MADE EASY
Leading Institute for ESE, GATE & PSUs

Detailed Solutions

ESE-2024
Mains Test Series

E & T Engineering
Test No : 11

Section A

Q.1 (a) Solution:

(i) Comparing the above transfer function with the standard second order given block diagram for $T_L = 0$, we get,

$$G(s) = \frac{10}{0.25s^2 + s}$$

$$H(s) = 1$$

$$T(s) = \frac{G(s)}{1 + G(s)H(s)} = \frac{10}{0.25s^2 + s + 10} = \frac{40}{s^2 + 4s + 40}$$

From the transfer function, we get,

$$\omega_n^2 = 40$$

$$\omega_n = \sqrt{40} = 6.324 \text{ rad/sec}$$

and $$2\xi\omega_n = 4$$

$$\xi = \frac{4}{2 \times 6.324} = 0.316$$

Peak overshoot, $$M_p = e^{-\frac{\pi\xi}{\sqrt{1-\xi^2}}}$$

$$M_p = e^{-\frac{0.316\pi}{\sqrt{1-(0.316)^2}}} = 0.3512$$

or $$\%M_p = 35.12\%$$

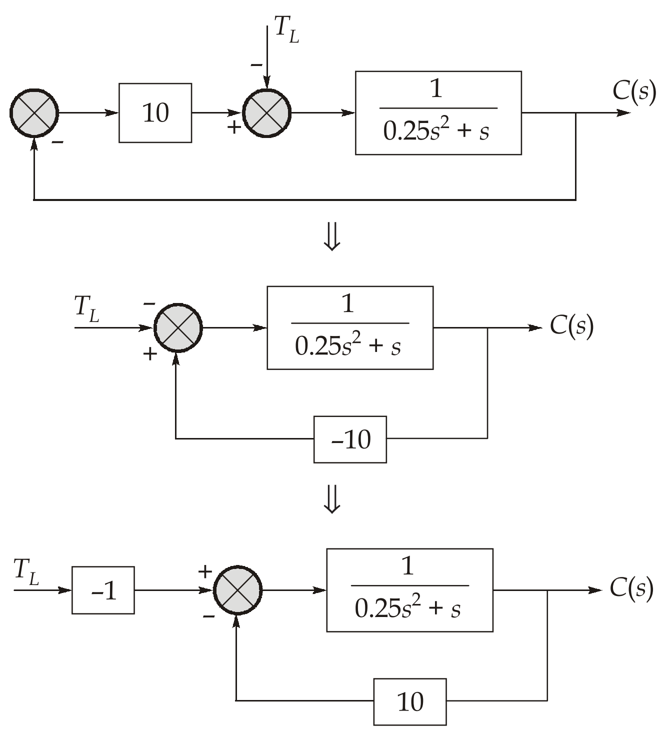
For 2% tolerance band, settling time

$$t_s = \frac{4}{\xi\omega_n} = \frac{4}{2} = 2\,\text{sec}$$

(ii) For this case, it is given that

$$R(s) = 0,\ T_L = 1\ \text{N-m}$$

The simplified block diagram can be drawn as below: [with $R(s) = 0$]



$$\frac{C(s)}{T_L(s)} = \frac{-1}{0.25s^2 + s + 10}$$

$$\text{Applied torque, } T_L(s) = \frac{1}{s}$$

Therefore, $$C(s) = \frac{-(4)}{s(s^2 + 4s + 40)}$$

$$\text{Steady state output, } C_{ss} = \lim_{s\to 0} sC(s)$$

$$= \lim_{s\to 0} \frac{-4}{s^2 + 4s + 40} = -0.1\ \text{units}$$

Q.1 (b) Solution:

(i) We have,

$$\text{Bit rate, } R_b = 50 \text{ Mbps}$$

number of bits per sample, $n = 7$

We know that

$$R_b = nf_s \quad \Rightarrow \quad f_s = \frac{R_b}{n}$$

$$f_s = \frac{50 \times 10^6}{7}$$

$$f_s = 7.14 \text{ MHz}$$

As per sampling theorem,

$$f_s \geq 2f_m$$

$$7.14 \text{ MHz} \geq 2 \times f_m$$

$$3.57 \text{ MHz} \geq f_m$$

Thus,

Maximum message bandwidth for which the system operates satisfactorily is 3.57 MHz.

(ii) For binary PCM system, the quantization noise amplitude is a random variable uniformly distributed between $\pm\Delta/2$, where Δ is the step-size

Maximum Quantization Noise amplitude = $\dfrac{\Delta}{2}$

where, $\Delta = \text{step size} = \dfrac{\text{Voltage swing}}{2^n} = \dfrac{V_s}{2^n}$

(n = number of bits/sample)

As per the given condition,

$$\frac{\Delta}{2} \leq \frac{P}{100} \times V_s$$

$$\frac{V_s}{2^{n+1}} \leq \frac{P \times V_s}{100}$$

$$\frac{1}{2^{n+1}} \leq \frac{P}{100}$$

$$2^n \geq \frac{50}{P}$$

Taking log on both sides,

$$n \log_{10} 2 \geq \log_{10}\left(\frac{50}{P}\right) \quad \Rightarrow \quad n \geq \log_2 10\left[\log_{10}\left(\frac{50}{P}\right)\right]$$

Q.1 (c) Solution:

The timing of various signals during interrupt acknowledge cycle of 8085 when RST n instruction is supplied by the interrupting devices are shown below.

1. In the first T- state of interrupt acknowledge cycle, the address is placed on the AD_0-AD_7 and A_8-A_{15} lines and ALE is asserted high. But the address is not used to read from memory. It specifies the instruction address stored in Program Counter. The other control signals are asserted as follows:

$$IO/\overline{M} = 1, S_0 = 1 \text{ and } S_1 = 1$$

In the middle of T_1, ALE is asserted low. The INTR signal can remain high or it can go low once the interrupt is accepted.

2. In the second T State (T_2), $\overline{INTA}$ is asserted low, and this enables the interrupting device to place the opcode of RST n instruction on the data bus.

3. At the end of T_3, the $\overline{INTA}$ is asserted high and the RST n opcode is latched into the processor. The time allowed for the external hardware to place the RST n opcode is the time during which $\overline{INTA}$ remains low.

4. The next three T states T_4, T_5 and T_6 are used for internal operations. The internal operations performed are decoding the instruction, encoding it into various machine cycles and the generation of the vector address for the RST n interrupt.

5. The T states T_7, T_8, and T_9 are used to store the high bytes of the Program Counter (PC) in the stack (using the content of the stack pointer (SP) as address).

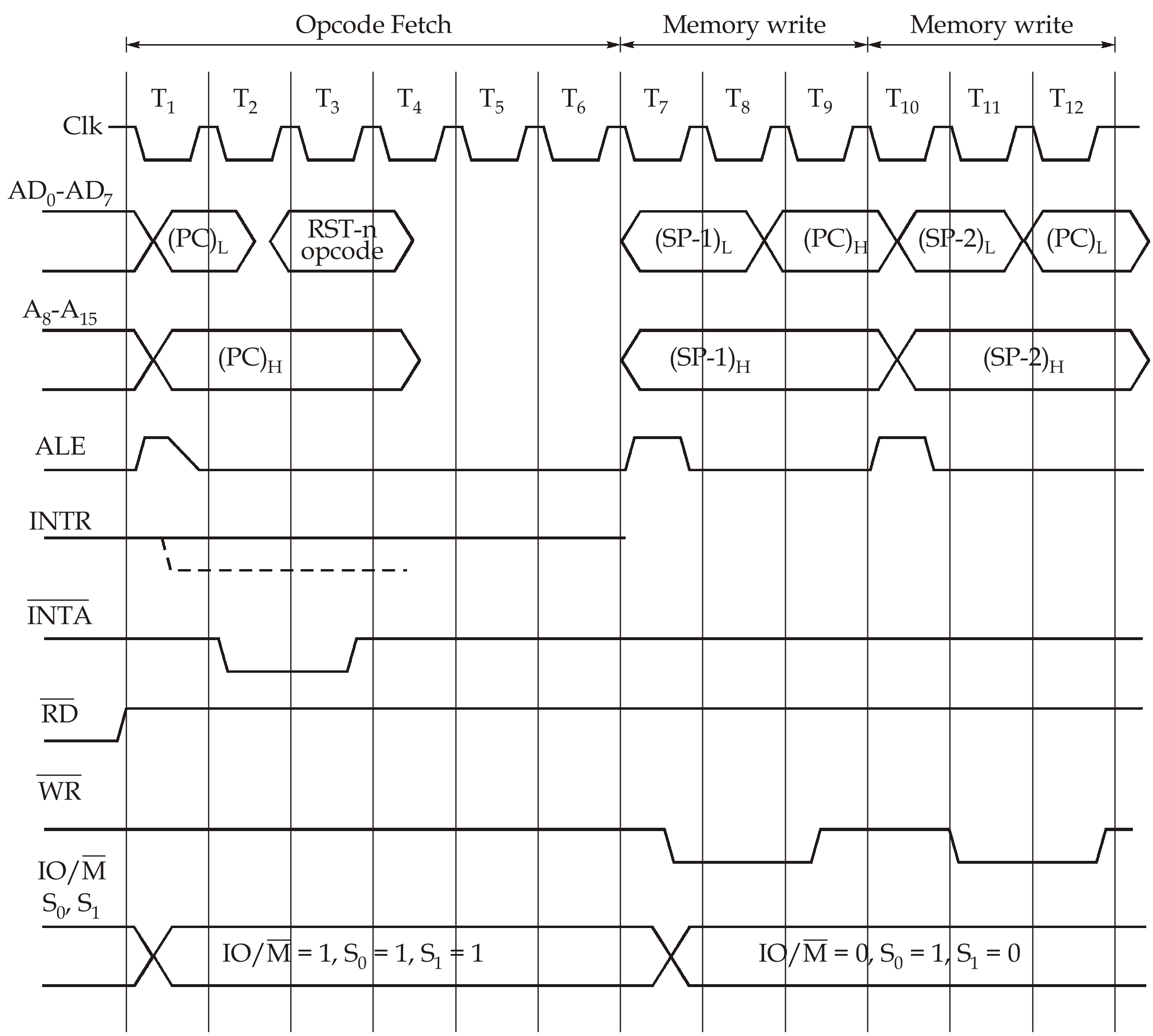
   In T_7, the content of SP is decremented by one and placed on AD_0-AD_7 and A_8-A_{15} lines. ALE is asserted high and then low, to latch the low byte of the address into the external latch. The status signals are asserted as $IO/\overline{M} = 0$, $S_0 = 1$ and $S_1 = 0$.

   In T_8, the high byte of the PC is placed on the AD_0-AD_7 lines and $\overline{WR}$ is asserted low to enable the stack memory for the write operation. At the end of T_9, $\overline{WR}$ is asserted high.

6. The T states T_{10}, T_{11}, and T_{12} are used to store the low byte of the program counter into the stack.

In T_{10}, the content of SP is again decremented by one and placed on the AD_0-AD_7 and A_8-A_{15} lines. ALE is asserted high and then low, to latch the low byte of address into the external latch. The status signals are asserted as $IO/\overline{M} = 0$, $S_0 = 1$ and $S_1 = 0$. In T_{11}, the low byte of PC is placed on AD_0-AD_7 lines and $\overline{WR}$ is asserted low to enable the stack memory for the write operation. At the end of T_{12}, $\overline{WR}$ is asserted high.

After the interrupt acknowledge machine cycle, the program counter (PC) will have the vector address of RST n instruction and so, the processor starts servicing the interrupt by executing the interrupt service subroutine stored at this address.



Q.1 (d) Solution:

The critical angle at the interface is

$$\theta_c = \sin^{-1}\left(\frac{\sqrt{\epsilon_2}}{\sqrt{\epsilon_1}}\right) = \sin^{-1}\left(\frac{1}{n}\right)$$

$$= \sin^{-1}\left(\frac{1}{3}\right) = 19.47°$$

Since, the angle of incidence is $60° > \theta_c$, the wave is total internally reflected at the interface. In dielectric medium, then we have superposition of the incident and the reflected wave and in air, we have exponentially decaying fields.

