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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-8 : Full Syllabus Test (Paper-II)

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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	43
Q.2	/
Q.3	/
Q.4	44
Section-B	
Q.5	58
Q.6	/
Q.7	50
Q.8	26
Total Marks Obtained	221

Signature of Evaluator .... Cross Checked by ....

Ch. Reeft

• Good attempt keep it up.

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IMPORTANT INSTRUCTIONS

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1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

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1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
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6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A

Q.1 (a) A continuously operating coherent BPSK system makes errors at the average rate of 100 errors per day. Data rate is 1 kbps. The single sided noise power spectral density is $\eta = 10^{-10}$ W/Hz.

(i) Assume the system to be wide sense stationary, what is the average bit error probability?

(ii) If the value of received average signal power is adjusted to be 10^{-6} W, will this received power be adequate to maintain the error rate obtained in part(i)?

(Assume, $Q(4.5) = 3.9 \times 10^{-6}$)

[6 + 6 marks]

Solution-:

given BPSK system

data rate (R_b) = 1 kbps

Double side power spectral density (η) = 10^{-10} W/Hz

average rate of ~~errors =~~ 100 errors per day

average error per second (P_e') = $\frac{100}{60 \times 60 \times 24}$

$P_e' = 0.0278$ 0.0012

3

(i) wide sense stationary process

mean = variance

average bit error rate (P_e) = $P(0) P_e' + P(1) P_e'$.

Assuming transmission of logic '0' and '1' are equiprobable so $P(0) = P(1) = 1/2$

So $P_e = \frac{1}{2} \times 2 P_e' = 0.0278$

Ans $\boxed{\text{average bit rate } (P_e) = 0.0278}$

(ii) Received power (P) = 10^{-6} W

$E = P \times T_b \Rightarrow E_b$ (energy) = P/R_b

$E_b = \frac{10^{-6}}{10^{3}} \Rightarrow 10^{-9}$ J

6

BER for PSK $BER = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$

$N_0 = \eta = 10^{-10}$

$BER = Q\left(\sqrt{\frac{2 \times 10^{-9}}{10^{-10}}}\right)$

Do not write in this margin

BER = Q(4.5)

given Q(4.5) = 3.9×10^{-6}

so BER = 3.9×10^{-6}

since in 1st part $BER_1 > BER_2$

Hence this system is adequate to maintain the bit rate rate.

Q.1 (b) An LTI system has the impulse response $h(t) = 5e^{-t}\,u(t) - 16\,e^{-2t}\,u(t) + 13\,e^{-3t}\,u(t)$. The input is $x(t) = 7\cos(2t)$. Compute the output $y(t)$.

[12 marks]

Solution

given

Impulse response $h(t) = 5e^{-t}u(t) - 16e^{-2t}u(t) + 13e^{-3t}u(t)$

by applying Laplace transform

$$H(s) = \frac{5}{s+1} - \frac{16}{s+2} + \frac{13}{s+3}$$

$$= \frac{5(s+2)(s+3) - 16(s+1)(s+3) + 13(s+1)(s+2)}{(s+1)(s+2)(s+3)}$$

$$= \frac{5s^2 + 75s + 30 - (16s^2 + 64s + 48) + 13s^2 + 39s + 26}{(s+1)(s+2)(s+3)}$$

$$H(s) = \frac{2s^2 + 50s + 8}{(s+1)(s+2)(s+3)}$$

$x(t) = 7\cos 2t$

By Laplace transform

$x(s) = \dfrac{7s}{s^2+4}$

So output $(Y(s)) = X(s)H(s) \Rightarrow \dfrac{7s}{s^2+4} \times \dfrac{2s^2+50s+8}{(s+1)(s+2)(s+3)}$

By using partial fraction

$Y(s) = \dfrac{As+B}{s^2+4} + \dfrac{C}{(s+1)} + \dfrac{D}{s+2} + \dfrac{E}{(s+3)}$

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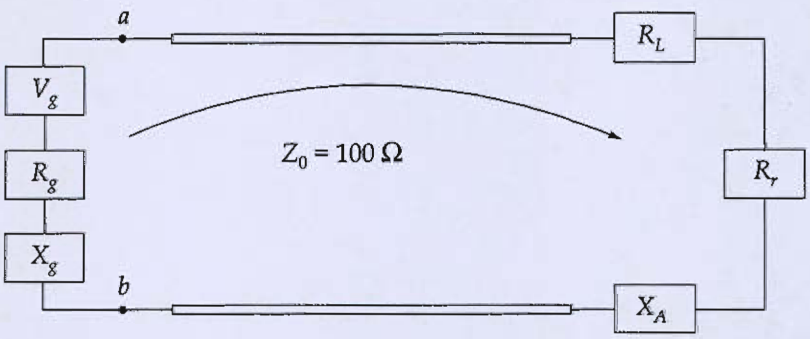
Q.1 (c) An antenna with a radiation resistance of 48 Ω, a loss resistance of 2 Ω and a reactance of 50 Ω is connected to a generator with open-circuit voltage of 10 V and internal impedance of 50 Ω via a $\dfrac{\lambda}{4}$-long transmission line with characteristic impedance of 100 Ω.



Determine the power radiated by the antenna (Given, $V_g = 10$ V, $R_g = 50\ \Omega$, $X_g = 0$).

[12 marks]

Q.1 (d) Measurements conducted on a servo mechanism show the system response to be

$c(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$

when subjected to a unit-step input

(i) obtain the expression for the closed-loop transfer function.

(ii) determine the undamped natural frequency and the damping ratio of the system.

