ESE

Electronics & Telecom. Engineering

Preliminary Examination

(Previous Years Solved Papers 1999 to 2000)

Volume-II

Contents

MADE EASY PUBLICATIONS

1 Control Systems

1. Basics, Block Diagrams & Signal Flow Graphs

1.1 When a human being tries to approach an object, his brain acts as
(a) an error measuring device
(b) a controller
(c) an actuator
(d) an amplifier [ESE-1999]

1.2 **Assertion (A):** Feedback control systems offer more accurate control over open-loop systems.
Reason (R): The feedback path establishes a link for input and output comparison and subsequent error correction.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

1.3 Consider the following statements:
1. The effect of feedback is to reduce the system error
2. Feedback increases the gain of the system in one frequency range but decreases in another.
3. Feedback can cause a system that is originally stable to become unstable
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE-2000]

2. Time Domain Analysis

2.1 The response $c(t)$ of a system is described by the differential equation

$$\frac{d^2c(t)}{dt^2} + 4\frac{dc(t)}{dt} + 5c(t) = 0$$

The system response is
(a) undamped (b) underdamped
(c) critically damped (d) oscillatory
[ESE-1999]

2.2 The system with the open-loop transfer function

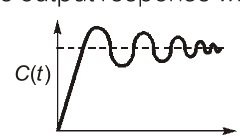
$$G(s)\,H(s) = \frac{1}{s(1+s)} \text{ is}$$

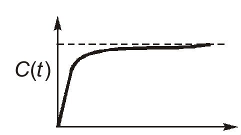
(a) type 2 and order 1
(b) type 1 and order 1
(c) type 0 and order 0
(d) type 1 and order 2 [ESE-1999]

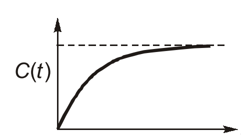
2.3 A step input is applied to a system with the transfer function

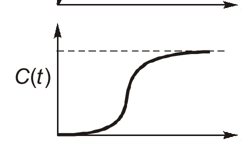
$$G(s) = \frac{e^{-s}}{1+0.5s}$$

The output response will be

(a) 

(b) 

(c) 

(d) 

[ESE-1999]

2.4 **Assertion (A):** The largest undershoot corresponding to a unit step input to an underdamped second order system with damping ratio ξ and undamped natural frequency of oscillation ω_n is $e^{-2\xi\pi/\sqrt{1-\xi^2}}$.

Reason (R): The overshoots and undershoots of a second order underdamped system is

$$e^{-\xi n\pi/\sqrt{1-\xi^2}}, n = 1, 2, \ldots\ldots$$

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-2000]**

2.5 Which one of the following transfer functions represents the critically damped system?

(a) $H_1(s) = \dfrac{1}{s^2 + 4s + 4}$

(b) $H_2(s) = \dfrac{1}{s^2 + 3s + 4}$

(c) $H_3(s) = \dfrac{1}{s^2 + 2s + 4}$

(d) $H_4(s) = \dfrac{1}{s^2 + s + 4}$ **[ESE-2000]**

2.6 A second order system has the damping ratio ξ and undamped natural frequency of oscillation ω_n. The settling time at 2% tolerance band of the system is

(a) $2/\xi\omega_n$ (b) $3/\xi\omega_n$
(c) $4/\xi\omega_n$ (d) $\xi\omega_n$ **[ESE-2000]**

3. Routh-Hurwitz Stability Criterion

3.1 First column elements of the Routh's tabulation are 3, 5, –3/4, 1/2, 2. It means that there

(a) is one root in the left half of s-plane
(b) are two roots in the left half of s-plane
(c) are two roots in the right half of s-plane
(d) is one root in the right half of s-plane **[ESE-1999]**

3.2 The open-loop transfer function of unity feedback control system if

$$G(s) = \frac{K}{s(s+a)(s+b)}, \; 0 < a \le b$$

The system is stable if

(a) $0 < K < \dfrac{(a+b)}{ab}$

(b) $0 < K < \dfrac{ab}{(a+b)}$

(c) $0 < K < ab(a + b)$
(d) $0 < K < a/b(a + b)$ **[ESE-2000]**

3.3 The Routh-Hurwitz criterion cannot be applied when the characteristic equation of the system contains any coefficients which is

(a) negative real and exponential functions of s
(b) negative real, both exponential and sinusoidal function of s
(c) both exponential and sinusoidal functions of s
(d) complex, both exponential and sinusoidal functions of s **[ESE-2000]**

3.4 Which one of the following characteristic equations of result in the stable operation of the feedback system?

(a) $s^3 + 4s^2 + s - 6 = 0$
(b) $s^3 + s^2 + 5s + 6 = 0$
(c) $s^3 + 4s^2 + 10s + 11 = 0$
(d) $s^4 + s^3 + 2s^2 + 4s + 6 = 0$ **[ESE-2000]**

3.5 Consider the following statements:
Routh-Hurwitz criterion gives

1. absolute stability
2. the number of roots lying on the right half of the s-plane
3. the gain margin and phase margin

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3 **[ESE-2000]**

4. Root Locus

4.1 Consider the loop transfer function

$$G(s)\,H(s) = \frac{K(s+6)}{(s+3)(s+5)}$$

In the root-locus diagram, the centroid will be located at

(a) –4 (b) –1
(c) –2 (d) –3 **[ESE-1999]**

4.2 Consider the following statements:
In root-locus plot, the breakaway points

1. Need not always be on the real axis alone
2. Must lie on the root loci
3. Must lie between 0 and –1

Which of these statements are correct?

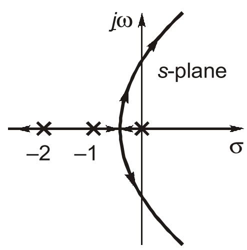
(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

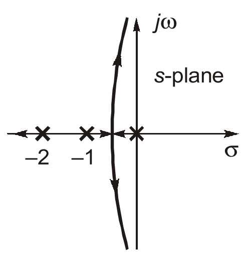
[ESE-1999]

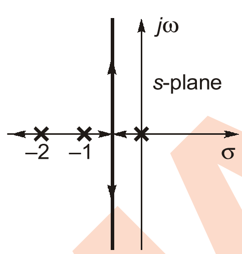
4.3 For a unity negative feedback control system, the open loop transfer function is

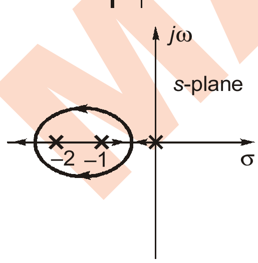
$$G(s) = \frac{K}{s(s+1)(s+2)}$$

The root-locus plot of the system is

(a)


(b)


(c)


(d)


[ESE-1999]

4.4 The intersection of asymptotes of root-loci of a system with open-loop transfer function

$$G(s)\,H(s) = \frac{K}{s(s+1)(s+3)} \text{ is}$$

(a) 1.44 (b) 1.33
(c) –1.44 (d) –1.33 [ESE-2000]

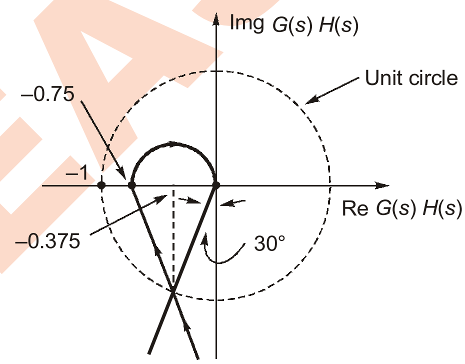
5. Frequency Domain Analysis

5.1 **Assertion (A):** The phase angle plot in Bode diagram is not affected by the variation in the gain of the system.

Reason (R): The variation in the gain of the system has no effect on the phase margin of the system.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-1999]

5.2 A portion of the polar plot of an open-loop transfer function is shown in the given figure



The phase margin and gain margin will be respectively

(a) 30° and 0.75 (b) 60° and 0.375
(c) 60° and 0.75 (d) 60° and 1/0.75

[ESE-1999]

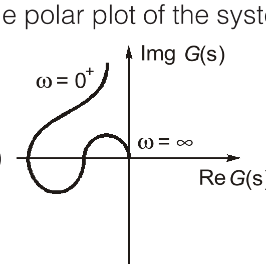
5.3 The polar plot of a transfer function passes through the critical point (–1, 0). The gain margin is

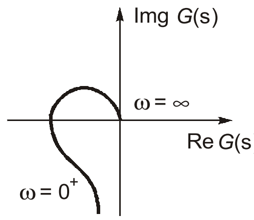
(a) 0 dB (b) –1 dB
(c) 1 dB (d) infinity [ESE-1999]

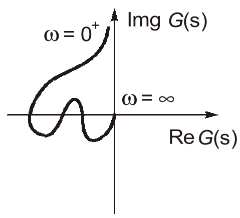
5.4 The open-loop transfer function of a unity negative feedback system is

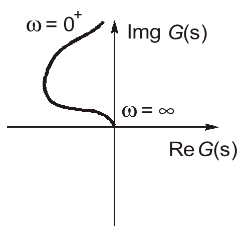
$$G(s) = \frac{K(s+10)(s+20)}{s^3(s+100)(s+200)}$$

The polar plot of the system will be

(a)


(b) 

(c) 

(d) 

[ESE-1999]

5.5 Match **List-I** (Scientist) with **List-II** (Contribution in the area of) and select the correct answer:

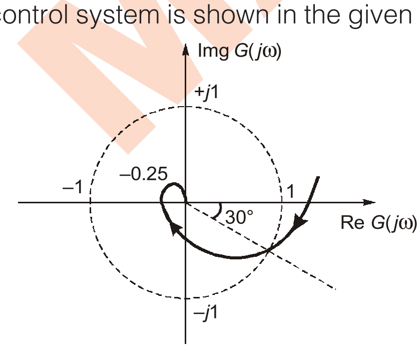
List-I	**List-II**
A. Bode	**1.** Asymptotic plots
B. Evans	**2.** Polar plots
C. Nyquist	**3.** Root-locus technique
	4. Constant M and N plots

Codes:

	A	B	C
(a)	1	4	2
(b)	2	3	4
(c)	3	1	4
(d)	1	3	2

[ESE-2000]

5.6 The polar plot (for positive frequencies) for the open-loop transfer function of a unity feedback control system is shown in the given figure



The phase margin and the gain margin of the system are respectively

(a) 150° and 4 (b) 150° and 3/4
(c) 30° and 4 (d) 30° and 3/4

[ESE-2000]

6. Compensators and Controllers

6.1 If the transfer function of a phase lead compensator is $(s + a)/(s + b)$ and that of a lag compensator is $(s + p)/(s + q)$, then which one of the following sets of conditions must be satisfied?

(a) $a > b$ and $p > q$ (b) $a > b$ and $p < q$
(c) $a < b$ and $p < q$ (d) $a < b$ and $p > q$

[ESE-1999]

6.2 The compensator

$$G_C(s) = \frac{5(1+0.3s)}{1+0.1s}$$

would provide a maximum phase shift of

(a) 20° (b) 45°
(c) 30° (d) 60°

[ESE-1999]

6.3 The transfer function $G(s)$ of a PID controller is

(a) $K\left[1+\frac{1}{T_i s}+T_d s\right]$ (b) $K[1 + T_i s + T_d s]$

(c) $K\left[1+\frac{1}{T_i s}+\frac{1}{T_d s}\right]$ (d) $K\left[1+T_i s+\frac{1}{T_d s}\right]$

[ESE-1999]

6.4 The industrial controller having the best steady-state accuracy is

(a) a derivative controller
(b) an integral controller
(c) a rate feedback controller
(d) a proportional controller

[ESE-1999]

6.5 PID control for a plant is shown in Figures I and II.

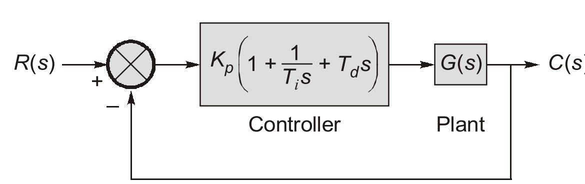


Figure-I

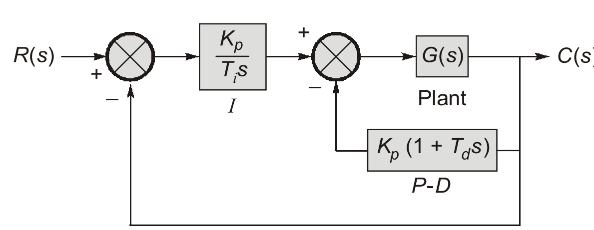


Figure-II

Assertion (A): Figure-II is preferred over Figure-I as it avoids large changes in control signal for a sudden change in reference input.

