TEST ID: 103

ACE
Engineering Academy

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ESE- 2020 (Prelims) - Offline Test Series Test- 5

ELECTRONICS & TELECOMMUNICATION ENGINEERING

SUBJECT: CONTROL SYSTEMS AND ELECTROMAGNETICS - SOLUTIONS

01. Ans: (b)

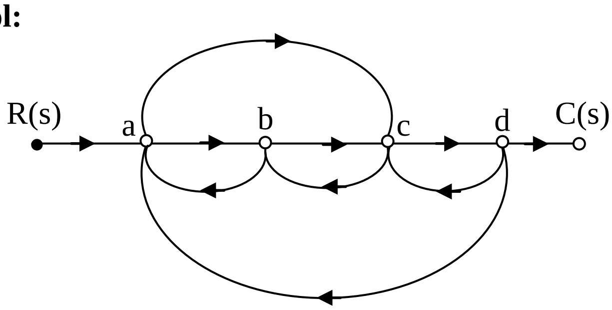
Sol: $C = aR - C\beta$

$C(1+\beta) = aR$

$$\frac{C}{R} = \frac{a}{1+\beta}$$

02. Ans: (b)

Sol:



Number of individual loops = 6

$\rightarrow$ aba, bcb, cdc, abcda, acda, acba

03. Ans: (a)

Sol: Human body system is a complex multi variable feedback system.

04. Ans: (d)

Sol: TF = $\dfrac{C(s)}{R(s)} = \dfrac{s+\omega}{s^2+\omega^2}$

$r(t) = \delta(t)$, $R(s) = 1$

$$C(s) = \frac{s+\omega}{s^2+\omega^2} = \frac{s}{s^2+\omega^2} + \frac{\omega}{s^2+\omega^2}$$

Apply inverse Laplace transform

$c(t) = \cos(\omega t) + \sin(\omega t)$

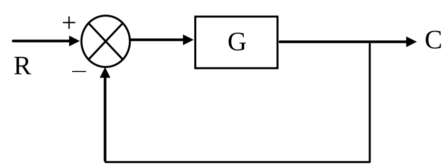
$$= \sqrt{2}\left[\frac{1}{\sqrt{2}}\cos(\omega t) + \frac{1}{\sqrt{2}}.\sin(\omega t)\right]$$

$$= \sqrt{2}\,[\sin 45^\circ \cos(\omega t) + \cos 45^\circ.\sin(\omega t)]$$

$$= \sqrt{2}\ \left(\sin(\omega t + 45^\circ)\right) = \sqrt{2}\sin\left(\omega t + \frac{\pi}{4}\right)$$

05. Ans: (b)

Sol:



$$\frac{C}{R} = \frac{s+4}{s^2+7s+13}$$

$$G(s) = \frac{s+4}{s^2+6s+9}$$

DC gain s = 0 $\Rightarrow$ G(0) = $\dfrac{4}{9}$

06. Ans: (a)

Sol: DC gain = 1.5

$$TF = \frac{K(s+3)}{(s+2)(s+4)} \Rightarrow \underset{s\to 0}{Lt}\frac{K(s+3)}{(s+2)(s+4)} = 1.5$$

$\therefore$ K = 4

07. Ans: (c)

Sol: Characteristic Equation

$= (s+1)^2(s+2) + (s^2+2s+3) = 0$

$\therefore$ Order of system is 3

08. Ans: (d)

Sol: $TF = \dfrac{k}{(s^2+1^2)^2}$

$IR = L^{-1}\left[\dfrac{k}{(s^2+1^2)^2}\right]$

IR = kt sin t

09. Ans: (c)

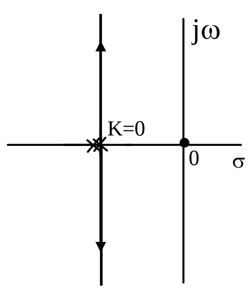
Sol:
- ⇒ PI controller is equivalent to lag compensator
- ⇒ PD controller is equivalent to lead compensator
- ⇒ PID controller is equivalent to lead - lag compensator.
- ⇒ ON-OFF controller is also known as relay controller

10. Ans: (b)

Sol: CE = 1+G(s) = 0

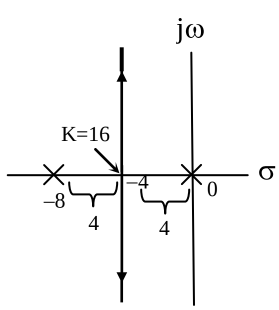
CE = $s^2 + 2s + K + 1 = 0$

$G(s) = \dfrac{K}{s^2+2s+1} = \dfrac{K}{(s+1)^2}$



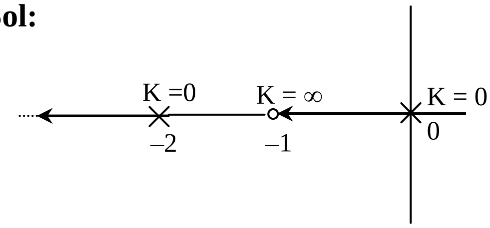
11. Ans: (c)