[6 + 6 marks]

Solution given

Response $c(t) = 1 + 0.2e^{-60t} + 1.2e^{-10t}$

By Laplace transform

$$C(s) = \frac{1}{s} + \frac{0.2}{s+60} - \frac{1.2}{s+10}$$

$$= \frac{(s+60)(s+10) + 0.2s(s+10) - 1.2s(s+60)}{s(s+60)(s+10)}$$

$$= \frac{s^2 + 70s + 600 + 0.2s^2 + 2s - 1.2s^2 - 72s}{s(s+60)(s+10)}$$

$$C(s) = \frac{600}{s(s+60)(s+10)} \quad -(1)$$

(i)

for step input $R(s) = \frac{1}{s}$

Transfer function $H(s) = \frac{C(s)}{R(s)}$

$$H(s) = \frac{\frac{600}{s(s+60)(s+10)}}{\frac{1}{s}}$$

$$H(s) = \frac{600}{(s+60)(s+10)}$$

$$H(s) = \frac{600}{s^2+70s+600} \quad -(2)$$

Ans: Closed loop transfer function $H(s)$

$$\boxed{H(s) = \frac{600}{s^2+70s+600}}$$

(ii) from equation (2)

characteristics equation $q(s) = s^2+70s+600$ —(3)

standard 2nd order system

$$q(s) = s^2 + 2\xi\omega_n s + \omega_n^2 \quad -(4)$$

on comparison of (3) & (4)

$\omega_n^2 = 600$

ω_n (undamped natural frequency) $= \cancel{24.95}$ rad/sec $= 24.495$

$2\xi\omega_n = 70$

$\xi = \frac{\cancel{70}}{2\times \cancel{24.95}}$ $\quad \xi = \frac{70}{2\times 24.495}$

$\xi = 1.42$ ($\xi > 1$ over damped system

Ans: $\boxed{\omega_n = 24.495 \text{ rad/sec} \quad \xi = 1.42}$

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.1 (e) Over an interval $|t| \le 1$, an angle-modulated signal is given by,

$$\phi_M(t) = 10\cos(13{,}000\pi t + 0.3\pi)$$

It is known that the carrier frequency $\omega_c = 12000\pi$ rad/sec.

(i) Assume the modulated signal is a PM signal with $k_p = 1000$ rad/V, determine $m(t)$ over the interval $|t| \le 1$.

(ii) Assume the modulated signal is a FM signal with $k_f = 1000$ rad/sec/volt, determine $m(t)$ over the interval $|t| \le 1$.

[6 + 6 marks]

Solution given

$\phi_m(t) = 10\cos(13{,}000\pi t + 0.3\pi)$ — (1)

(i) Modulated signal is PM signal

$K_p = 1000$ rad/V

Let

$\phi_m(t) = A_c\cos(\omega_c t + K_p m(t))$ — (2)

~~on comparision of (1) and (2)~~

$\phi_m(t) = 10\cos(12000\pi t + 1000\pi t + 0.3\pi)$ — (2)

on comparision of (1) and (2)

$K_p m(t) = 1000\pi t + 0.3\pi$

$m(t) = \dfrac{1000\pi t + 0.3\pi}{1000}$

$$m(t) = \pi t + \frac{3\pi}{10^4}$$

Ans $\boxed{m(t) = \pi t + \frac{3\pi}{10^4}}$

(iii) consider modulated signal is FM signal

$K_f = 1000$ rad/sec

As we know FM expression

$$\phi_m(t) = A_c \cos\left(\omega_c t + K_f \int_0^t m(\tau)\,d\tau\right) \quad - (3)$$

on comparision of (2) and (3)

$$K_f \int_0^t m(\tau)\,d\tau = 1000\pi t + 0.3\pi$$

$$\int_0^t m(\tau)\,d\tau = \frac{1000\pi t + 0.3\pi}{1000}$$

$$= \pi t + \frac{3\pi}{10^4}$$

Differentiation on both side

$$m(t) = \pi$$

Ans $\boxed{m(t) = \pi}$

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Q.2 (a) A transmission line channel has $(n-1)$ regenerative repeaters plus a terminal receiver in the transmission of binary information. The probability of error at the detector of each receiver (or repeater) is "p" and that errors among repeaters are statistically independent. Show that the binary error probability of the overall system is,

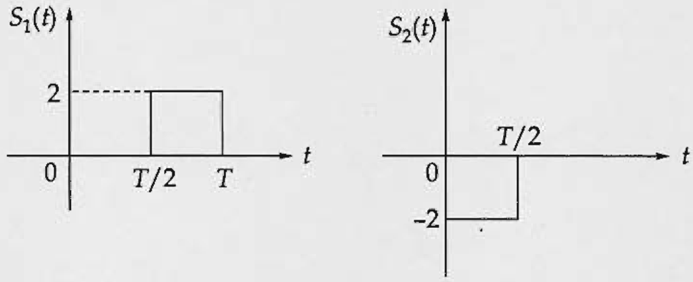
$$P_n = \frac{1}{2}\left[1-(1-2p)^n\right]$$

[20 marks]

Q.2 (b) Two hosts are connected via a packet switch with 10^8 bits per second links. Each link has a propagation delay of 40 μs. The switch begins forwarding a packet 60 μs after it receives the same. If 100000 bits of data are to be transmitted between the two hosts using a packet size of 25000 bits, then determine the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data.

[20 marks]

Q.2 (c) Express the following functions in terms of orthonormal components using Gram Schmidt procedure. Draw the constellation diagram for this signal set and find the minimum distance d_{min} between the constellation points.



[20 marks]

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Q.3 (a) In an air-filled rectangular waveguide with a = 2.286 cm and b = 1.016 cm, the y-component of the TE mode is given by

$$E_y = \sin\left(\frac{2\pi}{a}x\right)\cos\left(\frac{3\pi}{b}y\right)\sin(10\pi\times10^{10}t-\beta z)\ \text{V/m}$$

Find:

(i) The mode of operation.

(ii) The propagation constant.

(iii) H_x.

[20 marks]

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Q.3 (b) Explain different transfer modes of an 8237 DMA controller in active cycle.

[20 marks]

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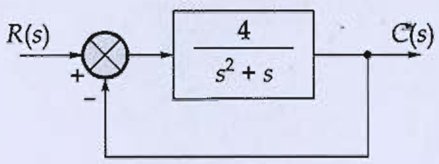
Q.3 (c) (i) Determine the order of a low-pass Butterworth filter that is to provide 40 dB attenuation at $\omega = 2\omega_0$. (Here, ω_0 is the cut-off frequency of low pass filter)

(ii) Write a 8085 program to generate continuous square wave with a period of 560 μs. Assume the system clock period is 350 ns and use I/O device connected at PORT 0 to output the square wave. Use register B as delay counter.

[10 + 10 marks]

Q.4 (a) A closed-loop control system with unity feedback is shown in figure. By using derivative control, the damping ratio is to be made 0.75. Determine the value of T_d. Also determine the rise time, peak time and peak overshoot without derivative control and with derivative control. Assume input to the system is a unit-step.