Reason (R): Placement of P-D action in the feedback path and larger values of K_p and T_d can be chosen in Figure-II.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

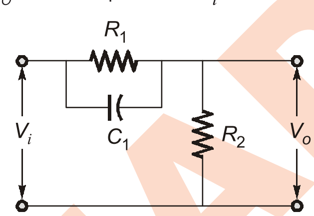
[ESE-2000]

6.6 **Assertion (A):** An on-off controller gives rise to self-sustained oscillation in the output.

Reason (R): Location of a pair of poles on the imaginary axis gives rise to self-sustained oscillation in the output.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

6.7 For the given network, the maximum phase lead ϕ_m of V_o with respect to V_i is



(a) $\sin^{-1}\left(\frac{R_1}{2R_2}\right)$ (b) $\sin^{-1}\left(\frac{R_1}{R_1+2R_2}\right)$

(c) $\sin^{-1}\left(\frac{R_1}{R_1+3R_2}\right)$ (d) $\sin^{-1}\left(\frac{R_1}{2R_2C_1}\right)$

[ESE-2000]

6.8 Consider the following statements:

A proportional plus derivative controller

1. has high sensitivity
2. increases the stability of the system
3. improves the steady-state accuracy

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE-2000]

7. State Space Analysis

7.1 The state model

$$x(k+1) = \begin{bmatrix} 0 & 1 \\ -\beta & -\alpha \end{bmatrix} x(k) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(k)$$

$$y(k) = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix}$$

is represented in the difference equation as

(a) $c(k+2) + \alpha c(k+1) + \beta c(k) = u(k)$
(b) $c(k+1) + \alpha c(k) + \beta c(k-1) = u(k-1)$
(c) $c(k-2) + \alpha c(k-1) + \beta c(k) = u(k)$
(d) $c(k-1) + \alpha c(k) + \beta c(k+1) = u(k+1)$

[ESE-1999]

7.2 Consider the following equations for the state transition matrix of the linear time-invariant continuous time system '$\phi(t)$':

1. $\phi(-t) = [\phi(t)]^{-1}$.
2. $[\phi(t)]^k = \phi(t^k)$ for any positive integer 'k'.
3. $\phi(t-t_0) = \phi(t)\,\phi(-t_0)$ for any constant t_0.

Which of these equations correctly define the properties of the given system?

(a) 1, 2, and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3 [ESE-2000]

8. Miscellaneous

8.1 For two-phase *AC* servomotor, if the rotor's resistance and reactance are respectively *R* and *X*, its length and diameter are respectively *L* and *D*, then

(a) X/R and L/D are both small
(b) X/R is large but L/D is small
(c) X/R is small but L/D is large
(d) X/R and L/D are both large

[ESE-1999]

8.2 Consider the following statements relating to synchros:

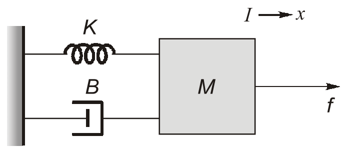
1. The rotor of the control transformer is either disc shaped
2. The rotor of the transmitter is so constructed as to have a low magnetic reluctance.
3. Transmitter and control transformer pair is used as an error detector

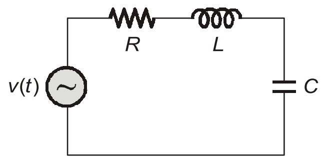
Which of these statements are correct?

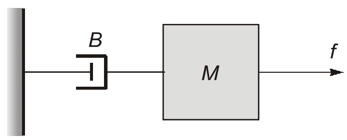
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

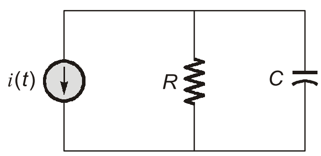
[ESE-1999]

8.3 Consider the following systems:

1. 

2. 

3. 

4. 

Which of these systems can be modelled by the differential equation,

$$a_2 \frac{d^2y(t)}{dt^2} + a_1 \frac{dy(t)}{dt} + a_0 y(t) = x(t)?$$

(a) 1 and 2 (b) 1 and 3
(c) 2 and 4 (d) 1, 2 and 4

[ESE-1999]

8.4 The radius of constant-N circle for $N = 1$ is

(a) 2 (b) $\sqrt{2}$
(c) 1 (d) $1/\sqrt{2}$ [ESE-1999]

8.5 The constant-M circle for $M = 1$ is the

(a) straight line; $x = -1/2$
(b) critical point $(-1, j0)$
(c) circle with $r = 0.33$
(d) circle with $r = 0.67$ [ESE-1999]

8.6 The open-loop transfer function $G(s)$ of a unity feedback control system is $\frac{1}{s(s+1)}$. The system is subjected to an input $r(t) = \sin t$. The steady state error will be

(a) zero (b) 1
(c) $\sqrt{2}\sin\left(t - \frac{\pi}{4}\right)$ (d) $\sqrt{2}\sin\left(t + \frac{\pi}{4}\right)$

[ESE-2000]

8.7 Which one of the following equations represents the constant magnitude locus in G-plane for $M = 1$? {x-axis is Re $G(j\omega)$ and y-axis is Im $G(j\omega)$}

(a) $x = -0.5$ (b) $x = 0$
(c) $x + y^2 = 1$ (d) $(x + 1)^2 + y^2 = 1$

[ESE-2000]

8.8 Which one of the following features is NOT associated with Nichols chart?

(a) (0 dB, –180°) point on Nichols charts represents the critical point $(-1 + j0)$
(b) It is symmetric about –180°
(c) The M loci are centred about (0 dB, –180°) point
(d) The frequency at the intersection of the $G(j\omega)$ locus and $M = +3$ dB locus gives bandwidth of the closed-loop system

[ESE-2000]

8.9 Match **List-I** (Functional components) with **List-II** (Devices) and select the correct answer:

List-I
A. Error detector
B. Servometer
C. Amplifier
D. Feedback

List-II
1. Three-phase FHP induction motor
2. A pair of synchronous transmitter and control transformer
3. Tachogenerator
4. Armature controlled FHP DC motor
5. Amplidyne

Codes:

	A	B	C	D
(a)	2	4	1	5
(b)	4	2	5	3
(c)	2	4	5	3
(d)	1	2	3	5

[ESE-2000]

8.10 Consider the following servomotors:

1. AC two-phase servomotor
2. DC servomotor
3. Hydraulic servomotor
4. Pneumatic servomotor

The correct sequence of these servomotors in increasing order of power handling capacity is

(a) 2, 4, 3, 1 (b) 4, 2, 3, 1
(c) 2, 4, 1, 3 (d) 4, 2, 1, 3

[ESE-2000]

■■■

Answers Control Systems

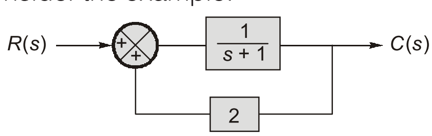
1.1	(b)	1.2	(a)	1.3	(a)	2.1	(b)	2.2	(d)	2.3	(d)	2.4	(a)	2.5	(a)	2.6	(c)
3.1	(c)	3.2	(c)	3.3	(d)	3.4	(c)	3.5	(b)	4.1	(c)	4.2	(b)	4.3	(a)	4.4	(d)
5.1	(c)	5.2	(d)	5.3	(a)	5.4	(a)	5.5	(d)	5.6	(a)	6.1	(d)	6.2	(c)	6.3	(a)
6.4	(b)	6.5	(a)	6.6	(b)	6.7	(b)	6.8	(a)	7.1	(a)	7.2	(c)	8.1	(c)	8.2	(c)
8.3	(a)	8.4	(d)	8.5	(a)	8.6	(*)	8.7	(a)	8.8	(d)	8.9	(c)	8.10	(c)		

Explanations Control Systems

1. Basics, Block Diagrams & Signal Flow Graphs

1.3 (a)

Feedback is applied to reduce the system error. Consider the example.



$$\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s)H(s)} = \frac{\frac{1}{s+1}}{1-\frac{2}{s+1}} = \frac{1}{s-1}$$

Thus, we see that the closed loop system is unstable while the open loop system is stable.

2. Time Domain Analysis

2.1 (b)

$$\omega_n = \sqrt{5} \text{ rad/s}$$

$$2\xi\omega_n = 4 \Rightarrow \xi = \frac{4}{2\sqrt{5}} < 1$$

$\Rightarrow$ System response is underdamped.

2.2 (d)

In the pole zero form,

$$G(s)\,H(s) = \frac{K(s+z_1)(s+z_2)\ldots}{s^n(s+p_1)(s+p_2)\ldots}$$

the type of the system is 'n' and order of the system is the highest power of s in the denominator.

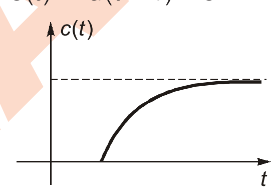
2.3 (d)

$$C(s) = G(s)\cdot R(s) = \frac{e^{-s}}{1+0.5s}\cdot\frac{1}{s}$$

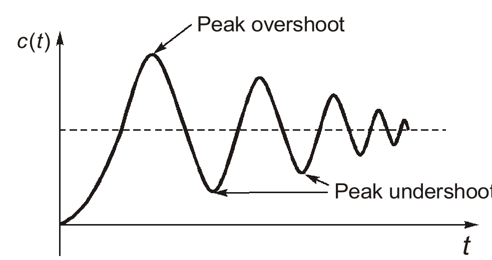
$$\Rightarrow \quad C(s) = \frac{2e^{-s}}{s(s+2)}$$

$$\Rightarrow \quad C(s) = \frac{e^{-s}}{s} - \frac{e^{-s}}{s+2}$$

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



2.4 (a)



$$M_P = e^{-\xi n\pi/\sqrt{1-\xi^2}} \quad \text{for } n = 1, 2, 3, \ldots$$

2.5 (a)

$$H_1(s) = \frac{1}{s^2+4s+4} = \frac{1}{(s+2)^2}$$

since both roots are negative real and equal, it is a critically damped system.

2.6 (c)

Settling time at 2% of tolerance band of the system,

$$t_s = \frac{4}{\xi\omega_n}$$

Settling time at 5% of tolerance band of the system,

$$t_s = \frac{3}{\xi\omega_n}$$

3. Routh-Hurwitz Stability Criterion

3.1 (c)

Number of roots in the right half of s-plane = number of sign changes

3.2 (c)

$$\frac{G(s)}{1+G(s)} = \frac{K}{s(s+a)(s+b)+K}$$

Characteristic equation is

$s^3 + (a+b)s^2 + abs + K$

Routh array is

$$\begin{array}{c|cc} s^3 & 1 & a+b \\ s^2 & ab & K \\ s & \dfrac{ab(a+b)-K}{ab} & 0 \\ s^0 & K & \end{array}$$

For the system to be stable,

$K > 0$

$ab(a+b) - K > 0 \Rightarrow K < ab(a+b)$

So $0 < K < ab\,(a+b)$

3.3 (d)

A necessary (but not sufficient) condition for stability of a linear system is that all the coefficients of its characteristic equation be real and have the same sign. Furthermore, none of the coefficients should be zero.

3.4 (c)

Using RH criterion.

3.5 (b)

Routh-Hurwitz criterion gives absolute stability and the number of roots lying on the right half of the s-plane but it does not tell about the gain margin and phase margin.