Sol: $G(s)H(s) = \dfrac{K}{s(s+8)}$



12. Ans: (c)

Sol:



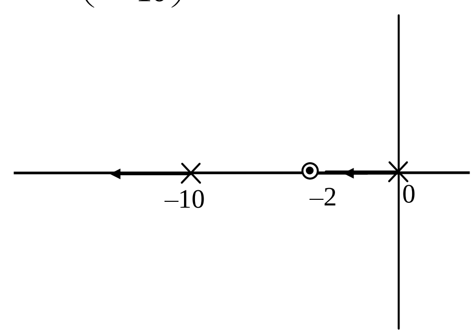
Break point does not exist

13. Ans: (c)

Sol: type 0 system: open loop pole at origin.

14. Ans: (b)

Sol: $TF = \dfrac{K\left(1+\dfrac{s}{2}\right)}{s\left(1+\dfrac{s}{10}\right)} = \dfrac{5K(s+2)}{s(s+10)}$

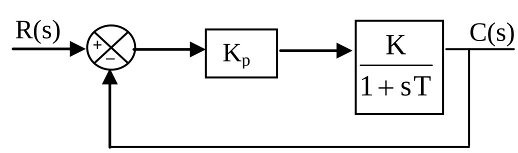


15. Ans: (c)

Sol: $\dfrac{V_0(s)}{V_i(s)} = \dfrac{1M+\dfrac{1}{s1\mu}}{1M+1M+\dfrac{1}{s1\mu}} = \left(\dfrac{s+1}{2s+1}\right)$

16. Ans: (b)

Sol:



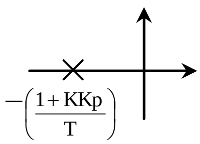
$\xrightarrow{e_{ss}}$ $G(s) = \dfrac{KKp}{1+sT}, H(s) = 1$

$e_{ss} = \dfrac{A}{1+K_p} = \dfrac{1}{1+KK_p}$

As K_p increases $\Rightarrow e_{ss}$ decreases

$$\text{CLTF} = \frac{KK_p}{sT+1+KK_p}$$

$$S = \frac{-(1+KK_p)}{T}$$



$$T_{CL} = \frac{T}{(1+KK_p)}$$

K_p increases $\rightarrow$ Time constant of closed loop system decreases.

17. Ans: (a)

Sol: N = P – Z

N = 0, P = 0

$\therefore$ Z = 0

18. Ans: (a)

Sol:

1. One pole at origin $\Rightarrow$ slope of bode plot $\frac{K}{s}$ is –20dB/dec

2. $G(s) = \frac{1-s}{1+s}$

   $G(j\omega) = \frac{1-j\omega}{1+j\omega}$

   $\omega = 0 \Rightarrow 1\angle 0°$

   $\omega = \infty \Rightarrow -1\angle -180°$

   $\therefore$ Nyquist plot not a straight line

3. $G(j\omega) = \frac{1}{1-j\omega}$

   At $\omega = 0 \Rightarrow \phi = -\tan^{-1}\omega = -\tan^{-1}(0) = 0°$

19. Ans: (d)

Sol: Since the system is unstable, the steady state output is unbounded.

20. Ans: (a)

Sol: $\angle \frac{10}{j\omega(j\omega+4)(j\omega+6)} = -180°$

$\omega = \sqrt{24}$ rad/sec

$$\left|\frac{10}{j\omega(j\omega+4)(j\omega+6)}\right| = \frac{10}{240}$$

$$GM = \frac{240}{10} = 24$$

21. Ans: (c)

Sol: **Minimum phase system:** It is a system in which poles and zeros will not lie in the right side of S-plane. For a minimum phase system

Eg: $G(s)H(s) = \frac{K(s+10)}{s(s+1)(s^2+2s+2)}$

Non minimum phase system: It is a system in which some of the poles and zeros may lie in the right side of s-plane. In particular zeros lie in the right side of s-plane.

Eg: $G(s)H(s) = \frac{K(s-10)}{s(s+20)}$

All pass system: It has constant gain at all frequencies, hence all frequencies are transmitted.

Eg: $G(s)H(s) = \frac{1-aTs}{1+aTs}$

22. Ans: (c)

Sol: $$G(s) = \frac{k}{s\left(1+\frac{s}{2}\right)\left(1+\frac{s}{8}\right)}$$

$$= \frac{k}{s(1+sT_1)(1+sT_2)}$$

20 log k = 26 dB

k = 20

point of intersection = $\frac{kT_1T_2}{T_1+T_2} = 2$

23. Ans: (d)

Sol: $|G(j\omega)|$ at ω = 40 = 60 – 12 = 48 dB

$|G(j\omega)|$ at ω = 160 = 48 – (6 × 2) = 36 dB

24. Ans: (d)

Sol: For system to be unstable

- One or more poles must lie in the right half of s - plane
- Repeated poles lie on the imaginary axis
- Repeated poles lie at the origin.