[20 marks]

Solution Case-1 ~~wh.~~ without derivative control

open loop transfer function $G(s) = \frac{4}{s^2+s}$

characteristics equation $q(s) = s^2+s+4$ — (1)

standard 2nd order system $q(s) = s^2 + 2\xi\omega_n s + \omega_n^2$ — (2)

on comparision $\omega_n = 2$ rad/sec

$2\xi\omega_n = 1$

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

$\xi = 0.25$

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

$= 2\sqrt{1-(0.25)^2}$

$\omega_d = 1.936$ rad/sec

① Rise time$(t_r) = \frac{\pi - \cos^{-1}(0.25)}{\omega_d}$

$= \frac{\pi - 1.318}{1.936}$

$t_r = 0.94$ sec

Ans (Rise time $(t_r) = 0.94$ sec)

⊗ peak time (t_p) = $\frac{\pi}{\omega_d}$ (considering 1st peak)

$= \frac{\pi}{1.936} \Rightarrow 1.623$ sec

Ans $\boxed{\text{peak time } (t_p) = 1.623 \text{ sec}}$

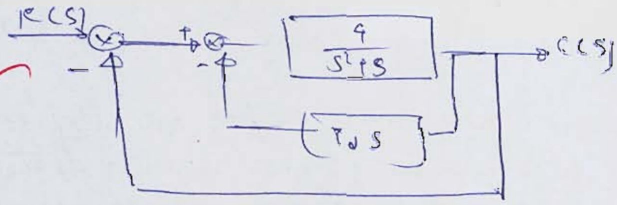
⊙ peak overshoot (M_p) = $e^{-\frac{\pi \xi}{\sqrt{1-\xi^2}}}$

$= e^{-\frac{\pi \times 0.25}{\sqrt{1-(0.25)^2}}}$

$= 44.4\%$

Ans $\boxed{\text{peak overshoot } (M_p) = 44.4\%}$

Case-2 when derivative control used



open loop transfer function

$GH(s) = \frac{4}{s^2 + (4T_d + 2)s}$

characteristic equation $q(s) = s^2 + (4T_d + 2)s + 4$ — (3)

on comparison of (3) and (2)

$\omega_n = 2$ rad/sec, $2\xi\omega_n = 4T_d + 2$

given $\xi = 0.75$

$2 \times 0.75 \times 2 = 4T_d + 2$

$T_d = 1.08$ sec

Ans $\boxed{T_d = 1.08 \text{ sec}}$

⊙ $\xi = 0.75$, $\omega_n = 2$ rad/sec

⊙ peak time (t_p) = $\frac{\pi - \cos^{-1}(\xi)}{\omega_d}$

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

$= 2\sqrt{1 - (0.75)^2}$

$\omega_d = 1.32$ rad/sec

Now

Now $t_r = \dfrac{\pi - \cos^{-1}(0.75)}{1.32}$

$= \dfrac{\pi - 0.7227}{1.32}$

$= 1.838 \text{ sec}$

Ans $\boxed{\text{Rise time } (t_r) = 1.83 \text{ sec}}$

// peak time $(t_p) = \dfrac{\pi}{\omega_d}$ (1st peak)

$= \dfrac{\pi}{1.32}$

$= 2.38 \text{ sec}$

Ans $\boxed{\text{peak time } (t_p) = 2.38 \text{ sec}}$

// peak overshoot $(M_p) = e^{-\frac{\pi \xi}{\sqrt{1-\xi^2}}}$

$= e^{-\frac{\pi \times 0.75}{\sqrt{1-(0.75)^2}}}$

$= 2.83\%$

Ans $\boxed{\text{peak overshoot } (M_p) = 2.83\%}$

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Q.4 (b) (i) Consider the following 5 processes with burst time (BT), arrival time (AT) and their priority as given below. Find the average waiting and turn around time using preemptive priority scheduling. Assume lower priority number implies highest priority.

Pid	Priority	AT (msec)	BT (msec)
1	3.	0	10
2	1	1	1
3	3	2	2
4	4	3	1
5	2	4	5

(ii) Realize a full adder using a (3 × 8 × 2) PLA.

[10 + 10 marks]

Solution(i):- Pre-emptive priority scheduling

criteria: priority

Mode: pre-emptive mode

It suffer from "Starvation".

Ready queue

time	process
t = 0	P1
t = 1	P1, P2
t = 2	P1, P3
t = 3	P1, P3, P4
t = 4	P1, P3, P4, P5

~~P1 → 10 9 8 7~~
~~P2 → 1~~
P3 → 2
P4 → 1
~~P5 → 5~~

Gantt Chart

Let quantum time (Tq) = 1 unit

P1	P2	P1	P5	P1	P3	P4

0 1 2 4 9 16 18 19

Pid	AT	BT	CT	TAT = CT - AT	WT = TAT - BT
P1	0	10	16	16	6
P2	1	1	2	1	0
P3	2	2	18	16	14
P4	3	1	19	16	15
P5	4	5	9	5	0

TAT(turn around time)
WT = waiting time

$$\text{average TAT} = \frac{16 + 2 + 16 + 16 + 5}{5}$$

$$= 10.8 \text{ msec}$$

$$\text{average WT time} = \frac{6 + 0 + 14 + 15 + 0}{5}$$

$$= 7 \text{ msec}$$

Ans: $\boxed{\begin{array}{l}\text{average TAT} = 10.8 \text{ msec} \\ \text{average WT} = 7 \text{ msec}\end{array}}$