For s-polarized wave, reflection coefficient can be written as

$$\Gamma_\perp = \frac{\sqrt{\frac{\epsilon_1}{\epsilon_2}}\cos\theta_i - j\sqrt{\frac{\epsilon_1}{\epsilon_2}\sin^2\theta_i - 1}}{\sqrt{\frac{\epsilon_1}{\epsilon_2}}\cos\theta_i + j\sqrt{\frac{\epsilon_1}{\epsilon_2}\sin^2\theta_i - 1}}$$

$$= \frac{3\left(\frac{1}{2}\right) - j\sqrt{9\left(\frac{\sqrt{3}}{2}\right)^2 - 1}}{3\left(\frac{1}{2}\right) + j\sqrt{9\left(\frac{\sqrt{3}}{2}\right)^2 - 1}}$$

$$= -0.4375 - 0.8992j$$

Hence, total electric field in dielectric medium is given by

$$E_1 = E_i + \Gamma_\perp E_i$$

$$= (0.5625 - 0.8992j) \times 10$$

$\Rightarrow$ Peak amplitude $= |E_1| = 10.606$ V/m

In the air, electrical field decays as we go away from the interface. In air, β is along the x-axis. New β_x will be given by

$$\beta_x = \beta_1 \sin\theta_i$$

Hence,

$$v_p = \frac{\omega}{\beta_1 \sin\theta_i} = \frac{c}{\sqrt{\epsilon_{r1}}\sin\theta_i}$$

$$= \frac{3\times 10^8}{3}\times\left(\frac{2}{\sqrt{3}}\right) = 1.155\times 10^8 \text{ m/s}$$

$$\beta_2 = \frac{\omega}{c} = \frac{2\pi \times 10^{10}}{3 \times 10^8} = \frac{200\pi}{3} \text{ rad/m}$$

$$\beta_1 \sin \theta_i = \frac{2\pi \times 10^{10}}{3 \times 10^8} \times 3 \times \frac{\sqrt{3}}{2} = 100\sqrt{3}\pi$$

Electric field in air is given by

$$E_{air} = 10 \times e^{-5\times10^{-3}\sqrt{(100\sqrt{3}\pi)^2 - (200\pi/3)^2}}$$
$$= 0.811 \text{ V/m}$$

Q.1 (e) Solution:

Let $y(n)$ be the resultant convoluted signal. Then

$$y(n) = \sum_{k=-\infty}^{\infty} x(k)h(n-k)$$

From the graph,

$$x_l = 0, x_r = 2, h_l = -1, h_r = 2$$

Therefore, the left and right extremes of $y(n)$ are found to be

$$y_l = x_l + h_l = 0 + (-1) = -1$$
$$y_r = x_r + h_r = 2 + 2 = 4$$

When $n = -1$

$$y(-1) = \sum_{k=-\infty}^{\infty} x(k)h(-1-k)$$
$$= ...+ x(0)\, h(-1) + x(1)\, h(-2) + x(2)\, h(-3) + ...$$
$$= 0 + (1)(1) + (2)(0) + 0 ... = 1$$

When $n = 0$

$$y(0) = \sum_{k=-\infty}^{\infty} x(k)h(-k)$$
$$= ... + x(0)\, h(0) + x(1)\, h(-1) + x(2)\, h(-2) + ...$$
$$= 0 + (1)(2) + (2)(1) + 0 = 4$$

When $n = 1$

$$y(1) = \sum_{k=-\infty}^{\infty} x(k)h(1-k)$$
$$= ... + x(0)\, h(1) + x(1)\, h(0) + x(2)\, h(-1) + x(3)\, h(-2) + ...$$
$$= 0 + (1)(-2) + (2)(2) + (3)(1) + 0 = 5$$

When $n = 2$

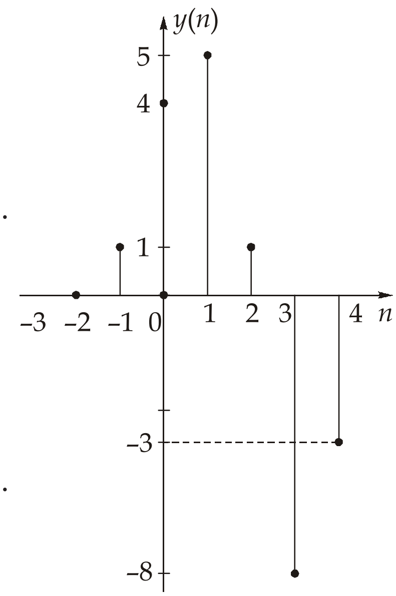
$$y(2) = \sum_{k=-\infty}^{\infty} x(k)h(2-k)$$
$$= ... + x(0)\,h\,(2) + x(1)\,h\,(1) + x(2)\,h\,(0) + ...$$
$$= 0 + (1)\,(-1) + (2)\,(-2) + 3(2) + 0 = 1$$

When $n = 3$

$$y(3) = \sum_{k=-\infty}^{\infty} x(k)h(3-k)$$
$$= ... + x(0)\,h\,(3) + x(1)\,h\,(2) + x(2)\,h\,(1) + ...$$
$$= 0 + (1)\,(0) + (2)\,(-1) + 3(-2) + 0 = -8$$

When $n = 4$

$$y(4) = \sum_{k=-\infty}^{\infty} x(k)h(4-k)$$
$$= ... + x(0)\,h\,(4) + x(1)\,h\,(3) + x(2)\,h\,(2) + ...$$
$$= 0 + (1)\,(0) + (2)\,(0) + 3(-1) + 0 = -3$$



These sequence values are plotted in given figure.

Q.2 (a) Solution:

$$x(t) = e^{At}x(0) + \int_0^t e^{A(t-z)}Bu(\tau)d\tau$$

Computation of $e^{AT} = \phi(t)$

$$A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

$$[sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} s-1 & 0 \\ -1 & s-1 \end{bmatrix}$$

$$[sI - A]^{-1} = \frac{1}{(s-1)(s-1)}\begin{bmatrix} s-1 & 0 \\ 1 & s-1 \end{bmatrix} = \begin{bmatrix} \dfrac{1}{s-1} & 0 \\ \dfrac{1}{(s-1)^2} & \dfrac{1}{(s-1)} \end{bmatrix}$$

$$\phi(t) = e^{At} = L^{-1}[sI - A]^{-1} = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}$$

Alternatively:

$$e^{At} = I + At + \frac{A^2t^2}{2!} + ...$$

$$A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

$$A^2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 2 & 1 \end{bmatrix}$$

$$e^{At} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}t + \frac{1}{2}\begin{bmatrix} 1 & 0 \\ 2 & 1 \end{bmatrix}t^2$$

$$e^{At} = \begin{bmatrix} 1 + t + \frac{t^2}{2} & 0 \\ t + t^2 & 1 + t + \frac{t^2}{2} \end{bmatrix} = \begin{bmatrix} 1 + t + \frac{t^2}{2} & 0 \\ t(1+t) & 1 + t + \frac{t^2}{2} \end{bmatrix}$$

$$= \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}$$

Thus,

$$x(t) = \phi(t)x(0) + \int_0^t \phi(t)Bu(\tau)d\tau$$

$$= \phi(t)\left[x(0) + \int_0^t \phi(-\tau)Bu(\tau)d\tau\right]$$

Computation of $\phi(-\tau)Bu(\tau)$

$$\phi(t) = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}$$

$$\phi(-\tau) = \begin{bmatrix} e^{-\tau} & 0 \\ -\tau e^{-\tau} & e^{-\tau} \end{bmatrix}$$

$$B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$u = 1$$

$$\phi(-\tau)Bu = \begin{bmatrix} e^{-\tau} & 0 \\ -\tau e^{-\tau} & e^{-\tau} \end{bmatrix}\begin{bmatrix} 1 \\ 1 \end{bmatrix}1 = \begin{bmatrix} e^{-\tau} \\ -\tau e^{-\tau} + e^{-\tau} \end{bmatrix}$$

Therefore, $$\int_0^t \phi(t-\tau)Bu(\tau)d\tau = \int_0^t \begin{bmatrix} e^{-\tau} \\ -\tau e^{-\tau} + e^{-\tau} \end{bmatrix} d\tau = \begin{bmatrix} 1-e^{-t} \\ te^{-t} \end{bmatrix}$$

Therefore, $$x(t) = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix} \left\{ \begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 1-e^{-t} \\ te^{-t} \end{bmatrix} \right\}$$

$$= \begin{bmatrix} e^t \\ te^t \end{bmatrix} + \begin{bmatrix} e^t - 1 \\ te^t \end{bmatrix} = \begin{bmatrix} 2e^t - 1 \\ 2te^t \end{bmatrix}$$

Q.2 (b) Solution:

(i) We have,

Temperature, $T = 290°K$

Bandwidth, $B = 100$ kHz

As, we know that,

Thermal noise is given by

$$E_n = \sqrt{4kTBR}$$

where, k = Boltzman's constant

$= 1.38 \times 10^{-23}$ Joules/Kelvin

1. For $R_1 = 20$ kΩ,

$$E_{n1} = \sqrt{4kTBR}$$

$$E_{n1} = \sqrt{4\times1.38\times10^{-23}\times290\times100\times10^3\times20\times10^3}$$

$$E_{n1} = 5.66\ \mu V$$

For $R_2 = 50$ kΩ,

$$E_{n2} = \sqrt{4\times1.38\times10^{-23}\times290\times100\times10^3\times50\times10^3}$$

$$E_{n2} = 8.95\ \mu V$$

2. For the two resistors in series

Effective resistance, $R = R_1 + R_2$

$R = 20 + 50$

$R = 70$ kΩ

Thermal noise voltage,

$$E_n = \sqrt{4\times1.38\times10^{-23}\times290\times100\times10^3\times70\times10^3}$$

$$E_n = 10.59\ \mu V$$

OR $$E_n = \sqrt{E_{n1}^2 + E_{n2}^2} = \sqrt{(8.95\times10^{-6})^2 + (5.66\times10^{-6})^2}$$

$$= 10.59\ \mu V$$

3. For two resistors in parallel:

The effective resistance, $R_p = \dfrac{20\times50}{20+50} = 14.29\ k\Omega$

$$E_n = \sqrt{4kTBR_p}$$

$$= \sqrt{4\times1.38\times10^{-23}\times290\times100\times10^3\times14.29\times10^3}$$

$$= 4.78\ \mu V$$

(ii) Flicker Noise:

Any noise with a power spectral density that is the inverse of the signal's frequency and is therefore most significant for low frequency signals. It can be expressed as $\frac{1}{f}$ and is therefore also referred to as $\frac{1}{f}$ noise. Flicker or $\frac{1}{f}$ noise is also called pink noise. The flicker noise will appear at frequencies below a few kilohertz. The mean square value of flicker noise voltage is proportional to the square of direct current flowing through the device.

Shot Noise:

Shot noise or Poisson noise is a type of noise which can be modeled by a Poisson process. In electronics, shot noise originates from the discrete nature of electric charge. Shot noise also occurs in photon counting in optical devices, where shot noise is associated with the particle nature of light.

Partition Noise:

Partition noise is generated when the current gets divided between two or more paths.

It is generated due to the random fluctuations in the division. Therefore the partition noise in a transistor will be higher than that in a diode. The devices like gallium arsenide FET draw almost zero gate bias current, hence keeping the partition noise to its minimum value.

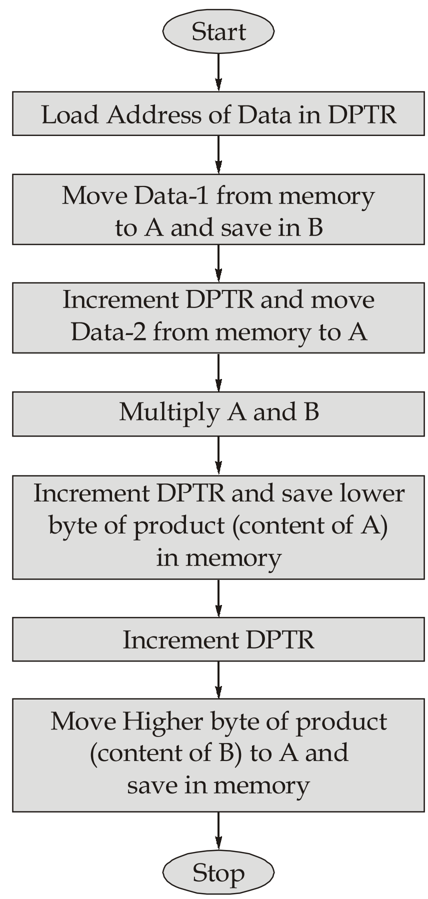
Q.2 (c) Solution:

Algorithm:

1. Load address of data in DPTR.
2. Move first data from external memory to A and save in B.
3. Increment DPTR and move second data from external memory in B.

4. Perform multiplication to get the product in A and B.
5. Increment DPTR and save A (which is lower byte of product) in memory.
6. Increment DPTR, move B (which is higher byte of product) to A and save it in memory.

Flowchart:



Assembly Language Program:

ORG 2100 H	:	Specify program starting address
MOV DPTR, #2400 H	:	Load address of 1st data in DPTR
MOVX A, @DPTR	:	Move the 1st data to A
MOV B, A	:	Save the first data in B
INC DPTR	:	Increment DPTR to point 2nd Data
MOVX A, @DPTR	:	Load 2nd data in A
MUL AB	:	Multiply the contents of register A with register B yielding a 16-bit result with lower 8 bits in A, and higher 8 bits in B.

INC DPTR	:	Increment DPTR
MOVX @DPTR, A	:	Save lower byte of product in external memory
INC DPTR	:	Increment byte
MOV A, B	:	Move higher byte of product to A,
MOVX @DPTR, A	:	Save higher byte of product in external memory
HALT : SJMP HALT	:	Remain idle in infinite loop
END	:	Program end

Q.3 (a) Solution:

(i) The direction of the wave is $\hat{r}$ and the direction of the electric field is $\hat{\theta}$. So, the direction of the magnetic field will be $\hat{\phi}$.