25. Ans: (a)

Sol: Characteristic Equation = $1+\frac{8k}{s(s+10)} = 0$

$$\begin{array}{c|cc} s^2 & 1 & 8k \\ s^1 & 10 & \\ s^0 & 8k & \end{array}$$

$s^2 + 10s + 8k = 0$

$8\,k > 0$

$k > 0$

For any value of k > 0 system is stable

26. Ans: (b)

Sol:

$$\begin{array}{c|ccc} +s^5 & 1 & 1 & 1 \\ +s^4 & 1 & 1 & 1 \\ +s^3 & 0(2) & 0(1) & 0 \\ +s^2 & \frac{1}{2} & 1 & 0 \\ -s^1 & -3 & 0 & \\ +s^0 & 1 & & \end{array}$$

$AE = s^4 + s^2 + 1 = 0$

$\frac{dA}{ds} = 4s^3 + 2s$

$= 2s^3 + s$

Two sign changes in the 1st column

$$\left.\begin{array}{r} \therefore \text{ Number of RHP} = 2 \\ j\omega P = 0 \\ LHP = 3 \end{array}\right\} \text{unstable}$$

27. Ans: (b)

Sol:

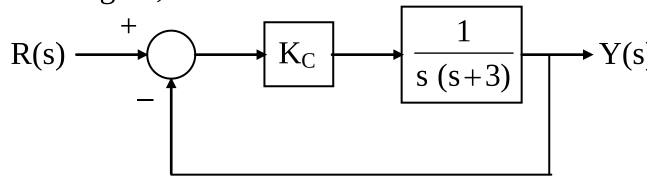
s^3	1	16
s^2	10	k
s^1	$\frac{160-k}{10}$	
s^0	k	

$160 - k = 0$

$k = 160$

28. Ans: (c)

Sol: Given block diagram is shown in below figure,



Characteristic equation is $s(s+3) + K_C = 0$

$s^2 + 3s + K_C = 0$

Poles to be on left of $s = -1$, put $s + 1 = z$

$(z-1)^2 + 3(z-1) + K_C = 0$ $\Rightarrow s = z - 1$

$z^2 + z + K_C - 2 = 0$

by applying Routh's criteria we get,

$$\begin{array}{c|cc} z^2 & 1 & K_C - 2 \\ z^1 & 1 & \\ z^0 & K_C - 2 & \end{array}$$

$K_C - 2 > 0$

$\Rightarrow K_C > 2$ for the poles to be on left of $s = -1$

29. Ans: (a)

Sol: Poles of the output are input and system poles i.e., –4, –1 and –10

$\therefore$ Time constants are $\frac{1}{4}$, 1 and $\frac{1}{10}$ sec

30. Ans: (c)

Sol: $M_p = \left(e^{\frac{-n\zeta\pi}{\sqrt{1-\zeta^2}}}\right) = e^{\left(-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}\right)^n}$

1^{st} under shoot = $\left(e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}\right)^2 = 0.25$

1^{st} over shoot = $e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} = 0.5$

2^{nd} over shoot $\left(e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}\right)^3 = (0.5)^3 = 0.125$

31. Ans: (d)

Sol: Let a = 2, b = 6 $\frac{s+a}{s+b}$

aT = 1/2, T = 1/6, a = 3, $\sin^{-1}\frac{a-1}{a+1} = 30^0$

32. Ans: (d)

Sol: CLTF : $\frac{C(s)}{R(s)} = \frac{6}{s+11}$

The unit step response is given by

$$C(s) = \frac{6}{s(s+11)} = \frac{6/11}{s} - \frac{6/11}{s+11}$$

$$c(t) = \left(\frac{6}{11} - \frac{6}{11}e^{-11t}\right)u(t)$$

33. Ans: (d)

Sol:
- Root loci starts at poles and ends at zero of the loop transfer function G(s) H(s)
- At poles of G(s) H(s) the value of k = 0
- At zeros of G(s) H(s) the value of k = ∞

34. Ans: (b)

Sol: $$TF = \frac{\frac{100}{s(1+4s)}}{1-\left[\frac{100(-1)}{s(1+4s)} + \frac{K_0 s(-1)}{s(1+4s)}\right]}$$

$$\frac{C(s)}{R(s)} = \frac{100}{s(1+4s)+K_0 s+100}$$

Characteristic Equation is

$$s^2 + \frac{(1+K_0)}{4}s + 25 = 0$$

$$\omega_n = 5\,\text{rad/sec} \qquad 2\zeta\omega_n = \frac{1+K_0}{4}$$

$$2\times 0.5\times 5 = \frac{(1+K_0)}{4}$$

$$K_0 = 19$$

35. Ans: (c)

Sol: $D = 4\pi\frac{A_e}{\lambda^2}$

$$A_{emax} = \frac{D\lambda^2}{4\pi} = \frac{4\pi}{4\pi}\lambda^2$$

$\therefore A_{emax} = \lambda^2$

36. Ans: (d)

Sol: For lossless transmission line, input impedance, $Z_{in} = Z_0\left[\frac{Z_R + jZ_0\tan\beta\ell}{Z_0 + jZ_R\tan\beta\ell}\right]$

