MADE EASY

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Detailed Solutions

ESE-2026 Mains Test Series

Electrical Engineering Test No : 9

Section A : Electromagnetic Theory + Control Systems + Communications Systems

Q.1 (a) Solution:

A single-tone AM signal can be expressed as

$$x_{Am}(t) = A\cos\omega_c t + \mu A\cos\omega_m t\cos\omega_c t$$

$$= A\cos\omega_c t + \frac{1}{2}\mu A\cos(\omega_c - \omega_m)t + \frac{1}{2}\mu A\cos(\omega_c + \omega_m)t$$

$$P_c = \text{Carrier power} = \frac{1}{2}A^2$$

$$P_c = \text{Sideband power}$$

$$= \frac{1}{2}\left[\left(\frac{1}{2}\mu A\right)^2 + \left(\frac{1}{2}\mu A\right)^2\right] = \frac{1}{4}\mu^2 A^2$$

The total power P_t is

$$P_t = P_c + P_s$$

$$= \frac{1}{2}A^2 + \frac{1}{4}\mu^2 A^2 = \frac{1}{2}\left(1 + \frac{1}{2}\mu^2\right)A^2$$

Thus,

$$\eta = \frac{P_s}{P_t} \times 100\%$$

$$= \frac{\frac{1}{4}\mu^2 A^2}{\left(\frac{1}{2} + \frac{1}{4}\mu^2\right)A^2} \times 100\% = \frac{\mu^2}{2 + \mu^2} \times 100\%$$

with the condition that $\mu \leq 1$.

(i) For, $\mu = 0.5$

$$\eta = \frac{(0.5)^2}{2+(0.5)^2}\times 100\% = 11.1\%$$

(ii) Since $\mu \leq 1$, it can be seen that η_{max} occurs at $\mu = 1$ and is given by

$$\eta = \frac{1}{3}\times 100\% = 33.3\%$$

Q.1 (b) Solution:

In the signal flow graph shown in figure, there are two forward paths, five loops and two pairs of two nontouching loops.

The forward paths and the gains associated with them are as follows:

Forward path (x_1-x_2-x_3-x_4-x_5-x_6), $M_1 = (1)(G_1)(G_2)(G_3)(1) = G_1G_2G_3$

Forward path (x_1-x_2-x_4-x_5-x_6), $M_2 = (1)(G_4)(G_3)(1) = G_4G_3$

The loops and the gains associated with them are as follows:

Loop (x_2-x_3-x_2), $L_1 = (G_1)(-H_1) = -G_1H_1$

Loop (x_4-x_5-x_4), $L_2 = (G_3)(-H_2) = -G_3H_2$

Loop (x_2-x_3-x_4-x_5-x_2), $L_3 = (G_1)(G_2)(G_3)(-H_3) = -G_1G_2G_3H_3$

Loop (x_2-x_4-x_5-x_2), $L_4 = (G_4)(G_3)(-H_3) = -G_4G_3H_3$

Loop (x_5-x_5), $L_5 = -H_4$

The pairs of two nontouching loops and the products of gains associated with them are as follows:

Loop (x_2-x_3-x_2) and (x_4-x_5-x_4), $L_{12} = (-G_1H_1)(-G_3H_2) = G_1G_3H_1H_2$

Loop (x_2-x_3-x_2) and (x_5-x_5), $L_{15} = (-G_1H_1)(-H_4) = G_1H_1H_4$

Since all the loops are touching both the forward paths, thus $\Delta_1 = 1$ and $\Delta_2 = 1$.

The determinant of the signal flow graph is

$\Delta = 1 - (L_1 + L_2 + L_3 + L_4 + L_5) + (L_{12} + L_{15})$

$\Delta = 1 - (-G_1H_1 - G_3H_2 - G_1G_2G_3H_3 - G_4G_3H_3 - H_4) + (G_1G_3H_1H_2 + G_1H_1H_4)$

$= 1 + G_1H_1 + G_3H_2 + G_1G_2G_3H_3 + G_4G_3H_3 + H_4 + G_1G_3H_1H_2 + G_1H_1H_4$

Applying Mason's gain formula, the transfer function is

$$\frac{x_6}{x_1} = \frac{M_1\Delta_1 + M_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_3 + G_4G_3}{1+G_1H_1+G_3H_2+G_1G_2G_3H_3+G_4G_3H_3+H_4+G_1G_3H_1H_2+G_1H_1H_4}$$

Q.1 (c) Solution:

(i)

$$\hat{a}_n = \hat{a}_z$$

$$E_{n_1} = \vec{E}_1 \cdot \hat{a}_n = 70 \text{ V/m}$$

$$\vec{E}_{n_1} = 70\hat{a}_z \text{ V/m}$$

$$\vec{E}_{t_1} = \vec{E}_1 - \vec{E}_{n_1}$$

$$\vec{E}_{t_1} = (-30\hat{a}_x + 50\hat{a}_y) \text{ V/m}$$

From the boundary conditions,

$$\vec{E}_{t_2} = \vec{E}_{t_1} = \left(-30\hat{a}_x + 50\hat{a}_y\right) \text{V/m}$$

$$\vec{D}_{n_2} = \vec{D}_{n_1}$$

So,

$$\vec{E}_{n_2} = \frac{\varepsilon_1}{\varepsilon_2}\vec{E}_{n_1} = \frac{2.5}{4}70\hat{a}_z \text{ V/m} = 43.75\hat{a}_z \text{ V/m}$$

(ii)

$$\left|\vec{E}_1\right| = [(-30)^2 + (50)^2 + (70)^2]^{1/2} = 91.10 \text{ V/m}$$

So,

$$\theta_1 = \cos^{-1}\left[\frac{E_{n_1}}{E_1}\right] = \cos^{-1}\left[\frac{70}{91.1}\right] = 39.79°$$

Q.1 (d) Solution:

Given that,

Message signal, $m(t) = \cos(2000\pi t) + 2\sin(2000\pi t)$

Carrier signal, $c(t) = 100\cos(2\pi f_c t);\ f_c = 100 \text{ kHz}$

(i) The standard time domain expression for the LSSB-AM signal can be given as,

$$s(t) = A_c m(t)\cos(2\pi f_c t) + A_c \hat{m}(t)\sin(2\pi f_c t)$$

$\hat{m}(t)$ is the Hilbert transform of the message signal $m(t)$.

$$\hat{m}(t) = \sin(2000\pi t) - 2\cos(2000\pi t)$$

So,

$$\begin{aligned} s(t) &= 100\,[\cos(2000\pi t) + 2\sin(2000\pi t)]\cos(2\pi f_c t) \\ &\quad + 100\,[\sin(2000\pi t) - 2\cos(2000\pi t)]\sin(2\pi f_c t) \\ &= 100\,[\cos(2\pi f_c t)\cos(2000\pi t) + \sin(2\pi f_c t)\sin(2000\pi t)] \\ &\quad + 200\,[\cos(2\pi f_c t)\sin(2000\pi t) - \sin(2\pi f_c t)\cos(2000\pi t)] \end{aligned}$$

$$s(t) = 100\cos[2\pi(f_c - 1000)t] - 200\sin[2\pi(f_c - 1000)t]$$

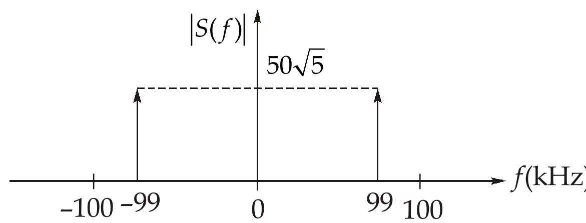
(ii) By taking the Fourier transform of the above time domain expression of LSSB-AM signal $s(t)$, we get,

$$S(f) = 50[\delta(f - f_c + 1000) + \delta(f + f_c - 1000)]$$
$$+ j100[\delta(f - f_c + 1000) - \delta(f + f_c - 1000)]$$
$$= (50 + j100)\,\delta(f - f_c + 1000) + (50 - j100)\,\delta(f + f_c - 1000)$$

Hence, the magnitude spectrum of the signal can be given as,

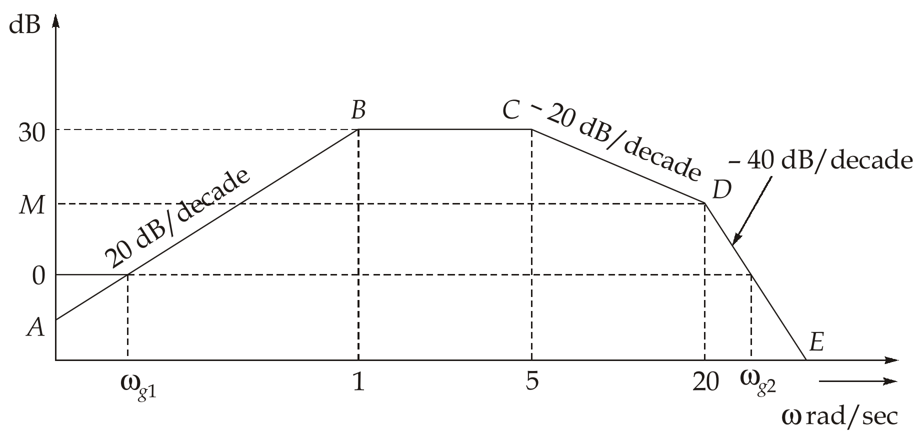
$$|S(f)| = \sqrt{(50)^2 + (100)^2}\left[\delta(f - f_c + 1000) + \delta(f + f_c - 1000)\right]$$
$$= 50\sqrt{5}\left[\delta(f - f_c + 1000) + \delta(f + f_c - 1000)\right]$$

The magnitude spectrum can be plotted, by taking f_c = 100 kHz, as follows



Q.1 (e) Solution:

The bode plot of the minimum phase system is given as below,



(i) In a bode plot, a change in the slope by –20 dB/dec at ω_c indicates the presence of a pole at $s = -\omega_c$ and thus, the term $\dfrac{1}{1+\dfrac{s}{\omega_c}}$ in the transfer function. Similarly, a change in the slope by 20 dB/dec at ω_c indicates the presence of a zero at $s = -\omega_c$ and thus, the term $1+\dfrac{s}{\omega_c}$ in the transfer function. Also, an initial slope of 20 dB/sec indicates the presence of zero at $s = 0$. Thus, the transfer function of the system is given by

$$G(s) = \frac{ks}{(1+s)\left(1+\frac{s}{5}\right)\left(1+\frac{s}{20}\right)}$$

For $0 < \omega < 1$, the magnitude, $|G(j\omega)|$ is given by

$$|G(j\omega)| = 20 \log k + 20 \log \omega$$

At $\omega = 1$ rad/sec,

$$30 = 20 \times 1 \log 1 + 20 \log k$$

$$k = 10^{\frac{30}{20}} = 31.622$$

$\therefore$
$$G(s) = \frac{31.622s \times 5 \times 20}{(s+1)(s+5)(s+20)} = \frac{3162.2s}{(s+1)(s+5)(s+20)}$$

(ii) Two gain crossover frequencies,

The slope for line *AB*, $\omega_{g1} = ?\quad \omega_{g2} = ?$

$$20 \text{ dB/decade} = \frac{30-0}{\log 1 - \log \omega_{g1}}$$

$$\log \frac{1}{\omega_{g1}} = \frac{30}{20}$$

$$\omega_{g1} = 0.0316 \text{ rad/sec.}$$

The slope for line *BC*,

$$-20 \text{ dB/decade} = \frac{M-30}{\log \frac{20}{5}}$$

$\Rightarrow$
$$M - 30 = -20 \log 4 = -12.04$$

$$M = 17.958 \text{ dB}$$

To calculate ω_{g2}, the slope for line *CD*,

$$-40 \text{ dB/decade} = \frac{0-M}{\log \omega_{g1} - \log 20} = \frac{0-17.958}{\log \frac{\omega_{g2}}{20}}$$

$$\log \frac{\omega_{g2}}{20} = 0.44895$$

$$\omega_{g2} = 56.234 \text{ rad/sec}$$

Q.2 (a) Solution:

Maxwell's equations:

(i) $$\oint \vec{B} \cdot d\vec{S} = 0$$

Net magnetic flux emerging through any closed surface is zero.