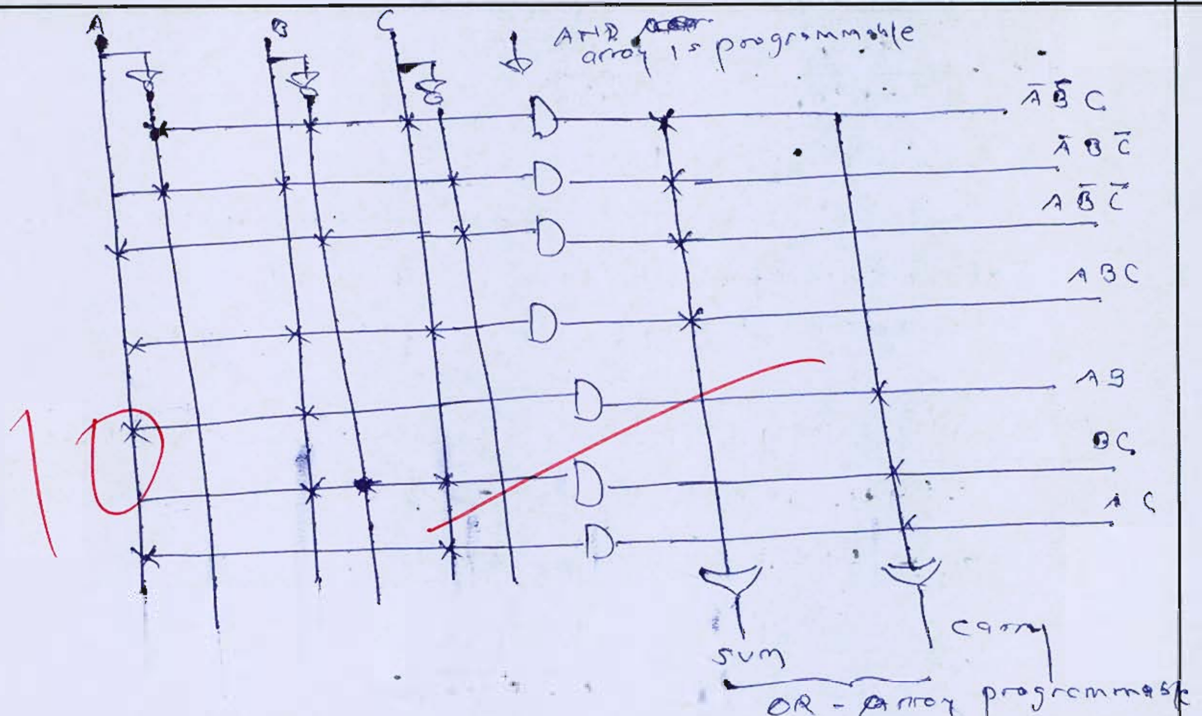
(iii) Full adder

As we know from truth ~~ab~~ table
SUM = $\Sigma m(1, 2, 4, 7)$
carry = $AB + BC + AC$.

sum = $\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

Implementing using PLA(programmable logic array)

PLA: both AND array and OR array are programmable.



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Q.4 (c) **(i)** In the ionospheric propagation, consider that the reflection takes place at a height of 400 km and that the maximum density in the ionosphere corresponds to a refractive index of 0.9 at frequency of 10 MHz. Determine the ground range for which this frequency is the MUF (Maximum Usable Frequency). Take the earth's curvature into consideration.

(ii) In a satellite link, the propagation loss is 200 dB. Margins and other losses account for another 3 dB. The receiver $[G/T]$ is 11 dB, and the [EIRP] is 45 dBW. Calculate the received [C/N] for a system bandwidth of 36 MHz.

[12 + 8 marks]

Solution (i)

ionosphere height (h) = 400 KM

given f_{muf} = 10 MHz (since it is not vertical incident case. Hence given frequency is muf.

At point of Reflection

$\theta_r = 90$, $\mu = \mu_{max}$

Snell's low

$\mu_1 \sin\theta_i = \mu_2 \sin\theta_r$

$\mu_1 = 1$, $\mu_2 = 0.9$

so $\sin\theta_i = 0.9$

so $\sec\theta_i = \sqrt{1-(0.9)^2}$

$\sec\theta_i = 0.435$

As we know $f_{muf} = f_c \sec\theta_i$

f_c = critical frequency

4

$$f_c = \frac{f_{muf}}{\sec\theta_i} = \frac{12}{0.435}$$

$f_c = 27.94$ MHz

since $f_{muf} < f_c$ Hence signal is not reflected back to ground.

Hence Range can not be calculated.

Solution(ii) propagation loss (L) = 200 dB or path loss

other loss (M) = 3 dB

$G/T = 11$ dB, EIRP = 45 dBW

Now $\frac{C}{N} = \frac{P_r}{N_o} \Rightarrow \frac{P_t G_t G_r}{N \times \text{path loss}}$

$= \frac{EIRP \times G}{KTB \times \text{path loss}}$

In dB

$\frac{C}{N}$ = EIRP + $\frac{G}{T}$ − path loss − other loss − 10 log K − 10 log B

K = Boltzmann constant

10 log K = −228.6 dB, B = 36 MHz given

$= 45 + 11 - 200 - 3 + 228.6 - 10\log(36 \times 10^6)$

= 6.036 dB

Ans $\boxed{\frac{C}{N} = 6.036 \text{ dB}}$

6

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Section B

Q.5 (a) Two rectangular waveguides are joined end-to-end. The waveguides have identical dimensions, where $a = 2b$. One guide is air-filled, and the other is filled with a dielectric characterized by '$\in_r$'. Determine the range of values of $\in_r$ such that single-mode operation can be simultaneously ensured in both guides at some frequency.

[12 marks]

Solution
Case-1 considering air field rectangular waveguide

for Dominant mode TE_{10}

cutoff frequency $(f_{c_1}) = \frac{mc}{2a}$

$$f_{c_1} = \frac{3\times10^{10}}{2a} = \frac{15}{a}\ GHz$$

for next higher mode TE_{20}

$$f_{c_2} = 2\times f_{c_1} \Rightarrow \frac{30}{a}\ GHz$$

for single mode of operation

$$\frac{15}{a} < f < \frac{30}{a} \quad -(1)$$

Case-2 for Dielectric field wave guide (ϵ_r)

cutoff frequency $(f_{c_1}') = \frac{mc}{2a\sqrt{\epsilon_r}} \Rightarrow \frac{15}{\sqrt{\epsilon_r}\,a}\ GHz$

for next higher higher mode TE_{20}

$$f_{c_2}' = 2\times f_{c_1}$$

$$= \frac{30}{\sqrt{\epsilon_r}\times a}\ GHz$$

for single mode of operation

$$\frac{15}{\sqrt{\epsilon_r}\times a} < f\,(GHz) < \frac{30}{\sqrt{\epsilon_r}\times a} \quad -(2)$$

when fiber is joined overall single mode frequency range

$$\frac{15}{\sqrt{\epsilon_r}\times a} < f\,(GHz) < \frac{30}{\sqrt{\epsilon_r}\times a}$$