4. Root Locus

4.1 (c)

Centroid,

$$= \frac{\Sigma \text{real parts of poles} - \Sigma \text{real parts of zeros}}{\text{Number of poles} - \text{Number of zeros}}$$

$$= \frac{-3-5-(-6)}{2-1} = \frac{-8+6}{1} = -2$$

So, the centroid will be located at -2.

4.2 (b)

Breakaway points need not always be on the real axis alone but it must lie on the root loci. It is not necessary that break away points must lie between 0 and -1.

4.3 (a)

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

Characteristic equation is

$s(s+1)(s+2) + K = 0$

or $s^3 + 3s^2 + 2s + K = 0$

Routh array is

$$\begin{array}{c|cc} s^3 & 1 & 2 \\ s^2 & 3 & K \\ s & \dfrac{6-K}{3} & 0 \\ s^0 & K & \end{array}$$

For marginal stability,

$$\frac{6-K}{3} = 0 \Rightarrow K = 6$$

$$3s^2 + K = 0 \Rightarrow 3(j\omega)^2 + 6 = 0$$

$$\Rightarrow \quad -\omega^2 + 2 = 0 \Rightarrow \omega^2 = 2$$

$$\Rightarrow \quad \omega = \sqrt{2} \text{ rad/sec}$$

So, the root locus intersects with the imaginary axis at $\pm j\sqrt{2}$.

4.4 (d)

Intersection of asymptotes, i.e. centroid

$$= \frac{\Sigma \text{real parts of poles} - \Sigma \text{real parts of zeros}}{\text{Number of poles} - \text{Number of zeros}}$$

$$= \frac{-1-3}{3} = \frac{-4}{3} = -1.33$$

5. Frequency Domain Analysis

5.2 (d)

Phase margin = 90° – 30° = 60°

Gain margin = 1/0.75

5.3 (a)

Gain margin = 1/1 = 1

= 20 log 1 dB = 0 dB

5.4 (a)

$$\angle G(j\omega)\big|_{\omega=0} = -270°$$
$$\angle G(j\omega)\big|_{\omega=\infty} = -270°$$

The polar plot intersects with the negative real axis as in making imaginary term of $G(j\omega)$ to be zero, the solution exists.

5.5 (d)

Bode → Asymptotic plots
Evans → Root - locus technique
Nyquist → Polar plots

5.6 (a)

Phase margin = 180° – 30° = 150°

$$\text{Gain margin} = \frac{1}{0.25} = 4$$

6. Compensators and Controllers

6.1 (d)

In phase lead compensator, zero is nearer to origin.
In phase lag compensator, pole is nearer to origin.

6.2 (c)

Maximum phase shift

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

$$\phi_m = \sin^{-1}\left(\frac{2/3}{4/3}\right) = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

6.3 (a)

$G(s)$ of PID controller is

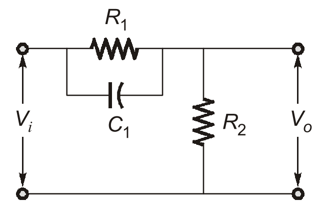
$$G(s) = K_P + \frac{K_i}{s} + sK_D$$

$$= K_P\left[1+\frac{K_i}{K_P s}+\frac{K_D s}{K_P}\right] = K_P\left[1+\frac{1}{T_i s}+T_D s\right]$$

6.4 (b)

(i) Integral controller improves the steady state response.
(ii) Derivative controller improves the transient response.

6.7 (b)



$$\frac{V_o(s)}{V_i(s)} = \frac{R_2}{R_2 + \dfrac{R_1\dfrac{1}{sC_1}}{R_1+\dfrac{1}{sC_1}}} = \frac{R_2}{R_2+\dfrac{R_1}{1+sR_1C_1}}$$

$$= \frac{R_2(1+sR_1C_1)}{(R_1+R_2)+sR_1R_2C_1}$$

Dividing by $R_1R_2C_1$,

$$\frac{V_o(s)}{V_i(s)} = \frac{s+\dfrac{1}{R_1C_1}}{s+\dfrac{(R_1+R_2)}{R_1R_2C_1}}$$

$$= \frac{s+\dfrac{1}{R_1C_1}}{s+\dfrac{1}{\left(\dfrac{R_2}{R_1+R_2}\right)R_1C_1}} = \frac{s+\dfrac{1}{\tau}}{s+\dfrac{1}{\alpha\tau}}$$

where, $\tau = \dfrac{1}{R_1C_1}$, $\alpha = \dfrac{R_2}{R_1+R_2}$

Maximum phase lead

$$\phi_m = \sin^{-1}\left(\frac{1-\alpha}{1+\alpha}\right) = \sin^{-1}\left(\frac{1-\dfrac{R_2}{R_1+R_2}}{1+\dfrac{R_2}{R_1+R_2}}\right)$$

$$\phi_m = \sin^{-1}\left(\frac{R_1}{R_1+2R_2}\right)$$

6.8 (a)

A proportional plus derivative controller has the following features:

(i) It adds an open loop zero on negative real axis.
(ii) Undamped natural frequency remains same and damping ratio increases.
(iii) Peak overshoot decreases.
(iv) Bandwidth increases.
(v) Rise time decreases.
(vi) Effect of external noise increases.

(vii) Settling time decreases, i.e. response becomes faster.

(viii) Stability improves.

(ix) e_{ss} decreases.

7. State Space Analysis

7.1 (a)

$$x_1(k+1) = x_2(k) \quad \text{... (i)}$$
$$x_2(k+1) = -\beta x_1(k) - \alpha x_2(k) + u(k) \quad \text{... (ii)}$$
$$y(k) = x_2(k) \quad \text{... (iii)}$$

From equation (i) and (ii)

$$x_1(k+2) = -\beta x_1(k) - \alpha x_1(k+1) + u(k)$$
$$\Rightarrow \quad c(k+2) = -\beta c(k) - \alpha c(k+1) + u(k)$$
$$\Rightarrow c(k+2) + \alpha c(k+1) + \beta c(k) = u(k)$$

7.2 (c)

Properties of state transition matrix:

(i) $\phi(0) = e^{A0} = I$

(ii) $\phi^{-1}(t) = \phi(-t)$

(iii) $\phi(t_1 + t_2) = \phi(t_1)\,\phi(t_2) = \phi(t_2)\,\phi(t_1)$

8. Miscellaneous

8.1 (c)

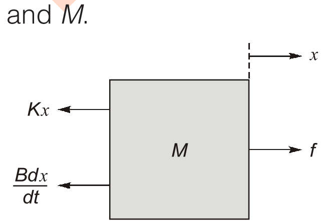
Small X/R gives linear speed torque characteristic. Large L/D gives less inertia and good acceleration characteristic.

8.2 (c)

Rotor of control transformer is made cylindrical in shape so that air gap is practically uniform.

8.3 (a)

This is a second order differential equation which means that there must be present all the three components in the system, i.e. either R, L and C or K, B and M.



Free body diagram of M in Fig. 1

In figure 1,

$$f - Kx - B\frac{dx}{dt} = M\frac{d^2x}{dt^2}$$

Or
$$M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx = f \quad \text{... (i)}$$

In figure 2,

$$v(t) = Ri + \frac{Ldi}{dt} + \frac{q}{c}$$

Or
$$v(t) = \frac{Ld^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{c} \quad \text{... (ii)}$$

Both the equations are symmetric to the given equation.

8.4 (d)

Equation for constant – N circle is

$$\left(x + \frac{1}{2}\right)^2 + \left(y - \frac{1}{2N}\right)^2 = \frac{N^2+1}{4N^2}$$

whose centre is $\left(\frac{-1}{2}, \frac{1}{2N}\right)$

and radius is $\frac{\sqrt{N^2+1}}{2N}$

8.5 (a)

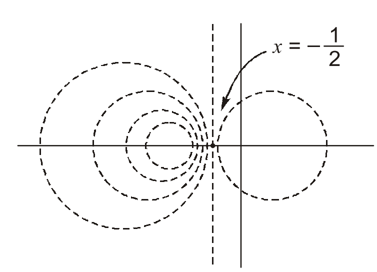
Equation for constant –M circle is

$$\left(x + \frac{M^2}{M^2-1}\right)^2 + y^2 = \frac{M^2}{(M^2-1)^2}$$

whose centre is $\left(-\frac{M^2}{M^2-1}, 0\right)$

and radius is $\frac{M}{M^2-1}$

The constant –M circle is the straight line at $x = -\frac{1}{2}$.



Locus of constant-M circles

8.6 (*)

The steady state calculation is not applicable for sine and cosine function.

8.7 (a)

Closed loop frequency response,

$$T(j\omega) = \frac{G(j\omega)}{1+G(j\omega)} = \frac{x+jy}{1+x+jy}$$

Magnitude, $M = \left[\frac{x^2+y^2}{(1+x)^2+y^2}\right]^{-1/2}$

$$\Rightarrow \quad M^2 = \frac{x^2+y^2}{x^2+2x+1+y^2}$$

Putting $M = 1$,

$$1 = \frac{x^2+y^2}{x^2+2x+1+y^2}$$

$$\Rightarrow x^2+2x+1+y^2 = x^2+y^2$$

$$\Rightarrow \quad 2x = -1$$

$$\Rightarrow \quad x = -0.5$$

■■■

2 Signals and Systems + DSP

1. Basics of Signals and Systems

1.1 Which one of the following pairs is NOT correctly matched? (input $x(t)$ and output $y(t)$).

(a) Unstable system: $\frac{dy(t)}{dt} - 0.1y(t) = x(t)$

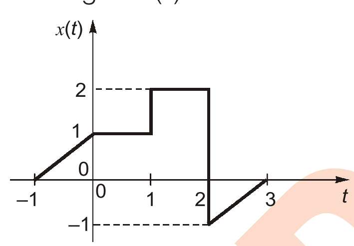
(b) Nonlinear system: $\frac{dy(t)}{dt} + 2t^2 y(t) = x(t)$

(c) Noncausal system: $y(t) = x(t+2)$

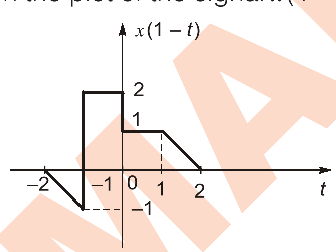
(d) Nondynamic system: $y(t) = 3x^2(t)$

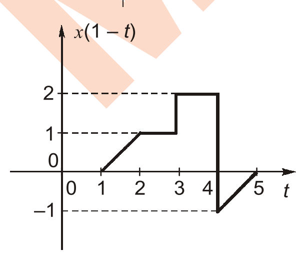
[ESE-1999]

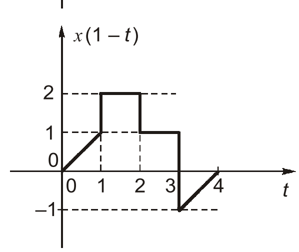
1.2 If a plot of signal $x(t)$ is as shown in the Figure,

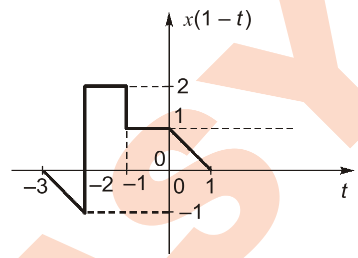


then the plot of the signal $x(1-t)$ will be

(a)


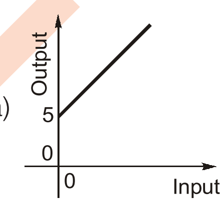
(b)


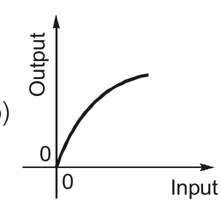
(c)


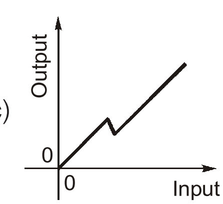
(d)


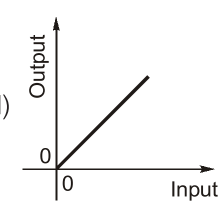
[ESE-1999]