(ii) $$\oint \vec{D} \cdot d\vec{S} = \int_V \rho_v \, dV$$

Total electric flux density or total electric displacement $(\vec{D})$ through the surface enclosing a volume v is equal to total charge within the volume.

(iii) $$\oint \vec{E} \cdot d\vec{L} = -\int_S \frac{d\vec{B}}{dt} \cdot \overrightarrow{ds}$$

The electromagnetic force around a closed path equal to the time derivative of magnetic flux density or magnetic displacement $\vec{B}$ through any surface bounded by the surface

(iv) $$\oint \vec{H} . d\vec{L} = \int_s \left(\vec{J} + \frac{d\vec{D}}{dt} \right) . dS \, ;$$

The magnetomotive force around a closed path is equal to the conduction current $\vec{J}$ plus time derivation of electric flux density or electric flux displacement $\vec{D}$ through any surface bounded by the path.

Solution for the numerical:

Given magnetic field intensity in free space

$$\vec{H} = \frac{20(x\hat{a}_x + y\hat{a}_y)}{(x^2 + y^2)} \text{ A/m}$$

The magnetic flux density is

$$\vec{B} = \mu_0 \vec{H} = \hat{a}_x B_x + \hat{a}_y B_y = \frac{20\mu_0 x\hat{a}_x}{(x^2+y^2)} + \frac{20\mu_0 y\hat{a}_y}{(x^2+y^2)}$$

The components of magnetic flux density are

$$B_x = \frac{20\mu_0 x}{(x^2+y^2)},$$

$$B_y = \frac{20\mu_0 y}{(x^2+y^2)}$$

and $$B_z = 0$$

$$\nabla \cdot \vec{B} = \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial y}\hat{a}_y + \frac{\partial}{\partial z}\hat{a}_z\right)\cdot\left(\frac{20\mu_0 x}{x^2+y^2}\hat{a}_x + \frac{20\mu_0 y}{(x^2+y^2)}\hat{a}_y\right)$$

$$= \frac{\partial}{\partial x}\left(\frac{20\mu_0 x}{(x^2+y^2)}\right) + \frac{\partial}{\partial y}\left(\frac{20\mu_0 y}{(x^2+y^2)}\right)$$

$$= 20\mu_0\left(\frac{x^2+y^2-2x^2}{(x^2+y^2)} + \frac{x^2+y^2-2y^2}{(x^2+y^2)}\right) = 0$$

Hencem $\nabla \cdot \vec{B} = 0$

The current density

$$\vec{J} = \nabla \times \vec{H} = 20\begin{bmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \frac{x}{(x^2+y^2)} & \frac{y}{(x^2+y^2)} & 0 \end{bmatrix}$$

$$= 20\left(\frac{\partial}{\partial x}\frac{y}{(x^2+y^2)} - \frac{\partial}{\partial y}\frac{x}{(x^2+y^2)}\right)a_z$$

Thus, $$J_z = 20\left[\frac{\partial}{\partial x}\left(\frac{y}{(x^2+y^2)}\right) - \frac{\partial}{\partial y}\left(\frac{x}{(x^2+y^2)}\right)\right]$$

$$J_z = 20y\frac{-2x}{(x^2+y^2)^2} - 20x\frac{-2y}{(x^2+y^2)^2} = 0$$

Therefore, current density, $\vec{J} = 0$

Q.2 (b) Solution:

The steady state-error for ramp input to be zero, the system must be of type-2 i.e. two open-loop poles at the origin. Since one pole at $s = 0$ is already present in the given transfer function, thus the controller should have an integrator.

The closed loop system also has a zero. So, the controller will be proportional + integral (PI) controller.

Let the transfer function of the controller be,

$$G_c(s) = k_p + \frac{k_I}{s}$$

The forward-path transfer function of the controlled unity negative feedback system is

$$G(s) = G_p(s) \times G_c(s)$$

$$= \frac{4}{s(s+9)} \cdot \left(k_p + \frac{k_I}{s}\right)$$

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

The closed loop transfer function,

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)}$$

$$= \frac{\dfrac{4(k_p s + k_I)}{s^2(s+9)}}{1 + \dfrac{4(k_p s + k_I)}{s^2(s+9)}} = \frac{4(k_p s + k_I)}{s^2(s+9) + 4(k_p s + k_I)}$$

$$\frac{C(s)}{R(s)} = \frac{4(k_p s + k_I)}{s^3 + 9s^2 + 4k_p s + 4k_I}$$

Given that the closed-loop system has a zero at $s = -3$, thus

$$k_p s + k_I = 0$$

i.e., $$k_p(-3) + k_I = 0$$

$\therefore$ $$k_I = 3k_p \quad \text{...(1)}$$

The characteristic equation of the controlled system is,

$$s^3 + 9s^2 + 4k_p s + 4k_I = 0 \quad \text{...(2)}$$

The system has complex poles which occur in conjugate pair, and let the third pole be at $s = -\alpha$

The characteristic equation can thus be written as

$$(s + \alpha)(s^2 + 2\xi\omega_n s + \omega_n^2) = 0$$

or, $s^3 + (2\xi\omega_n + \alpha)s^2 + (\omega_n^2 + 2\xi\omega_n\alpha)s + \alpha\omega_n^2 = 0$ ...(3)

On comparing equation (2) and (3),

$$2\xi\omega_n + \alpha = 9 \quad \text{...(4)}$$

and $$\omega_n^2 + 2\xi\omega_n\alpha = 4k_p \quad \text{...(5)}$$

$$\alpha\omega_n^2 = 4k_I = 12k_p \quad \text{...(6)}$$

Given, $$\omega_n = 5 \text{ rad/sec.}$$

From equation (4),

$$10\xi + \alpha = 9$$

$$\xi = \frac{9-\alpha}{10} \quad \text{...(7)}$$

From equation (5),

$$25 + 10\xi\alpha = 4k_p \quad \text{...(8)}$$

From equation (6),

$$25\alpha = 12k_p$$

$$25\alpha = 3(25 + 10\xi\alpha) \quad \text{...using equation (8)}$$

$$25\alpha = 75 + 30\xi\alpha$$

$$25\alpha = 75 + 30\alpha\left(\frac{9-\alpha}{10}\right) \quad \text{...using equation (7)}$$

$$25\alpha = 75 + 27\alpha - 3\alpha^2$$

$$3\alpha^2 - 2\alpha - 75 = 0$$

On solving above quadratic equation,

$$\alpha = \frac{2 \pm \sqrt{904}}{6} = \frac{2 \pm 30.06}{6}$$

$$\alpha = 5.344, -4.677$$

Considering, $\alpha = 5.344$

[$\because$ $\alpha = -4.677$ leads to $\xi > 1$ and thus, no complex poles]

$$\xi = \frac{9-\alpha}{10} = \frac{9-5.344}{10} = 0.3656$$

$\therefore$ $\xi = 0.3656$

$$k_p = \frac{25\alpha}{12} = \frac{25 \times 5.344}{12} = 11.133$$

$$k_I = 3k_p = 3 \times 11.133 = 33.4$$

So, the controller will be

$$G_C(s) = k_p + \frac{k_I}{s} = 11.133 + \frac{33.4}{s}$$

$$G_C(s) = 11.133\left(1 + \frac{3}{s}\right)$$

Q.2 (c) Solution:

The transfer function is, $H(s) = \frac{1}{(s^2+3s+2)} = \frac{1}{(s+2)(s+1)}$

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

By taking inverse Laplace transform, we get,

Impulse response, $h(t) = \left(e^{-t} - e^{-2t}\right)u(t)$

The relation between impulse $\delta(t)$ and step function $u(t)$ is,

$$u(t) = \int_{-\infty}^{t} \delta(t)\,dt$$

So, the unit step response of the system can be given as,

$$s_1(t) = \int_{-\infty}^{t} h(t)\,dt = \int_{-\infty}^{t} \left(e^{-t} - e^{-2t}\right)u(t)\,dt$$

$$= \int_{0}^{t}\left(e^{-t} - e^{-2t}\right)dt \;; \quad \text{for } t > 0$$

$$= \left(-e^{-t} + \frac{1}{2}e^{-2t}\right)\Bigg|_0^t ; \quad \text{for } t > 0$$

$$= \left(-e^{-t} + \frac{1}{2}e^{-2t} + \frac{1}{2}\right)u(t)$$

Similarly the response of the system for the excitation of $tu(t)$ can be given as,

$$s_2(t) = \int_{-\infty}^{t} s_1(t)\,dt = \int_{0}^{t}\left(-e^{-t} + \frac{1}{2}e^{-2t} + \frac{1}{2}\right)dt \,; \text{ for } t > 0$$

$$= \left[e^{-t} - \frac{1}{4}e^{-2t} + \frac{1}{2}t\right]_0^t ; \qquad \text{for } t > 0$$

$$= \left(e^{-t} - \frac{1}{4}e^{-2t} + \frac{1}{2}t - \frac{3}{4}\right)u(t)$$

The response for the excitation of $\frac{t^2}{2}u(t)$ can be given as,

$$s_3(t) = \int_{-\infty}^{t} s_2(t)\,dt = \int_{0}^{t}\left(e^{-t} - \frac{1}{4}e^{-2t} + \frac{1}{2}t - \frac{3}{4}\right)dt \,; \text{ for } t > 0$$

$$= \left[-e^{-t} + \frac{1}{8}e^{-2t} + \frac{t^2}{4} - \frac{3}{4}t\right]_0^t \text{ ; for } t > 0$$

$$= \left(-e^{-t} + \frac{1}{8}e^{-2t} + \frac{t^2}{4} - \frac{3}{4}t + \frac{7}{8}\right)u(t)$$

Given excitation is, $r(t) = 4t^2u(t) + 8tu(t)$

$$= 8\left[\frac{t^2}{2}u(t)\right] + 8[tu(t)]$$

The corresponding response of the system is,

$$c(t) = 8s_3(t) + 8s_2(t)$$

$$= [-8e^{-t} + e^{-2t} + 2t^2 - 6t + 7]\,u(t) + [8e^{-t} - 2e^{-2t} + 4t - 6]u(t)$$

$$c(t) = (1 - 2t + 2t^2 - e^{-2t})\,u(t)$$

Q.3 (a) Solution:

We know that,

Due to presence of a pole slope of the curve decrease by 20 dB/dec whereas because a zero slope of the curve is improve by 20 dB/dec.