Consider $f > \frac{15}{\sqrt{\epsilon_r}\times a}$

$$\epsilon_r > \frac{225}{a^2 f^2} \quad -(3)$$

And $f < \dfrac{30}{\sqrt{\epsilon_r} \times 9}$

$$\epsilon_r < \frac{900}{9^2 f^2} \quad \text{--- (4)}$$

from (3) and (4)

Range of 'ϵ_r'

$$\frac{225}{(9f)^2} < \epsilon_r < \frac{900}{(9f)^2}$$

Ans

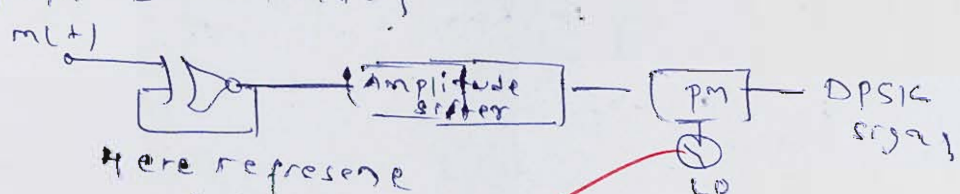
$$\boxed{\text{Range of } \epsilon_r \quad \frac{225}{(9f)^2} < \epsilon_r < \frac{900}{(9f)^2}}$$

Q.5 (b) The bit stream 1011100011 is to be transmitted using DPSK. Determine the encoded sequence and transmitted phase sequence.

[12 marks]

Solution :- DPSK signal

DPSK transmitter



Here represent bit is required

Let Reference bit is '1'

m(t)	1	0	1	1	1	0	0	0	1	1
X-NOR output	1	0	0	0	0	1	0	1	1	1
phase sequence	0	π	π	π	π	0	π	0	0	0

'1' → $A_c \cos \omega_c t$

'0' → $-A_c \cos \omega_c t$

Ans

Transmitted phase sequence

0 π π π π 0 π 0 0 0

- DPSK have more probability of error as compaired to BPSK.
- $Pe = \frac{1}{2} e^{-\frac{E_b^2}{N_0}}$

  E_b = bit energy

  N_0 = PSD of noise.

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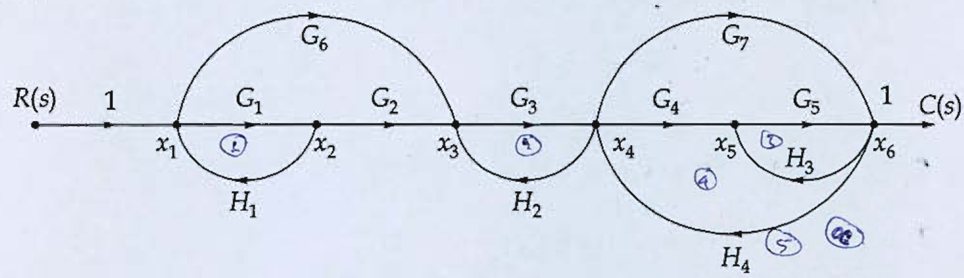
Q.5 (c) Find the transfer function of the system whose signal flow graph is shown in figure below:



Solution-:

[12 marks]

Number of forward path (K) = 4

Forward path gains

$P_1 = G_1 G_2 G_3 G_4 G_5$, $\Delta_1 = 1 - 0 \Rightarrow 1$

$P_2 = G_1 G_2 G_3 G_7$ $\Delta_2 = 1$

$P_3 = G_6 G_3 G_4 G_5$, $\Delta_3 = 1$

$P_4 = G_6 G_3 G_7$, $\Delta_4 = 1$

$\Delta K = 1 -$ (sum of individual loops gains who not tuch K^{th} forward path)

Number of individual loops (n) = 5

loops gains

$L_1 = G_1 H_1$, $L_2 = H_2 G_3$, $L_3 = G_5 H_3$

$L_4 = H_4 G_7$, $L_5 = H_4 G_4 G_5$, ~~$L_6 = H_4$~~

$\Delta = 1 -$ (sum of individual loops gains) + (sum of product of two non-touching loops) + (sum of product of '3' non-touching loops)

$\Delta = 1 - (G_1 H_1 + H_2 G_3 + G_5 H_3 + H_4 G_7 + H_4 G_4 G_5)$

$+ (G_1 G_3 H_1 H_2 + G_1 G_5 H_3 H_1 + G_1 H_1 G_4 G_5 H_4 + G_1 H_1 H_4 G_7)$

$+ (G_1 H_1 G_3 H_2 * G_5 H_3)$.

By using Mason's Gain formula

Transfer function $\frac{C(s)}{R(s)} = \frac{\sum_{k=1}^{4} P_k \Delta_k}{\Delta}$

$$= \frac{P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4}{\Delta}$$

$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3G_4G_5 + G_1G_2G_3G_7 + G_6G_3G_4G_5 + G_6G_3G_7}{1-(G_1H_1 + G_3H_2 + G_5H_3 + G_7H_4 + G_4G_5H_4 + (G_1G_3H_1H_2 + G_1G_5H_1H_3 + G_1G_4G_5H_1H_4 + G_1G_7H_1H_4) + G_1G_3G_5H_1H_2H_3}$$

Ans

12

Q.5 (d) A ground based communication system transmits to a geo-synchronous satellite located 41935 km from the transmitter at a frequency of 1 GHz. The gain of the ground based antenna is 25 dBi, and the satellite antenna has a gain of 15 dBi.
Assuming free-space propagation path loss, what must be the transmitter power in watts to produce 5 μV (rms) at the output of satellite antenna?
(Assume satellite antenna is matched to 50 Ω)

[12 marks]

Solution

satellite — earth Receiver

$P_r = 5 \times 10^{-6}\,W$

$G_r = 25\,dBi$

$P_t = ?$

$G_t = 15\,dBi$

distance (R) = 41935 KM

frequency (f) = 1 GHz

By using friss-wave equation

Received power (P_r) $= \dfrac{P_t G_t G_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$ — (1)

path loss $= \left(\dfrac{4\pi R}{\lambda}\right)^2 = FSL$

Free space loss (FSL) = 32.45 + 20 log f (MHz) + 20 log R (Km)