1.3 Which one of the following input-output relationships is that of a linear system?

(a)


(b)


(c)


(d)


[ESE-1999]

1.4 The discrete-time equation $y(n+1) + 0.5n\; y(n) = 0.5x\;(n+1)$ is NOT attributable to a

(a) memoryless system

(b) time-varying system

(c) linear system

(d) causal system

[ESE-1999]

1.5 The period of the function $\cos[\pi/4(t-1)]$ is

(a) 1/8 s (b) 8 s

(c) 4 s (d) 1/4 s

[ESE-1999]

1.6 Match **List-I** (Characteristic of $f(t)$) with **List-II** (Functions) and select the correct answer using the codes given below the lists:

List-I

A. $f(t)\,(1 - u(t)) = 0$

B. $f(t) + K df(t)/dt = 0$; K is a positive constant

C. $f(t) + K\dfrac{d^2 f(t)}{dt^2} = 0$; K is a positive constant

D. $f(t)\,(g(t) - g(0)) = 0$; for any arbitrary $g(t)$

List-II

1. Decaying exponential
2. Growing exponential
3. Impulse
4. Causal
5. Sinusoid

Codes:

	A	B	C	D
(a)	4	1	5	3
(b)	1	4	5	3
(c)	4	2	5	1
(d)	2	5	4	1

[ESE-1999]

1.7 A continuous-time system is governed by the equation $3y^3(t) + 2y^2(t) + y(t) = x^2(t) + x(t)$.
{$y(t)$ and $x(t)$ respectively are output and input}.
The system is
(a) linear and dynamic
(b) linear and non-dynamic
(c) non-linear and dynamic
(d) non-linear and non-dynamic

[ESE-2000]

1.8 Which one of the following systems is a causal system?
[$y(t)$ is output and $u(t)$ is a input step function]
(a) $y(t) = \sin(u(t + 3))$
(b) $y(t) = 5u(t) + 3u(t - 1)$
(c) $y(t) = 5u(t) + 3u(t + 1)$
(d) $y(t) = \sin(u(t - 3)) + \sin(u(t + 3))$

[ESE-2000]

2. Continuous and Discrete Time LTI Systems

2.1 Figure-I and Figure-II show respectively the input $x(t)$ to a linear time-invariant system and the impulse response $h(t)$ of the system.

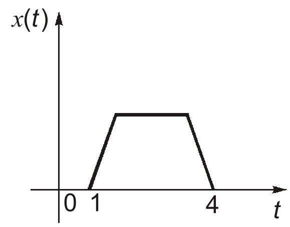


Figure I

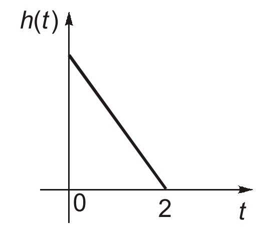


Figure II

The output of the system is zero everywhere except for the time-interval
(a) $0 < t < 4$ (b) $0 < t < 5$
(c) $1 < t < 5$ (d) $1 < t < 6$

[ESE-1999]

2.2 If the step response of a causal, linear time-invariant system is $a(t)$, then the response of the system to a general input $x(t)$ would be

(a) $\displaystyle\int_{0^+}^{t} \frac{da(\tau)}{d\tau} x(t-\tau)\,d\tau$

(b) $\displaystyle a(0)\,x(t) + \int_{0^+}^{t} \frac{da(\tau)}{d\tau} x(t-\tau)\,d\tau$

(c) $\displaystyle x(0)\,a(t) + \int_{0^+}^{t} x(\tau)\,a(t-\tau)\,d\tau$

(d) $\displaystyle x(0)\,a(t) + \int_{0^+}^{t} \frac{da(\tau)}{d\tau} x(t-\tau)\,d\tau$

[ESE-2000]

2.3 **Assertion (A):** The 'zero-state' response of a linear constant-parameter continuous-time system can have components having the 'natural frequencies' of the system.
Reason (R): The 'forced frequency' components in the response of the state for any given input may not add up to the given zero initial value of the state. The 'natural frequency' components may be needed to bridge the gap.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE-2000]

3. Fourier Series

3.1 The Fourier series representations of a periodic current

$$[2+6\sqrt{2}\cos\omega t+\sqrt{48}\sin 2\omega t]A$$

The effective value of the current is

(a) $[2+6+\sqrt{24}]A$ (b) 8 A
(c) 6 A (d) 2 A

[ESE-2000]

3.2 Match **List-I** (Properties) with **List-II** (Characteristics of the trigonometric form) in regard to Fourier series of periodic f(t) and select the correct answer using the codes given below the lists:

List-I	List-II
A. $f(t)+f(-t)=0$	1. Even harmonics can exist
B. $f(t)-f(-t)=0$	2. Odd harmonics can exist
C. $f(t)+f(t-T/2)=0$	3. The dc and cosine terms can exist
D. $f(t)-f(t-T/2)=0$	4. sine terms can exist
	5. cosine terms of even harmonics can exist

Codes:

	A	B	C	D
(a)	4	5	3	1
(b)	3	4	1	2
(c)	5	4	2	3
(d)	4	3	2	1

[ESE-2000]

3.3 Consider the following statements regarding the fundamental component $f_1(t)$ of an arbitrary periodic signal $f(t)$:
It is possible for
1. the amplitude of $f_1(t)$ to exceed the peak value of $f(t)$.
2. $f_1(t)$ to be identically zero for a non-zero $f(t)$.
3. the effective value of $f_1(t)$ to exceed the effective value of $f(t)$.

Which of these statements is/are correct?
(a) 1 alone (b) 1 and 2
(c) 2 and 3 (d) 1 and 3 [ESE-2000]

3.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. $f(t)=-f(-t)$	1. Exponential form of Fourier series
B. $\sum_{n=-\infty}^{\infty} C_n e^{jn\omega_0 t}$	2. Fourier transform
C. $\int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$	3. Convolution integral
D. $\int_0^t f_1(\tau)f_2(t-\tau)d\tau$	4. z-transform
	5. Odd function wave symmetry

Codes:

	A	B	C	D
(a)	5	1	2	3
(b)	2	1	5	3
(c)	5	4	2	1
(d)	4	5	1	2

[ESE-2000]

4. Continuous Time Fourier Transform

4.1 Match **List-I** (Fourier transform) with **List-II** (Functions of time) and select the correct answer using the codes given below the lists:

List-I	List-II
A. $\dfrac{\sin k\omega}{\omega}$	1. A constant
B. $e^{-j\omega d}$	2. Exponential function
C. $\dfrac{1}{(j\omega+2)^2}$	3. t-multiplied exponential function
D. $k\delta(\omega)$	4. Rectangular pulse
	5. Impulse function

Codes:

	A	B	C	D
(a)	4	5	3	1
(b)	4	5	3	2
(d)	3	4	2	1
(d)	3	4	2	5

[ESE-1999]

4.2 A voltage signal $v(t)$ has the following Fourier transform:

$$V(j\omega)=\begin{cases} e^{-j\omega d} & \text{for } |\omega|<1 \\ 0 & \text{for } |\omega|>1 \end{cases}$$

The energy that would be dissipated in a 1 Ω resistor fed from $v(t)$ is

(a) $2/\pi$ Joules (b) $2e^{-2d}/\pi$ Joules

(c) $1/\pi$ Joules (d) $1/2\pi$ Joules

[ESE-2000]

5. Laplace Transform

5.1 Laplace transform of $\sin(\omega t + \alpha)$ is

(a) $\dfrac{\alpha}{s^2+\alpha^2}\exp(s/\alpha\omega)$

(b) $\dfrac{\omega}{s^2+\omega^2}\exp(s/\alpha\omega)$

(c) $\dfrac{s}{s^2+\alpha^2}\exp(s/\alpha\omega)$

(d) $\dfrac{\omega}{s^2+\alpha^2}\exp(s/\alpha\omega)$

[ESE-1999]

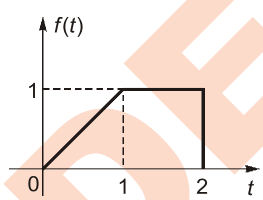
5.2 The function $f(t)$ shown in the given figure will have Laplace transform as

(a) $\dfrac{1}{s^2}-\dfrac{1}{s}e^{-s}-\dfrac{1}{s^2}e^{-2s}$

(b) $\dfrac{1}{s^2}(1-e^{-s}-e^{-2s})$

(c) $\dfrac{1}{s}(1-e^{-s}-e^{-2s})$

(d) $\dfrac{1}{s^2}(1-e^{-s}-se^{-2s})$



[ESE-1999]

5.3 Inverse Laplace transform of the function $\dfrac{2s+5}{s^2+5s+6}$ is

(a) 2 exp (–2.5 t) cos h 0.5t

(b) exp (–2t) – exp(–3t)

(c) 2 exp (–2.5t) sin h 0.5t

(d) 2 exp (–2.5t) cos 0.5t [ESE-1999]

5.4 The output of a linear system to a unit step input u(t) is t^2e^{-2t}. The system function $H(s)$ is

(a) $\dfrac{2}{s^2(s+2)}$ (b) $\dfrac{2}{(s+2)^2}$

(c) $\dfrac{2}{(s+2)^3}$ (d) $\dfrac{2s}{(s+2)^3}$

[ESE-2000]

5.5 Match **List-I** (System function) with **List-II** (Impulse response) and select the correct answer using the codes given below the lists:

List-I

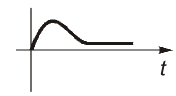
A. $\dfrac{e^{-s}}{s+1}$

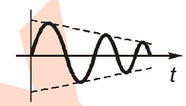
B. $\dfrac{1}{s^2+s+1}$

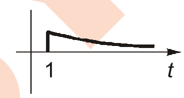
C. $\dfrac{1}{(s+1)^2}$

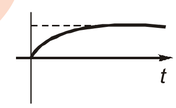
D. $\dfrac{1}{s^2+s}$

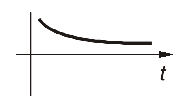
List-II

1. 

2. 

3. 

4. 

5. 

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	5	2	3	4
(c)	3	2	1	4
(d)	5	4	3	2

[ESE-2000]

5.6 **Assertion (A):** When a linear time-invariant system having a system function $H(s)$ is driven by an input $x(t) = e^{s_0t}$ the forced part of the output is $H(s_0)\,e^{s_0t}$.

Reason (R): In the partial fraction expansion of the Laplace transform of the output, the term corresponding to the pole at s_0 is $\dfrac{H(s_0)}{s-s_0}$. The inverse transform of $\dfrac{H(s_0)}{s-s_0}$ is $H(s_0)e^{s_0t}$.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE-2000]

8. Z-Transform

8.1 **Assertion (A):** An LTI discrete system represented by the difference equation $y(n+2) - 5y(n+1) + 6y(n) = x(n)$ is unstable.
Reason (R): A system is unstable if the roots of the characteristic equation lie outside the unit circle.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-1999]**

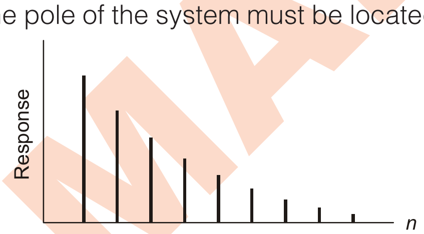
8.2 Consider the following statements regarding a linear discrete-time system

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

1. The system is stable.
2. The initial value $h(0)$ of the impulse response is –4.
3. The steady-state output is zero for a sinusoidal discrete time input of frequency equal to one-fourth the sampling frequency.