Hence,
$$\vec{H}_s = \frac{\cos 2\theta}{\eta_0 r} e^{-j\beta r}\,\hat{\phi} = \frac{\cos 2\theta}{120\pi r} e^{-j\beta r}\,\hat{\phi} \text{ A/m}$$

(ii) The Poynting vector,

$$\vec{P}_{\text{avg}} = \frac{\left|\vec{E}_s\right|^2}{2\eta_0}\hat{r} = \frac{\cos^2(2\theta)}{240\pi r^2}\hat{r} \text{ W/m}^2$$

The total power radiated can be given by,

$$P_{\text{rad}} = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} \frac{\cos^2(2\theta)}{240\pi r^2} r^2 \sin\theta\, d\theta\, d\phi \text{ W}$$

$$= \frac{1}{240\pi}(2\pi)\int_{\theta=0}^{\pi} \cos^2(2\theta)\sin\theta\, d\theta \text{ W}$$

$$= \frac{1}{120}\int_{\theta=0}^{\pi} (2\cos^2\theta - 1)^2 \sin\theta\, d\theta \text{ W}$$

Let, $u = \cos\theta \Rightarrow du = -\sin\theta\, d\theta$

So,
$$P_{\text{rad}} = -\frac{1}{120}\int_{1}^{-1}(2u^2-1)^2\, du = \frac{1}{120}\int_{-1}^{1}(4u^4 - 4u^2 + 1)\, du \text{ W}$$

$$= \frac{2}{120}\left[\frac{4}{5}u^5 - \frac{4}{3}u^3 + u\right]_0^1 = \frac{2}{120}\times\frac{7}{15} = 7.78 \text{ mW}$$

(iii) The power radiated in the belt 60° < θ < 120° is,

$$P_{\text{belt}} = -\frac{1}{120}\int_{1/2}^{-1/2}(4u^4 - 4u^2 + 1)\,du \ \text{ W}$$

$$= \frac{2}{120}\left[\frac{4}{5}u^5 - \frac{4}{3}u^3 + u\right]_0^{1/2} = \frac{1}{60}\left(\frac{4}{160} - \frac{4}{24} + \frac{1}{2}\right)\text{W}$$

$$= \frac{43}{60\times 120}\text{ W} = 5.972 \text{ mW}$$

The required fraction is,

$$\frac{P_{\text{belt}}}{P_{\text{rad}}} = \frac{\dfrac{43}{(60\times 120)}}{\dfrac{14}{(120\times 15)}} = 0.7678 \text{ (or) } 76.78\%$$

Q.3 (b) Solution:

Given input signal,

$$x(n) = [1, -2, \underset{\substack{\uparrow \\ n=0}}{3}, -4, 5, -6]$$

The signal $x[n]$ can be represented using N-point DFT, $X(k)$ as

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k)e^{jk2\frac{\pi}{N}n}$$

For the given $x(n)$, $N = 6$. Thus,

$$x(n) = \frac{1}{6}\sum_{k=0}^{5} X(k)e^{jk2\frac{\pi}{3}n}$$

where $X(k) = \text{DFT}\,[(\underset{\uparrow}{3}, -4, 5, -6, 1, -2)]$

∵ $x(n)$ is a periodic signal.

By the definition of DFT,

$$X(k) = \sum_{n=0}^{N-1} x(n)e^{-j\frac{2\pi}{N}kn}$$

We have,

$$X(0) = \sum_{n=0}^{5} x(n) = -3$$

$$X(1) = \sum_{n=0}^{5} x(n)e^{-j\frac{\pi}{3}(1)(n)} = 3 - j\sqrt{3} = 3 - j1.732$$

$$X(2) = \sum_{n=0}^{5} x(n)e^{-j\frac{\pi}{3}(2)(n)}$$

$$= x(0) + x(1)e^{-j\frac{2\pi}{3}} + x(2)e^{-j\frac{2\pi}{3}(2)} + x(3)e^{-j\frac{2\pi}{3}(3)}$$

$$+x(4)e^{-j\frac{2\pi}{3}(4)} + x(5)e^{-j\frac{2\pi}{3}(5)}$$

$$X(2) = -3 - j5.196$$

$$X(3) = \sum_{n=0}^{5} x(n)e^{-j\pi n} = 3 + 4 + 5 + 6 + 1 + 2 = 21$$

$$X(4) = \sum_{n=0}^{5} x(n)e^{-j\frac{4\pi}{3}n} \quad \text{(or)} \quad X(4) = X^*(2)$$

$$= x(0) + x(1)e^{-j\frac{4\pi}{3}} + x(2)e^{-j\frac{8\pi}{3}} + x(3)e^{-j4\pi} + x(4)e^{-j\frac{16\pi}{3}}$$

$$+x(5)e^{-j\frac{20\pi}{3}}$$

$$X(4) = -3 + j5.196$$

$$X(5) = \sum_{n=0}^{5} x(n)e^{-j\frac{5\pi}{3}n} = X^*(1) = 3 + j1.732$$

Given impulse response of LTI system,

$$h(n) = 0.8^{|n|}$$

or

$$h(n) = 0.8^n u(n) + \left(\frac{1}{0.8}\right)^n u(-n-1)$$

or

$$h(n) = (0.8)^n u(n) + 1.25^n u(-n-1)$$

The frequency response of the LTI system is

$$H(\omega) = \text{DTFT}[h(n)]$$

$$= \text{DTFT}[(0.8^n u(n) + (1.25^n u(-n-1)]$$

$$= \frac{1}{1-0.8e^{-j\omega}} - \frac{1}{1-1.25e^{-j\omega}}$$

$$= \frac{e^{j\omega}}{e^{j\omega}-0.8} - \frac{e^{j\omega}}{e^{j\omega}-1.25}$$

where, $$H(k) = H(\omega)\Big|_{\omega=\frac{2k\pi}{n}=\frac{k\pi}{3}}$$

$$\therefore \quad H(k) = \frac{e^{jk\frac{\pi}{3}}}{e^{jk\frac{\pi}{3}}-0.8} - \frac{e^{jk\frac{\pi}{3}}}{e^{jk\frac{\pi}{3}}-1.25}$$

where, $k = 0, 1, ..., 5$

The one period of output signal is given by

$$y[n] = \text{IDFT}\{H(k)X(k)\} \qquad n = 0, ..., 5$$

$$\therefore \quad H(k)\Big|_{k=0} = H(0) = \frac{1}{1-0.8} - \frac{1}{1-1.25} = 9$$

$$H(1) = \frac{e^{j\frac{\pi}{3}}}{e^{j\frac{\pi}{3}}-0.8} - \frac{e^{j\frac{\pi}{3}}}{e^{j\frac{\pi}{3}}-1.25} = 0.4286$$

$$H(2) = \frac{e^{j\frac{2\pi}{3}}}{e^{j\frac{2\pi}{3}}-0.8} - \frac{e^{j\frac{2\pi}{3}}}{e^{j\frac{2\pi}{3}}-1.25} = 0.1475$$

$$H(3) = \frac{e^{j\pi}}{e^{j\pi}-0.8} - \frac{e^{j\pi}}{e^{j\pi}-1.25} = 0.1111$$

$$H(4) = \frac{e^{j\frac{4\pi}{3}}}{e^{j\frac{4\pi}{3}}-0.8} - \frac{e^{j\frac{4\pi}{3}}}{e^{j\frac{4\pi}{3}}-1.25} = 0.1475$$

$$H(5) = \frac{e^{j\frac{5\pi}{3}}}{e^{j\frac{5\pi}{3}}-0.8} - \frac{e^{j\frac{5\pi}{3}}}{e^{j\frac{5\pi}{3}}-1.25} = 0.4286$$

Q.3 (c) Solution:

(i) The major axis of the elliptical orbit is a straight line between the apogee and perigee. Hence, for a semimajor axis length a, earth radius r_e, perigee height h_p, and apogee height h_a,

$$2a = 2r_e + h_p + h_a = 2 \times 6378.14 + 1000 + 4000$$
$$= 17756.28 \text{ km}$$

Thus the semimajor axis of the orbit has a length $a = 8878.14$ km

Using this value of a, gives an orbital period T seconds where

$$T^2 = \frac{(4\pi^2 a^3)}{\mu} = \frac{4\pi^2 \times (8878.14)^3}{3.986004418} \times 10^{-5} s^2$$

$$= 6.930872802 \times 10^7 s^2$$

$$T = 8325.1864 = 138 \text{ min } 45.19 = 2\text{h } 18 \text{ min } 45.19$$

The eccentricity of the orbit is given by e, which can be found by considering the instant at which the satellite is at perigee. When the satellite is at perigee, the eccentric anomaly $E = 0$ and $r_0 = r_e + h_p$.

$$r_0 = a(1 - e\cos E) \text{ and } \cos E = 1$$

Hence, $$r_e + h_p = a(1 - e)$$

$$e = 1 - \frac{(r_e + h_p)}{a} = 1 - \frac{7378.14}{8878.14} = 0.169$$

$$e = 0.169$$

(ii) Given data:

$$G_t = 60 \text{ dB}; \quad P_t = 100 \text{ W}; \quad f = 7.2 \text{ GHz};$$

$$d = 38000 \text{ km} = 3.8 \times 10^7 \text{ m}$$

$$G_r = 28 \text{ dB}; \quad T = 400 \text{ K}; \quad B = 40 \text{ MHz}; \quad G_{Tr} = 100 \text{ dB}$$

1. At 7.2 GHz if the wavelength is 0.052 m, then

$$\text{Path loss} = 32.45 + 20\log f_{\text{MHz}} + 20\log d_{\text{km}}$$

$$= 32.45 + 20\log(7200) + 20\log(38000)$$

$$FSL = 201.192 \text{ dB}$$

2. The power at the output port of the satellite antenna,

$$P_r = P_t + G_t + G_r - FSL$$

$$= 10\log 100 + 60 + 28 - 201.192$$

$$= -93.192 \text{ dB W}$$

3. The carrier power at transponder output

$$P_{\text{transponder}} = P_r + G_{Tr}$$

$$= -93.192 + 100$$

$$= 6.808 \text{ dB W}$$

In Watt

$$10\log_{10} P_{Tr} = 6.808$$

$$P_{Tr} = 10^{6.808/10}$$

$$P_{Tr} = 4.795 \text{ W}$$

Q.4 (a) Solution:

(i)
$$G(s)H(s) = \frac{K}{s(s+1)(s+2)}$$

$$\text{Magnitude, } M = \frac{K}{\omega\sqrt{1+\omega^2}\sqrt{4+\omega^2}}$$

$$\text{Phase, } \phi = -90^\circ - \tan^{-1}\omega - \tan^{-1}\frac{\omega}{2}$$

when
$$\omega = 0, \quad M\angle\phi = \infty\angle -90^\circ$$

$$\omega = 1, M\angle\phi = \frac{K}{\sqrt{10}}\angle -162^\circ$$

$$\omega = 2, M\angle\phi = \frac{K}{4\sqrt{10}}\angle -198.4^\circ$$

$$\omega = \infty, M\angle\phi = 0\angle -270^\circ$$

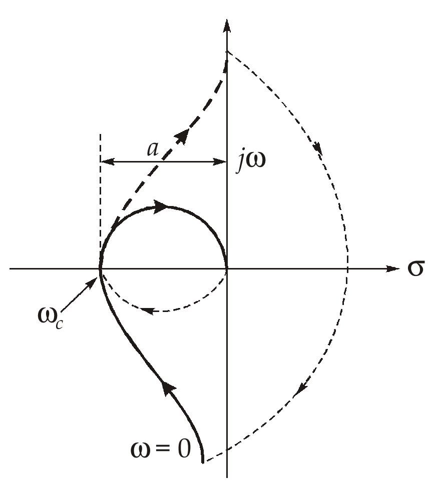
Comparing the given transfer function with $G(s)H(s) = \dfrac{K}{s(1+sT_1)(1+sT_2)}$, we have

$T_1 = 1$ and $T_2 = 0.5$. Thus, the polar plot cuts the real axis at

$$\omega_c = \frac{1}{\sqrt{T_1T_2}} = \frac{1}{\sqrt{1\times 0.5}} = \sqrt{2}$$

$$a = \frac{K}{2}\left(\frac{T_1T_2}{T_1+T_2}\right) = \frac{K}{2}\left(\frac{1\times 0.5}{1+0.5}\right) = \frac{K}{6}$$

From the above data, the Nyquist plot can be drawn as below:



For stability, $N = P - Z$

Since, $P = 0$, $Z = -N$. But, for stability Z should be zero, i.e., N should be zero; which means that the point $(-1 + j0)$ should not be encircled by the Nyquist plot. This will only happen, if

$$a < 1 \quad \text{or} \quad \frac{K}{6} < 1 \quad \text{or} \quad K < 6$$

Hence, $0 < K < 6$ for the system to be stable.