= 32.45 + 20 log 1000 + 20 log 41935

FSL = 184.9 dB

using equation (1) into

$P_r = 10 \log 5 \times 10^{-6}$

$P_r = -53\,dB$

$P_r = P_t(dB) + G_t + G_r - FSL$

P_t = Transmitted power

$P_t = P_r - G_t - G_r + FSL$

$= -53 - 25 - 15 + 184.9$

$P_t = 91.9\,dB$

$P_t = 10^{9.19}$ watt

$P_t = 1.54 \times 10^{9}$ watt

Ans [Transmitted power (P_t) = 1.54×10^{9} watt]

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Q.5 (e) In target-search ground mapping radars, it is desirable to have echo power received from a target of constant cross section to be independent of its range. For one such application; the desirable radiation intensity of the antenna is given by

$$U(\theta,\phi)=\begin{Bmatrix} 1 & ; & 0° < \theta < 20° \\ 0.342\text{cosec}(\theta) & ; & 20° \le \theta < 60° \\ 0 & ; & 60° \le \theta \le 180° \end{Bmatrix}, 0° \le \phi \le 360°$$

Find the directivity (in dB) of the antenna.

[12 marks]

Solution

As given

$$U(\theta,\phi) = \begin{cases} 1 ; & 0 < \theta < 20 \\ 0.342\,\text{cosec}\,\theta ; & 20° \le \theta \le 60 \\ 0 , & 60 < \theta \le 180°\end{cases}$$

$$\text{Directivity } (D) = \frac{4\pi\, U(\theta,\phi)_{max}}{\int U(\theta,\phi)\, d\Omega}$$

$U(\theta,\phi)_{max} = 1$

Now $\oint d\Omega = \sin\theta\, d\theta\, d\phi$

Now $\int U(\theta,\phi)\, d\Omega = \int_{\theta=0}^{20}\int_{\phi=0}^{2\pi} 1 \cdot \sin\theta\, d\theta\, d\phi$

$$+ \int_{\theta=20}^{60}\int_{\phi=0}^{2\pi} 0.342\,\text{cosec}\,\theta \times \sin\theta\, d\theta\, d\phi$$

$$\int U(\theta,\phi)\, d\Omega = -2\pi \cos\theta \Big|_{0}^{20} + 0.342 \times 2\pi \left(80-20\right) \times \pi/180$$

$$= 2\pi \left[0.06 + 0.2387\right]$$

$$= 2\pi \times 0.2987$$

Now $\quad D = \dfrac{4\pi \times 1}{2\pi \times 0.2987}$

$$D = 6.69$$

$$D = 10\log_{10} 6.69$$

$$= 8.26\,dB$$

Ans $\boxed{\text{Directivity } (D) = 8.26\,dB}$

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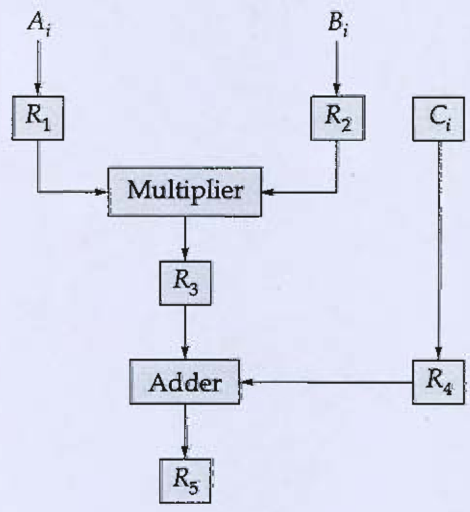
Q.6 (a) **(i)** Write a program in 8086 microprocessor to find out the largest among 8-bit n numbers where size "n" is stored at memory address 2000 : 500 and the numbers are stored from memory address 2000 : 501. Store the result (largest number) into memory address 2000 : 600. (Assume instructions starting from Memory address 0400H)

(ii) Explain the Bus Interface Unit of 8086 microprocessor.

[10 + 10 marks]

Q.6 (b) The pipeline of figure shown has the following propagation times: 40 nsec for the operands to be read from memory into registers R_1 and R_2, 45 nsec for the signal to propagate through the multiplier, 5 nsec for the transfer into R_3 and 15 nsec to add the two numbers into R_5.



(i) What is the minimum clock cycle time that can be used?

(ii) A non-pipeline system can perform the same operation by removing R_3 and R_4. How long will it take to multiply and add the operands without using the pipeline?

(iii) Calculate the speedup that can be achieved with pipeline for 10 tasks.

(iv) What is the maximum speed up that can be achieved?

[20 marks]

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Q.6 (c) Draw the complete root locus for the system with open-loop transfer function,

$$G(s)H(s) = \frac{K}{s(s+6)(s^2+4s+13)}$$

[20 marks]

Do not write in this margin

Q.7 (a) (i) Given message signal as $m(t) = e^{-t^2/100}$, carrier frequency $f_c = 10^4$ Hz, frequency and phase sensitivities as 500π rad/sec/V and 1.2π rad/V respectively. Find the frequency deviation for FM and PM.

(ii) The output signal to noise ratio (SNR) of a 10-bit PCM was found to be 30 dB. The desired SNR is 42 dB. It was decided to increase the SNR to the desired value by increasing the number of quantization levels. Find the fractional increase in the transmission bandwidth required for this increase in SNR.