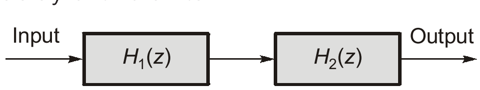
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3
[ESE-1999]

8.3 The impulse response of a discrete system with a simple pole shown in the below figure.
The pole of the system must be located on the



(a) real axis at $z = -1$
(b) real axis between $z = 0$ and $z = 1$
(c) imaginary axis at $z = j$
(d) imaginary axis between $z = 0$ and $z = j$
[ESE-2000]

8.4 Consider the compound system shown in the below figure. Its output is equal to input with a delay of two units.



If the transfer function of the first system is given by

$$H_1(z) = \frac{z-0.5}{z-0.8},$$

then the transfer function of the second system would be

(a) $H_2(z) = \dfrac{z^{-2} - 0.2z^{-3}}{1 - 0.4z^{-1}}$

(b) $H_2(z) = \dfrac{z^{-2} - 0.8z^{-3}}{1 - 0.5z^{-1}}$

(c) $H_2(z) = \dfrac{z^{-1} - 0.2z^{-3}}{1 - 0.4z^{-1}}$

(d) $H_2(z) = \dfrac{z^{-2} + 0.8z^{-3}}{1 + 0.5z^{-1}}$ **[ESE-2000]**

8.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. $\alpha^n u(n)$
B. $-\alpha^n u(-n-1)$
C. $-n\alpha^n u(-n-1)$
D. $n\alpha^n u(n)$

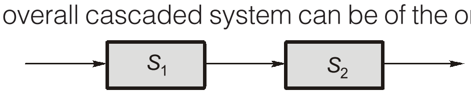
List-II
1. $\dfrac{\alpha z^{-1}}{(1-\alpha z^{-1})^2}$ ROC: $|z| > |\alpha|$
2. $\dfrac{1}{(1-\alpha z^{-1})}$ ROC: $|z| > |\alpha|$
3. $\dfrac{1}{(1-\alpha z^{-1})}$ ROC: $|z| < |\alpha|$
4. $\dfrac{\alpha z^{-1}}{(1-\alpha z^{-1})^2}$ ROC: $|z| < |\alpha|$

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	1	3	4	2
(c)	1	4	3	2
(d)	2	3	4	1

[ESE-2000]

8.6 Two linear time-invariant discrete time systems S_1 and S_2 are cascaded as shown in the below figure. Each system is modelled by a second order difference equation. The difference equation of the overall cascaded system can be of the order of



(a) 0, 1, 2, 3 or 4 (b) either 2 or 4
(c) 2 (d) 4 **[ESE-2000]**

Answers Signals and Systems + DSP

1.1	(b)	1.2	(a)	1.3	(d)	1.4	(a)	1.5	(b)	1.6	(a)	1.7	(d)	1.8	(b)	2.1	(d)
2.2	(a)	2.3	(b)	3.1	(b)	3.2	(d)	3.3	(b)	3.4	(a)	4.1	(a)	4.2	(c)	5.1	(*)
5.2	(d)	5.3	(a)	5.4	(d)	5.5	(c)	5.6	(a)	8.1	(a)	8.2	(c)	8.3	(b)	8.4	(b)
8.5	(d)	8.6	(a)														

Explanations Signals and Systems + DSP

1. Basics of Signals and Systems

1.1 (b)

(i) For the system to be stable, the roots of the characteristic equation should lie in the LHS of s-plane.

$$\frac{dy(t)}{dt} - 0.1y(t) = x(t)$$

$$\Rightarrow \quad \frac{Y(s)}{X(s)} = \frac{1}{s - 0.1}$$

$\Rightarrow s = 0.1$ which is in RHS of s-plane, hence the system is unstable.

(ii) The system is linear if the response to $ax_1(t) + bx_2(t)$ is $ay_1(t) + by_2(t)$.

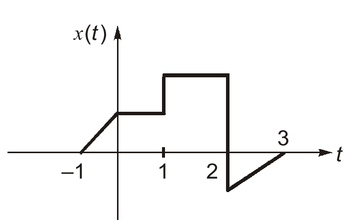
$$\frac{dy(t)}{dt} + 2t^2 y(t) = x(t)$$

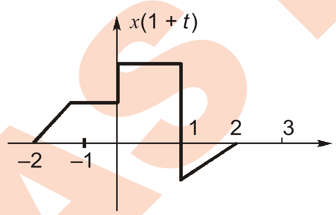
The condition of linearity is satisfied here, hence the system is linear.

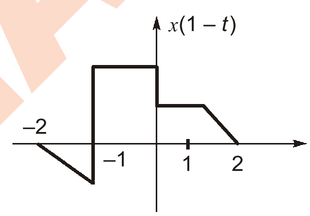
(iii) A system is causal if the output at any time depends only on values of the input at the present time and in the past.

(iv) A system is said to be memoryless or static if its output for each value of the independent variable at a given time is dependent only on the input at the same time.

1.2 (a)







$x(1 + t)$ is the shifted version of $x(t)$ towards left by one unit. $x(1 - t)$ is the mirror image of $x(1 + t)$ along vertical axis.

1.3 (d)

A linear system, in continuous time or discrete time, is a system that possesses the important property of superposition.

A direct consequence of the superposition property is that, for linear systems, an input which is zero for all time results in an output which is zero for all time.

NOTE: Let $y_1(t)$ and $y_2(t)$ be the responses of a continuous time system to the inputs $x_1(t)$ and $x_2(t)$ respectively. Then the system is linear if:

(i) The response to $x_1(t) + x_2(t)$ is $y_1(t) + y_2(t)$.
$\Rightarrow$ **Additivity property.**

(ii) The response to $ax_1(t)$ is $ay_1(t)$, where a is any complex constant.
$\Rightarrow$ **Scaling or homogeneity property.**

1.4 (a)

Since the output for each value of the independent variable at a given time is not dependent on the input at the same time, hence the system is having memory. Therefore, the system is not attributable to a memoryless system.

NOTE: A system is said to be memoryless if its output for each value of the independent variable at a given time is dependent only on the input at the same time.

(i) Memoryless system is also called static system.

(ii) A system having memory is also called dynamic system.

1.5 (b)

$$f(t) = \cos\left[\frac{\pi}{4}(t-1)\right]$$

$$\text{Period} = \frac{2\pi}{\omega} = \frac{2\pi}{\pi/4} = 8 \text{ s}$$

1.6 (a)

(i) $f(t) + K\dfrac{df(t)}{dt} = 0$

Taking Laplace transform,

$(1 + Ks)\,F(s) = 0$

characteristic equation is $1 + Ks = 0$

complementary function C.F. = $e^{-t/K}$

which is decaying exponential.

(ii) $f(t) + \dfrac{Kd^2f(t)}{dt^2} = 0$

Its Laplace transform is

$(1 + Ks^2)\,F(s) = 0$

characteristic equation is $1 + Ks^2 = 0$

Roots are $s = \pm j\dfrac{1}{\sqrt{K}}$

$$\text{C.F.} = \cos\frac{1}{\sqrt{K}}t + \sin\frac{1}{\sqrt{K}}t$$

which is a sinusoid function.

(iii) $f(t)\,\{1 - u(t)\} = 0$

$\because \quad u(t) = 1 \quad \text{for } t > 0$

$\qquad\qquad\; 0 \quad \text{for } t < 0$

So for $t < 0$, $f(t) = 0$

Therefore, $f(t)$ is a causal function.

1.7 (d)

$3y^3(t) + 2y^2(t) + y(t) = x^2(t) + x(t)$

Since the output for each value of the independent variable at a given time is dependent only on the input at the same time, the system is memoryless or static or non-dynamic.

For a system to be linear, if $x(t) = ax_1(t) + b\,x_2(t)$, then $y(t) = ay_1(t) + by_2(t)$. Since the given system does not satisfy the condition of linearity, it is a non-linear system.

1.8 (b)

A system is causal if the output at any time depends only on values of the input at the present time and in the past.

2. Continuous and Discrete Time LTI Systems

2.1 (d)

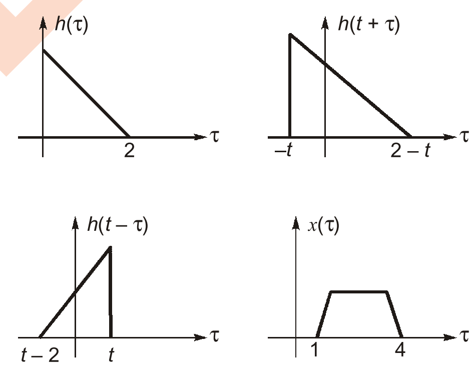
$$y(t) = \int_{-\infty}^{\infty} x(\tau)\,h(t-\tau)\,d\tau$$

$y(t) = 0$ when $t < 1$

$y(t) = 0$ when $t - 2 > 4$ or $t > 6$

so, $\quad y(t) = 0$ for $1 < t$ and $t > 6$

so, $y(t)$ is zero everywhere except for $1 < t < 6$



2.2 (a)

$\because$ step response of LTI system is a(t)

$\therefore$ Impulse response of LTI system is $\dfrac{da(t)}{dt}$

$$y(t) = \int_{0+}^{t} \frac{da(\tau)}{d\tau}\,x(t-\tau)\,d\tau$$

2.3 (b)

A solution to the differential equation with the input set to zero is often referred to as the natural response of the system.

Note:

(i) Auxiliary equation

$\Rightarrow$ Complementary Function

$\Rightarrow$ Transient Response

$\Rightarrow$ Natural Response

(ii) Particular Integral
$\Rightarrow$ Forced Response
$\Rightarrow$ Steady State Response

3. Fourier Series

3.1 (b)

$$I_{eff} = \sqrt{I_{dc}^2 + I_{1\,rms}^2 + I_{2\,rms}^2}$$

$$= \sqrt{(2)^2 + \left(\frac{6\sqrt{2}}{\sqrt{2}}\right)^2 + \left(\frac{\sqrt{48}}{\sqrt{2}}\right)^2}$$

$$= \sqrt{4+36+24} = \sqrt{64} = 8\text{ A}$$

3.2 (d)

(i) $f(t) + f(-t) = 0$

$\Rightarrow$ $f(t) = -f(-t)$

$\Rightarrow$ $f(t)$ is an odd function

$\Rightarrow$ sine terms exist in Fourier series of $f(t)$

(ii) $f(t) - f(t) = 0$

$\Rightarrow$ $f(t) = f(-t)$

$\Rightarrow$ $f(t)$ is an even function

$\Rightarrow$ The dc and cosine terms exist in Fourier series of $f(t)$

(iii) $f(t) + f\left(t - \dfrac{T}{2}\right) = 0$

$\Rightarrow f\left(t - \dfrac{T}{2}\right) = -f(t)$

$\Rightarrow$ $f(t)$ is a half wave symmetric function

$\Rightarrow$ Odd harmonics exist

(iv) $f(t) = f(t - T/2)$

$\Rightarrow$ Even harmonics exist.

3.3 (b)

Let $f(t) = Af_1(t) + Bf_2(t) + Cf_3(t) + \ldots$

Let amplitude of $f(t)$ be P.

(i) Then, it is possible that $A > P$ as

$$P = A + B + C + \ldots$$

and other coefficients may be negative

(ii) $\because P^2 = A^2 + B^2 + C^2 + \ldots$

$\therefore$ Effective value of $f_1(t)$ can never exceed to that of $f(t)$.

(iii) $f_1(t)$ can not be identically zero for a non-zero $f(t)$.