From the curve, we get

At,

$s = 0$, ω and ω_3 poles are present whereas

at $s = \omega_2$ one zero is present.

Thus we can write transfer function as,

$$G(s) = \frac{K(s+\omega_2)}{s(s+\omega_1)(s+\omega_3)}$$

Now, our task is to calculate, K, ω_2, ω_2 and ω_3.

A pole is at origin i.e.,

$$20 \log K - 20 \log \omega = 36 \text{ at } \omega = \omega_1$$

$$20 \log K - 20 \log \omega_1 = 36 \quad \text{...(i)}$$

Now using slope concept in between ω_1 and 4 rad/sec, we get,

$$\frac{y_2 - y_1}{x_2 - x_1} = -40 \text{ dB/dec}$$

$$\frac{36 - 0}{\log \omega_1 - \log 4} = -40 \text{ dB/dec}$$

$$36 = -40(\log \omega_1 - \log 4)$$

$$36 = -40 \log \omega_1 + 40 \log 4$$

$$\frac{36 - 40\log 4}{-40} = \log \omega_1$$

$$\omega_1 = 0.5 \text{ rad/sec}$$

Substituting $\omega_1 = 0.5$ rad/sec in equation (i) we get

$$20 \log K - 20 \log 0.5 = 36$$

$$20 \log K = 36 + 20 \log 0.5$$

$$K = 31.55$$

Similarly, using slope concept 4 rad/sec and ω_2, we get

$$\frac{y_2 - y_1}{x_2 - x_1} = -40 \text{ dB/dec}$$

$$\frac{0 - (-12)}{\log 4 - \log \omega_2} = -40$$

$$\frac{12}{\log 4 - \log \omega_2} = -40$$

$$12 = -40 \log 4 + 40 \log \omega_2$$

$$\frac{12 + 40\log 4}{40} = \log \omega_2$$

$$\omega_2 = 7.98 \text{ rad/sec}$$

Now, on applying slope concept in between $\omega_2 = 7.98$ rad/sec and ω_3, we get

$$\frac{y_2 - y_1}{x_2 - x_1} = -20 \text{ dB/dec}$$

$$\frac{-12 - (-21)}{\log \omega_2 - \log \omega_3} = -20$$

$$\frac{-12 + 21}{\log 7.98 - \log \omega_3} = -20$$

$$9 = -20 \log 7.98 + 20 \log \omega_3$$

$$\frac{9 + 20\log 7.98}{20} = \log \omega_3$$

$$\omega_3 = 22.49 \text{ rad/sec}$$

On combining all the term, we get the open-loop transfer as,

$$G(s) = \frac{31.55\left(\frac{s}{7.98}+1\right)}{s\left(\frac{s}{0.5}+1\right)\left(\frac{s}{22.49}+1\right)}$$

$$G(s) = \frac{31.55(0.125s+1)}{s(2s+1)(0.044s+1)}$$

Q.3 (b) Solution:

Given that message signal, $m(t) = 10\sin(2\pi \times 10^4 t)$

$\therefore$ $f_m = 10^4 \text{ Hz} = 10 \text{ kHz}$ ...(i)

Carrier frequency, $f_c = 25 \text{ MHz}$

(i) Given that, $\beta_p = 10, \quad \beta_f = 10$

We know that, $\beta_p = \dfrac{K_p A_m}{f_m}$

Where $K_p A_m$ maximum phase deviation,

$$\beta_p = \frac{K_p \times 10}{10^4}$$

$$K_p = \frac{10 \times 10^4}{10} = 10^4 \text{ rad/V} \quad \text{...(ii)}$$

$K_p \rightarrow$ phase deviation constant

$\beta_f = \dfrac{K_f A_m}{f_m}$ K_f - frequency deviation constant

$K_f = 10^4 \text{ Hz/V}$ ...(iii)

Effective bandwidth of angle modulated signal which contains atleast 98% of the signal power is given by Carson's rule

$$\text{B.W.} = 2(\beta + 1)f_m$$

$\therefore$ (i) for phase modulated signal

$$\text{B.W.} = 2(\beta_p + 1)f_m$$

$$\text{B.W.} = 2(10 + 1) \times 10^4$$

$$\text{B.W.} = 240 \text{ kHz for PM}$$

$\because$ $\beta_p = \beta_f$

$\therefore$ B.W. of frequency modulated signal will be same

B.W. of FM modulated signal = 220 kHz for FM

(ii) When modulating frequency is doubled

i.e. $f'_m = 2f_m = 2 \times 10^4 \text{ Hz}$

∴ New modulation index for phase modulated and frequency modulated signals.

$$\beta'_p = \frac{K_p A_m}{f'_m} = \frac{10^4 \times 10}{2 \times 10^4} = 5$$

$$\beta'_f = \frac{K_f A_m}{f'_m} = \frac{10^4 \times 10}{2 \times 10^4} = 5$$

∴ B.W. of phase modulated signal,

$$\text{B.W.} = 2(\beta'_p + 1) f'_m$$

$$\text{B.W.} = 2(5 + 1) \times 2 \times 10^4$$

$$\text{B.W.} = 240 \text{ kHz for PM}$$

∵ $$\beta'_p = \beta'_f$$

∴ B.W. of frequency modulated signal

$$\text{B.W.} = 240 \text{ kHz for FM}$$

(iii) Now amplitude of modulating signal is halved.

$$A'_m = Am/2 = 10/2 = 5$$

∴ New modulation index of phase and frequency modulated signals.

$$\beta''_p = \frac{K_p A'_m}{f'_m} = \frac{10^4 \times 5}{2 \times 10^4} = 2.5$$

∴ New bandwidth of phase and frequency modulated signals

$$\text{B.W.} = 2(\beta''_p + 1) f'_m$$

$$\text{B.W.} = 2(2.5 + 1) \times 2 \times 10^4$$

$$\text{B.W.} = 140 \text{ kHz for PM}$$

∵ $$\beta''_p = \beta''_f$$

⇒ B.W. for both signals will be same.

∴ B.W. of frequency modulated signal will be

$$\text{B.W.} = 140 \text{ Hz for FM}$$

Q.3 (c) Solution:

(i) $A = \begin{bmatrix} 5 & 0 \\ 1 & -1 \end{bmatrix}$: $B = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$: $C^T = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$

To check the controllability of the system:

$$Q_c = [B : AB] = \begin{bmatrix} 1 & 5 \\ -1 & 2 \end{bmatrix}$$

$$|Q_c| = \begin{vmatrix} 1 & 5 \\ -1 & 2 \end{vmatrix} = 2 + 5 = 7 \neq 0$$

So, the given system is controllable

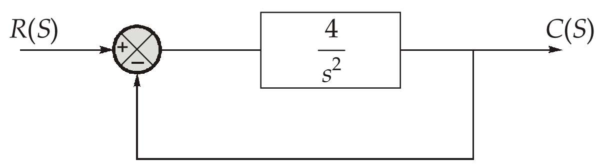
To check the observability of the system:

$$Q_0 = [C^T : A^T C^T] = \begin{bmatrix} 1 & 6 \\ 1 & -1 \end{bmatrix}$$

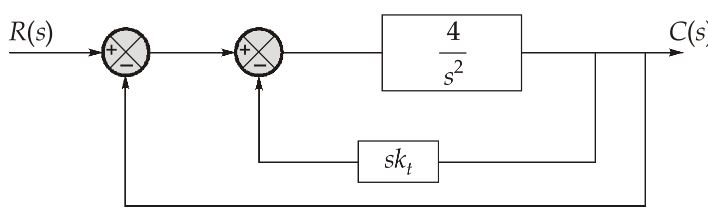
$$|Q_0| = -2 - 6 = -8 \neq 0$$

So the given system is observable.

(ii) Given uncompensated system,



With tachometer feedback, the block diagram of the compensated system is



The overall transfer function

$$\frac{C(s)}{R(s)} = \frac{\dfrac{\dfrac{4}{s^2}}{1+\dfrac{4}{s^2}(sk_t)}}{1+\dfrac{\dfrac{4}{s^2}}{1+\dfrac{4}{s^2}(sk_t)}} = \frac{\dfrac{4}{s^2+4sk_t}}{1+\dfrac{4}{s^2+4sk_t}} = \frac{4}{s^2+4sk_t+4}$$

The characteristic equation,

$$q(s) = s^2 + 4sk_t + 4$$

Comparing it with standard second order characteristic equation, we get.

$$\omega_n = \sqrt{4} \text{ rad/sec} = 2 \text{ rad/sec}$$

$$2\xi\omega_n = 4k_t$$

$$\xi = \frac{4k_t}{2\times 2} = k_t \qquad \text{...(i)}$$

Now given,

$$\% M_p = 50\%$$

$$0.5 = e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}$$

$$-\frac{\xi\pi}{\sqrt{1-\xi^2}} = \ln(0.5)$$

$$\xi^2 = 0.3245$$

Substituting this value in equation (i),

$$2 \times 0.569 \times 2 = 4k_t$$

$$\therefore \quad k_t = 0.569$$

Q.4 (a) Solution:

(i) Advantages of Angle Modulation:

Noise immunity: Probably the most significant advantage of angle modulation transmission (FM and PM) over amplitude modulation transmission is noise immunity. Most noise (including man-made noise) results in unwanted amplitude variations in the modulated wave (i.e., AM noise). FM and PM receivers include limiters that remove most of the AM noise from the received signal before the final demodulation process occurs—a process that cannot be used with AM receivers because the information is also contained in amplitude variations, and removing the noise would also remove the information.

Noise performance and signal-to-noise ratio improvement: With the use of limiters, FM and PM demodulators can actually reduce the noise level and improve the signal-to-noise, ratio during the demodulation process. This is called FM thresholding. With AM, once the noise has contaminated the signal, it cannot be removed.

Capture effect: With FM and PM, a phenomenon known as the capture effect allows a receiver to differentiate between two signals received with the same frequency. Providing one signal at least twice as high in amplitude as the other, the receiver will capture the stronger signal and eliminate the weaker signal. With amplitude modulation, if two or more signals are received with the same frequency, both will be demodulated and produce audio signals. One may be larger in amplitude than the other, but both can be heard.

Power utilization and efficiency: With AM transmission (especially DSBFC), most of the transmitted power is contained in the carrier while the information is contained in the much lower-power sidebands. With angle modulation, the total power remains constant regardless if modulation is present. With AM, the carrier power remains constant with modulation, and the side-band power simply adds to the carrier power. With angle modulation, power is taken from the carrier with modulation and redistributed in the sidebands; thus, you might say, angle modulation puts most of its power in the information.**Disadvantages of Angle Modulation:**

Bandwidth: High-quality angle modulation produces many side frequencies, thus necessitating a much wider bandwidth than is necessary for AM transmission. Narrowband FM utilizes a low modulation index and, consequently, produces only one set of sidebands. Those side-bands, however, contain an even more disproportionate percentage of the total power than a comparable AM system. For high-quality transmission, FM and PM require much more bandwidth than AM. Each station in the commercial AM radio band is assigned 10 kHz of bandwidth, whereas in the commercial FM broadcast band, 200 kHz is assigned each station.