[15 + 5 marks]

Solution (i) - case-1

given $m(t) = e^{-t^2/100}$, $f_c = 10^4$ Hz

$K_f = 500\pi$ rad/sec, $K_p = 1.2\pi$ rad/sec

standard FM signal

$x_{FM}(t) = A_c \cos(\omega_c t + K_f \int_0^t m(\tau)\, d\tau)$

instantaneous phase $\theta_i(t) = \omega_c t + K_f \int_0^t m(\tau)\, d\tau$

$f_i(t) = \frac{d\theta_i(t)}{dt} \times \frac{1}{2\pi}$

$=$

$= f_c + \frac{K_f}{2\pi} m(t)$

Frequency deviation $(\Delta f) = f_i(t) - f_c = \frac{K_f}{2\pi} m(t)$

$\Delta f = \frac{K_f}{2\pi} m(t)$

Maximum deviation $(\Delta f)_{max} = \frac{500\pi}{2\pi} \cdot m(t)|_{max}$

$m(t)|_{max} = 1$, occurs $t = 0$

$(\Delta f)_{max} = 250$ Hz

Ans $\boxed{\text{Maximum deviation } (\Delta f)_{max} = 250 \text{ Hz}}$

case-2 when consider PM signal

PM expression

$x_{PM}(t) = A_c \cos(\omega_c t + K_p m(t))$

$\theta_i(t) = \omega_c t + K_p m(t)$

$$f_i(t) = \frac{1}{2\pi} \frac{d\theta_i(t)}{dt}$$

$$= f_c + \frac{K_p}{2\pi} \frac{dm(t)}{dt}$$

Maximum frequency deviation $(\Delta f)_{max} = f_i(t) - f_c$

i.e. $$[\Delta f]_{max} = \frac{K_p}{2\pi} \frac{dm(t)}{dt}\Big|_{max}$$

$$= \frac{1.2\pi}{2\pi} \frac{d}{dt} m(t)\Big|_{max}$$

$$(\Delta f)_{max} = 0.6 \frac{d}{dt} m(t)\Big|_{max} - (1).$$

given $m(t) = e^{-t^2/100}$

$$\frac{dm(t)}{dt} = e^{-t^2/100} \times \left(\frac{-t}{50}\right)$$

Solution (ii) given

SNR = 30 dB for $n_1 = 10$ bit PCM

Required SNR = 42 dB

improvement

for sinusoidal signal

$$SNR = (6n_2 + 1.8) \geq 42$$

$$n_2 = 7 \text{ bit}$$

Improve SNR = 42 - 30 = 12 dB

Hence number of bits in PCM is increased by 2 $\left(\because \Delta n = \frac{12}{6} = 2\right)$

Now, New bit $n_2 = 12$ bit PCM used now

As Bandwidth (BW) $\propto n$

$$\frac{BW_2}{BW_1} = \frac{n_2}{n_1} \Rightarrow BW_2 = \frac{12}{10} BW_1$$

$$BW_2 = 1.2\, BW_1$$

the ~~$BW_2 = BW_1$~~

$BW_2 = 1.2\, BW_1$

Hence more Bandwidth is required.

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Q.7 (b) An angle-modulated signal with carrier frequency, $\omega_c = 2\pi \times 10^5$ rad/sec is described by the equation

$$\phi(t) = 10\cos(\omega_c t + 5\sin 3000t + 10\sin 2000\pi t)$$

(i) Find the power of the modulated signal.

(ii) Find the frequency deviation Δf.

(iii) Find the deviation ratio β.

(iv) Estimate the bandwidth of $\phi(t)$.

[20 marks]

Solution (b)

given Modulated signal

$\phi(t) = 10\cos(\omega_c t + 5\sin 3000t + 10\sin 2000\pi t)$ - (1)

(i) power of modulated signal i.e., P.

$$P = \frac{A_c^2}{2}$$

$$P = \frac{(10)^2}{2}$$

$$P = 50W$$

Ans $\boxed{\text{power } (P) = 50W}$

(ii) from (1)

instantaneous phase $\theta_i(t)$

$\theta i(t) = w_c t + 5 \sin 3000t + 10 \sin 2000\pi t$

Instantaneous frequency $(f_i) = \frac{1}{2\pi} \frac{d\,\theta_i(t)}{dt}$

$f_i = f_c + \frac{5 \times 3000}{2\pi} \cos 3000t + \frac{10 \times 2000\pi}{2\pi} \cos 2000\pi t$

frequency deviation $(\Delta f) = f_i - f_c$

$\Delta f = 2387.324 \cos 3000t + 10000 \cos 2000\pi t$

Maximum deviation

$[\Delta f]_{max} = [2387.324 \cos 3000t + 10000 \cos 2000\pi t]_{max}$

Maximum value occurs at $t = 0$

so $[\Delta f]_{max} = 2387.324 + 10000$

$= 12.38\,KHz$

Ans $\boxed{\text{Maximum deviation } (\Delta f) = 12.38\,KHz}$

(iii) Deviation ratio $(\beta) = \frac{[\Delta f]_{max}}{f_m}$

f_m (message signal Bandwidth) $= Max(1000, 477.46)$

$f_m = 1\,KHz$

So $\beta = \frac{12.38}{1}$

$\boxed{\beta = 12.38}$

Ans $\boxed{\beta = 12.38}$

(iv) Bandwidth $(BW) = 2(\Delta f + f_m)$

$= 2(12.38 + 1)$

$= 26.76\,KHz$

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Ans $\boxed{\text{Bandwidth } (BW) = 26.76\,KHz}$

Q.7 (c) (i) Write short notes on pure ALOHA and slotted ALOHA.

(ii) Determine the maximum throughput that can be achieved using ALOHA and slotted ALOHA protocols.

[10 + 10 marks]

Solution (i)

pure - ALOHA :

- pure ALOHA is also called origional ALOHA.
- In this all user can transmit the frames when they wants to sends.
- when a station (user) sends a frame than wait for acknowedgment. If station gets acknowedgment, than frame is successfully delivered.
- If station does not get any acknowedgment after certain random back up time, than station thinks that frame is lost. And station is resend the frams.

Slotted ALOHA-:

- In this, Slotted ALOHA is network access layer protocol.
- In this entired transmission medium is divided to into time slots.
- Any station can sents a from at a time but they can send only at ~~start~~ start of time slot.

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- Slotted ALOHA is improved verision of pure ALOHA.

Solution (ii)

In pure ALOHA throughput is given by

$$\boxed{\text{Throughput} = G \times e^{-2G}}$$

For slotted ALOHA throughput is given ~~by~~

$$\boxed{\text{Throughput} = G \times e^{-G}}$$

6

Q.8 (a) (i) The open-loop transfer function of a servo system with unity feedback is

$$G(s) = \frac{10}{s(0.1s+1)}.$$

Evaluate the static error coefficients (K_p, K_v, K_a) for the system.