4. Continuous Time Fourier Transform

4.1 (a)

Signal $f(t)$	Fourier Transform $F(\omega)$
1	$2\pi\delta(\omega)$
$\text{rect}\left(\frac{t}{\tau}\right)$	$\tau\,\text{sinc}\left(\frac{\omega\tau}{2}\right)$
$t^n e^{-at} u(t)$	$\frac{n!}{(a+j\omega)^{n+1}}$
$\delta(t)$	1

Time shifting property:

If $f(t) \xleftrightarrow{FT} F(\omega)$

then $f(t - t_0) \xleftrightarrow{FT} e^{-j\omega t_0} F(\omega)$

so $\delta(t-d) \xleftrightarrow{FT} e^{-j\omega d}$

4.2 (c)

$$E = \frac{1}{2\pi}\int_{-\infty}^{\infty} |V(j\omega)|^2 d\omega$$

$$E = \frac{1}{2\pi}\int_{-1}^{1} 1\, d\omega$$

$\because$ magnitude of $e^{-j\omega t} = 1$.

$$E = \frac{1}{2\pi} \times 2 = \frac{1}{\pi}$$

5. Laplace Transform

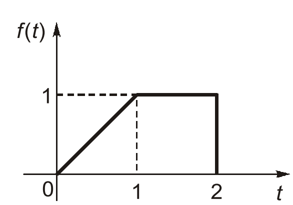
5.1 (*)

$$f(t) = \sin(\omega t + \alpha)$$

$$F(s) = \exp\left(\frac{\alpha}{\omega}\cdot s\right)\cdot LT\{\sin\omega t\}$$

$$F(s) = \frac{\omega}{s^2+\omega^2}\exp\left(\frac{\alpha}{\omega}\cdot s\right)$$

5.2 (d)



$$f(t) = tu(t) - (t-1)\,u(t-1) - u(t-2)$$

$$\Rightarrow \quad F(s) = \frac{1}{s^2} - \frac{e^{-s}}{s^2} - \frac{e^{-2s}}{s}$$

$$\Rightarrow \quad F(s) = \frac{1}{s^2}(1 - e^{-s} - s\,e^{-2s})$$

5.3 (a)

$$F(s) = \frac{2s+5}{s^2+5s+6} = \frac{1}{s+2} + \frac{1}{s+3}$$

$$\Rightarrow \quad f(t) = e^{-2t} + e^{-3t}$$

$$= 2e^{-2.5t}\left[\frac{e^{0.5t}+e^{-0.5t}}{2}\right]$$

$$= 2e^{-2.5t}\cos h\, 0.5t$$

5.4 (d)

$$x(t) = u(t) \text{ and } y(t) = t^2 \cdot e^{-2t}$$

$$X(s) = \frac{1}{s}$$

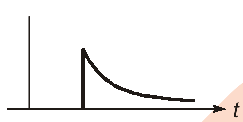
$$Y(s) = \frac{2}{(s+2)^3}$$

$$H(s) = \frac{Y(s)}{X(s)} = \frac{2s}{(s+2)^3}$$

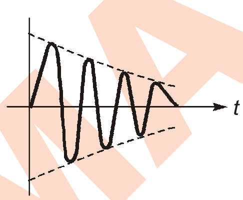
5.5 (c)

Inverse Laplace transforms of the functions are as follows:

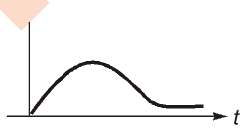
(i) $\frac{e^{-s}}{s+1} \xleftrightarrow{(LT)^{-1}} e^{-(t-1)}\,u(t-1)$



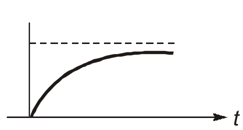
(ii) $\frac{1}{s^2+s+1} \xleftrightarrow{(LT)^{-1}} \frac{2}{\sqrt{3}} e^{-t/2} \sin\left(\frac{\sqrt{3}}{2}t\right)$



(iii) $\frac{1}{(s+1)^2} \xleftrightarrow{(LT)^{-1}} te^{-t}\,u(t)$



(iv) $\frac{1}{s^2+s} \xleftrightarrow{(LT)^{-1}} (1-e^{-t})\,u(t)$



5.6 (a)

Input, $\quad x(t) = e^{s_0 t}$

$$\Rightarrow \quad X(s) = \frac{1}{s-s_0}$$

Output, $\quad Y(s) = X(s)\,H(s) = \frac{H(s)}{s-s_0}$

On partial fraction expansion,

$$Y(s) = \frac{H(s_0)}{s-s_0}$$

So, $\quad y(t) = H(s_0)\,e^{s_0 t}$

8. Z-Transform

8.1 (a)

Difference equation is

$y(n+2) - 5y(n+1) + 6y(n) = x(n)$

Taking z-transform,

$(z^2 - 5z + 6)\; Y(z) = X(z)$

$$\frac{Y(z)}{X(z)} = \frac{1}{z^2-5z+6} = H(z)$$

where $H(z)$ is transfer function

$$H(z) = \frac{1}{(z-2)(z-3)}$$

The characteristic equation has roots

$$z = 2, 3.$$

Since the characteristic equation has the roots outside the unit circle, hence the system is unstable.

8.2 (c)

(i) Characteristic equation is $(z + 0.5)(z - 0.5) = 0$.
Its roots are $z = 0.5$, -0.5.
Since both roots are inside the unit circle, hence the system is stable.

(ii) $$h(0) = \lim_{z\to\infty} H(z)$$

$$= \lim_{z\to\infty} \frac{z^2+1}{(z+0.5)(z-0.5)} = 1$$

8.3 (b)

The given impulse response has the form

$$H(z) = \frac{z}{z-a}, \quad |z| > 0$$

$$\Rightarrow \quad h(n) = a^n u(n),\; 0 < a < 1$$

So, the pole of the system must be located on the real axis between $z = 0$ and $z = 1$.

8.4 (b)

$$y(n) = x(n-2)$$
$$Y(z) = z^{-2} X(z)$$
$$\Rightarrow \quad H(z) = H_1(z)\,H_2(z) = \frac{Y(z)}{X(z)} = z^{-2}$$
$$\Rightarrow \quad \left(\frac{z-0.5}{z-0.8}\right) H_2(z) = z^{-2}$$
$$\Rightarrow \quad H_2(z) = \frac{z^{-1} - 0.8z^{-2}}{z-0.5}$$
$$\Rightarrow \quad H_2(z) = \frac{z^{-2} - 0.8z^{-3}}{1-0.5z^{-1}}$$

8.6 (a)

$$H(s) = H_1(s) \cdot H_2(s)$$
$$= (as^2 + \dots)\,(ms^2 + \dots)$$
$$= (ps^4 + \dots)$$

where a, m and p are constants

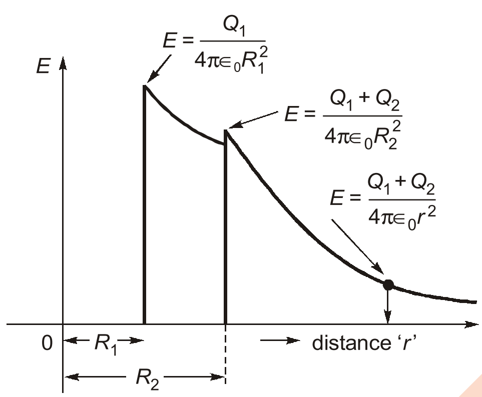
Thus the overall cascaded system will have the difference equation of the order of 4.

■■■

3 Electromagnetics

1. Basic of Electromagnetics

1.1 The given figure represents the variation of electric field 'E'



(a) due to a spherical volume charge $Q = Q_1 + Q_2$

(b) due to two concentric shells of charges Q_1 and Q_2 uniformly distributed over spheres of radii R_1 and R_2

(c) due to two point charges Q_1 and Q_2 located at any two points 'r' (= R_1 and R_2)

(d) in a single spherical shell of charges Q uniformly distributed, $Q = Q_1 + Q_2$

[ESE-1999]

1.2 Two small diameter 5 g dielectric balls can slide freely on a vertical nonconducting thread. Each ball carries a negative charge of 2 μC. If the lower ball is restrained from moving, then the separation between the two balls will be

(a) 8570 mm (b) 857 mm
(c) 85.7 mm (d) 8.57 mm

[ESE-1999]

1.3 Solutions of Laplace's equation, which are continuous through the second derivative, are called

(a) Bessel functions
(b) odd functions
(c) harmonic functions
(d) fundamental functions [ESE-1999]

1.4 Charge needed within a unit sphere centred at the origin for producing a potential field, $V = -\frac{6r^5}{\epsilon_o}$, for $r \le 1$ is

(a) 12π C (b) 60π C
(c) 120π C (d) 180π C

[ESE-1999]

1.5 The region between two concentric conducting cylinders with radii of 2 and 5 cm contains a volume charge distribution of $-10^{-8}(1 + 10r)$ C/m^3. If E_r and V both are zero at the inner cylinder and $\epsilon = \epsilon_0$, the potential V at the outer cylinder will be

(a) 0.506 V (b) 5.06 V
(c) 50.6 V (d) 506 V [ESE-1999]

1.6 **Assertion (A):** Net charge within a conductor is always zero.

Reason (R): The conductor has a very large number of free electrons.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-1999]

1.7 Match **List-I** (Laws) with **List-II** (Applications) and select the correct answer:

List-I
A. Ampere's law
B. Biot's law
C. Coulomb's law
D. Gauss's law

List-II
To find the
1. force on a charge
2. field due to a current element
3. electric flux density at a point
4. magnetic flux density at a point

	A	B	C	D
(a)	3	2	1	4
(b)	4	2	1	3
(c)	4	1	2	3
(d)	3	1	2	4

[ESE-2000]

1.8 A solid cylindrical conductor of radius 'R' has a uniform current density. The magnetic field 'H' inside the conductor at a distance 'r' from the axis of the conductor is
(a) $I/2\pi r$ (b) $I/4\pi r$
(c) $Ir/2\pi R^2$ (d) $Ir/4\pi R^2$
[ESE-2000]

1.9 The equation $\nabla \cdot \vec{J} = 0$ is known as
(a) Poisson's equation
(b) Laplace equation
(c) Continuity equation
(d) Maxwell equation [ESE-2000]

1.10 In a hundred-turn coil, if the flux through each turn is $(t^3 - 2t)$ mWb, the magnitude of the induced emf in the coil at a time of 4s is
(a) 46 mV (b) 56 mV
(c) 4.6 V (d) 5.6 V [ESE-2000]

1.11 The dimensions of magnetic flux density are
(a) $MT^{-1}Q^{-1}$ (b) $MT^{-2}Q^{-2}$
(c) $MT^{1}Q^{1}$ (d) $MT^{-1}Q^{-2}$ [ESE-2000]

1.12 **Assertion (A):** The solution of Poisson's equation is the same as the solution of Laplace's equation.
Reason (R): Laplace's equation is a special case of Poisson's equation for source-free region.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

2. Uniform Plane Waves

2.1 A TEM wave impinges obliquely on a dielectric-dielectric boundary with $\epsilon_{r_1} = 2$ and $\epsilon_{r_2} = 1$. The angle of incidence for total reflection is:
(a) 30° (b) 60°
(c) 45° (d) 90°
[ESE-1999]

2.2 The function $F = e^{-\alpha z}\sin\frac{\omega}{v}(x - vt)$ satisfies the wave equation $\nabla^2 F = \frac{F}{c^2}$ provided
(a) $v = c\left(1 + \frac{\alpha^2 c^2}{\omega^2}\right)^{-1/2}$
(b) $v = c(1 + \omega^2\alpha^2 c)^{-1/2}$
(c) $v = c\omega(\alpha^2 c^2 - 1)^{-1/2}$
(d) $v = \frac{1}{c}\left(1 + \frac{\omega^2 c^2}{\alpha^2}\right)^{-1/2}$ [ESE-1999]

2.3 A plane electromagnetic wave is travelling in an unbounded loss-less dielectric having $\mu_r = 1$ and $\epsilon_r = 4$. The time average Poynting vector of the wave is 5 W/m^2. The phase velocity v_p (assuming velocity of light as 3×10^8 m/s) is
(a) 1.5×10^8 m/s (b) 3×10^8 m/s
(c) 2.5×10^8 m/s (d) 0.5×10^8 m/s
[ESE-1999]

2.4 When a plane wave is incident normally from dielectric '1'(μ_0, ϵ_1) onto dielectric '2' (μ_0, ϵ_2), the electric field of the transmitted wave is –2 times the electric field of the reflected wave. The ratio ϵ_2/ϵ_1 is
(a) 0.5 (b) 1
(c) 2 (d) 4
[ESE-1999]