Circuit complexity and cost: PM and FM modulators, demodulators, transmitters and receivers are more complex to design and build than their AM counterparts. At one time, more complex meant more expensive. Today, however, with the advent of inexpensive, large-scale integration ICs, the cost of manufacturing FM and PM circuits is comparable to their AM counterparts.

(ii) Capture effect:

The inherent ability of FM to diminish the effects of interfering signals is called the *capture effect*. Unlike in AM receivers, FM receivers have the ability to differentiate between two signals received at the same frequency. Therefore, if two stations are received simultaneously at the same or nearly the same frequency, the receiver locks onto the stronger station while suppressing the weaker station. The *capture ratio* of an FM receiver is the minimum dB difference in signal strength between two received signals necessary for the capture effect to suppress the weaker signal. Capture ratios of 1 dB are typical for high quality FM receivers.

Threshold effect:

It is observed experimentally that when the signal to noise ratio $(S/N)_r$ at the FM receiver input becomes even slightly less than unity, an impulse or spike of noise generated. This noise impulse appears at the output of the FM receiver in the form of a "click" sound. When the $(S/N)_r$ is slightly less than unity, the frequency of spike generation is small, and each spike produces individual clicking sound at the receiver output. But, when the $(S/N)_r$ is moderately less than unity, the spikes are generated rapidly and the clicks merge into a *sputtering sound*. This phenomena is known as *threshold effect* in FM. The minimum $(S/N)_r$ for which the sputtering effect cannot cause distortion in the FM receiver is called as *threshold* of the FM receiver.

- The threshold effect is more serious in FM compared to AM. The process of lowering the threshold level is known as threshold improvement or threshold reduction.
- The popularly using methods for threshold improvement in FM are,
  (a) Using pre-emphasis and de-emphasis circuits.
  (b) Frequency modulation with feedback (FMFB), i.e. using PLL for FM demodulation.

Q.4 (b) (i) Solution:

1. Given that, $f_m = 1$ kHz

   Hence, minimum sampling frequency = $2f_m$ = 2 kHz

   and minimum sampling rate = 2000 samples per second

2. Resolution is given as 0.01%.

   Therefore, the minimum number of quantization levels = $\frac{100}{0.01} = 10000.$

   The minimum number of bits in the digital code (N) should satisfy the relation

   $$2^N \geq 10000$$

   This gives, $N = 14$

3. The voltage range is given as 0 to 10 V

   Hence,

   $$\text{the analog value of LSB} = \frac{1}{2^{14}} \times 10 \text{ V} = 610.35\ \mu\text{V}$$

4. The mean square value of quantization noise is $\frac{S^2}{12}$

   where, S = Separation between two successive quantization levels

   $$= \frac{\text{Voltage range}}{\text{Number of quantization levels}} = \frac{10}{2^{14}}$$

   Hence, the root mean square (r.m.s.) value of quantization noise

   $$= \sqrt{\frac{S^2}{12}} = \frac{S}{2\sqrt{3}} = \frac{10}{2^{14} \times 2\sqrt{3}} \text{ V}$$

   $$= 176.19\ \mu\text{V}$$

Q.4 (b) (ii) Solution:

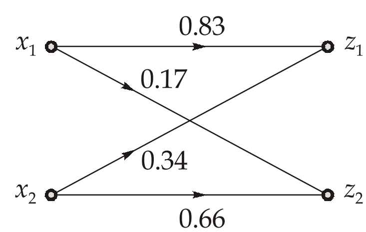
1. By equation,

$$[P(Y)] = [P(X)]\,[P(X\,|\,Y)]$$
$$[P(Z)] = [P(Y)]\,[P(Z\,|\,Y)]$$
$$= [P(X)]\,[P(Y\,|\,X)]\,[P(Z\,|\,Y)]$$
$$= [P(X)]\,[P(Z\,|\,X)]$$

Thus, from figure

$$[P(Z\,|\,X)] = [P(Y\,|\,X)]\,[P(Z\,|\,Y)]$$
$$= \begin{bmatrix} 0.9 & 0.1 \\ 0.2 & 0.8 \end{bmatrix}\begin{bmatrix} 0.9 & 0.1 \\ 0.2 & 0.8 \end{bmatrix} = \begin{bmatrix} 0.83 & 0.17 \\ 0.34 & 0.66 \end{bmatrix}$$

The resultant equivalent channel diagram is shown below in figure.



2.

$$[P(Z)] = [P(X)]\,[P(Z\,|\,X)]$$
$$= \begin{bmatrix} 0.5 & 0.5 \end{bmatrix} = \begin{bmatrix} 0.83 & 0.17 \\ 0.34 & 0.66 \end{bmatrix} = \begin{bmatrix} 0.585 & 0.415 \end{bmatrix}$$

Hence, $P(z_1) = 0.585$ and $P(z_1) = 0.415$

Q.4 (c) (i) Solution:

The torque T_2 on the loop L_2 is due to field B_1 produced by loop L_1

Hence, $$\vec{T}_2 = \vec{m}_2 \times \vec{B}_1$$

Since m_1 for loop L_1 is along $\hat{a}_z$, we find B_1 using the equation

$$\vec{B}_1 = \frac{\mu_0 m_1}{4\pi r^3}(2\cos\theta\,\hat{a}_r + \sin\theta\,\hat{a}_\phi)$$

We transform m_2 from cartesian to spherical coordinates :

$$\vec{m}_2 = 3\hat{a}_y = 3(\sin\theta\sin\phi\,\hat{a}_r + \cos\theta\sin\phi\,\hat{a}_\theta + \cos\phi\,\hat{a}_\phi)$$

At (4, –3, 10), $$r = \sqrt{4^2 + 3^2 + 10^2} = 5\sqrt{5}$$

$$\tan\theta = \frac{\rho}{z} = \frac{5}{10} = \frac{1}{2}$$

$\Rightarrow$ $$\sin\theta = \frac{1}{\sqrt{5}} \text{ and } \cos\theta = \frac{2}{\sqrt{5}}$$

$$\tan\phi = \frac{y}{x} = \frac{-3}{4} \Rightarrow \sin\phi = \frac{-3}{5},\ \cos\phi = \frac{4}{5}$$

Hence, $$\vec{B}_1 = \frac{4\pi\times 10^{-7}\times 5}{4\pi\times 625\sqrt{5}}\left(\frac{4}{\sqrt{5}}\hat{a}_r + \frac{1}{\sqrt{5}}\hat{a}_\theta\right)$$

$$\vec{B}_1 = \frac{10^{-7}}{625}(4\hat{a}_r + \hat{a}_\theta)\text{T}$$

and $$m_2 = 3\left[\frac{-3\hat{a}_r}{5\sqrt{5}} - \frac{6\hat{a}_\theta}{5\sqrt{5}} + \frac{4\hat{a}_\phi}{5}\right]$$

Now, $$\vec{T} = \vec{m}_2 \times \vec{B}_1$$

$$= \frac{10^{-7}\times 3}{625\times 5\sqrt{5}}(-3\hat{a}_r - 6\hat{a}_\theta + 4\sqrt{5}\hat{a}_\phi)\times(4\hat{a}_r + \hat{a}_\phi)$$

$$= 4.293\times 10^{-11}(-6\hat{a}_r + 38.78\hat{a}_\theta + 24\hat{a}_\phi)$$

$$T = (-0.2589\hat{a}_r + 1.665\hat{a}_\theta + 1.03\hat{a}_\phi)\mu\text{N-m}$$

Q.4 (c) (ii) Solution:

Given surface : $f(x, y) = y - x - 2 \le 0$

The unit normal vector to the surface is given as

$$\hat{a}_n = \frac{\nabla f}{|\nabla f|} = \frac{-\hat{a}_x + \hat{a}_y}{\sqrt{1^2+1^2}} = \frac{-\hat{a}_x + \hat{a}_y}{\sqrt{2}}$$

$$\vec{H}_{1n} = (H_1\cdot\hat{a}_n)\hat{a}_n = \frac{(2+6)}{\sqrt{2}}\cdot\frac{(-\hat{a}_x + \hat{a}_y)}{\sqrt{2}} = -4\hat{a}_x + 4\hat{a}_y$$

But $$\vec{H}_1 = \vec{H}_{1n} + \vec{H}_{1T}$$

$\Rightarrow$ $$\vec{H}_{1t} = \vec{H}_1 - \vec{H}_{1n} = (-2\hat{a}_x + 6\hat{a}_y + 4\hat{a}_z) - (-4\hat{a}_x + 4\hat{a}_y)$$

$$= 2\hat{a}_x + 2\hat{a}_y + 4\hat{a}_z$$

Using the boundary conditions, we have

$$\vec{H}_{2t} = \vec{H}_{1t} = 2\hat{a}_x + 2\hat{a}_y + 4\hat{a}_z$$

and $$\vec{B}_{2n} = \vec{B}_{2n} \Rightarrow \mu_2\vec{H}_{2n} = \mu_1\vec{H}_{1n}$$

$$\vec{H}_{2n} = \frac{5}{2}(-4\hat{a}_x + 4\hat{a}_y) = -10\hat{a}_x + 10\hat{a}_y$$

Thus,
$$\vec{H}_2 = \vec{H}_{2n} + \vec{H}_{2T}$$
$$= (-8\hat{a}_x + 12\hat{a}_y + 4\hat{a}_z)\text{A/m}$$

and
$$\vec{B}_2 = \mu_0\mu_{r2}\vec{H}_2$$
$$= 4\pi \times 10^{-7} \times 2[-8\hat{a}_x + 12\hat{a}_y + 4\hat{a}_z]\ \text{Wb/m}^2$$
$$= (-20.10\hat{a}_x + 30.16\hat{a}_y + 10.05\hat{a}_z)\ \mu\text{Wb/m}^2$$

Section B : Computer Fundamentals-2 + Electrical & Electronic Measurements-2

Q.5 (a) Solution:

(i) Given,
Area, $A = 5 \times 10^{-4}\ \text{m}^2$
$C = 950\ \text{pF}$
$\epsilon_r = 81$

1. We know that,

Capacitance measured by the capacitive transducer,

$$C = \frac{\epsilon A}{d} = \frac{\epsilon_0 \epsilon_r A}{d}$$

$$950 \times 10^{-12} = \frac{8.85 \times 10^{-12} \times 81 \times 5 \times 10^{-4}}{d}$$

$$\therefore \quad d = \frac{8.85 \times 10^{-12} \times 81 \times 5 \times 10^{-4}}{950 \times 10^{-12}}$$

$$\therefore \quad d = 3.77 \times 10^{-4}\ \text{m}$$

2. Sensitivity with respect to distance,

$$S = \frac{\partial C}{\partial d}$$

but,
$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

$$S = \frac{\partial C}{\partial d} = -\epsilon_0 \epsilon_r A\left(\frac{1}{d^2}\right)$$

$$= -81 \times 8.85 \times 10^{-12} \times 5 \times 10^{-4}\left(\frac{1}{(3.77 \times 10^{-4})^2}\right)$$

$$\therefore \quad S = -2.5 \times 10^{-6}\ \text{F/m}$$

(ii) Given, $3\frac{1}{2}$ digit DVM,

$$\text{Accuracy specification} = \pm 1\% \text{ of full scale}$$

$$\text{Reading} = 100 \text{ mV on its } 200 \text{ mV full scale range}$$

For the given DVM, 100 mV reading on the 200 mV full scale range is represented as 100.0 mV