1. Gain margin $= 20\log\frac{1}{a} = 3$

i.e.,
$$20\log\frac{6}{K} = 3$$

$$\frac{6}{K} = 1.41 \quad \text{or} \quad K = \frac{6}{1.41} = 4.25$$

2. At Gain cross-over frequency,

$$M = 1 \text{ i.e., gain is 0 dB}$$

$$\therefore \quad M = \frac{K}{\omega\sqrt{1+\omega^2}\sqrt{4+\omega^2}} = 1$$

$$(4.25)^2 = \omega^2(1+\omega^2)(4+\omega^2)$$

(considering the value of K obtained in part 1)

$$\omega^2(\omega^4 + 5\omega^2 + 4) = 18.0625$$

$$\omega^6 + 5\omega^4 + 4\omega^2 - 18.0625 = 0$$

Let $\omega^2 = x$

$$x^3 + 5x^2 + 4x - 18.0625 = 0$$

$$x_1 = 1.396$$

$$x_2 = -3.198 \pm 1.644i$$

Consider $x = 1.396$, then $\omega = \sqrt{1.396} = 1.1815$ rad/sec

Gain crossover frequency is

$$\omega_{gc} = 1.1815 \text{ rad/sec}$$

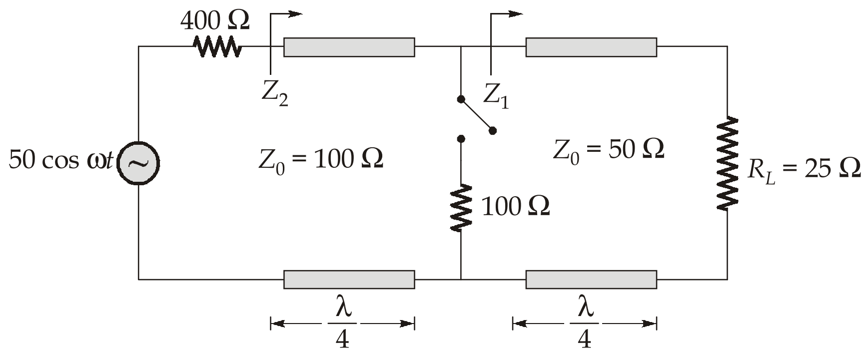
$$\text{Phase margin P.M} = \angle G(j\omega)H(j\omega)\Big|_{\omega_{gc}=1.1815} + 180^\circ$$

$$= \left\{\left(-90^\circ - \tan^{-1}\omega - \tan^{-1}\frac{\omega}{2}\right)\Bigg|_{\omega = 1.1815}\right\} + 180^\circ$$

$$= -90° - \tan^{-1}(1.1815) - \tan^{-1}\frac{1.1815}{2} + 180°$$

$$= 9.67°$$

(ii) 1. With the switch open, looking into the first $\frac{\lambda}{4}$ transformer,

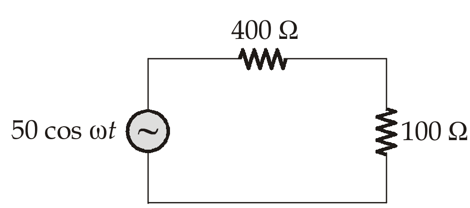


$$Z_1 = \frac{(Z_0)^2}{Z_L} = \frac{(50)^2}{25} \Rightarrow Z_1 = 100\ \Omega$$

Z_1 acts as a load to the second $\frac{\lambda}{4}$ transformer

$$\therefore \quad Z_2 = \frac{(Z_0)^2}{Z_1} = \frac{(100)^2}{100} = 100\ \Omega$$

Therefore, the equivalent circuit at source end of transmission line is



∴ Power delivered to source,

$$P_{source} = I_{rms}^2 \cdot R = \frac{V_m^2}{2R}$$

where, $V_m = 50$ V

$$P_{source} = \frac{1}{2} \times \frac{50 \times 50}{500} = 2.5\ \text{W}$$

2. With the switch is closed,

$$Z_1 = \frac{(Z_0)^2}{Z_L} = \frac{(50)^2}{25} = 100\ \Omega$$

The load on the second $\frac{\lambda}{4}$ line is

$$Z_L' = 100 \,||\, 100 = 50\ \Omega$$

$$\therefore \quad Z_2 = \frac{(Z_0)^2}{Z_L'} = \frac{(100)^2}{50} = 200\ \Omega$$

$\therefore$ Power delivered to source,

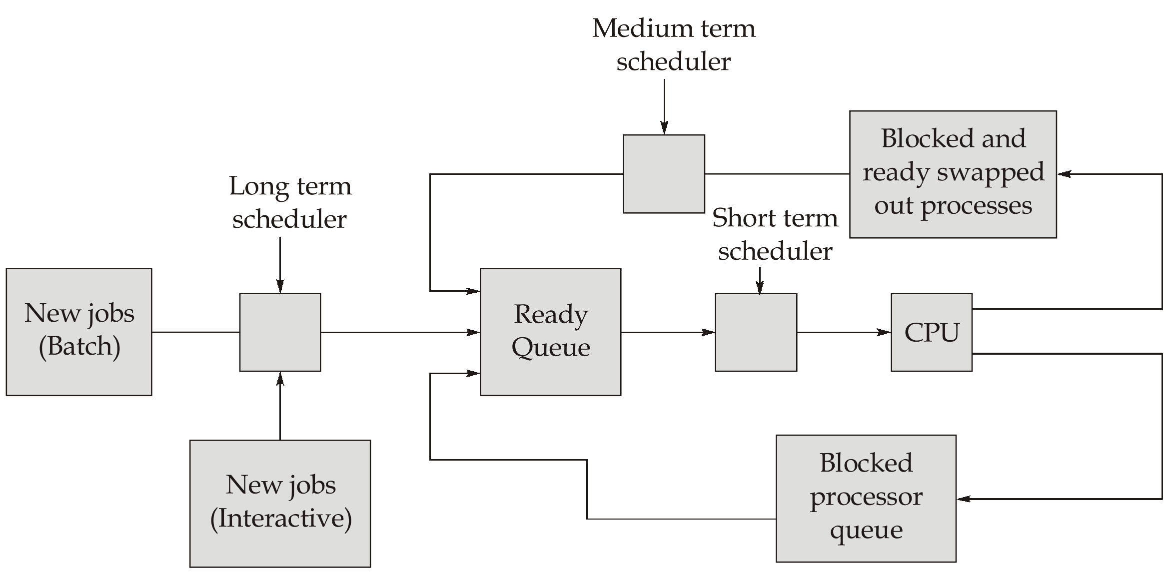
$$P_{source} = \frac{V_m^2}{2 \times Z_2} = \frac{1}{2} \times \frac{(50)^2}{600}$$

$$\therefore \quad P_{source} = 2.08\ W$$

Q.4 (b) Solution:

(i) Scheduler is responsible for selecting a process for scheduling/operating with the resource, from the queues serving the resource.

There are three types of scheduler. The function of each are given below:



Scheduling Levels

Long term Scheduler:

1. Also referred as job scheduler.
2. It selects processes from the disk and loads them into memory for execution.
3. It controls the degree of multiprogramming.

Short term Scheduler:

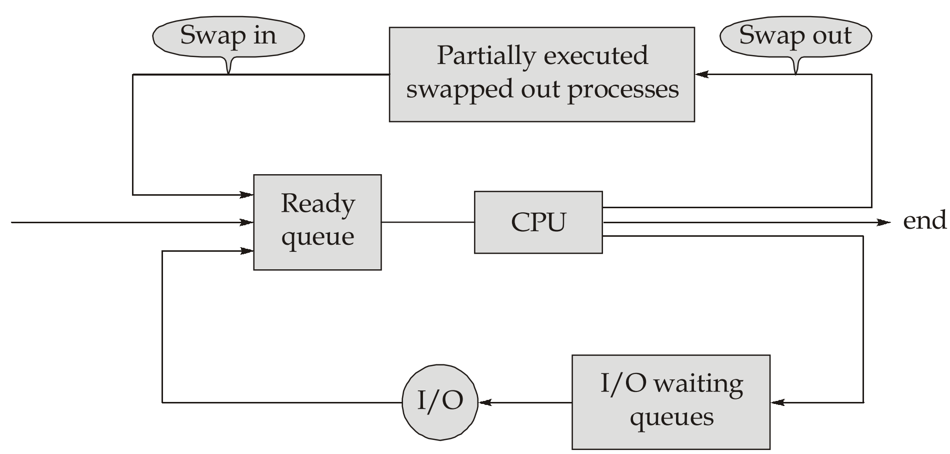
1. Also referred as CPU scheduler.
2. It selects a process from among the processes in the ready queue for allocation of the CPU.
3. Its frequency of execution is more compared to other schedulers.

Medium term Scheduler:

1. It introduces an intermediate level of scheduling.
2. It is used to decrease the degree of multiprogramming at times so as to complete remaining processes faster by reducing the CPU contention, giving better performance and optimizing memory usage.
3. It is used to decrease the load on the CPU.
4. It requires swapping.

It removes processes (partially executed) from main memory, thereby reducing CPU contention and degree of multiprogramming. When the load on the system is less, it re-introduces the processes into main memory and their execution continues from where they left off.

Queuing diagram for medium term scheduler:



(ii) Given: $t_n = 50$ ns; $K = 6$; $t_p = 10$ ns; $n = 100$

Time taken to execute 'n' tasks on a non-pipeline system, $T_{\text{nonpipeline}} = nt_n$

Time taken to execute 'n' tasks on a k-stage pipelined system, $T_{\text{pipeline}} = (k + n - 1)t_p$

$$\text{Speed-up, } S = \frac{T_{\text{nonpipeline}}}{T_{\text{pipeline}}} = \frac{nt_n}{(k+n-1)t_p}$$

$$S = \frac{100 \times 50}{(6+100-1)\times 10}$$

$$S = 4.76$$

An ideal pipeline system has CPI = 1 i.e. $T_{pipeline} = nt_p$

$$S_{max} = \frac{t_n}{t_p} = \frac{50}{10} = 5$$

(iii) Given: $T_C = 100$ ns; $T_M = 1000$ ns; $H = 0.9$

1. Considering only read only access,

$T_{avg} = H \times T_C + (1 - H)(T_C + T_M)$

$T_{avg} = 0.9 \times 100 + 0.1 \times (100 + 1000)$

$T_{avg} = 200$ nsec

2. Considering both read and write access,

$$T_{avg} = 0.2 \times \underbrace{1000}_{\text{Write access}} + 0.8 \times \underbrace{200}_{\text{read access from } (i)}$$

$T_{avg} = 0.2 \times 1000 + 0.8 \times 200$

$T_{avg} = 360$ nsec

Q.4 (c) Solution:

The state diagram is already given. with the states assigned.

Based on the given information, the state table can be written as below:

Present state		Next state		Output	
Y_1	Y_2	$X = 0$	$X = 1$	$X = 0$	$X = 1$
0	0	0 1	0 0	0 0	0 0
0	1	1 1	1 1	0 1	0 1
1	1	1 0	1 0	1 1	1 1
1	0	1 0	0 0	1 0	1 0

Two state variables are required. Two state variables can have a maximum of four states. So, there are no invalid states.

Using SR flip-flops, the excitation table can be obtained as below:

Excitation table:

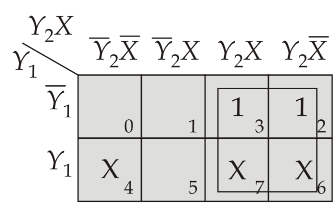
S.No.	Present state Y_1	Y_2	Input X	Next state Y_1'	Y_2'	Required Excitations S_1	R_1	S_2	R_2	Output Z_1	Z_2
0	0	0	0	0	1	0	x	1	0	0	0
1	0	0	1	0	0	0	X	0	X	0	0
2	0	1	0	1	1	1	0	X	0	0	1
3	0	1	1	1	1	1	0	X	0	0	1
6	1	1	0	1	0	X	0	0	1	1	1
7	1	1	1	1	0	X	0	0	1	1	1
4	1	0	0	1	0	X	0	0	X	1	0
5	1	0	1	0	0	0	1	0	X	1	0

Now, draw the K-maps, simplify them and obtain the minimal expressions for S_1, R_1, S_2, R_2 and Z_1, Z_2 in terms of Y_1, Y_2 as shown below:

From the excitation table, we can see that $Z_1 = Y_1$ and $Z_2 = Y_2$.

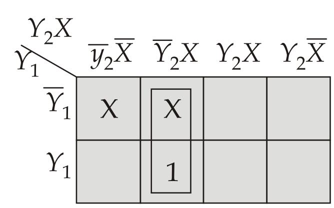
K-Maps:

For S_1:



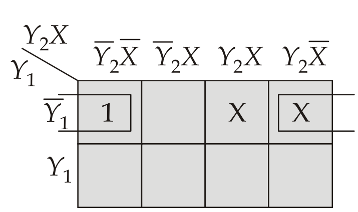
$$S_1 = Y_2$$

For R_1:



$$R_1 = \overline{Y}_2X$$

For S_2:



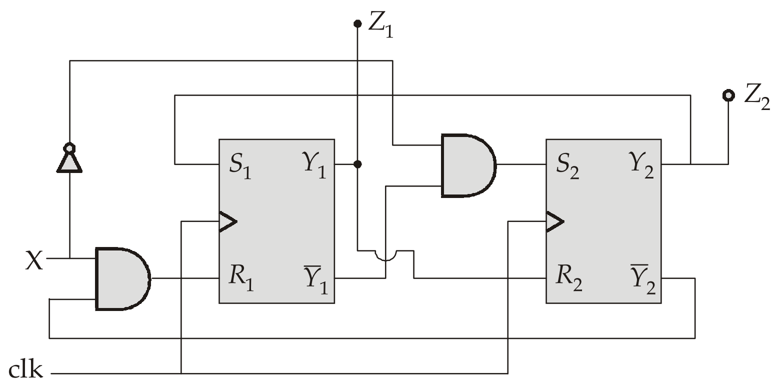
$$S_2 = \overline{Y}_1\overline{X}$$

For R_2:

$Y_1 \backslash Y_2X$	$\overline{Y}_2\overline{X}$	$\overline{Y}_2X$	Y_2X	$Y_2\overline{X}$
$\overline{Y}_1$		X		
Y_1	X	X	1	1

$$R_2 = Y_1$$

The logic circuit using S-R flip flops based on these minimal expressions is shown below:



Section B

Q.5 (a) Solution:

(i) Integral and derivative controllers are not used alone in practice because

Integral controller:

- It slows down the response of the system.
- It also induces oscillations in the response of the system.