2.5 If for the transmission of a parallel polarized wave from a dielectric medium of permittivity ϵ_1 into a dielectric medium of permittivity ϵ_2, there exists a value of the angle of incidence θ_p for which the reflection coefficient is zero, then
(a) $\tanh\theta_p = \sqrt{\epsilon_1/\epsilon_2}$
(b) $\tan\theta_p = \sqrt{\epsilon_1/\epsilon_2}$
(c) $\tan\theta_p = \sqrt{\epsilon_2/\epsilon_1}$
(d) $\tanh\theta_p = \sqrt{\epsilon_2/\epsilon_1}$
[ESE-1999]

2.6 For an elliptically polarized wave incident on the interface of a dielectric at the Brewster angle, the reflected wave will be

(a) elliptically polarized
(b) linearly polarized
(c) right circularly polarized
(d) left circularly polarized

[ESE-1999]

2.7 For electromagnetic wave propagation in free space, the free space is defined as

(a) $\sigma = 0, \in = 1, \mu \neq 1, \vec{p} \neq 0, \vec{j} = 0$

(b) $\sigma = 0, \in = 1, \mu = 1, \vec{p} = 0, \vec{j} = 0$

(c) $\sigma \neq 0, \in > 1, \mu < 1, \vec{p} \neq 0, \vec{j} = 0$

(d) $\sigma = 0, \in = 1, \mu = 1, \vec{p} \neq 0, \vec{j} \neq 0$

[ESE-1999]

2.8 A plane wave of 10 GHz is incident normally on a dielectric plate of 3 mm thickness. If the phase shift on transmission through the sheet is 90°, then the dielectric constant is

(a) 2.5 (b) 3.25
(c) 4.5 (d) 6.25

[ESE-1999]

2.9 Polystyrene has a relative permittivity of 2.7. If the wave is incident at an angle 'θ_1' of 30° from air onto polystyrene, the angle of transmission will be nearly

(a) 0.2° (b) 2°
(c) 18° (d) 48° **[ESE-2000]**

2.10 Match **List-I** with **List-II** and select the correct answer using the codes given below: (Notations have their usual meaning):

List-I
A. Permeability
B. Force
C. Velocity of EM wave
D. Displacement density

List-II
1. QE
2. $\dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$
3. $\mu_0 \mu_r$
4. $\sqrt{\dfrac{\mu}{\in}}$
5. εE

Codes:

	A	B	C	D
(a)	3	2	4	5
(b)	3	1	2	5
(c)	4	1	2	3
(d)	4	2	5	3

[ESE-2000]

2.11 The Poynting vector $\vec{P} = \vec{E} \times \vec{H}$ has the dimensions of

(a) Power/unit area (b) Volts
(c) Power (d) Volt/unit length

[ESE-2000]

2.12 Consider the following statements regarding a plane wave propagating through free space:
The direction of field
1. 'E' is perpendicular to the direction of propagation
2. 'H' is perpendicular to the direction of propagation
3. 'E' is perpendicular to the direction of field 'H'

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE-2000]

2.13 If the velocity of electromagnetic wave in free space is 3×10^8 m/s, the velocity in a medium with ε_r of 4.5 and μ_r of 2 would be

(a) 1×10^8 m/s (b) 3×10^8 m/s
(c) 9×10^8 m/s (d) 27×10^8 m/s

[ESE-2000]

2.14 If $\vec{H} = 0.1 \sin(10^8 \pi t + \beta y) \hat{a}_x$ A/m for a plane wave propagating in free space, then the time average Poynting vector is

(a) $(0.6\pi \sin^2 \beta y) \hat{a}_y$ W/m^2

(b) $-0.6\pi\, \hat{a}_y$ W/m^2

(c) $1.2\pi\, \hat{a}_x$ W/m^2

(d) $-1.2\pi\, \hat{a}_x$ W/m^2

[ESE-2000]

3. Transmission Lines

3.1 A 50 Ω characteristic impedance line is connected to a load which shows a reflection coefficient of 0.268. If V_{in} = 15 V, then the net power delivered to the load will be
(a) 0.139 W (b) 1.39 W
(c) 0.278 W (d) 2.78 W **[ESE-1999]**

3.2 For a transmission line with homogeneous dielectric, the capacitance per unit length is 'C', the relative permittivity of the dielectric is 'ϵ_r' and velocity of light in free space is 'v'. The characteristic impedance Z_0 is equal to

(a) $\frac{\epsilon_r}{vC}$ (b) $\frac{\epsilon_r}{\sqrt{vC}}$

(c) $\frac{\sqrt{\epsilon_r}}{vC}$ (d) $\sqrt{\frac{\epsilon_r}{vC}}$

[ESE-1999]

3.3 It is desired to reduce the reflection at an air porcelain by use of λ/4 plate. (For porcelain $\mu = \mu_0$ and $\epsilon_r = 2$). The thickness of the polystyrene plate required at 10 GHz will be
(a) 5.039 cm (b) 50.39 cm
(c) 0.5039 cm (d) 0.05039 cm
[ESE-1999]

3.4 A quarter-wave transformer is used for matching a load of 225 ohms connected to a transmission line of 256 ohms in order to reduce the SWR along the line to 1. The characteristic impedance (in ohms) of the transformer is
(a) 225 (b) 240
(c) 256 (d) 273
[ESE-1999]

3.5 For distortionless transmission through a channel, the channel should be such that
(a) its attenuation response is an even function and phase response is an odd function of frequency
(b) its attenuation response is flat and phase response is linear with frequency
(c) the ratio of line inductance to line capacitance is constant
(d) its termination is by a matched impedance
[ESE-1999]

3.6 When VSWR is 3, the magnitude of the reflection coefficient will be
(a) 1/4 (b) 1/3
(c) 1/2 (d) 1 **[ESE-1999]**

3.7 A coaxial *RF* cable has the characteristic impedance of 50 Ω and a nominal capacitance of 40 pF/m. The inductance of the cable is
(a) 1 μH/m (b) 10 μH/m
(c) 0.1 μH/m (d) 0.0 μH/m
[ESE-1999]

3.8 A transmission line has primary constants R, L, G and C, and secondary constants Z_0 and $\gamma(= \alpha + j\beta)$. If the line is lossless, then
(a) $R = 0$, $G \neq 0$ and $\alpha = 0$
(b) $R = 0$, $G \neq 0$ and $\beta = |\gamma|$
(c) $G = 0$ and $\alpha = \beta$
(d) $R = 0$, $G = 0$, $\alpha = 0$ and $\beta = |\gamma|$
[ESE-2000]

3.9 A transmission line having 50 Ω impedance is terminated in a load of (40 + j30) Ω. The VSWR is
(a) j0.033 (b) 0.8 + j0.6
(c) 1 (d) 2 **[ESE-2000]**

3.10 A(75 – j40)Ω load is connected to a coaxial line of Z_0 = 75 Ω at 6 MHz. The load matching on the line can be accomplished by connecting.
(a) a short-circuited stub at the load
(b) an inductance at the load
(c) a short-circuited stub at a specific distance from the load
(d) a capacitance at a specific distance from the load
[ESE-2000]

3.11 A quarter-wave transformer matching a 75 Ω source with a 300 Ω load should have a characteristic impedance of
(a) 50 Ω (b) 100 Ω
(c) 150 Ω (d) 200 Ω **[ESE-2000]**

4. Waveguides

4.1 A rectangular waveguide 2.29 cm × 1.02 cm operates at a frequency of 11 GHz in TE_{10} mode. If the maximum potential gradient of the signal is 5 kV/cm, then the maximum power handling capacity of the waveguide will be
(a) 31.11 mW (b) 31.11 W
(c) 31.11 kW (d) 31.11 MW
[ESE-1999]

4.2 When the phase velocity of an electromagnetic wave depends on frequency in any medium, the phenomenon is called
(a) scattering (b) polarization
(c) absorption (d) dispersion
[ESE-1999]

4.3 Consider the following statements:
If the narrow dimension of a standard rectangular waveguide carrying the dominant mode is reduced, then the
1. wave impedance will increase
2. attenuation will increase
3. guide wavelength will decrease
4. power handling capability will decrease
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 4
(c) 3 and 4 (d) 1 and 3 [ESE-2000]

4.4 The cut-off wavelength λ_c for TE_{20} mode for a standard rectangular waveguide is
(a) $2/a$ (b) $2a$
(c) a (d) $2a^2$
[ESE-2000]

4.5 Phase velocity 'v_p' and the group velocity 'v_g' in a waveguide ('v' is velocity of light) are related as
(a) $v_p\, v_g = c^2$
(b) $v_p + v_g = c$
(c) $v_p/v_g = a$ constant
(d) $v_p + v_g = a$ constant [ESE-2000]

5. Antennas and Radar

5.1 A dipole antenna, with some excitation in free space was radiating a certain amount of the power. If this antenna is immersed in a lake where water is non-magnetic and non-dissipative but has a dielectric constant of 81, the radiated power with the same excitation will
(a) decrease to finite non-zero value
(b) remain the same
(c) increase
(d) decrease to zero [ESE-1999]

5.2 A broadside array operating at 100 cm wavelength consists of 4 half-wave dipoles spaced 50 cm apart. Each element carries radio frequency current in the same phase and of magnitude 0.5 A. The radiated power will be
(a) 146 W (b) 73 W
(c) 36.5 W (d) 18.25 W
[ESE-1999]

5.3 An antenna has a gain of 44 dB. Assuming that the main beam of the antenna is circular in cross-section, the beam width will be
(a) 0.4456° (b) 1.4456°
(c) 2.4456° (d) 3.4456° [ESE-1999]

5.4 A dipole antenna of $\lambda/8$ length has an equivalent total loss resistance of 1.5 Ω. The efficiency of the antenna is:
(a) 0.89159% (b) 8.9159%
(c) 89.159% (d) 891.59%
[ESE-1999]

5.5 **Assertion (A):** In a small flare angle pyramidal horn excited by a TE_{10} rectangular waveguide, the operative field distribution is also very nearly that of TE_{10} mode.
Reason (R): In a small flare angle horn, the throat acts as a mode filter.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-1999]

5.6 For an aperture antenna of aperture dimension D and wavelength of radiation from the antenna λ, the far-field is at a distance greater than
(a) $D^2/2\lambda$ (b) $2D^2/\lambda$
(c) D^2/λ (d) $(2D)^2/\lambda$
[ESE-1999]

5.7 Consider the following statements about advantages and disadvantages of offset parabolic reflector antenna:
1. It reduces aperture blocking but degrades sidelobe level.
2. It can be used as a multibeam or dual polarised antenna.
3. A linearly polarised illumination causes no cross-polarised components in the radiation pattern.
4. It improves isolation between reflector and primary feed.
Which of these statements are correct?
(a) 1 and 2 (b) 3 and 4
(c) 1 and 3 (d) 2 and 4
[ESE-1999]

5.8 In a radar system, if the peak transmitted power is increased by a factor of 16 and the antenna diameter is increased by a factor of 2, then the maximum range will increase by a factor of
(a) 16 (b) 8
(c) 4 (d) $\sqrt{8}$
[ESE-1999]

5.9 The electric field at a point from a transmitter radiating a certain power is 2.5 mV/m. If the transmitter power is doubled, the yield strength at that point will be about
(a) 2.5 mV/m (b) 3.5 mV/m
(c) 5 mV/m (d) 10 mV/m
[ESE-1999]

5.10 **Assertion (A):** One of the functions of the radar beacon is to identify itself.
Reason (R): Radar beacon cannot operate over a large distance.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE-1999]

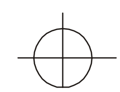
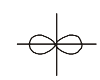
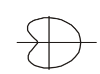
5.11 For identifying a radar target in a non-lossy medium, the range of the target is to be doubled, the *RF* power radiated must be increased by
(a) 2 times (b) 4 times
(c) 8 times (d) 16 times
[ESE-1999]

5.12 An altimeter is basically
(a) a CW radar
(b) a FM radar
(c) a Doppler radar
(d) a device to indicate the direction at height
[ESE-2000]