Given: length of the line $\ell = \frac{\lambda}{2}$

$$\ell = \frac{\lambda}{2} \Rightarrow \beta\ell = \frac{2\pi}{\lambda}\times\frac{\lambda}{2} = \pi$$

$\tan\beta l \equiv \tan\pi = 0$

$$Z_{in} = Z_0\left(\frac{Z_R + j0}{Z_0 + j0}\right)$$

$\therefore Z_{in} = Z_R = (40 + j30)\Omega$

37. Ans: (b)

Sol: Far electric field intensity, $E \propto \frac{1}{r}$

$$\frac{E_2}{E_1} = \frac{r_1}{r_2}$$

Given

$r_1 = 100\text{m} \quad E_1 = 200\text{V/m (rms)}$

$r_2 = 1000\text{m}$

$$\frac{E_2(\text{rms})}{E_1(\text{rms})} = \frac{100}{1000}$$

$$E_2(\text{rms}) = \frac{100}{1000}\times 200 = 20\text{ V/m}$$

Average power density, $W_{avg} = \frac{E_2^2(\text{rms})}{\eta_0}$

$$W_{avg} = \frac{400}{\eta_0}\text{ W/m}^2$$

38. Ans: (a)

Sol: Consider lossless transmission line, with R = 0 and G = 0.

Propagation constant,

$$P \equiv \alpha + j\beta = \sqrt{(0 + j\omega L)(0 + j\omega C)}$$

$$P \equiv \alpha + j\beta = j\omega\sqrt{LC}$$

→ Propagation constant is purely imaginary

→ Attenuation constant $\alpha = 0$

→ No attenuation for the wave and hence there is no frequency distortion

→ Phase shift constant $\beta = \omega\sqrt{LC}$

Phase velocity, $v_p \equiv \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}}$

$$= \frac{1}{\sqrt{LC}}$$

→ Phase velocity is independent of frequency

→ Characteristic impedance,

$$Z_0 = \sqrt{\frac{0 + j\omega L}{0 + j\omega C}}$$

$$Z_0 = \sqrt{\frac{L}{C}} = R_0$$

Therefore for the given positive real values of L and C, characteristic impedance is purely resistive.

39. Ans: (c)

Sol: Propagation constant of distortionless transmission line is given by

$$P \equiv \alpha + j\beta = \frac{R}{L}\sqrt{LC} + j\omega\sqrt{LC}$$

(or) $\frac{G}{C}\sqrt{LC} + j\omega\sqrt{LC}$

$$\alpha = \frac{R}{L}\sqrt{LC}(\text{or})\frac{G}{C}\sqrt{LC}$$

→ independent of frequency.

$\beta = \omega\sqrt{LC}(\text{or})\ \beta\,\alpha\,\omega$, phase is linear with frequency and phase velocity is independent of frequency.

→ when the phase shift constant is linearly varying with frequency (or) phase velocity is independent of frequency then the delay distortion (or) phase distortion on the transmission line can be eliminated.

40. Ans: (d)

Sol: Given: line is lossless, $\alpha = 0$, $P = j\beta$

$v_p = 2 \times 10^8$ m/sec

$f = 50$MHz

$Z_0 = 50\Omega$

$Z_R = (30 + j40)$ ohm

wavelength, $\lambda = \frac{v_p}{f} = \frac{2\times10^8}{50\times10^6} = 4$m

$l = 1$m

$\lambda = 4$m

and hence $\ell = \frac{\lambda}{4}$ (quarter wave transmission line)

for QWT, $Z_{in} = \frac{Z_0^2}{Z_R} = \frac{50^2}{(30 + j40)}$

$$= \frac{2500(30 - j40)}{(30 + j40)(30 - j40)}$$

$$= \frac{2500(30 - j40)}{(900 + 1600)}$$

$\therefore Z_{in} = (30 - j40)$ohm

41. Ans: (a)

Sol: Given:

20log S = 40

log S = 2

S = 100

Reflection coefficient, $|K| = \frac{S - 1}{S + 1}$

$$|K| = \frac{100 - 1}{100 + 1}$$

$\therefore |K| = 0.98$

42. Ans: (c)

Sol: Given: transmission line is open-circuited [$Z_R \approx \infty$] and lossless.