Derivative controller:

- It is also known as anticipatory controller, since it sends a control signal in anticipation of errors. The output of the D-controller depends on the rate of change of error with respect to time.
- It cannot respond to certain types of error signals such as constant signal.

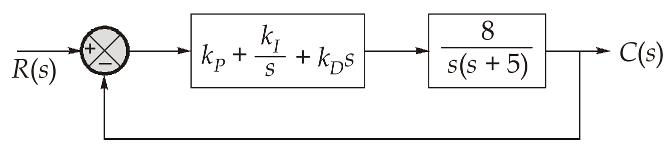
So, integral and derivative controllers are used in combination with proportional controllers such as PD, PI and PID.

(ii) Let the PID controller be,

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

The transfer function of the closed loop system is given by

$$T(s) = \frac{C(s)}{R(s)} = \frac{\frac{8}{s(s+5)}\left[\frac{k_P s + k_I + k_D s^2}{s}\right]}{1 + \frac{8\left[k_P s + k_I + k_D s^2\right]}{s^2[s+5]}}$$



$$\frac{C(s)}{R(s)} = \frac{8\left[k_I + k_P s + k_D s^2\right]}{s^3 + 5s^2 + 8k_D s^2 + 8k_P s + 8k_I}$$

Now desired location of poles are

$$s = -10 \text{ and } s = -3 \pm 4j$$

$\therefore$ characteristic equation $= (s + 10)[s - (-3 + 4j)]\,[s - (-3 - 4j)]$

$$= (s + 10)(s^2 + 6s + 25)$$

$$= s^3 + 16s^2 + 85s + 250$$

Comparing with C.E $= s^3 + (5 + 8k_D)s^2 + 8k_P s + 8k_I$, we get

$$5 + 8\,k_D = 16 \Rightarrow k_D = 1.375$$

$$8\,k_P = 85 \Rightarrow k_P = 10.625$$

$$8k_I = 250$$

$$k_I = 31.25$$

Hence, the transfer function of PID controller is given as

$$G_c(s) = 10.625 + \frac{31.25}{s} + 1.375s$$

Q.5 (b) Solution:

(i) Pulse broadening due to pulse dispersion is given by

$$\Delta T_{mat} = \frac{\Delta\tau_s L}{C}\left|\lambda\frac{d^2n}{d\lambda^2}\right|$$

or pulse broadening per km is given as:

$$\Delta T_{max} \text{ (per km)} = \frac{\Delta\tau_s \times 10^3}{C}\left|\lambda \frac{d^2n}{d\lambda^2}\right|$$

$$= \frac{45\times10^{-9}\times10^3\times0.9\times10^{-6}}{3\times10^8}\times4\times10^{-2}(10^6)^2$$

$$= 5.4 \times 10^{-9} \text{ s/km}$$

$$\Delta T_{max} \text{ (per km)} = 5.4 \text{ ns/km}$$

(ii) 1. For a single-mode transmission, cut-off wavelength is given by

$$\lambda_c = \frac{2\pi a n_1\sqrt{2\Delta}}{2.405},$$

where Δ = relative refractive index difference, n_1 is the refrative index of core and a is the core radius. Substituting the given values,

$$1.3 \times 10^{-6} = \frac{2\pi\times\left(\frac{10}{2}\times10^{-6}\right)\times1.55\sqrt{2\Delta}}{2.405}$$

$$\Delta = 0.00206$$

Hence, the maximum value of Δ can be 0.00206.

2. We know,

$$\frac{n_2}{n_1} = 1 - \Delta$$

$$n_2 = n_1(1 - \Delta)$$

$$= 1.55(1 - 0.00206)$$

$$n_2 = 1.547$$

3. We know,

$$\text{Acceeptance angle, } \phi = \sin^{-1}(\text{NA})$$

$$= \sin^{-1}\left[n_1\sqrt{2\Delta}\right]$$

$$= \sin^{-1}\left[1.55\sqrt{2\times0.00206}\right]$$

$$= 5.7°$$

Q.5 (c) Solution:

For the waveguide of dimension $a \times b$, we have,

$$a^2 + b^2 = d^2 = (0.05)^2 = 25 \times 10^{-4} \quad \text{...(i)}$$

where 'd' is the diameter of the hole.

The electric field expressions for the TE_{10} mode can be obtained as below:

$$E_y = \frac{\omega\mu}{h^2}\left(\frac{\pi}{a}\right)D\sin\left(\frac{\pi x}{a}\right)\sin(\omega t\text{-}\beta z)$$

where $h^2 = (m\pi/a)^2 + (n\pi/b)^2 = (\pi/a)^2$ for TE_{10} mode

It is given that the amplitude of E should be less than 1 kV/m, i.e.,

$$\frac{\omega\mu a}{\pi}D \le 1\text{ kV/m}$$

$$\Rightarrow \qquad D \le \frac{10^3\pi}{\omega\mu a}\text{ V/m} \qquad \text{...(ii)}$$

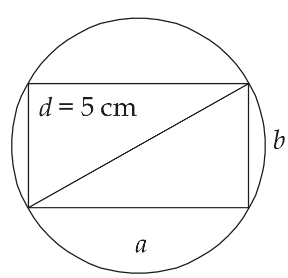
The magnetic field expression for the TE_{10} mode in the x-direction is given by

$$H_x = \frac{-\beta}{h^2}\left(\frac{\pi}{a}\right)D\sin\left(\frac{\pi x}{a}\right)\sin(\omega t\text{-}\beta z)$$

The power density, $$P = \frac{1}{2}E_y\cdot H_x^* = \frac{\omega\mu\beta a^2|D|^2}{2\pi^2}\sin^2\left(\frac{\pi x}{a}\right)$$

The power carried by the waveguide is

$$W = \int_0^b\int_0^a P\,dx\,dy \frac{\omega\mu\beta a^3 b|D|^2}{4\pi^2} \qquad \text{...(iii)}$$



The phase constant, β is given by

i.e., $$\beta = \sqrt{\omega^2\mu\in - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2}$$

For TE_{10} mode, m = 1 and n = 0. Thus, we get

$$\beta = \sqrt{\omega^2\mu\in - \left(\frac{\pi}{a}\right)^2} \qquad \text{...(iv)}$$

Using equations (i), (ii), (iii) and (iv), we get

$$W = \frac{\omega\mu\sqrt{\omega^2\mu \in -(\pi/a)^2} \cdot a^3\sqrt{d^2 - a^2}}{4\pi^2} \frac{10^6\pi^2}{\omega^2\mu^2 a^2}$$

$$= \frac{10^6}{4\omega\mu} a\sqrt{\omega^2\mu \in -(\pi/a)^2}\sqrt{d^2 - a^2}$$

For maximum power $\partial W/\partial a = 0$, i.e.,

$$\partial(W^2)/\partial a = 0$$

$$\Rightarrow \quad \frac{\partial}{\partial a}\left\{(\omega^2\mu \in a^2 - \pi^2)(d^2 - a^2)\right\} = 0$$

$$\Rightarrow \quad 2a\omega^2\mu\in (d^2 - a^2) - 2a(\omega^2\mu\in a^2 - \pi^2) = 0$$

$$\Rightarrow \quad 2a[\omega^2\mu\in (d^2 - a^2) - (\omega^2\mu\in a^2 - \pi^2) = 0$$

$$\Rightarrow \quad a = 0 \quad \text{or} \quad a = \sqrt{\frac{d^2}{2} + \frac{\pi^2}{2\omega^2\mu \in}}$$

For $a = 0$ the area of cross section of the waveguide goes to 0 and therefore the power carried goes to zero. The maximum power corresponds to

$$a = \sqrt{\frac{d^2}{2} + \frac{\pi^2}{2\omega^2\mu \in}} = \sqrt{\frac{d^2}{2} + \frac{\lambda^2}{8}}$$

At 10 GHz, the wavelength $\lambda = 3$ cm. Hence, we get

$$a = \sqrt{\frac{25}{2} + \frac{9}{8}} = 3.69 \text{ cm}$$

$$b = \sqrt{25 - a^2} = 3.37 \text{ cm}$$

The waveguide dimensions for maximum power transfer, therefore are 3.69 cm × 3.37 cm.

Q.5 (d) Solution:

An operating system is a complex system that engages in organizing basic functions in the computer, managing software and hardware resources, controlling peripherals and also arranging computing tasks. It is performed by distributing system into well-defined portions with specific input and output commands.

Components:

The main components of an OS mainly includes kernel, API or application program interface, user interface and file system, hardware devices and device drivers.

Kernel

The kernel in operating system provides the basic level of control on almost every computer peripherals.

It is the most vital and fundamental part of an OS. Kernel resides in the main memory so that memory accessibility can be managed for the programs within the RAM. It helps the user to interact with the hardware. It resets the operating states of the CPU for the best operation at all times.

Application Programming Interface (API)

An application programming interface (API) is software which functions as a mediator between two programs. It handles all the requests made to access a particular resource and then delivers the response.

User Interface:

A GUI or user interface (UI) helps the users to interact with the OS. Users do all the stuff they want to do through UI.

Memory Management

The main function of operating system is management of memory during the processing. It is used to manage operations between main memory and disk during process execution. The main aim of memory management is to achieve efficient utilization of memory. Memory management keeps track of each and every memory location, regardless of either it is allocated to some process or it is free. It checks how much memory is to be allocated to processes and decides which process will get memory at what time. It tracks whenever some memory gets free or unallocated and correspondingly, it updates the status.

Multitasking:

Operating system can perform multiple operations on PC. It allows user to run multiple tasks in computer which operating system execute efficiently by time sharing process in which each task use specific time of computer for executing functions of operating system:

Process Execution:

The OS gives an interface between the hardware as well as an application program so that the program can connect through the hardware device by simply following procedures & principles configured into the OS. The program execution mainly includes a process created through an OS kernel that uses memory space as well as different types of other resources.

Interrupt:

Interrupt allows operating system to connect and react to the surroundings. It is basically a signal that directs operating system to do a specific task and leave previous one. When a computer receives an interrupt signal, then the hardware of the computer puts on hold automatically whatever computer program is running presently, keeps its status & runs a computer program specified by the interrupt.

Device Management:

Operating systems provide essential functions for managing devices connected to a computer. These functions include allocating memory, processing input and output requests, and managing storage devices. This device could be a keyboard, mouse, printer, or any other devices.

File Management:

Operating systems are responsible for managing the files on a computer. This includes creating, opening, closing, and deleting files. The operating system is also responsible for organizing the files on the disk.

Q.5 (e) Solution:

(i) The interconnect effects in deep sub-micron region impose many challenges as described below:

1. The accurate estimation of interconnect delay is very difficult during the early stage of design. Due to inaccuracy in wire delay estimation, many timing violations may be seen only at the physical design stage. In order to fix these violations, it is required to perform high level design modifications based on the physical information acquired, so design flow must be iterated. But these high level modifications result in new timing violation. Therefore, once again it is required to perform iteration. These iterations results in slow IC design process with no guarantee for the convergence. This is known as timing closure problem.
2. To minimize the delay associated with global interconnect, the advisable solution is to use repeaters. With advancement in technology, the number of used repeaters increased tremendously which consume a lot of chip area and significantly change the floor planning and placement of design. Increased integration intensity and chip coomplexity lay the foundation for more interconnect routing in the same area.

   Both these problems result in area constraint violation and are called layout closure problem.
3. In modern technology, delay of global interconnects becomes larger than the clock period due to increase in the chip size and clock frequency which makes it necessary to pipeline the signal propagation in global interconnects. This can be achieved by inserting memory units. The price paid for this is that the

introduction of additional latencies to interconnect typically leads to incorrect signal behaviour. Therefore, the prediction of interconnect latencies has to be performed accurately in the early stage of design.