Total number of counts is from 0 – 1999 = 2000 counts

1 count on this 200 mV full scale corresponds to

$$\frac{200 \text{ mV}}{2000} = 0.1 \text{ mV}$$

$$\text{percentage error in reading} = \left(\frac{+1}{100} \times 200 \text{ mA}\right)$$

$$= \pm 2\%$$

Therefore, the worst case error can be calculated as,

$$\text{Error} = \pm\left[\frac{2}{100} \times 100 \text{ mV} + 1 \times 0.1 \text{ mV}\right]$$

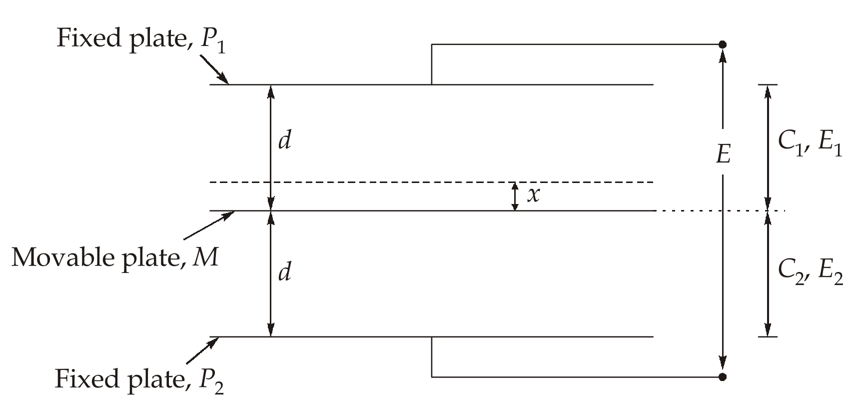
$$= \pm[2 \text{ mV} + 0.1 \text{ mV}]$$

$$= \pm 2.1 \text{ mV}$$

$\therefore$ The worst case error in the reading is ± 2.1 mV

Q.5 (b) Solution:

Given data: $d = 5$ mm; $E = 1000$ volt rms; $x = 0.01$ mm



Let the movable plate be moved up due to displacement x. Therefore the values C_1 and C_2 becomes different resulting in a differential voltage output.

Now, $$C_1 = \frac{\in A}{d-x}$$

$$C_2 = \frac{\in A}{d+x}$$

$\therefore$ $$E_1 = \frac{EC_2}{C_2+C_1} = \frac{\frac{\in A}{d+x}}{\frac{\in A}{d+x}+\frac{\in A}{d-x}}E$$

$$= \frac{E(\in A)(d-x)}{\in A(d-x+d+x)} = \frac{E(d-x)}{2d}$$

$$E_1 = \frac{E(d-x)}{2d}$$

and $$E_2 = \frac{EC_1}{C_1+C_2} = \frac{E\left(\frac{\in A}{d-x}\right)}{\left(\frac{\in A}{d-x}\right)+\left(\frac{\in A}{d+x}\right)}$$

$$= \frac{E(\in A)(d+x)}{(\in A)[d+x+d-x]}$$

$$E_2 = \frac{E(d+x)}{2d}$$

$\therefore$ Differential output voltage,

$$\Delta E = E_2 - E_1$$

$$\Delta E = \frac{(d+x)E}{2d} - \frac{(d-x)E}{2d} = \frac{E}{2d}[d+x-d+x]$$

$$= \frac{2Ex}{2d} = \frac{Ex}{d}$$

Substituting the values $$\Delta E = \frac{1000 \times 0.01}{5}$$

$$\Delta E = 2 \text{ Volt}$$

Sensitivity, $$S = \frac{\Delta E}{x} = \frac{E}{d} = \frac{2}{0.01}$$

$$S = 200 \text{ V/mm}$$

Q.5 (c) Solution:

(i) Total secondary circuit resistance

$$= 1.2 + 0.2 = 1.4\ \Omega$$

Total secondary circuit reactance

$$= 0.5 + 0.3 = 0.8\ \Omega,$$

Secondary circuit phase angle

$$\delta = \tan^{-1}\left(\frac{0.8}{1.4}\right) = 29.745°$$

$$\cos\delta = 0.8682 \text{ and } \sin\delta = 0.4961$$

Primary winding turns, $N_p = 1$

Secondary winding turns, $N_s = 200$

$\therefore$ Turns ratio, $n = 200$

$$\text{Magnetizing current, } I_m = \frac{\text{magnetizing mmf}}{\text{primary turns}} = \frac{100}{1} = 100 \text{ A}$$

$$\text{Loss component, } I_e = \frac{\text{mmf equivalent to iron loss}}{\text{primary winding turns}} = \frac{50}{1} = 50 \text{ A}$$

$$\therefore \quad \text{Actual ratio, } R = n + \frac{I_e\cos\delta + I_m\sin\delta}{I_s}$$

$$= 200 + \frac{50\times 0.8682 + 100\times 0.4961}{5} = 218.6$$

Primary current, I_p = actual transformation ratio × secondary current

$$= 218.6 \times 5 = 1093 \text{ A}$$

$$\%\text{ ratio error} = \frac{K_n - R}{R}\times 100\% = \frac{200 - 218.60}{218.60} = -8.51\%$$

(ii) In order to eliminate the ratio error, we must reduce the secondary winding turns or in other words we must reduce the turns ratio.

The nominal ratio is 200 and therefore for zero ratio error the actual transformation ratio should be equal to the nominal ratio,

Nominal ratio, $K_n = 200$

$$\text{Actual ratio, } R = n + \frac{I_e\cos\delta + I_m\sin\delta}{I_s}$$

$\therefore$ For zero ratio error, $K_n = R$

or $$200 = n + \frac{50 \times 0.8682 + 100 \times 0.4961}{5}$$

$$= n + 18.6$$

Turns ratio, $n = 181.4$

Hence secondary winding turns

$$N_s = nN_p = 181.4 \times 1 = 181.4$$

Reduction in secondary winding turns

$$= 200 - 181.4 \approx 19$$

Q.5 (d) Solution:

(i) Let cache access time be 1 and main memory access time be 20.

Requested instruction is found in the cache with probability of 0.96 or 96%.

∴ Every instruction that is executed must be fetched from the cache and an additional fetch from the main memory must be performed for 4% of these cache accesses.

Speedup is defined as the ratio of program execution time without the cache to program execution time with cache.

∴ $$\text{Speedup factor} = \frac{\text{Program execution time without cache}}{\text{Program execution time with cache}}$$

$$= \frac{1 \times 20}{[1 \times 1 + 0.04 \times 20]} = \frac{20}{1.8}$$

Speedup factor 'S' = 11.1

(ii) **Case (2)** When size of the cache is doubled, it is given that the requested instructions are found in the cache with probability of 98%.

Hence requested instructions are to be accessed from the main memory with probability of 2%

∴ Additional fetch from main memory must be performed for 2% of these cache accesses.

∴ $$\text{Speedup factor '}S\text{'} = \frac{\text{Program execution time without cache}}{\text{Program execution time with cache}}$$

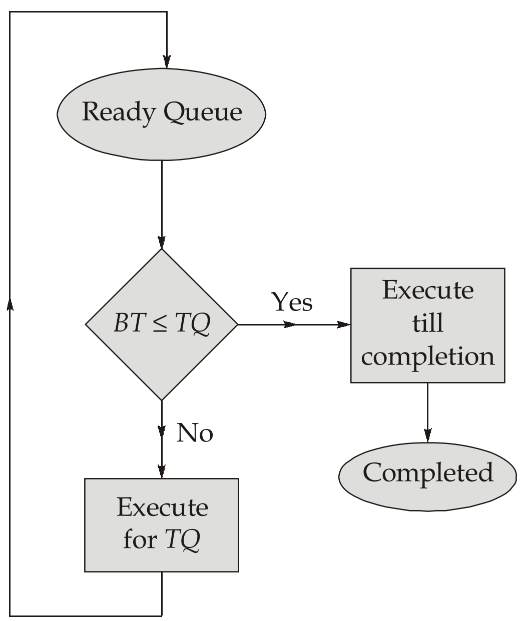
$$= \frac{1 \times 20}{[1 \times 1 + 0.02 \times 20]}$$

$$S = 14.29$$

Q.5 (e) Solution:

Round Robin Scheduling Algorithm: Round Robin scheduling algorithm is one of the most popular scheduling algorithm mainly used for multitasking and can be implemented in most of the operating systems.

This is the preemptive version of first come first serve scheduling. The algorithm focuses on time sharing. In this algorithm, every process gets executed in a cyclic way. A certain time slice is defined in the system which is called time quantum. Each process present in the ready queue is assigned the CPU for that time quantum, if the execution of the process is completed during that time then the process will terminate else the process will go back to the ready queue and waits for the next turn to complete the execution.



Here AT → Arrival Time, BT → Burst Time (remaining), TQ → Time Quantum

P_{id}	AT	BT	CT	TAT = CT – AT	WT = TAT – BT
P_1	0	8	25	25	17
P_2	5	2	14	9	7
P_3	1	7	26	25	18
P_4	6	3	17	11	8
P_5	8	5	28	20	15
P_6	2	3	9	7	4

Ready Queue: $P_1\ P_3\ P_6\ P_1\ P_2\ P_4\ P_3\ P_5\ P_1\ P_3\ P_5$

Gantt Chart:

P_1	P_3	P_6	P_1	P_2	P_4	P_3	P_5	P_1	P_3	P_5

0 3 6 9 12 14 17 20 23 25 26 28

$$\therefore \text{ Average waiting time, } T_{avg} = \frac{17+7+18+8+15+4}{6} = \frac{69}{6}$$

$$T_{avg} = 11.5 \text{ nsec}$$

Q.6 (a) Solution:

(i) **1.** RMS value of voltage supplied = 100 V

Maximum value of voltage,

$$V_m = \sqrt{2} \times 100 \text{ Volt}$$

Instantaneous value of voltage,

$$v = \sqrt{2} \times 100 \sin\theta$$

Resistance in the forward direction,

$$R_f = 50 + 50 = 100\ \Omega$$

Resistance in the reverse direction,

$$R_r = 250 + 50 = 300\ \Omega$$

Instantaneous value of current in the forward direction

$$i_f = \frac{v}{R_f} = \frac{\sqrt{2} \times 100 \sin\theta}{100}$$

$$i_f = \sqrt{2}\sin\theta$$

Instantaneous value of current in the reverse direction

$$i_r = \frac{v}{R_r} = \frac{\sqrt{2} \times 100 \sin\theta}{300}$$

$$i_r = \frac{\sqrt{2}}{3}\sin\theta$$

RMS value of current,

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi}(\sqrt{2}\sin\theta)^2 d\theta + \frac{1}{2\pi}\int_{\pi}^{2\pi}\left[\left(\frac{\sqrt{2}}{3}\right)\sin\theta\right]^2 d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} 2\sin^2\theta d\theta + \int_{\pi}^{2\pi}\frac{2}{9}\sin^2\theta d\theta\right]}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi}\frac{2(1-\cos 2\theta)}{2}d\theta + \int_{\pi}^{2\pi}\frac{2}{9}\left(\frac{1-\cos 2\theta}{2}\right)d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\left[\pi - \left(\frac{\sin 2\theta}{2}\right)_0^{\pi}\right] + \frac{1}{2\pi}\times\frac{1}{9}\left[\pi - \left(\frac{\sin 2\theta}{2}\right)_{\pi}^{2\pi}\right]}$$

$$= \sqrt{\frac{1}{2\pi}[\pi] + \frac{1}{2\pi}\times\frac{1}{9}\pi}$$

$$= \sqrt{\frac{1}{2} + \frac{1}{18}}$$

$$I_{\text{rms}} = 0.745 \text{ A}$$

Average value of current

$$I_{\text{av}} = \frac{1}{2\pi}\left[\int_0^{\pi}\sqrt{2}\sin\theta d\theta + \int_{\pi}^{2\pi}\frac{\sqrt{2}}{3}\sin\theta d\theta\right]$$

$$= \frac{1}{2\pi}\left[\sqrt{2}(-\cos\theta)_0^{\pi} + \frac{\sqrt{2}}{3}(-\cos\theta)_{\pi}^{2\pi}\right]$$

$$= \frac{1}{2\pi}\left[2\sqrt{2} - \frac{\sqrt{2}}{3}\times 2\right]$$

$$I_{av} = 0.3 \text{ A}$$

∴ Reading of dynamometer ammeter = 0.745 A

and Reading of moving coil ammeter = 0.3 A

2. Power taken from the mains = Power supplied in the forward half cycle
+ Power supplied in the backward half cycle

$$= \frac{1}{2}\left[\frac{V^2}{R_f} + \frac{V^2}{R_r}\right] = \frac{1}{2}\left[\frac{100^2}{100} + \frac{100^2}{300}\right]$$

$$= 66.67 \text{ W}$$

Power consumed in 50 Ω resistor

$$= I_{\text{rms}}^2 R$$

$$= (0.745)^2 \times 50$$

$$= 27.75 \text{ W}$$

3. Power dissipated in rectifier

$$= \text{Total power supplied} - \text{Power consumed in resistor}$$
$$= 66.67 - 27.75$$
$$= 38.92 \text{ W}$$

(ii) Given : $I = 4\theta^n$ A

We know, for a moving iron ammeter

Deflection in radian, $\theta = \frac{1}{2}\frac{I^2}{K}\frac{dL}{d\theta}$

Rate of change of self inductance

$$\frac{dL}{d\theta} = \frac{2K\theta}{I^2}$$

$$\frac{dL}{d\theta} = \frac{2K\theta}{(4\theta^n)^2} = \frac{2K\theta}{16\theta^{2n}}$$

$$\frac{dL}{d\theta} = \frac{K\theta}{8\theta^{2n}} = \frac{K\theta^{(1-2n)}}{8}$$

$$dL = \frac{K}{8}\theta^{(1-2n)}d\theta$$

Integrating the above expression

$$L = \frac{K}{8}\times\frac{\theta^{2-2n}}{(2-2n)}+C \quad ...(1)$$

where C is a constant.

We have $I = 0$ when $L = 10 \times 10^{-3}$ H

From eqn. (1)

$$10 \times 10^{-3} = C$$

$$\therefore \quad L = \frac{K}{8}\times\frac{\theta^{2-2n}}{(2-2n)}+10\times 10^{-3}\text{H}$$

With $n = 0.75$

$$L = \frac{K}{16(1-0.75)}\times\theta^{2(1-0.75)}+10\times 10^{-3}$$

$$L = \frac{0.16}{16\times 0.25}\times\theta^{0.5}+10\times 10^{-3}$$

$$L = 0.04\theta^{0.5} + 10 \times 10^{-3}$$

Put $L = 60$ mH

$$60 \times 10^{-3} = 0.04 \times \theta^{0.5} + 10 \times 10^{-3}$$

$$50 \times 10^{-3} = 0.04 \times \theta^{0.5}$$

Deflection, $\theta = 1.5625$ rad

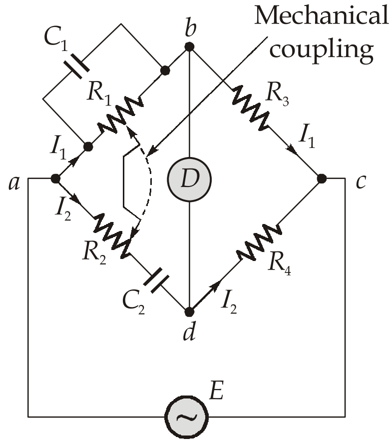
Current, $I = 4\theta^{n}$

$$= 4(1.5625)^{0.75}$$

Current, $I = 5.59$ A

Q.6 (b) Solution:

Basic layout of Wein's bridge is shown below,



At balance condition,

$$Z_{ab} \cdot Z_{cd} = Z_{ad} \cdot Z_{bc}$$

$$\left(R_1 \,||\, \frac{1}{j\omega C_1}\right) R_4 = \left(R_2 + \frac{1}{j\omega C_2}\right) R_3$$

$$\Rightarrow \quad \frac{R_1 R_4}{1 + j\omega C_1 R_1} = R_3\left[R_2 + \frac{1}{j\omega C_2}\right]$$

$$\Rightarrow \quad R_1 R_4 = R_3\left[R_2 + \frac{C_1}{C_2} R_1\right] + jR_3\left[\omega C_1 R_1 R_2 - \frac{1}{\omega C_2}\right]$$

Equating real part, we get

$$R_1 R_4 = R_2 R_3 + \frac{C_1}{C_2} R_1 R_3$$

$$\therefore \quad \frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2}$$

Equating imaginary part, we get

$$\omega C_1 R_1 R_2 - \frac{1}{\omega C_2} = 0$$

$$\therefore \qquad \omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \text{ rad/sec}$$

also, $$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \text{ Hz}$$

Generally, in most of the Wein's bridges,

$$R_1 = R_2 = R$$

and $$C_1 = C_2 = C$$

then, equation becomes,

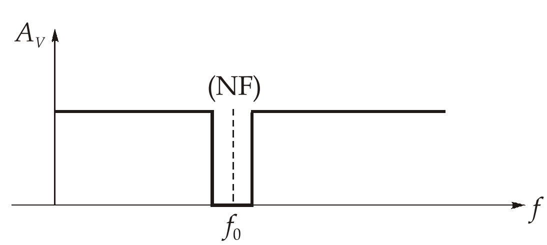
$$R_4 = 2R_3$$

and, $$\omega = \frac{1}{RC} \text{ and } f = \frac{1}{2\pi RC}$$

Wein's Bridge Applications:

- It may be employed in a "Harmonic distortion analyzer" where it is used as "Notch filter".
- It also finds applications in Audio and High frequency oscillators as the frequency determining device (100 Hz-100 KHz).
- The bridge may be used in "Frequency-determining device" balanced by a single control and this control may be calibrated directly in terms of frequency.
- It may also be used for the measurement of "Capacitance".
- Because of its "Frequency sensitivity", the Wein's bridge may be difficult of balance (unless the waveform of the supplied voltage is sinusoidal).
- It is possible to obtain an accuracy of 0.1 – 0.5%.

Wein's Bridge (WB) as "Notch Filter"



- "Wein's Bridge" rejects only one particular frequency "f_0" signal for which it is tuned, while it passes all other frequencies. Hence, Wein's Bridge is acting as a "Notch Filter".

Q.6 (c) Solution:

(i) Virtual address = 47 bits

Page size = 16 kB

Page table entry size (PTES) = 8 Byte

We have to perform multi-level paging until page table size ≤ Page size.

I^{st} level paging:

$$\text{Number of pages} = \frac{\text{Virtual address}}{\text{Page size}} = \frac{2^{47}}{2^{14}} = 2^{33}$$

$$\text{Page table size} = \text{Number of pages} \times \text{PTES}$$

$$= 2^{33} \times 8 = 64 \text{ GB}$$

Since page table size > page size, so

II^{nd} level paging:

$$\text{page table size} = \frac{64\text{ GB}}{2^{14}} \times 8\text{B} = \frac{2^{36}}{2^{14}} \times 2^3\text{B} = 32 \text{ MB}$$

Since page table > page size, so

III^{rd} level paging

$$\text{page table size} = \frac{32\text{ MB}}{2^{14}} \times 8\text{B} = \frac{2^{25}}{2^{14}} \times 2^3\text{B}$$

$$= 2^{14}\text{B} = 16 \text{ kB}$$

Now, page table size = page size

So, 3 levels are required to map logical address space if every page table is required to fit in single page.

(ii) (a) Disk capacity = #Surface in disk × #Tracks per surface × #Sectors per track × #Bytes per sector

$$= 32 \times 2 \times 256 \times 512 \times 1024 \text{ Bytes}$$

$$= 2^{33} = 8 \text{ GB}$$

(b) Seek time = 12.5 msec

- Rotational latency depends on rotational speed.

8800 revolution = 60 sec

$$1 \text{ revolution} = \frac{60}{8800} = 6.81 \text{ msec}$$

$$\text{Average rotational latency} = \frac{1}{2} \times 6.81 = 3.40 \text{ msec}$$

- Transfer time depends on rotational speed

  1 revolution access = 1 track (i.e., 512 sequential sectors)

  Transfer time for 72 sequential sectors = $\dfrac{72 \times 6.81}{512} = 0.957$ msec

  So, Time required to access 72 sequential sectors,

$$T_{avg} = 12.5 + 3.4 + 0.957 + 0$$
$$= 16.857 \text{ ms}$$

(c) Random sector accessing requires adjustment for every sector, so

1 Revolution —— 1 Track (512 sectors)

? —— 1 Sector

Transfer time for 1 sector = $\dfrac{6.81 \times 1}{512} = 0.0133$ msec

So,

Time required to access one sector = (12.5 + 3.4 + 0.0133 + 0) ms

Time required to access 120 random sectors = (12.5 + 3.4 + 0.0133) × 120

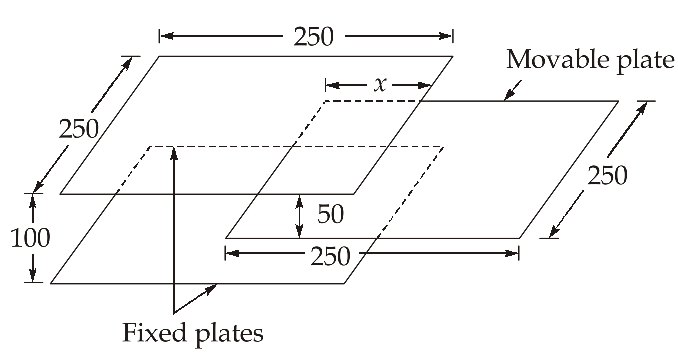
$$= 1909.6 \text{ ms}$$
$$= 1.91 \text{ sec}$$

(d) In one revolution, 512 x 1024 bytes of data can be accessed. Since one revolution time is 6.81 msec, hence Data Transfer Rate

$$= \frac{512 \times 1024}{6.81} \times 10^3 = 76.987 \times 10^6 \text{ Bytes/sec}$$
$$= 76.987 \text{ MBps}$$

Q.7 (a) Solution:

The arrangement of plates is shown below when the movable plate has moved in a distance x mm.



