^8}{\frac{1}{\sqrt{3}}} = \sqrt{3} \times 10^8 \text{ m/sec} \quad \text{............. (1)}$$

But, $v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\varepsilon_0\varepsilon_r}}$ {For dielectric medium}

$$v = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \times \frac{1}{\sqrt{\varepsilon_r}}$$

But, $v_0 = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$ = velocity in free space

$= 3 \times 10^8$ m/sec

$$v = \frac{3\times10^8}{\sqrt{\varepsilon_r}} \quad \text{..............(2)}$$

From equation (1) & (2)

$$\frac{3\times10^8}{\sqrt{\varepsilon_r}} = \sqrt{3}\times10^8$$

$\Rightarrow \varepsilon_r = 3$

64. Ans: (d)

Sol: Boundary condition at the interface between two dielectrics:

Case-(i): If the interface has non-zero

Charge density, ρ_s c/m^2,

then $D_{n_1} - D_{n_2} = \rho_s$ and

$\in_1 E_{n_1} - \in_2 E_{n_2} = \rho_s$

Case-(ii): If the interface is charge-free ($\rho_s = 0$)

then $D_{n_1} = D_{n_2}$ and

$\in_1 E_{n_1} = \in_2 E_{n_2}$

Boundary condition at the interface between two magnetic media:

Case-(i): If the interface has non-zero surface current density, $\vec{K}$ A/m

Then $H_{t_1} - H_{t_2} = K$ and

$$\frac{B_{t_1}}{\mu_1} - \frac{B_{t_2}}{\mu_2} = K$$

Case-(ii): If the interface is current-free ($\vec{K}$ =0) then $H_{t_1} = H_{t_2}$ and $\frac{B_{t_1}}{\mu_1} = \frac{B_{t_2}}{\mu_2}$

$\therefore$ Correct code: A–5, B –2, C–3, D – 4

65. Ans: (a)

Sol: loss tangent, $\tan\phi = \dfrac{\sigma}{\omega\varepsilon}$

or dissipation factor

if $\dfrac{\sigma}{\omega\varepsilon} >> 1 \Rightarrow$ good conductor

$\dfrac{\sigma}{\omega\varepsilon} = \infty \Rightarrow$ perfect conductor

$\dfrac{\sigma}{\omega\varepsilon} << 1 \Rightarrow$ good dielectric

$\dfrac{\sigma}{\omega\varepsilon} = 0 \Rightarrow$ perfect dielectric

66. Ans: (a)

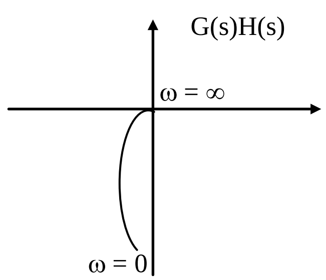
Sol: Given $G(s)H(s) = \dfrac{10(s+4)}{s(s+2)}$

$|G(j\omega)H(j\omega)| = \dfrac{10\sqrt{\omega^2+16}}{\omega\sqrt{\omega^2+4}}$

$\angle G(j\omega)H(j\omega) = -90^o - \tan^{-1}\left(\dfrac{\omega}{2}\right) + \tan^{-1}\left(\dfrac{\omega}{4}\right)$

$\omega = 0 \quad \infty\angle{-90^o}$

$\omega = \infty \quad 0\angle{-90^o}$



Nyquist plot does not intersect the negative real axis hence GM = ∞.

67. Ans: (c)

Sol: Number of right half of s-plane poles can not be found from the Bode plot.

68. Ans: (c)

Sol: By adding pole to the open loop system order increases hence rise time increases.
Rise time is inversely proportional to bandwidth. Hence statement (II) wrong.

69. Ans: (a)

Sol: CE = $s^2 + 4s + 4 = 0$

$2\zeta\omega_n = 4$

$\omega_n = 2$ rad/sec,

$\zeta = 1$

$\therefore M_P = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}} = 0$

70. Ans: (d)

Sol: If open loop control system is stable we can not say exactly closed loop control system is stable. Closed loop system may or may not be stable.

71. Ans: (b)

Sol: **Statement (I):** $\because \sigma_c \neq \infty$ and $\sigma_d = 0$

attenuation is only due to conductivity of the walls (i.e) $\alpha = \alpha_c$ Np/m

$$\text{where, } \alpha_c = \frac{R_s\left[1+\frac{2b}{a}\left(\frac{f_c}{f}\right)^2\right]}{\eta b} \rightarrow (1)$$

$\therefore$ for $\frac{a}{b} = \text{constant} \Rightarrow a \propto b$ (i.e) as 'a' increases (or) decrease, 'b' has to increase (or) decreases in the same proportion.