(ii) Given, total chip area $A = 0.4 \times 0.5 \text{ cm}^2$

$$\therefore \quad A = 0.20 \text{ cm}^2$$

$$\text{critical area, } A_c = 0.25 \text{ A} = 0.25(0.20)$$

$$\therefore \quad A_c = 0.05 \text{ cm}^2$$

$$\text{defect density, } D_0 = 2 \text{ cm}^{-2}$$

From Poission's model, yield Y is

$$Y = e^{-A_c \cdot D_0} = e^{-(0.05 \times 2)} = e^{-0.1}$$

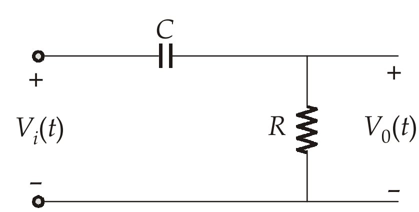
$$\therefore \quad Y = 0.905$$

Q.6 (a) Solution:

Assume,

$$\text{message signal, } m(t) = Ae^{-t/\tau}$$

(i) A high pass RC circuit is represented in the figure below:



The transfer function of the circuit is

$$H(s) = \frac{V_0(s)}{V_i(s)}$$

Using voltage division principle,

$$V_0(s) = \frac{V_i(s)R}{R + \frac{1}{sC}}$$

$$\frac{V_0(s)}{V_i(s)} = \frac{sRC}{RsC + 1}$$

$$H(s) = \frac{sRC}{RsC+1}$$

Since, $\tau = RC$

$$H(s) = \frac{s\tau}{s\tau+1}$$

Put, $s = j\omega$

$$H(j\omega) = \frac{j\omega\tau}{j\omega\tau+1} \quad \text{or} \quad H(j\omega) = \frac{j\omega RC}{j\omega RC+1} \quad \text{...(i)}$$

Given: $\tau = 8$ sec

$$\therefore \quad H(j\omega) = \frac{j8\omega}{j8\omega+1}$$

(ii) From equation (i), we have

$$H(j\omega) = \frac{j\omega RC}{j\omega RC+1}$$

$$|H(j\omega)| = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}}$$

Considering $\tau = RC$

$$|H(j\omega)| = \frac{\omega\tau}{\sqrt{1+\omega^2\tau^2}}$$

As, $V_i(t) = Ae^{-t/\tau}u(t)$

$$V_i(s) = \frac{A}{\left(s+\frac{1}{\tau}\right)}$$

Put $s = j\omega$,

$$V_i(j\omega) = \frac{A}{\left(j\omega+\frac{1}{\tau}\right)}$$

$$|V_i(j\omega)| = \frac{A}{\sqrt{\left(\frac{1}{\tau}\right)^2+\omega^2}}$$

Since, $V_0(s) = H(s)V_i(s)$ or $V(j\omega) = H(j\omega) \times V_i(j\omega)$

We get, $$|V_0(j\omega)| = \frac{\omega\tau}{\sqrt{1+\omega^2\tau^2}} \times \frac{A\tau}{\sqrt{1+\omega^2\tau^2}}$$

$$|V_0(j\omega)| = \frac{\omega A\tau^2}{(1+\omega^2\tau^2)}$$

Energy spectral density of the output signal is given by

$$E_{0(\text{ESD})} = |V_0(j\omega)|^2$$

$$E_{0(\text{ESD})} = \frac{A^2\omega^2\tau^4}{(1+\omega^2\tau^2)^2} \text{ Joule/Hz}$$

(iii) Given, input signal is $V_i(t) = Ae^{-t/\tau}\, u(t)$

$$V_i(j\omega) = \frac{1\times A}{\left(j\omega+\frac{1}{\tau}\right)} = \frac{A\tau}{(j\omega\tau+1)}$$

Energy of the input signal,

$$E_i = \frac{1}{2\pi}\int |V_i(j\omega)|^2\, d\omega$$

$$E_i = \frac{1}{2\pi}\int_{-\infty}^{\infty} \frac{A^2\tau^2}{\left(1+\omega^2\tau^2\right)} d\omega$$

Let $$\omega\tau = y$$

$$d\omega = \frac{dy}{\tau}$$

$$E_i = \frac{A^2}{2\pi}\int_{-\infty}^{\infty} \frac{\tau}{1+y^2} dy$$

$$E_i = \frac{A^2\tau}{2} \text{ Joule}$$

Energy of the output signal, E_0 is given by

$$E_0 = \frac{1}{2\pi}\int_{-\infty}^{\infty} E_{0(ESD)} d\omega$$

$$E_0 = \frac{1}{2\pi}\int_{-\infty}^{\infty} \frac{A^2\omega^2\tau^4}{(1+\omega^2\tau^2)^2} d\omega$$

Let $$\omega\tau = y$$

$$d\omega = \frac{dy}{\tau}$$

$$E_0 = \frac{A^2}{2\pi}\tau^2 \int_{-\infty}^{\infty} \frac{y^2}{(1+y^2)^2}\frac{dy}{\tau}$$

$$E_0 = \frac{A^2\tau}{2\pi}\int_{-\infty}^{\infty} \frac{y^2}{(1+y^2)^2}dy$$

We can evaluate this integral using integration by parts. Let

$$u = y \quad \Rightarrow \quad du = dy$$

$$dV = \frac{y}{(1+y^2)^2} \Rightarrow V = \frac{-1}{2(1+y^2)}$$

Hence,
$$E_0 = \frac{A^2\tau}{2\pi}\left[\left(\frac{-y}{2(1+y^2)}\right)_{y=-\infty}^{\infty} + \frac{1}{2}\int_{-\infty}^{\infty}\frac{1}{1+y^2}\cdot dy\right]$$

$$E_0 = \frac{A^2\tau}{2\pi}\left[0 + \frac{1}{2}\left[\tan^{-1} y\right]_{-\infty}^{\infty}\right]$$

$$E_0 = A^2\tau \times \frac{1}{2\pi}\times\frac{\pi}{2} = \frac{A^2\tau}{4} \text{ (joules)}$$

Thus,
$$E_0 = \frac{E_i}{2} \text{ Hence, proved.}$$

Q.6 (b) Solution:

Sequential control flow instructions are the instructions which after execution, transfer control to the next instruction appearing immediately after it in the program. For example, the arithmetic, logical, data transfer and processor control instructions are sequential control flow instructions. The various addressing modes of 8086 for sequential control flow instructions are:

(i) Immediate addressing mode: In this addressing mode, data is a part of instruction, and appears in the form of successive byte or bytes. e.g., MOV AX, 0020 H : Here, the 16 bit data to be moved to the register AX is 0020 H.

(ii) Direct addressing mode: In this addressing mode, a 16 bit offset address of the memory location containing the data is specified in the instruction.

Example: MOV AX, [0020 H]; Here, the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment (DS) is 0020 H. The effective address of the memory location is "10H × [DS] + 0020H".

(iii) Register addressing mode: In this addressing mode, the data is stored in a register and the register is referred in the instruction. All the registers, except IP, may be used in this mode. Both 8-bit or 16-bit data can be specified depending on the size of the register.

Example: MOV AX, BX; Here, the 16 bit data to be moved to the register AX is present in the register BX.

(iv) Register Indirect addressing mode: In this addressing mode, the offset address of the memory location containing the data is specified indirectly, using the offset registers. In this addressing mode, the offset address is in either BX or SI or DI register and the default segment register is either DS or ES.

Example: MOV AX, [BX]: Here, the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment is in the register BX. The effective address of the memory location is "10H × [DS] + BX".

(v) Indexed addressing mode: In this addressing mode, the offset address of the memory location containing the data is specified indirectly, using one of the index registers and 8 or 16-bit displacement. DS is the default segment register for index registers SI and DI respectively. This addressing mode is a special case of the "register indirect addressing mode".

Example: MOV AX, [SI]: Here the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment is in the register SI. The effective address of the memory location is "10H × [DS] + [SI]".

(vi) Register relative addressing mode: In this addressing mode, the offset address of the memory location containing the data is obtained by adding an 8 bit or 16 bit displacement to the content of any one of the registers BX, BP, SI and DI. The default segment register for this addressing mode is either DS or ES.

e.g., MOV AX, 50 H [BX]; Here the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment is obtained by adding 50 H to the content of the register BX. The effective address of the memory location is 10H × [DS] + 50 H + [BX].

(vii) Based indexed addressing mode: In this addressing mode, the offset address of the memory location containing the data is obtained by adding the content of a base register (BX or BP) to the content of an indexed register (SI and DI). The default segment register for this addressing mode is either DS or ES.

Example: MOV AX, [BX][SI]; Here, the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment, is obtained by adding the content of the register BX to the content of the register SI. The effective address of the memory location is "10H × [DS] + [BX] + [SI].

(viii) Relative based indexed addressing mode: In this addressing mode, the offset address of the memory location containing the data is obtained by adding an 8 bit or 16 bit displacement to the sum of the content of a base register (BX or BP) and the content of an indexed register (SI and DI). The default segment register for this addressing mode is either DS or ES.

Example: MOV AX, 50 H[[BX][SI]]: Here, the 16 bit data to be moved to the register AX is present in a memory location in the data segment. The offset address of the memory location in the data segment is obtained by adding 50 H to the sum of the content of the register BX and the content of the register SI. The effective address of the memory location is "10H × [DS] + 50 H + [BX] + [SI]".

Q.6 (c) Solution:

(i) The nominal etch time, $t_{\text{nominal}} = \dfrac{d_{ox}}{r_{ox}} = \dfrac{0.50}{0.30}\text{ minutes} = \dfrac{5}{3}\text{ minutes}$. The overetch is done to make sure all the oxide is etched for the worst case condition; that means for the thickest oxide and the slowest etch rate.

$$d_{ox\,(\max)} = 0.5(1.05) = 0.525\ \mu\text{m}$$

$$r_{ox\,(\min)} = 0.3(0.95) = 0.285\ \mu\text{m/minute}$$

The time taken to etch the worst case,

$$t_{\max} = \frac{d_{ox(\max)}}{r_{ox(\min)}} = \frac{0.525}{0.285} = \frac{35}{19}\text{ minutes}$$

The amount of overetch, in % time, can be given by,

$$\text{overetch} = \frac{t_{\max} - t_{\text{nominal}}}{t_{\text{nominal}}} \times 100$$

$$= \frac{\frac{35}{19} - \frac{5}{3}}{\frac{5}{3}} \times 100 = \frac{200}{19} = 10.5263\%$$

(ii) Comparison of FPGA and ASIC

FPGA	ASIC
• FPGA stands for field programmable Gate Array.	• ASIC stands for application specific integrated circuit.
• FPGA are used for prototyping hardware.	• ASIC are used in real time for specific applications.
• Faster time to market.	• The design process takes considerable time.
• FPGAs provide lower NRE (Non-recurring expenses) as this integrated circuit is comprised of thousands of logic blocks that can be reconfigured.	• ASICs provide higher NRE cost.
• FPGA tools are cheap.	• ASIC design tools are very much expensive.
• It has a simple design cycle.	• It has a complex design cycle.
• FPGA eliminates the complex and time-consuming floor planning, place and route, timing analysis.	• The design of ASIC requires floor planning, place and route, timing analysis.
• FPGA can be reprogrammed in a snap.	• ASICs takes more cost and more than 4-6 weeks to make the changes.
• Power consumption in FPGA is more.	• Consumes less power due to the functionality-specific design
• Reusability of FPGA is main advantage. Prototype of the design can be implemented on FPGA which could be verified for almost accurate results.	• ASIC gives design flexibility. This gives enormous opportunity for speed optimization.

Q.7 (a) Solution:

(i) The directivity is defined as

$$D = \frac{U_{max}}{U_{avg}}$$

From the given U radiation intensity,

$$U_{max} = 2$$

The expression for the average radiated intensity,

$$U_{avg} = \frac{1}{4\pi}\int U(\theta, \phi)\, d\Omega$$

$$= \frac{1}{4\pi}\int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi} 2\sin\theta\sin^3\phi\sin\theta\, d\theta\, d\phi$$

$$= \frac{1}{2\pi}\int_0^{\pi} \sin^2\theta\, d\theta \int_0^{\pi} \sin^3\phi\, d\phi$$

$$= \frac{1}{2\pi}\int_0^{\pi} \frac{1}{2}(1-\cos 2\theta)d\theta \int_0^{\pi}(1-\cos^2\phi)d(-\cos\phi)$$

$$= \frac{1}{2\pi}\cdot\frac{1}{2}\left(\theta - \frac{\sin 2\theta}{2}\right)\Bigg|_0^{\pi}\left(\frac{\cos^3\phi}{3} - \cos\phi\right)\Bigg|_0^{\pi}$$

$$= \frac{1}{2\pi}\cdot\frac{\pi}{2}\left(\frac{4}{3}\right) = \frac{1}{3}$$

Hence, $D = 2 \times 3 = 6$

(ii) For a 2-element array of antennas, the array factor $AF = \cos(\psi/2)$, where $\psi = \alpha + \beta d \cos\theta$.