Area of plates: $A = 250 \times x \text{ mm}^2 = 250x \times 10^{-6} \text{ m}^2$

Distance between the plates $d = 50 \text{ mm} = 50 \times 10^{-3}$ m

The capacitance of the arrangement is

$$C_{eq} = C_1 + C_2 \text{ [There are two capacitors in parallel]}$$

Since all the dimensions are same ∴ $C_1 = C_2$

$$\therefore \quad C_{eq} = 2\,C = \frac{2 \times \varepsilon_0 A}{d}$$

$$\therefore \quad C_{eq} = \frac{2 \times 8.85 \times 10^{-12} \times 250x \times 10^{-6}}{50 \times 10^{-3}}$$

$$C_{eq} = 8.85x \times 10^{-14} \text{ F}$$

On account of the movement of the movable plate, the effective capacitance changes.

Rate of change of capacitance is given by

$$\frac{dC}{dx} = 0.0885 \times 10^{-12} \frac{\text{F}}{\text{mm}}$$

Let x_0 be the initial displacement of moving plate in mm.

$$\therefore \quad \text{Net displacement} = x - x_0$$

Hence,
$$x - x_0 = \frac{1}{2}\frac{V^2}{K}\frac{dC}{dx}$$

For $V = 12 \text{ kV} = 12000 \text{ V}$, $x = \frac{250}{4} = 62.5 \text{ mm}$

$$62.5 - x_0 = \frac{1}{2}\left[\frac{(12000)^2}{K}\right] \times 0.0885 \times 10^{-12}$$

$$62.5 - x_0 = \frac{6.372 \times 10^{-6}}{K} \quad \text{...(1)}$$

For $V = 32 \text{ kV} = 32000 \text{ V}$, $x = \frac{250}{2} = 125 \text{ mm}$

$$\therefore \quad 125 - x_0 = \frac{1}{2}\left[\frac{(32000)^2}{K}\right] \times 0.0885 \times 10^{-12}$$

$$\therefore \quad 125 - x_0 = \frac{45.31}{K} \times 10^{-6} \quad \text{...(2)}$$

On solving equation (1) and (2),

we get, $x_0 = 52.3 \text{ mm and } K = 0.623 \times 10^{-6} \text{ N/m}$

Let the voltage applied for a displacement moving plate of three quarter way in be V.

Hence, for $x = 0.75 \times 250 = 187.5$ mm, Voltage is V.

$$\therefore \quad 187.5 - 52.3 = \frac{1}{2} \times \frac{V^2}{0.623 \times 10^{-6}} \times 0.0885 \times 10^{-12}$$

$$\therefore \quad V = 43.6 \text{ kV}$$

Q.7 (b) Solution:

(i) **First group:** Each customer needs 256 = 2^8 address. Therefore, 8-bits are needed to define each host. The prefix length is 32 – 8 = 24 bits.

The addresses are:

1st customer = 190.100.0.0/24 – 19.100.0.255/24
2nd customer = 190.100.1.0/24 – 190.100.1.255/24
⋮
64th customer = 190.100.63/0/24 – 190.100.63.255/24
Total addresses allocated = 64 × 256 = 16384

(ii) **Second Group:** For this group, each customer needs 128 addresses. Therefore, 7-bits are needed to define each host.

The suffix length is 7 ($\because$ 2^7 = 128). The prefix length is then 32 – 7 = 25.

The addresses are:

1st customer = 190.100.64.0/25 – 190.100.64.127/25
2nd customer = 190.100.64.128/25 – 190.100.64.255/25
⋮
128th customer = 190.100.127.128/25 – 190.100.127.255/25
Total addresses allocated = 128 × 128 = 16384

(iii) **Third Group:** For this group, each customer needs 64 address. Therefore, 6-bits are needed to define each host.

This means suffix length is 6 ($\because$ 2^6 = 64). The prefix length is then 32 – 6 = 26.

The addresses are:

1st customer = 190.100.128.0/26 – 190.100.128.63/26
2nd customer = 190.100.128.64/26 – 190.100.128.127/26
⋮
128th customer = 190.100.159.192/26 – 190.100.159.255/26
Total addresses allocated = 128 × 64 = 8192

Hence, number of addresses granted to the ISP = 65536

Number of allocated addresses by the ISP = 16384 + 16384 + 8192 = 40960.

Number of available addresses by the ISP = 65536 – 40960 = 24576.

Hence, 24576 addresses are available, with the available addresses are from 190.100.160.0 to 190.100.255.255.

Q.7 (c) Solution:

Principle of operation: The signal wave form is converted to trigger pulses and is applied continuity to an AND gate, as shown in figure below. A pulse of 1s is applied to the other terminal and the number of pulses counted during this period indicates the frequency.

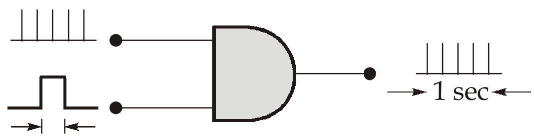
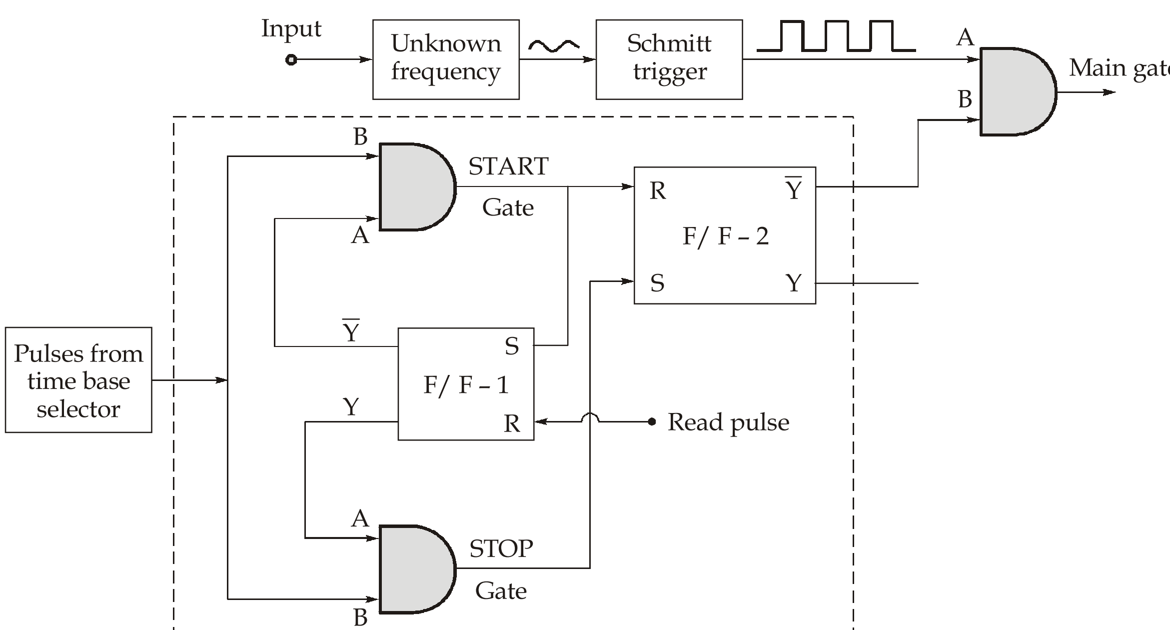


Fig: Principle of digital frequency measurement

The signal whose frequency is to be measured is converted into a train of pulses, one pulse for each cycle of the signal. The number of pulses occurring in adequate interval of time is then counted by an electronic counter. Since each pulse represents the cycle of the unknown signal, the number of counter is a direct indication of the frequency of the signal.

Basic circuit for frequency measurement: The basic circuit or frequency measurement is as shown in figure below. The output of the unknown frequency is applied to a Schmitt trigger, producing positive pulses at the output. These pulses are called the counter signals and are present at point A of the main gate. Positive pulses from the time base selector are present at point B of the start gate and at point B of the stop gate.



Initially the flip-flop (FF – 1) is at its logic 1 state. The resulting voltage from output Y is applied to point A of the STOP gate and enables this gate. The logic 0 stage at the output $\bar{Y}$ of the F/F – 1 is applied to the input A of the START gate and disables the gate.
As the STOP gate is enabled, the positive pulses from the time base pass through the STOP gate to the set (S) input of the F/F – 2 thereby setting F/F – 2 to the 1 state and keeping it there.

The resulting 0 output level from $\bar{Y}$ of F/F – 2 is applied to terminal B of the main gate. Hence no pulses from the unknown frequency source can pass through the main gate.
In order to start the operation, a positive pulse is applied to (read input) reset input of F/F – 1, thereby causing its state to change. Hence $\bar{Y}$ = 1, Y = 0 and as a result the STOP gate is disabled and the START gate is enabled.
The pulse from the unknown frequency source pass through the main gate to the counter and the counter starts counting. This same pulse from the START gate is applied to the set input of F/F – 1, changing its state from 0 to 1. This disables the START gate and enables this stop gate. However, till the main gate is enabled, pulses from the unknown frequency continue to pass through the main gate to the counter.
The counter counts the number of pulses occurring between two successive pulses from the time base selector. If the time interval between this two successive pulses from the time base selector is one second, then the number of pulses counted within this interval is the frequency of the unknown frequency source, in hertz.

Q.8 (a) Solution:

Algorithm Logic :

Step 1 : Create a function to check if the string is a palindrome.
Ispalindrome(str)

Step 2 : Initialize indexes for low and high levels to be 0 and (n – 1) respectively.

Step 3 : Until the low index (l) is lower than the high index (h), do the following :

(i) If str (l) is different from str (h) return false.

(ii) If str (l) and str (h) are same
then increment l, i.e., i++
and decrement h, i.e., h– –

Step 4 : If we reach this step, means there is no mismatch and the string is a Palindrome.
Otherwise, step 3 (i) is true, it is not a Palindrome.