$Z_{in} \equiv Z_{oc} = Z_0 \cot hP\ell$

as line is lossless, $\alpha = 0$, $P = j\beta$

$Z_{in} \equiv Z_{oc} = -jZ_0 \cot \beta l$

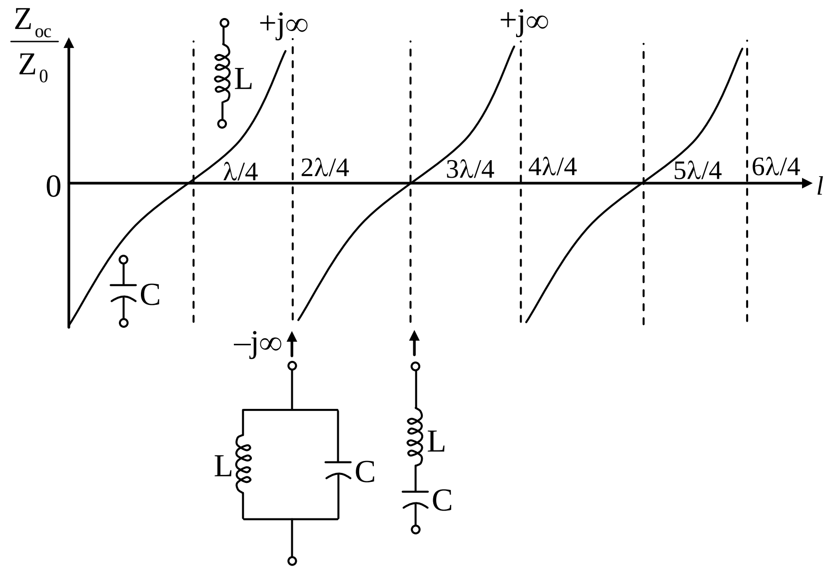
Consider the variation of Z_{oc} :

$$\frac{Z_{oc}}{Z_0} = -j\cot\beta\ell$$

Let

$$\ell = 0, \frac{\lambda}{4}, \frac{2\lambda}{4}, \frac{3\lambda}{4}, \frac{4\lambda}{4}, \text{-------- and}$$

$$\beta\ell = 0, \frac{\pi}{2}, \frac{2\pi}{2}, \frac{3\pi}{2}, \frac{4\pi}{2}, \text{--------}$$



→ At $\ell = \frac{5\lambda}{8}\left[\frac{2\lambda}{4} < \ell < \frac{3\lambda}{4}\right]$,

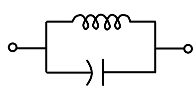
input impedance (Z_{oc}) is negative reactive impedance and hence the equivalent resonant component is capacitor.

→ At $\ell = \frac{3\lambda}{8}\left[\frac{\lambda}{4} < \ell < \frac{2\lambda}{4}\right]$,

input impedance (Z_{oc}) is positive reactive impedance and hence the equivalent resonant component is inductor.

→ When the length of the line is even multiples of $\frac{\lambda}{4}$, the OC line exhibits parallel resonance.

Hence the equivalent resonant circuit is parallel combination of L and C.

ex. at $\ell = \frac{6\lambda}{4}(\text{or})\frac{3\lambda}{2} \rightarrow$ 

→ When the length of the line is odd multiples of $\frac{\lambda}{4}$, then OC line exhibits series resonance.

Hence the equivalent resonant circuit is series combination of L and C.

Therefore the correct matching code is A–4, B–1, C–2, D–3

43. Ans: (d)

Sol: $\oiint \overline{D}.\overline{dS} = \iiint \rho_v dv$

$\oint \overline{E}.d\overline{\ell} = -\iint \frac{\partial \overline{B}}{\partial t}.\overline{dS}$

$\oint \overline{H}.d\overline{\ell} = \iint \left(\overline{J} + \frac{\partial \overline{D}}{\partial t}\right).\overline{dS}$

$\oiint \overline{B}.\overline{dS}$ = zero

44. Ans: (b)

Sol: The equation of a plane wave travelling in y-direction is given by $\frac{\partial^2 E_x}{\partial y^2} = \mu\varepsilon \frac{\partial^2 E_x}{\partial t^2}$

45. Ans: (b)

Sol: Given: $Z_R = Z_0$ (or) $R_R = R_0$ ($\because$ for lossless transmission line $Z_0 = R_0$)

This line is said to be matched transmission line

$$K = \frac{Z_R - Z_0}{Z_R + Z_0} = \frac{R_0 - R_0}{R_0 + R_0} = 0$$

$$\therefore \text{VSWR} = \frac{1+|K|}{1-|K|} = 1$$

46. Ans: (b)

Sol: $\frac{E_x}{H_y} = \eta_o = 120\pi$

$$H_y = \frac{E_x}{120\pi} = \frac{10}{120\pi}\cos(3\pi\times10^8 t - \pi z)$$

$$H_y = \frac{1}{12\pi}\cos(3\pi\times10^8 t - \pi z)$$

$$B_y = \mu_o H_y = \frac{4\pi\times10^{-7}}{12\pi}\cos(3\pi\times10^8 t - \pi z)$$

$$B_y = \frac{1}{3}\times10^{-7}\cos(3\pi\times10^8 t - \pi z)$$

$$\overline{B} = \frac{1}{3}\times10^{-7}\cos(3\pi\times10^8 t - \pi z)\hat{y}$$

47. Ans: (c)

Sol: $\nabla^2\overline{E}$ and $\mu\varepsilon\frac{\partial^2\overline{E}}{\partial t^2}$ are the term for wave phenomenon.