The normalized field pattern of the array is obtained by the multiplication of unit pattern and group pattern as as

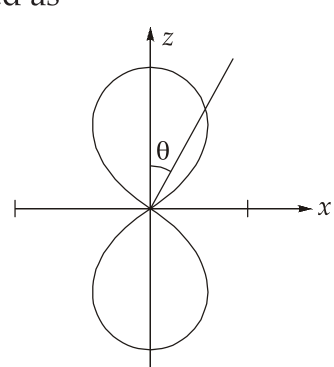
$$F(\theta) = \left|\cos\theta \cos\left[\frac{1}{2}(\beta d \cos\theta + \alpha)\right]\right|$$

If $\alpha = \frac{\pi}{2}, d = \frac{\lambda}{4}$, we have $\beta d = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$

$$F(\theta) = |\cos\theta| \left|\cos\frac{\pi}{4}(\cos\theta + 1)\right|$$

Resultant pattern = unit pattern × group pattern

The unit pattern is obtained as



Unit pattern

For the group pattern, the null occurs when

$$\cos\left[\frac{\pi}{4}(1+\cos\theta)\right] = 0$$

$$\frac{\pi}{4}(1+\cos\theta) = \frac{\pi}{2}$$

$$1 + \cos\theta = 2$$

$$\cos\theta = 1 \quad \Rightarrow \quad \theta = 0, 2\pi, 4\pi, \ldots$$

For maxima

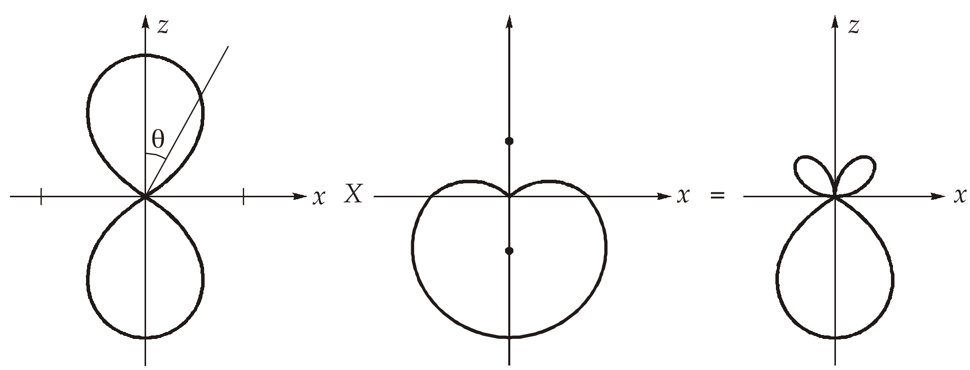
$$\theta = \pi, 3\pi$$

For half power first null

$$\theta = \frac{\pi}{2}$$

The field pattern is obtained by varying θ = 0°, 10°, 15°, ... 180°. Note that θ = 180° corresponds to the maximum values of AF, whereas θ = 0° corresponds to the null. Thus, the unit group and resultant patterns in the plane containing the axis of the elements are shown in figure.

The end-fire array ($\alpha = \beta d$) in figure is predominately unidirectional.



Unit pattern Group pattern Resultant pattern

(iii) The wavelength of radiation,

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{12\times10^9}$$

$$= \frac{1}{40}\text{ m} = 0.025\text{ m}$$

Since, the dish is circularly symmetric the antenna beam will be circular. If the HPBW is θ_{HPBW} the solid angle of the beam is

$$= \frac{\pi}{4}(\theta_{HPBW})^2$$

Directivity of the antenna

$$D = 30 \text{ dB} = 10^3$$

We know,
$$D = \frac{4\pi}{\frac{\pi}{4}(\theta_{HPBW})^2}$$

$$10^3 = \frac{4\pi}{\frac{\pi}{4}(\theta_{HPBW})^2}$$

$$\theta_{HPBW} = \frac{4}{\sqrt{1000}} = 0.126 \text{ rad}$$

If the efficiency of the antenna is assumed to be 100%, then gain of the antenna, $G = D$. The effective aperture is

$$A_e = \frac{G\lambda^2}{4\pi} = \frac{1000 \times (0.025)^2}{4\pi} = 0.0497 \text{ m}^2$$

Q.7 (b) Solution:

(i) We know that, amplitude modulated signal is given by

$$S_{AM}(t) = A_c[1 + K_a m(t)]\cos 2\pi f_c t$$

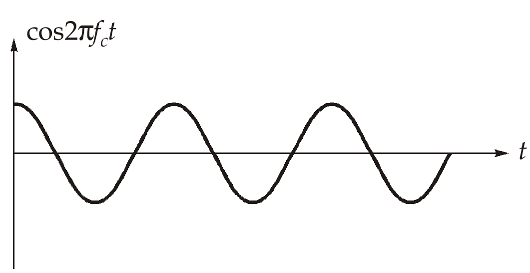
Since, K_a is not given, we assume

$$K_a = \frac{1}{A_c} = \frac{1}{10} = 0.1 \text{ V}^{-1}$$

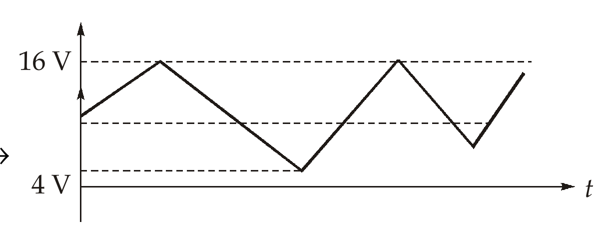
$$S_{AM}(t) = 10[1 + 0.1\, m(t)]\cos 2\pi f_c t$$

$$S_{AM}(t) = [10 + m(t)]\cos 2\pi f_c t \qquad \text{...(i)}$$

As, $\cos 2\pi f_c t \longleftrightarrow$



and $(10 + m(t)) \longleftrightarrow$



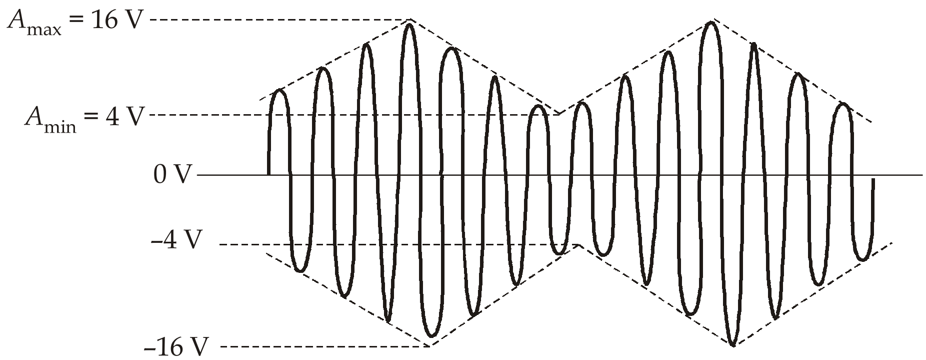
for $m(t)|_{max} = 6$ V

$$10 + m(t) = 10 + 6 = 16 \text{ V}$$

for $m(t)|_{min} = -6$ V

$$10 + m(t) = 10 - 6 = 4 \text{ V}$$

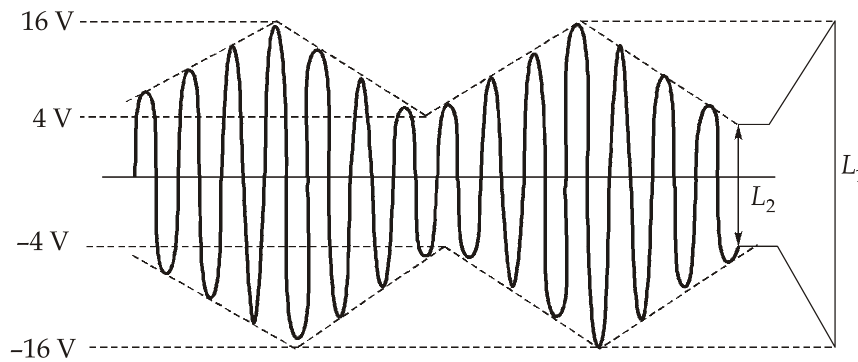
Thus, the AM signal $[10 + m(t)]\cos 2\pi f_c t$ can be plotted as below:



(ii) We know that,

$$\text{modulation index, } \mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

or $$\mu = \frac{A_m}{A_c} = \frac{6}{10} = 0.6$$



For the trapezoidal pattern as shown above,

$$L_1 = 2A_{max}$$

$$L_2 = 2A_{min}$$

$$\frac{L_1}{L_2} = \frac{2A_{max}}{2A_{min}}$$

$$\frac{L_1}{L_2} = \frac{A_{max}}{A_{min}} = \frac{16}{4} = 4$$

(iii) As, $S_{AM} = [A_c + m(t)]\cos 2\pi f_c t$

$$\text{Total power, } P_t = \frac{A_c^2}{2} + \frac{P_m}{2}$$

$$P_t = P_c + P_{SB}$$

$$P_t = \frac{(10)^2}{2} + \frac{A_m^2}{3\times 2}$$

$$P_t = 50 + \frac{36}{6}$$

$$P_t = 56 \text{ Watt}$$

and $P_{SB} = 6$ Watt

We know that, efficiency $\eta = \dfrac{P_{SB}}{P_t}$

$$\eta = \frac{6}{56}\times 100$$

$$\eta = 0.107$$

$$\eta\% = 10.7\%$$

(iv) We know that,

$$\text{modulation index, } \mu = K_a |m(t)|_{\text{max}}$$

According to question, $\mu' = 0.3$

$$0.3 = K_a \times 6$$

$$K_a = \frac{0.3}{6}$$

$$K_a = 0.05$$

As K_a is not given in the question, hence by default $K_a = \dfrac{1}{A_c}$

Here, $K_a = \dfrac{1}{A_c + A_c'} = 0.05$

$$\frac{1}{A_c + A_c'} = 0.05$$

$$A_c + A_c' = 20$$

$$A_c' = 20 - A_c = 20 - 10$$

$$A_c' = 10 \text{ V}$$

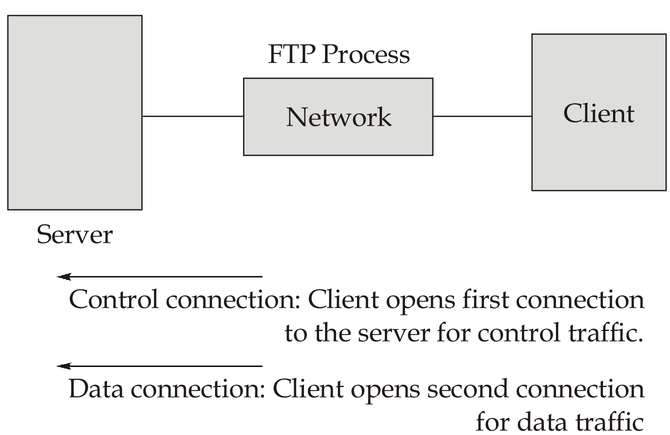
Hence, to get $\mu = 0.3$, an amplitude of carrier must be increased by 10 V.

Q.7 (c) Solution:

(i) FTP : File Transfer Protocol

The file transfer protocol (FTP) is a commonly used application layer protocol. FTP was developed to allow for file transfer between a client and a server. An FTP client is an application that runs on a computer that is used to push and pull files from a server running the FTP daemon (FTPd). To successfully transfer files, FTP requires two connections between the client and server, one for commands and replies the other for the actual file transfer.

The client establishes the first connection to the server on TCP port 21. This connection is used for control traffic consisting of client commands and server replies. The client establishes the second connection to the server over TCP port 20. This connection is for the actual file transfer and is created every time there is a file transferred. The file transfer can happen in either direction. The client can download (pull) a file from the server or the client can upload (push) a file to the server.



(ii) **SMTP:** Simple Mail Transfer Protocol

The SMTP is TCP/IP protocol that supports electronic mail (e-mail) on the internet. It is the system for sending messages to other computer users based on email address.

An e-mail address contains two parts:

1. Local part
2. Domain part

Represented as Local part @domain part

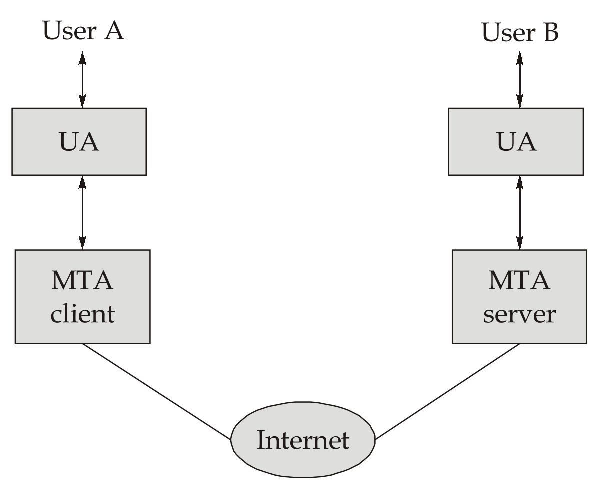
e.g. madeeasy@yahoo.com

In SMTP, there are two types of agents:

1. UA (User agent)
2. MTA (Mail transfer agent)

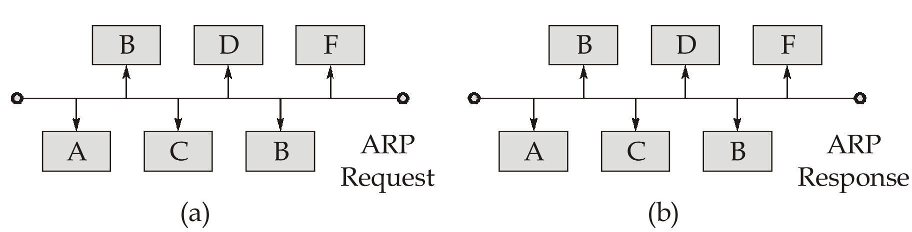
- **User Agent (UA):** UA prepares the message, creates the envelope and put the message in the envelope. The user agent is a program normally used to send and receive mail.
- **Mail Transfer Agent (MTA):** The actual mail transfer is done through MTA. To send a mail system must have client MTA and to receive mail system must have server MTA.