$\therefore$ from (1) as 'a' increases, 'b' also increases then $\alpha_c \downarrow \left[\because \alpha_c \propto \frac{1}{b}\right]$

and similarly as 'a' decreases, 'b' also decreases then $\alpha_c \uparrow \left[\because \alpha_c \propto \frac{1}{b}\right]$

$\therefore$ "S_1" is true

Statement (II): $f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

as 'f' increases, 'f_c' also has to increase in the same proportion in order to maintain the frequency band always between f_c and $2f_c$. So, from the above relation we can say for 'f_c' to increase the dimensions of the waveguide must decreases

$\therefore$ S_2 is true

72. Ans: (b)

Sol: **Statement (I):** For TEM wave $\eta = \sqrt{\frac{\mu}{\varepsilon}}$

For TE wave, $Z_{TE} = \dfrac{\eta}{\sqrt{1-\left(\dfrac{f_c}{f}\right)^2}} \rightarrow (1)$

For TM wave, $Z_{TM} = \eta\sqrt{1-\left(\dfrac{f_c}{f}\right)^2} \rightarrow (2)$

$Z_{TE} \times Z_{TM} = \eta^2$

$\therefore$ 'S1' is true

Statement (II): We can represent the field components of TE and TM modes as sum and differences of TEM waves.

for example, TE_{mn} ($E_z = 0$, $H_z \neq 0$)

$$H_z = H_0 \cos\left(\frac{m\pi}{a}x\right)\cos\left(\frac{n\pi}{b}y\right)e^{-j\beta_z z}$$

$$H_z = H_0 \cos(\beta_x x)\cos(\beta_y y)e^{-j\beta_z z}$$

$$= H_0\left(\frac{e^{j\beta_x x} + e^{-j\beta_x x}}{2}\right)\left(\frac{e^{j\beta_y y} + e^{-j\beta_y y}}{2}\right)e^{-j\beta_z z}$$

$$= \frac{H_0}{4}\left[\left(e^{j(\beta_x x-\beta_z z)} + e^{-j(\beta_x x+\beta_z z)}\right)\left(e^{j\beta_y y} + e^{-j\beta_y y}\right)\right]$$

$$= \frac{H_0}{4}\begin{bmatrix} e^{j(\beta_x x+\beta_y y-\beta_z z)} + e^{j(\beta_x x-\beta_z z-\beta_y y)} \\ + e^{-j(\beta_x x+\beta_z z-\beta_y y)} + e^{-j(\beta_x x+\beta_z z+\beta_y y)} \end{bmatrix}$$

$\therefore$ In the above expression each term represents an TEM wave

$\therefore TE_{mn}$ mode can be represented as summation (or) differences of TEM modes.

73. Ans: (d)

Sol: From Maxwell's equations:

(i) $\nabla \times \vec{H} = \vec{J}$ & $\nabla \times \dfrac{\vec{B}}{\mu} = \vec{J}$

(ii) $\nabla.\vec{B} = 0$ & $\nabla.\mu\vec{H} = 0$

For current-free medium: $\vec{J} = 0$

(i) $\nabla \times \vec{H} = 0$ & $\nabla \times \dfrac{\vec{B}}{\mu} = 0$

(ii) $\nabla.\vec{B} = 0$ & $\nabla.\mu\vec{H} = 0$

If the medium is inhomogeneous then

(i) $\nabla \times \vec{H} = 0$ & $\nabla \times \vec{B} \neq 0$

(ii) $\nabla.\vec{B} = 0$ & $\nabla.\vec{H} \neq 0$

From the above two equations:
In a current-free, inhomogeneous medium magnetic flux density is solenoidal but not irrotational.
If the medium is homogeneous

Then (i) $\nabla \times \vec{H} = 0$ & $\nabla \times \vec{B} = 0$

(ii) $\nabla . \vec{B} = 0$ & $\nabla . \vec{H} = 0$

Above two equations states that the magnetic field intensity is solenoidal and irrotational, when the medium is current-free and homogeneous.
Therefore statement-I is false and statement-II is true.

74. Ans: (b)

Sol: Statement (I): power absorbed in terminating resistive load 'P_L' is

$$P_L = \frac{V_{out}^2 R_{load}}{(R_{load} + R_{ant})^2}$$

The power re-radiated from the antenna is P_R

$$P_R = \frac{V^2 R_{ant}}{(R_{load} + R_{ant})^2}$$

Now when $R_{load} = R_{ant}$ (matched condition) $\Rightarrow P_L = P_R$.
(i.e) as much power is scattered as is absorbed

Statement (II): When an E-field is oriented relative to a receive antenna at some angle α, the induced open circuit voltage in the antenna is $V_{oc} = \ell_e(\theta) E \cos\alpha$ - - - - - - (1)

Where $E\cos\alpha \rightarrow$ is the component of E-field that lies along the axis of the antenna.

$\ell_e(\theta) \rightarrow$ is the effective length of the antenna

$\therefore$ From (1) we can see that if $\alpha = 90^o$ then $\cos\alpha = 0^o$ and no signal will be received.

Note: Such situations imply that two orthogonally linearly polarized antennas can carry information at the same frequency with out interfering with each other. This is a technique called polarization diversity.

75. Ans: (a)

Sol: According to Faraday's experiment, electric flux (or) displacement is independent of dielectric constant (ε_r) or relative permittivity of medium.

As electric flux (or) displacement flux is independent of permittivity of medium displacement flux density (or) electric flux density is also independent of permittivity of medium.

Ex: $\vec{D}$ due to point charge is given by

$$\vec{D} = \frac{Q}{4\pi r^2} \hat{a}_r C/m^2$$

Hence Statement (I) and Statement (II) are true and Statement (II) is the correct explanation for Statement (I).

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