48. Ans: (b)

Sol: **+ve x** **–ve x**

$$\frac{E_y}{H_z} = \frac{-E_z}{H_y} = \eta_o \qquad -\frac{E_y}{H_z} = \frac{E_z}{H_y} = \eta_o$$

$$\overline{H} = \left(\frac{1}{\eta_o}\hat{z} - \frac{1}{\eta_o}\hat{y}\right)f(x-vt) + \left(\frac{-\hat{z}}{\eta_o} + \frac{\hat{y}}{\eta_o}\right)f(x+vt)$$

$$\overline{H} = (\hat{z}-\hat{y})\frac{f(x-vt)}{\eta_o} + (\hat{y}-\hat{z})\frac{f(x+vt)}{\eta_o}$$

49. Ans: (b)

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

$$\vec{J} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 4 & -2y & 3 \end{vmatrix} = 0$$

50. Ans: (b)

Sol: A. $\alpha = 0$ $\rightarrow$ 1. No-loss

B. $\alpha \approx \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}}$ $\rightarrow$ 2. Low-loss

C. $\alpha \approx \sqrt{\frac{\omega\mu\sigma}{2}}$ $\rightarrow$ 3. High-loss

D. $\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}}\left[\sqrt{1+\frac{\sigma^2}{\omega^2\varepsilon^2}} - 1\right]^{1/2}$ $\rightarrow$ 4. Material medium.

51. Ans: (c)

Sol: Electric field at a point p(x, y, z) is given as,

$$\vec{E} = \frac{\rho_L}{2\pi\varepsilon_0\rho}\hat{a}_\rho$$

here, $\rho = \sqrt{(6)^2 + (8)^2} = 10\text{m}$

$$\Rightarrow \vec{E} = \frac{100\times10^{-9}}{2\pi\times\frac{1}{36\pi}\times10^{-9}\times10}\hat{a}_\rho$$

$$= 180\hat{a}_\rho \text{ V/m}$$

$$|\vec{E}| = 180 \text{V/m}$$

52. Ans: (c)

Sol: $\frac{|\overline{E}|}{|\overline{H}|} = \eta_o = 120\pi$

$\frac{40\pi}{|\overline{H}|} = 120\pi \qquad |\overline{H}| = \frac{40\pi}{120\pi} = \frac{1}{3}\text{A/m}$

53. Ans: (d)

Sol: Let z = 0

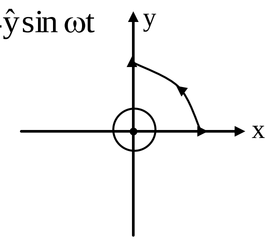
$\overline{E}(0,t) = 3\hat{x}\cos\omega t + 4\hat{y}\sin\omega t$

$\omega t = 0$

$\overline{E}(0,t) = 3\hat{x}$

$\omega t = \pi/2$

$\overline{E} = 4\hat{y}$



54. Ans: (d)

Sol:
A. $\text{curl}(\vec{F}) = 0$ → 2. Irrotational
B. $\text{Div}(\vec{F}) = 0$ → 3. Solenoidal
C. Div Grad(ϕ) = 0 → 1. Laplace equation
D. Div Div (ϕ) = 0 → 4. Not defined.

55. Ans: (a)

Sol: As $\vec{P}$ and $\vec{Q}$ are solenoidal, hence,

$\nabla.\vec{P} = 0, \ \nabla.\vec{Q} = 0$

Also, $\nabla\times(\vec{P}\times\vec{Q}) = (\nabla.\vec{Q})\vec{P} - (\nabla.\vec{P})\vec{Q} = 0$

Now, $\because \nabla\times(\vec{P}\times\vec{Q}) = 0$,

Therefore $(\vec{P}\times\vec{Q})$ is conservative.

56. Ans: (d)

Sol: Magnetic vector potential is defined as,

$\vec{B} = \nabla\times\vec{A}$ .... (1)

Consider the Maxwell's equation,

$\nabla.\vec{B} = 0$ (always)

$\Rightarrow \nabla.(\nabla\times\vec{A}) = 0$ .... (2)

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

$\Rightarrow \nabla\times\vec{E} + \nabla\times\frac{\partial\vec{A}}{\partial t} = 0$

$\Rightarrow \nabla\times\left(\vec{E} + \frac{\partial\vec{A}}{\partial t}\right) = 0$ .... (3)

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

$\Rightarrow \nabla\times\vec{B} = \mu_0\vec{J} \qquad (\because \vec{B} = \mu_0\vec{H})$

$\Rightarrow (\nabla\times(\nabla\times\vec{A})) = \mu_0\vec{J}$ ...... (4)

57. Ans: (a)

Sol: Let P(r, θ, ϕ) in spherical coordinate system and P(x, y, z) in Cartesian coordinate system, then

x = r sinθ cosϕ

y = r sinθ sinϕ

z = r cosθ

$\because r = 5, \theta = 60^o, \phi = 30^o$

$\therefore x = 5\times\frac{\sqrt{3}}{2}\times\frac{\sqrt{3}}{2} = \frac{15}{4}$

$y = 5\times\frac{\sqrt{3}}{2}\times\frac{1}{2} = \frac{5\sqrt{3}}{4}$

$z = 5\times\frac{1}{2} = \frac{5}{2}$

58. Ans: (b)

Sol: The magnetic field is non-conservative,

$\because \oint\vec{B}.\vec{d\ell} = \mu I$ (non-zero)

The magnetic flux is conserved.