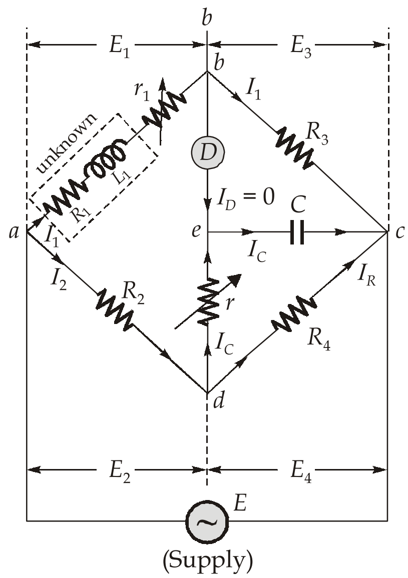
Code :

```
#include <stdio.h>
#incluce <string.h>
void Ispalindrome (char str[])
{
int l=0;
int h= strlen(str)–1;
while (h>l)
{
if [str[(l++]! = str[h--])
{
Printf("%S is not a Palindrome string\n", str);
return;
}
}
Printf("%S is a Palindrome string\n",str);
}
int main( )
{
    Is Palindrome("level");
    Is Palindrome("radar");
    Is Palindrome("END");
    return 0;
}
```

Q.8 (b) (i) Solution:

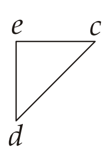
Anderson's Bridge:

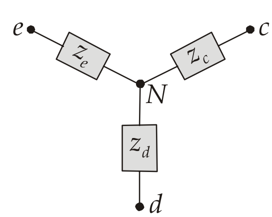
- It is a modification of the Maxwell's Inductance-Capacitance bridge.
- In this bridge method, the self inductance is measured in terms of standard capacitor



At balanced condition,

$$V_b = V_e \quad \text{So,} \quad I_D = 0$$

Also for the Delta network  we can convert this in star form as,



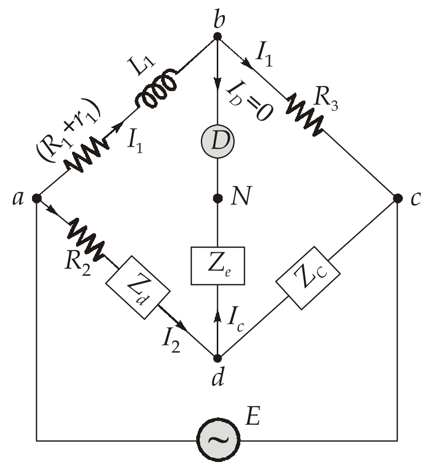
So,

$$Z_e = \frac{r(1/j\omega C)}{r + R_4 + (1/j\omega C)} = \frac{r}{1 + j\omega C(r + R_4)}$$

$$Z_c = \frac{R_4(1/j\omega C)}{r + R_4 + (1/j\omega C)} = \frac{R_4}{1 + j\omega C(r + R_4)}$$

$$Z_d = \frac{r \cdot R_4}{r + R_4 + (1/j\omega C)} = \frac{j\omega C R_4 r}{1 + j\omega C(r + R_4)}$$

Now the circuit can be represented as,



For balance condition,

$$Z_{ab} \cdot Z_{cd} = Z_{ad} \cdot Z_{bc}$$

or, $$\{(R_1 + r_1) + j\omega L_1\} \times \frac{R_4}{1 + j\omega C(r + R_4)} = R_3 \cdot \left\{R_2 + \frac{j\omega C R_4 r}{1 + j\omega C(r + R_4)}\right\}$$

or $$(R_1 + r_1)R_4 + j\omega L_1 R_4 = R_3[R_2 + j\omega C\{R_2(r + R_4) + rR_4\}]$$

Equating real part, we get

$$(R_1 + r_1)R_4 = R_2 R_3$$

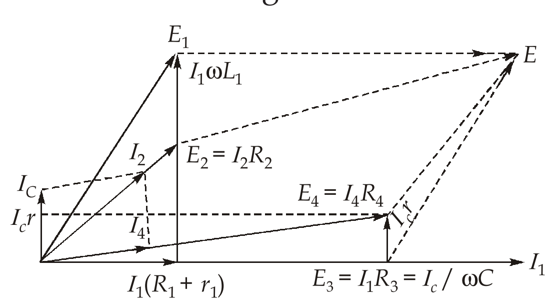
$\therefore$ $$R_1 = \frac{R_2 R_3}{R_4} - r_1$$

Now equating imaginary part, we get

$$L_1 R_4 = R_3 C [R_2 R_4 + rR_2 + rR_4]$$

$$L_1 = C\frac{R_3}{R_4} [R_2 R_4 + r(R_2 + R_4)]$$

- Phasor diagram for Anderson's bridge network.



- Quality factor = $Q = \dfrac{\omega L_1}{R_1}$
- It is suitable for Low Q-coils (i.e. $Q < 1$).

Merits:

- It may be used for accurate estimation of capacitance in terms of inductance.
- It is relatively cheaper because here fixed capacitance is used.
- It is much easier to obtain the balance.

Demerits:

- It is more complex circuit.
- The balance equations are not simple and infact are much more tedious.
- An additional junction point increases the difficulty of shielding the bridge network.

Q.8 (b) (ii) Solution:

$$\text{Power consumed by load} = 25 \times 10 \times 0.174 = 43.5 \text{ W}$$

In figure (a), the current coil is on the load side,

$$\text{Power factor, } \cos\phi = 0.174$$

$$\therefore \quad \phi = 80° \text{ lagging}$$

$$\text{Current, } I = 10(\cos 80° - j\sin 80°)$$

$$= 10(0.1736 - j0.985) = (1.736 - j9.85) \text{ A}$$

$$\text{Voltage drop across current coil} = (1.736 - j9.85)(0.06 + j0.02)$$

$$= (0.301 - j0.5563) \text{ V}$$

$$\text{Voltage across pressure coil, } V_p = 25 + 0.301 - j0.5563$$

$$= 25.307\angle{-1.26°} \text{ V}$$

$$\text{Power indicated by wattmeter} = 25.307 \times 10 \times \cos(80° - 1.26°) = 49.415 \text{ W}$$

Alternate Method:

$$\text{Reading of wattmeter} = \text{Power consumed in load + power consumed in CC}$$

$$= 43.5 + (10)^2 \times 0.06 = 49.5 \text{ W}$$

$$\text{Error} = \frac{49.5 - 43.5}{43.5} \times 100 = 13.8\%$$

When the pressure coil is on the load side as in figure (b).

$$\text{Power lost in pressure coil} = \frac{(25)^2}{6250} = 0.1 \text{ W}$$

$$\text{Power indicated by wattmeter} = 43.5 + 0.1 = 43.6 \text{ W}$$

$$\text{Error} = \frac{43.6 - 43.5}{43.5} \times 100 = 0.23\%$$

Q.8 (c) Solution:

Data-acquisition systems are used to measure and record analog signals in basically two different ways:

(a) Signals which originate from direct measurement of electrical quantities. These signals may be d.c. or a.c. voltages, frequency or resistance, etc.

(b) Signals which originate from use of transducers.

Types of Instrumentation Systems: The instrumentation systems can be classified into two distinct categories:

(a) **Analog System:** These systems deal with information in analog form. An analog signal may be defined as continuous function, such as a plot of voltage versus time or displacement versus force.

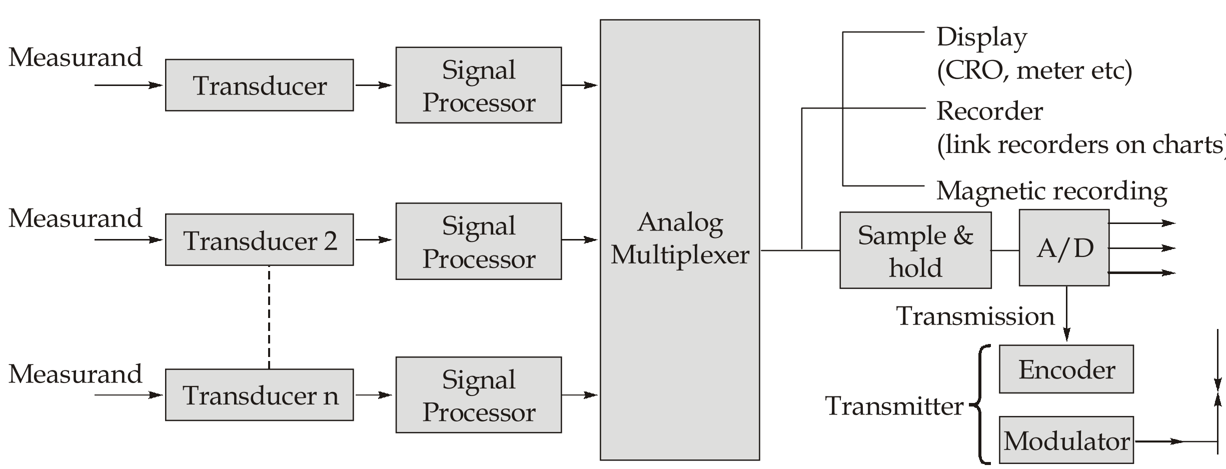
(b) **Digital System:** A digital quantity may consist of a number of discrete or discontinuous pulses whose time relationship contains information about the magnitude and the nature of the quantity under measurement.

Components of an Analog Data-Acquisition System:

(a) **Transducers:** It is desirable that an emf obtained from the transducer proportional to the quantity being measured is used as an input to the data acquisition system.

(b) **Signal Conditioning Equipment:** Signal conditioning equipment includes any equipment that assists in transforming the output of transducer to the desired magnitude or form required by the next stage of the data acquisition system. It also produces the required conditions in the transducers so that they work properly.

(c) **Multiplexer:** Multiplexing is the process of sharing a single channel with more than one output. Thus a multiplexer accepts multiple analog inputs and connects them sequentially to one measuring input.



(d) **Calibrating Equipment:** Before each test there is a pre-calibration, and often after each test there is a post-calibration. This usually consists of a millivolt calibration of all input circuits and shunt calibration of all bridge-type transducer circuits.

(e) **Integrating Equipment:** It is often desirable to know the integral or summation of a quantity.

(f) **Visual Display Devices:** Visual display devices are required for continuous monitoring of the input signals.

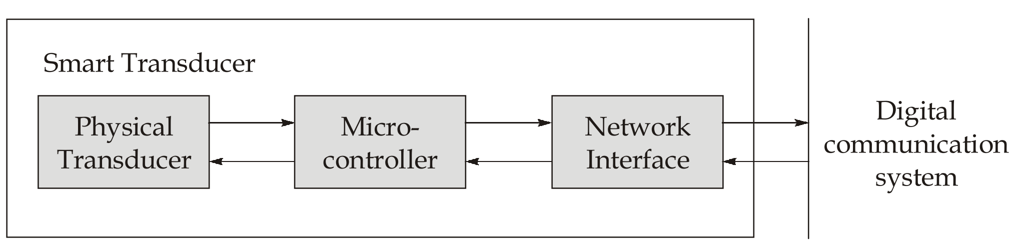
(g) **Analog Recoders:** The methods of recording data in analog form.

(h) **Analog Computers:** The function of a data acquisition system is not only to record data acquired by the transducers and the sensors but also to reduce this data to the desired form. An analog computer may be used as a data reduction device. The output voltage of an analog computer can either be recorded in analog form or be converted to a digital form for recording and further computation.

(i) **High Speed Cameras and TV Equipment:** In many industrial processes, engine testing, and aerodynamic testing it is not possible for the test operator to have a view of the equipment being tested. Therefore, closed circuit TV is used to enable the operator to make visual observations of the test. Also high speed cameras are employed to obtain a complete visual record of the process for further analysis.

Smart Transducer:

As sensors and actuators becomes more complex they provide support for various modes of operation and interfacing. Some applications require additionally fault-tolerance and distributed computing. Such high full functionality can be achieved by adding an embedded micro-controller to the classical sensor actuator, which increases the ability to cope with complexity at a fair price. This integration of an analog or digital sensor/actuator, a processing unit and a communication interface is reference to as smart transducer.



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