  SMTP allows a more complex system by adding a relaying system. Instead of just having one MTA at sending side and one at receiving side, more MTAs can be added, acting either as a client or server to relay the email. The relaying system without TCP/IP protocol can also be used to send the emails to users, and this is achieved by the use of the mail gateway. The mail gateway is a relay MTA can receive mail prepared by protocol other than SMTP and transfer it to SMTP format before sending it and vice-versa.



(iii) ARP: Address Resolution protocol

Address resolution protocol (ARP) is a protocol for mapping an internet protocol address (IP address) to a physical machine address that is recognized in the local network. It converts 32-bit IP address to 48-bit MAC address.



ARP broadcasts a request packet in a special format to all the machines on the LAN to see if any of the machine has that IP address associated with it.

A machine that recognizes the IP address as its own returns a reply indicating so. ARP updates the ARP cache for future references and then sends the packet to the MAC address that replied. Since protocol details differ for each type of local area network, there are separate ARP requests for comments (RFC) for ethernet, ATM, Fiber distributed-data interface, HIPPI and other protocols.

(iv) RARP: Reverse Address Resolution Protocol

RARP is a protocol by which a physical machine in a local area network can request to learn its IP address from a gateway server's address resolution protocol (ARP) table or cache. A network administrator creates a table in a local area network's gateway router that maps the physical machine (or Media Access Control-MAC address) addresses to corresponding internet protocol addresses.

When a new machine is set up, its RARP client program requests from the RARP server on the router to send its IP address. Assuming that an entry has been set up in the router table, the RARP server will return the IP address to the machine which can store it for future use. RARP is available for ethernet, fiber distributed-Data Interface, and token ring LANs.

Q.8 (a) Solution:

(i) Given,

$$f(t) = e^{-t/2};\ 0 < t \le \pi$$

$$T_0 = \pi \sec$$

$$\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{\pi} = 2 \text{ rad/sec}$$

For the existence of Fourier series,

$$\int_{<T>} |f(t)|\, dt < \infty$$

We have,

$$\int_0^{\pi} \left|e^{-t/2}\right| dt = -2\left[e^{-\frac{t}{2}}\right]_0^{\pi}$$

$$= -2\left[e^{-\frac{\pi}{2}} - 1\right] < \infty$$

which is a finite value, Hence, the Fourier series exists.

(ii) The Trigonometric Fourier series representation of the signal is given as

$$f(t) = a_0 + \sum_{n=-\infty}^{\infty} \{a_n \cos(n\omega_o t)\} + b_n \sin(n\omega_0 t)\}$$

where a_0, a_n and b_n are Trigonometric coefficients, obtained as below:

$$a_0 = \frac{1}{\pi}\int_0^{\pi} e^{-t/2}dt$$

$$= \frac{-2}{\pi}\left[e^{-\frac{t}{2}}\right]_0^{\pi} = \frac{-2}{\pi}\left[e^{-\frac{\pi}{2}} - 1\right] = \frac{2}{\pi}\left[1 - e^{-\pi/2}\right]$$

$$\therefore \quad a_0 \cong 0.504$$

$$a_n = \frac{2}{\pi}\int_0^{\pi} f(t)\cos(n\omega_0 t)dt$$

$$= \frac{2}{\pi}\int_0^{\pi} e^{-t/2}\cos(2nt)dt$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{t}{2}}}{\left(-\frac{1}{2}\right)^2 + (2n)^2}\left[-\frac{1}{2}\cos(2nt) + (2n)\sin(2nt)\right]\right\}_0^{\pi}$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{\pi}{2}}}{\left(-\frac{1}{2}\right)^2 + (2n)^2}\left[-\frac{1}{2}\cos(2n\pi) + (2n)\sin(2n\pi)\right]\right\}$$

$$-\frac{2}{\pi}\left\{\frac{1}{\left(\frac{-1}{2}\right)^2 + (2n)^2}\left[\frac{-1}{2}\cos(0) + (2n)\sin(0)\right]\right\}$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{\pi}{2}}}{\left(\frac{1}{4}\right) + 4n^2}\left(\frac{-1}{2}\right)\right\} - \frac{2}{\pi}\left\{\frac{1}{\frac{1}{4} + 4n^2}\left(\frac{-1}{2}\right)\right\}$$

$$a_n = \frac{2}{\pi}\left[\frac{1 - e^{-\frac{\pi}{2}}}{2\left(\frac{1}{4} + 4n^2\right)}\right] = \frac{4\left(1 - e^{-\frac{\pi}{2}}\right)}{\pi(1 + 16n^2)}$$

Similarly,

$$b_n = \frac{2}{\pi}\int_0^{\pi} f(t)\sin(n\omega_0 t)dt$$

$$= \frac{2}{\pi}\int_0^{\pi} e^{-\frac{t}{2}} \sin(2nt)dt$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{t}{2}}}{\left(-\frac{1}{2}\right)^2 + (2n)^2}\left[-\frac{1}{2}\sin(2nt) - (2n)\cos(2nt)\right]\right\}_0^{\pi}$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{\pi}{2}}}{\frac{1}{4} + 4n^2}\left[\frac{-1}{2}\sin(2\pi n) - 2n\cos(2\pi n)\right]\right\}$$

$$-\frac{2}{\pi}\left\{\frac{1}{\frac{1}{4} + 4n^2}\left[\frac{-1}{2}\sin(0) - 2n\cos(0)\right]\right\}$$

$$= \frac{2}{\pi}\left\{\frac{e^{-\frac{\pi}{2}}}{\frac{1}{4} + 4n^2}[0 - 2n]\right\} + \frac{2}{\pi}\left\{\frac{1}{\frac{1}{4} + 4n^2}(2n)\right\}$$

$$= \frac{2}{\pi}\left\{\frac{2n\left(1 - e^{-\frac{\pi}{2}}\right)}{\frac{1}{4} + 4n^2}\right\}$$

$$b_n = \frac{16n\left(1 - e^{-\frac{\pi}{2}}\right)}{\pi(1 + 16n^2)}$$

(iii) The complex fourier series coefficient C_n is given by

$$|C_n| = \frac{1}{2}\sqrt{a_n^2 + b_n^2}$$

$$= 0.5\sqrt{\left(\frac{4\left(1 - e^{-\frac{\pi}{2}}\right)}{\pi(1 + 16n^2)}\right)^2 + \left(\frac{16n\left(1 - e^{-\frac{\pi}{2}}\right)}{\pi(1 + 16n^2)}\right)^2}$$

$$C_n = \frac{2\left(1 - e^{-\frac{\pi}{2}}\right)}{\pi\sqrt{1 + 16n^2}}$$

Signal average power,

$$P_f = \frac{1}{\pi}\int_0^{\pi}\left(e^{-\frac{t}{2}}\right)^2 dt = \frac{1}{\pi}\int_0^{\pi} e^{-t}dt = \frac{1}{\pi}\left[-e^{-t}\right]_0^{\pi} = \frac{1}{\pi}\left[1-e^{-\pi}\right]$$

$$\therefore \quad P_f = 0.304 \text{ W}$$

The average signal power contained in the first 6 harmonics is obtained using Parseval's Theorem as

$$P_{f,6} = \sum_{n=-6}^{6} |C_n|^2$$

where, $|C_0| = a_0 = 0.504$ and $|C_{-n}| = |C_n|$

$$P_{f,6} = C_0 + 2\left[|C_1|^2 + |C_2|^2 + |C_3|^2 + |C_4|^2 + |C_5|^2 + |C_6|^2\right]$$

$$|C_1| = \frac{2\left(1-e^{-\frac{\pi}{2}}\right)}{\pi\sqrt{1+16}} = 0.1225$$

$$|C_2| = 0.0625$$

$$|C_3| = 0.042$$

$$|C_4| = 0.0315$$

$$|C_5| = 0.025$$

$$|C_6| = 0.021$$

$$P_{f,6} = (0.504)^2 + 2\left[0.1225^2 + 0.0625^2 + 0.042^2 + 0.0315^2 + 0.025^2 + 0.02^2\right]$$

$$= (0.504)^2 + 0.04547$$

$$P_{f,6} = 0.299 \text{ W}$$

$$\therefore \quad P_{f,6} \cong \frac{0.299}{0.304} \times 100\% = 98.35\% \text{ of } P_f$$

Q.8 (b) Solution:

(i) Yes, it's possible to have a combination of hardwired control and control memory in a control unit. This hybrid approach can provide flexibility and efficiency by utilizing both methods.

- **Hardwired Control:**

  Some control signals can be directly generated by combinational logic circuits without the need for a control memory. This approach is faster and can be used for frequently used control signals or simple operations.

- **Control Memory:**

  For more complex control sequences or signals that need to be changed or updated easily, a control memory like ROM or PLA can be used. Control words stored in the memory can be fetched and decoded to produce control signals.

  By combining hardwired control with control memory, designers can optimize performance, reduce complexity, and enhance flexibility in the control unit of a microprocessor or other digital system.

(ii)

Time	1	2	3	4	5	6	7	8	9	10	11	12
Page reference	2	3	2	1	5	2	4	5	3	2	5	2

FIFO: The FIFO algorithm replaces the oldest page in memory when a page fault occurs.

2^*	2^*	2^*	2^*	5	5
	3	3	3	3^*	2
			1	1	1^*
		Hit			

5^*	5^*	3	3	3	3^*
2	2	2^*	2^*	5	5
4	4	4	4	4^*	2
	Hit		Hit		

$$\text{Hit ratio} = \frac{3}{12} = 0.25$$

LRU: Whenever a page fault occurs, the least recently used page will be replaced with a new page.

2^*	2^*	2	2	2^*	2
	3	3^*	3^*	5	5
			1	1	1^*
		Hit			Hit

2	2^*	3	3	3^*	3^*
5^*	5	5	5^*	5	5
4	4	4^*	2	2	2
	Hit			Hit	Hit

$$\text{Hit ratio} = \frac{5}{12} = 0.416$$

OPT: In optimal page replacement algorithm, pages are replaced which would not be used for the longest duration of time in the future.

2	2	2	2	2	2
	3	3	3	3	3
			1	5	5
		Hit			Hit

4	4	4	2	2	2
3	3	3	3	3	3
5	5	5	5	5	5
	Hit	Hit		Hit	Hit

$$\text{Hit ratio} = \frac{6}{12} = 0.5$$

It is observed that LRU recognizes that P_2 and P_5 are referenced more frequently than other pages, whereas FIFO does not. Thus, FIFO replaces P_2 twice, but LRU does so only once. The highest page hit ratio is achieved by OPT, and the lowest by FIFO. The page hit ratio of LRU is quite close to that of OPT, a property that seems to hold generally. Optimum replacement policy is not practically used because we can't predict what will come next.

Q.8 (c) Solution:

From the bode plot transfer function of the system can be written as:

$$G_1(s) = \frac{k}{s\left(\frac{s}{3}+1\right)\left(\frac{s}{10}+1\right)}$$

At ω = 0.05 rad/sec,

$$20 \log|G_1(s)| = 40 \text{ dB}$$

The equation of the initial slope is given by

$$y = mx + c \quad \Rightarrow \quad y = -20 \log \omega + 20 \log k$$

$$40 = -20 \log(0.05) + 20 \log k$$

$$k = 5$$

Transfer function $G_1(s)$, thus can be written as

$$G_1(s) = \frac{5}{s\left(\frac{s}{3}+1\right)\left(\frac{s}{10}+1\right)}$$

$$G_1(s) = \frac{150}{s(s+3)(s+10)}$$

At gain cross-over frequency,

$$|G_1(s)|_{s=j\omega_{gc}} = 20\log|G_1(s)|_{s=j\omega_{gc}} = 0 \text{ dB}$$

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Given gain crossover frequency,

$$\omega_{gc} = 3.5 \text{ rad/s}$$

$$\angle G_1(s)\big|_{\omega=\omega_{gc}} = \phi$$

So, phase margin of system with open loop transfer function $G_1(s)$ can be given as 180° + ϕ, where

$$\phi = \angle G_1(s)\big|_{s=j\omega_{gc}}$$

$$G_1(j\omega) = \frac{150}{j\omega(j\omega+3)(j\omega+10)}$$

$$\phi = -90° - \tan^{-1}\frac{\omega}{3} - \tan^{-1}\frac{\omega}{10}\bigg|_{\omega=3.5\text{ rad/s}}$$

$$= -90° - \tan^{-1}\frac{3.5}{3} - \tan^{-1}\frac{3.5}{10}$$

$$\phi = -158.688° \quad \text{...(1)}$$

In question,

$$G(s)H(s) = e^{-2Ts}G_1(s)$$

$$G(j\omega)H(j\omega) = e^{-2j\omega T}G_1(j\omega)$$

So,

$$\angle G(j\omega)H(j\omega) = -2\omega T \times \frac{180°}{\pi} + \angle G_1(j\omega) \quad \text{...(2)}$$

Given, phase margin of the system = 18.2°

So, $180° + \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = 18.2°$

$$\angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = -161.8°$$

From (1) and (2),

$$-161.8° = -2\omega_{gc}T \times \frac{180°}{\pi} - 158.688°$$

$$2\omega_{gc}T \times \frac{180°}{\pi} = 3.112°$$

$$T = \frac{3.112 \times \pi}{180 \times 2 \times 3.5} = 0.00776 \text{ sec}$$

$$T = 7.76 \text{ ms}$$

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