$\because$ The total net flux through a closed surface (incoming and outgoing) is zero. $(\nabla.\vec{B} = 0)$

The magnetic field is rotational ($\because \nabla\times$ B = J$\mu \neq 0$)

59. Ans: (d)

Sol: Given:

L = 625 × 10^{-9}H/m

$C = 250 \times 10^{-12}$ F/m

Characteristic impedance of lossless transmission line is given by

$$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{625\times10^{-9}}{250\times10^{-12}}}$$

$$= \sqrt{2.5\times10^{3}}$$

$$= 5 \times 10$$

$\therefore\ Z_0 = 50\Omega$

60. Ans: (d)

Sol: In TE_{10} mode

$$P = \text{(constant times)} \int_{x=0}^{a}\int_{y=0}^{b}\left|E_y\right|^2 dxdy$$

$$\text{(or) } P = \text{(constant times)} \int_{x=0}^{a}\int_{y=0}^{b}\left|H_x\right|^2 dxdy$$

$\therefore$ both (1) and (2) are wrong

61. Ans: (b)

Sol: In a parallel plane waveguide, cutoff frequency $f_{cm} = \dfrac{mc}{2a\sqrt{\varepsilon_r}}$.

For the modes to propagate inside the waveguide then their cutoff of frequencies must be less than the operating frequency f = 1GHz

(i.e) $f_{cm} < f$

$$\frac{mc}{2a\sqrt{\varepsilon_r}} < 1\times10^{9}$$

$$\therefore\ m < \frac{1\times10^{9}\times2a\sqrt{\varepsilon_r}}{c}$$

$$m < \frac{1\times10^{9}\times2\times50\times3}{3\times10^{10}}$$

$\Rightarrow m < 10$

highest cut-off frequency is for m = 9

$$\text{(i.e) } f_{C_9} = \frac{9c}{2a\sqrt{\varepsilon_r}} = \frac{9\times3\times10^{10}}{2\times50\times3} = 0.9\text{GHz}$$

62. Ans: (b)

Sol: $\dfrac{E_y}{H_x} = \eta_{TE_{10}}$

$$E_y = \eta_{TE_{10}} H_x$$

$$\text{where } \eta_{TE_{10}} = \frac{\eta_0}{\sqrt{1-\left(\dfrac{f_{C_{10}}}{f}\right)^2}}$$

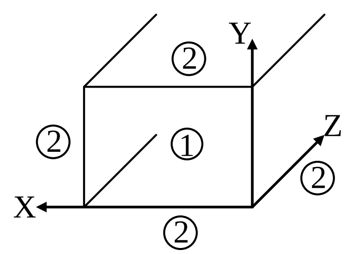
$$\text{(or) } \eta_{TE_{10}} = \frac{120\pi}{\sqrt{1-(0.8)^2}} = \frac{120\pi}{0.6} = 200\pi\Omega$$

$$\therefore\ E_y = 200\pi\times0.05\sin\left(\frac{\pi}{a}x\right)\hat{a}_y$$

$$E_y = 10\pi\sin\left(\frac{\pi}{a}x\right)\hat{a}_y \text{ V/m}$$

inside waveguide consider the medium as (1)

outside waveguide consider the medium as (2)



at y = b and x = $\dfrac{a}{2}$

from B.C's

$$\overline{E}_y.\hat{a}_{n_{21}} = \frac{\rho_s}{\varepsilon_0}$$

$$\text{(i.e) } E_y\hat{a}_y.(-\hat{a}_y) = \frac{\rho_s}{\varepsilon_0}$$

$$\therefore \rho_s = -\varepsilon_0 E_y = -\frac{10^{-9}}{36\pi}\times10\pi\sin\left(\frac{\pi}{a}\times\frac{a}{2}\right)$$

$$= -0.28\text{nC/m}^2$$

63. Ans: (c)

Sol: From the boundary condition

(1) The normal component of E-field and tangential component of H-field are non zero at the walls of waveguide and hence E_x and H_z will exist
So, statement (1) is correct

(2) From B.C's
The tangential component of E-field and normal component of H-field are zero at the walls of waveguide and hence E_z and H_x are zero
$\therefore$ So, statement (2) is wrong

(3) If TEM wave is propagating along y-direction then longitudinal components $E_y = 0$ and $H_y = 0$ and for this to happen E and H fields must be function of only "y"
$\therefore$ Statement (3) is correct

64. Ans: (b)

Sol: If $1 < \frac{a}{b} < 2$, then the operating frequency range for single mode is $f_{c_{10}} < f < f_{c_{01}}$ (or) $\frac{c}{2a} < f < \frac{c}{2b}$.