(ii) Obtain the steady-state error the system when subjected to an input given by the polynomial,

$$r(t) = a_0 + a_1 t + \frac{a_2}{2} t^2 ; t > 0$$

Also evaluate the dynamic error using the dynamic error coefficients.

[10 + 10 marks]

Solution (i) :-

given $G(s) = \frac{10}{s(0.1s+1)}$

Static error coefficient

$K_p = \lim_{s \to 0} G(s)$

$= \lim_{s \to 0} \frac{10}{s(0.1s+1)}$

$\boxed{K_p = \infty}$ Ans

for $K_v = \lim_{s \to 0} s\,G(s)$

$= \lim_{s \to 0} s \left[\frac{10}{s(0.1s+1)}\right]$

$K_v = 10$

$\boxed{K_v = 10}$ Ans

for $K_a = \lim_{s \to 0} s^2 G(s)$

$= \lim_{s \to 0} s^2 \times \frac{10}{s(0.1s+1)}$

$= 0$

$\boxed{K_a = 0}$ Ans

Solution (iii)

input $r(t) = a_0 + a_1 t + \frac{a_2 t^2}{2}$

apply Laplace Transform

$$R(s) = \frac{a_0}{s} + \frac{a_1}{s^2} + \frac{a_2}{s^3}$$

$$R(s) = \frac{a_0 s^2 + a_1 s + a_2}{s^3}$$

steady state error $(e_{ss}) = \lim_{s \to 0} \frac{sR(s)}{1+GH(s)}$

$$= \lim_{s \to 0} \frac{s\left[\frac{a_0 s^2 + a_1 s + a_2}{s^3}\right]}{1 + \frac{10}{s(0.1s+1)}}$$

$$= \lim_{s \to 0} \left[\frac{(a_0 s^2 + a_1 s + a_2)(0.1s+1)}{s[s(0.1s+1)+10]}\right]$$

$e_{ss} = \infty$

Ans $\boxed{\text{Steady state error } (e_{ss}) = \infty}$

Dynamic error when

Case-1 $K_p = \infty$, $e_{ss} = \frac{1}{1+K_p} = 0$

$\boxed{e_{ss} = 0}$ Ans

Case-2 when $K_v = 10$

error $(e_{ss}) = \frac{1}{K_v} = 0.1$, $\boxed{e_{ss} = 0.1}$ Ans

Case-3 when $K_a = 0$

error $(e_{ss}) = \frac{1}{K_a} = \infty$

$\boxed{e_{ss} = \infty}$ Ans

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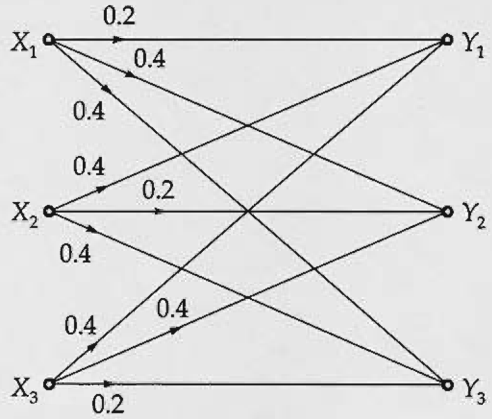
Q.8 (b) (i) Consider the following channel having equal probability of source symbols:



Determine the capacity of above channel.

(ii) A certain transmission line 2 m long terminated by a load of $20 + j50\ \Omega$ has $\alpha = 8$ dB/m, $\beta = 1$ rad/m and $Z_o = (60 + j40)\ \Omega$. Calculate the input impedance of transmission line.

[10 + 10 marks]

Solution (ii) - 8

input impedence $(Z_{in}) = Z_0 \left[\dfrac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)} \right]$

γ = propagation constant

$\gamma = (\alpha + j\beta)$

$\alpha = 8$ dB/m

1 NP = 8.686 dB

$\alpha = \dfrac{8}{8.686}$ NP/m

$\alpha = 0.92$ NP/m

so $\gamma = (0.92 + j1)\ m^{-1}$

$\gamma l = (0.92 + j1) \times 2 = (1.84 + j2)$

$Z_{in} = (60 + j40) \left[\dfrac{(20 + j50) + (60 + j40)\tanh(1.84 + j2)}{(60 + j40) + (20 + j50)\tanh(1.84 + j2)} \right]$

8

Q.8 (c) **(i)** Determine $H(z)$ using the impulse invariant technique for the following analog system function:

$$H(s) = \frac{1}{(s+0.5)(s^2+0.5s+2)}$$

(ii) Consider a signal $x(t)$ with Fourier transform $X(\omega)$. Suppose we are given the following facts:

1. $x(t)$ is real and non-negative.
2. $F^{-1}[(1+j\omega)X(\omega)] = Ae^{-2t}u(t)$, where A is independent of t.
3. $\int_{-\infty}^{\infty} |X(\omega)|^2 \, d\omega = 2\pi.$

Determine the closed-form expression of $x(t)$. (Where F^{-1}: Inverse Fourier Transform)

[10 + 10 marks]

OOOO

Space for Rough Work

Space for Rough Work

P1 → 10 % 8 7
P2 − 1
P3 − 2
P4 − 1
P5 − 5

t = 0	P1
t = 1	P1, P2
t = 2	P1, P3
t = 3	P1, P3, P4
t = 4	P1, P3, P4, P5

P1	P2	P1
0	1	2	4

AB\C	00	01	11	10
0		1		1
1	1			1

1, 0.9

$\sqrt{1-(0.9)^2}$

$\dfrac{A}{s^2+4}$

$\dfrac{4}{s^2+4}$ / $1 + \dfrac{4}{s^2+4} + T_d s$

$\dfrac{4}{s^2+s+4T_d s}$

$\dfrac{4}{s(s^2+4T_d+1)}$

$\dfrac{4}{s^2+(4T_d+1)s}$

$7 \dfrac{s}{s^2+4}$

$7 \dfrac{s}{s^2+4}$ $\dfrac{7s}{s^2+4}$

$\dfrac{s}{4} = \dfrac{s}{4/12}$

$s^2+2s+3s+6$
s^2+5s+6
$5s^2+25s+30$

$s^2+s+3s+3$
$s^2+4s+3)$

7, 15
56
48

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

$s^2+60s+10s+600$
$s^2+70s+600$

$s^2+60s+10s+600$
$s^2+70s+600$