If $\frac{a}{b} \geq 2$, the operating frequency range for single mode is $f_{c_{10}} < f < f_{c_{20}}$ (or) $\frac{c}{2a} < f < \frac{c}{a}$

From the above we can say that operating bandwidth is maximum if $\frac{a}{b} \geq 2$ (i.e.)

$$b \leq \frac{a}{2} \text{ (i.e.) } b_{max} = \frac{a}{2}$$

Given $f_{c_{10}} = \frac{c}{2a} = 5\times10^9$

$$\Rightarrow a = \frac{c}{2f_{c_{10}}} = \frac{3\times10^{10}}{2\times5\times10^9} = 3\text{cm}$$

$$\therefore b_{max} = \frac{a}{2} = \frac{3}{2} = 1.5\text{cm}$$

65. Ans: (c)

Sol: Antenna is a reciprocal device whose characteristics are the same when it is transmitting (or) receiving. It is a transducer

66. Ans: (c)

Sol: Power gain (G_p), efficiency (η) and directivity are related as

$G_p = \eta D$

For lossless antenna, efficiency =1

$G_p = D$

$\therefore$ Directivity, D =10

In dB D = 10log10 = 10 dB

67. Ans: (c)

Sol: In phase lead compensator, compensating pole is located left of the compensating zero hence Statement (II) is wrong

68. Ans: (a)

Sol: For stability (–1, j0) should not be enclosed by the Nyquist plot

69. Ans: (b)

Sol: Block diagram techniques used for simplification of control system, but for complicated systems, the block diagram reduction is tedious and time consuming hence signal flow graphs are used.
Signal flow graph is a graphical representation for the variables representing the output of the various blocks of the control system.

70. Ans: (a)

Sol: For a minimum phase system to be stable, both PM and GM must be positive.

$$\left.\begin{array}{l} GM = 10\text{dB} \\ PM = 20^\circ \end{array}\right\} \text{both positive}$$

Thus, Statement (II) is correct explanation to Statement (I).

71. Ans: (b)

Sol: Steady state error of a type 1 system to a Ramp input is finite. Position error coefficient of type-1 system is infinite both Statements are correct but Statement (II) is not correct explanation for Statement (I).

72. Ans: (a)

Sol: Let dW_{mag} be the work done by a magnetic field, displacing a charge Q by $\overrightarrow{d\ell}$ distance then,

$dW_{mag} = \vec{F}_{mag}.\overrightarrow{d\ell}$

$\because$ Lorentz force law gives,

$\vec{F}_{mag} = Q(\vec{v}\times\vec{B})$

$dW_{mag} = Q(\vec{v}\times\vec{B}).(\vec{v}\,dt)$

$\Rightarrow dW_{mag}$ is perpendicular to both $\vec{v}$ and $\vec{B}$,

$\therefore W_{mag} = 0$

73. Ans: (d)

Sol: If load impedance, $Z_R = \infty$ (open-circuit)

then reflection coefficient, $K = \dfrac{Z_R - Z_0}{Z_R + Z_0}$

$K = 1$

$|K| = 1$

Hence magnitude of reflection coefficient is unity

$$VSWR = \frac{1+|K|}{1-|K|} = \frac{1+1}{1-1} = \infty$$

when the line is terminated by open-circuit(infinitely large impedance), then the magnitude of reflection coefficient is unity and VSWR is infinity.

Therefore S1 is false and S2 is true

74. Ans: (a)

Sol: $\because I = -\dfrac{dQ}{dt}$

but, $Q = \int_v \rho_v.dv$

$\Rightarrow I = -\int_v \dfrac{d\rho_v}{dt}dv$

also, $I = \oint_s \vec{J}.\overrightarrow{dS}$

$\Rightarrow \oint_s \vec{J}.\overrightarrow{dS} = -\int_v \dfrac{d\rho_v}{dt}.dv$

Applying Gauss's diversion theorem,

$\oint_s \vec{J}.\overrightarrow{dS} = \int_v (\nabla\cdot\vec{J}).dv$

$\Rightarrow \nabla\cdot\vec{J} = -\dfrac{d\rho_v}{dt}$

For steady current,

ρ_v = constant(charge entering the volume is equal to charge leaving, so that net charge in the volume is constant with respect to time)

$\Rightarrow \dfrac{d\rho_v}{dt} = 0$

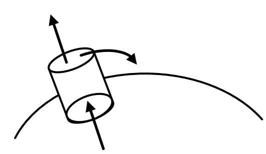
$\Rightarrow \nabla.\vec{J} = 0 \Rightarrow \oint \vec{J}.\overrightarrow{ds} = 0$

i.e, net flow of current through a closed volume is zero.

75. Ans: (a)

Sol: Consider a boundary as shown in the figure,

Using Maxwell's equation, $\oint_c \vec{B}.\overrightarrow{ds} = 0$ (net flux through a closed surface is zero)



$\Rightarrow B_{N_1}(\Delta S) - B_{N_2}(\Delta S) = 0$

$\Rightarrow B_{N_1} = B_{N_2}$