5.13 An antenna has 40 Ω antenna resistance and 60 Ω radiation resistance. The efficiency of the antenna is
(a) 30% (b) 40%
(c) 50% (d) 60% [ESE-2000]

5.14 **Assertion (A):** A knowledge of the amplitude and the phase of the field at each point at the mouth of a horn antenna may be used to predict the expected radiation pattern.
Reason (R): The electromagnetic field at any point in space may be obtained by considering each point on a wavefront as a source of spherical waves and superimposing the effect of all those sources at that point.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

5.15 Match **List-I** (Antennas) with **List-II** (Radiation patterns) and select the correct answer:

List-I	List-II
A. Simple dipole	**1.** 
B. Omni-directional antenna	**2.** 
C. Loop antenna	**3.** 

Codes:

	A	B	C
(a)	1	2	3
(b)	2	1	1
(c)	3	2	1
(d)	1	1	2

[ESE-2000]

5.16 A vertical wire of 1m length carries a current of 1 A at 10 MHz. The total radiated power is nearly
(a) 0.13 W (b) 0.88 W
(c) 7.3 W (d) 73 W [ESE-2000]

5.17 A Yagi antenna has a driven antenna
(a) only with a director
(b) only with a reflector
(c) with one or more directors
(d) with a reflector and one or more directors
[ESE-2000]

■■■

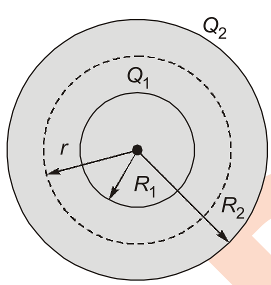
Answers Electromagnetics

1.1	(b)	1.2	(b)	1.3	(c)	1.4	(c)	1.5	(a)	1.6	(b)	1.7	(b)	1.8	(c)	1.9	(c)
1.10	(c)	1.11	(a)	1.12	(d)	2.1	(c)	2.2	(a)	2.3	(a)	2.4	(d)	2.5	(c)	2.6	(b)
2.7	(b)	2.8	(d)	2.9	(c)	2.10	(b)	2.11	(a)	2.12	(d)	2.13	(a)	2.14	(b)	3.1	(b)
3.2	(c)	3.3	(c)	3.4	(b)	3.5	(b)	3.6	(c)	3.7	(c)	3.8	(d)	3.9	(d)	3.10	(c)
3.11	(c)	4.1	(c)	4.2	(d)	4.3	(b)	4.4	(c)	4.5	(a)	5.1	(c)	5.2	(c)	5.3	(b)
5.4	(c)	5.5	(a)	5.6	(b)	5.7	(a)	5.8	(c)	5.9	(b)	5.10	(c)	5.11	(d)	5.12	(a)
5.13	(d)	5.14	(b)	5.15	(b)	5.16	(b)	5.17	(d)								

Explanations Electromagnetics

1. Basic of Electromagnetics

1.1 (b)



where, $r < R$

$E = 0$ as charge enclosed is zero

Applying Gauss Law for

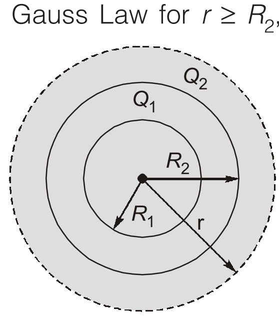
$R_1 \le r < R_2$,

$$\oiint_s \vec{E} \cdot d\vec{s} = \frac{Q_1}{\epsilon_o}$$

$$E \cdot 4\pi r^2 = \frac{Q_1}{\epsilon_o}$$

$$E = \frac{Q_1}{4\pi \epsilon_o r^2}$$

Applying Gauss Law for $r \ge R_2$,



$$\Rightarrow \oiint_s \vec{E} \cdot d\vec{s} = \frac{Q_1 + Q_2}{\epsilon_o}$$

$$E \cdot 4\pi r^2 = \frac{Q_1 + Q_2}{\epsilon_o}$$

$$E = \frac{Q_1 + Q_2}{4\pi \epsilon_o r^2}$$

Plot of E vs r will be the same as drawn in the question.

1.2 (b)

At equilibrium, since the lower ball does not move, Coulombic force will be equal to gravitational force.

$$\frac{q_1 q_2}{4\pi \epsilon_o r^2} = mg$$

where r is the separation between the two balls.

$$\frac{2 \times 10^{-6} \times 2 \times 10^{-6} \times 9 \times 10^9}{r^2} = 5 \times 10^{-3} \times 9.8$$

$$\Rightarrow \quad r^2 = 0.7347$$

$$\Rightarrow \quad r = 0.857 \text{ m} = 857 \text{ mm}$$

1.3 (c)

Laplace operator is second order derivative with space.

Continuous means giving same function after second order derivative which means it is harmonic.

1.4 (c)

By Poisson's equation:

$$\nabla^2 V = -\frac{\rho_v}{\varepsilon_0}$$

$$\frac{1}{r^2}\left[\frac{\partial}{\partial r} r^2 \frac{\partial}{\partial r}\left(-\frac{6r^5}{\varepsilon_0}\right)\right] = -\frac{\rho_v}{\varepsilon_0}$$

$$\rho_v = 30r^3$$

$$Q = \iiint \rho_v \, dv$$

$$= \int_{r=0}^{1}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} 180r^3 \cdot r^2 \sin\theta d\phi \, d\theta \, dr$$

$$= 180\frac{r^6}{6}\Big|_0^1 \cdot (-\cos\theta)\Big|_0^\pi \times 2\pi$$

$$= 180 \times \frac{1}{6} \times 2 \times 2\pi = 120\pi C$$

1.5 (a)

Applying $\nabla^2 V = -\frac{\rho_v}{\in}$ Poisson's equation

V is a function of ρ.

$$\nabla^2 V = \frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho \frac{\partial V}{\partial \rho}\right) = -\frac{\rho_v}{\in}$$

$$\rho_v = -10^{-8}(1 + 10\rho)$$

All initial conditions on the inner cylinder being zero (V and E both).

Solving for V gives 0.5 V.

1.6 (b)

The conductor has a very large number of free electrons and because it is electrical neutral the net charge within a conductor is always zero.

1.8 (c)

$$I_1 = \oint \vec{H} \cdot d\vec{l}$$

$$\frac{I}{\pi R^2} \cdot \pi r^2 = H \times 2\pi r$$

$$\Rightarrow \quad H = \frac{Ir}{2\pi R^2}$$

1.9 (c)

$$\nabla \cdot \vec{J} = -\frac{\partial \rho_v}{\partial t} \text{ general continuity equation}$$

The equation of continuity for steady currents is

$$\nabla \cdot \vec{J} = 0 \text{ for charge free region}$$

1.10 (c)

$$V_{ind} = -N\frac{d\phi}{dt}$$

$$= -100\frac{d(t^3 - 2t)}{dt} \times 10^{-3}$$

$$V_{ind}\Big|_{t=4s} = -100 \cdot (3t^2 - 2)\Big|_{t=4} \times 10^{-3}$$

$$= 100 \times (3 \times 4^2 - 2) \times 10^{-3}$$

$$= 4.6 \text{ V}$$

1.11 (a)

Lorentz law

$$F = Q(V \times B)$$

$$B = \frac{\text{Newton}}{\text{Coulomb} \times \frac{\text{meters}}{\text{second}}}$$

$$= \frac{\text{Mass} \times \text{Acceleration}}{\text{Coulomb} \times \frac{\text{meters}}{\text{second}}}$$

$$B = \frac{MLT^{-2}}{Q\frac{L}{T}} = MT^{-1}Q^{-1}$$

1.12 (d)

The solution of Poisson's equation is not same as that of Laplace's equation.

2. Uniform Plane Waves

2.1 (c)

For total reflection, angle of refraction $\theta_r = 90°$.

$$\frac{\sin\theta_i}{\sin\theta_r} = \sqrt{\frac{\in_{r_2}}{\in_{r_1}}}$$

$$\Rightarrow \quad \sin\theta_i = \sqrt{\frac{\in_{r_2}}{\in_{r_1}}} \cdot \sin 90°$$

$$\Rightarrow \quad \sin\theta_i = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \quad \theta_i = 45°$$

$\Rightarrow$ Angle of incidence $\theta_i = 45°$ for total reflection.

2.2 (a)

$$\nabla^2 F = \frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial z^2}$$

$$F = e^{-\alpha z}\sin\frac{\omega}{V}(x - Vt)$$

$$\frac{\partial F}{\partial x} = \frac{\omega}{V} e^{-\alpha z} \cos \frac{\omega}{V}(x - Vt)$$

$$\frac{\partial^2 F}{\partial x^2} = -\frac{\omega^2}{V^2} e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt)$$

$$\frac{\partial F}{\partial z} = -\alpha e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt)$$

$$\frac{\partial^2 F}{\partial z^2} = \alpha^2 e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt)$$

$$\therefore \nabla^2 F = -\frac{\omega^2}{V^2} e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt) + \alpha^2 e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt)$$

$$\Rightarrow \nabla^2 F = e^{-\alpha z} \sin \frac{\omega}{V}(x - Vt)\left[-\frac{\omega^2}{V^2} + \alpha^2\right]$$

$$\Rightarrow \nabla^2 F = F\left[\alpha^2 - \frac{\omega^2}{V^2}\right]$$

$$\therefore \alpha^2 - \frac{\omega^2}{V^2} = \frac{1}{C^2}$$

$$\Rightarrow \alpha^2 - \frac{1}{C^2} = \frac{\omega^2}{V^2}$$

$$\Rightarrow \frac{\alpha^2 C^2 - 1}{C^2} = \frac{\omega^2}{V^2}$$

$$\Rightarrow V = \frac{\omega C}{(\alpha^2 C^2 - 1)^{1/2}} = \omega C(\alpha^2 C^2 - 1)^{-1/2}$$

2.3 (a)

Phase velocity

$$v_p = \frac{c}{\sqrt{\epsilon_r}} = \frac{3 \times 10^8}{\sqrt{4}}$$

$$= 1.5 \times 10^8 \text{ m/s}$$

2.4 (d)

Given that

$$E_t = -2E_r$$

where E_t = Electric field of transmitted wave

E_r = Electric field of reflected wave

Or $$\frac{E_t}{E_i} = -\frac{2E_r}{E_i}$$

where E_i = Electric field of incident wave.

But $$\frac{E_t}{E_i} = \frac{2\eta_2}{\eta_2 + \eta_1}$$

and $$\frac{E_r}{E_i} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

So, $$\frac{2\eta_2}{\eta_2 + \eta_1} = -2\frac{(\eta_2 - \eta_1)}{\eta_2 + \eta_1}$$

$$\Rightarrow \eta_2 = -\eta_2 + \eta_1$$

$$\Rightarrow \frac{\eta_1}{\eta_2} = 2$$

But $$\eta \propto \frac{1}{\sqrt{\epsilon}}$$

So, $$\sqrt{\frac{\epsilon_2}{\epsilon_1}} = 2$$

or $$\frac{\epsilon_2}{\epsilon_1} = 4$$

2.5 (c)

Brewster's angle: This is the angle of incidence for parallel polarized wave for which the reflection coefficient is zero and the electromagnetic wave is transmitted completely in the second medium.

$$\tan \theta_B = \sqrt{\frac{\epsilon_2}{\epsilon_1}}$$

where, θ_B = Brewster's angle

2.6 (b)

Since the wave is incident at Brewster angle, the component normal to the interface will be the only component which is parallel to the interface. Hence the reflected wave is linearly polarized.

2.7 (b)

Free space properties are

$\sigma = 0$ conductivity

$\mu_R = \epsilon_R = 1$

$\bar{p} = 0$ dipole moment

$\bar{j} = 0$ current density

2.8 (d)

$$\text{Phase difference} = \frac{2\pi}{\lambda}.\ \text{Path difference}$$

$$90 = \frac{2 \times 180}{\lambda} \times 3 \times 10^{-3}$$

$$\Rightarrow \lambda = 12 \times 10^{-3} \text{ m}$$

$$v = \frac{c}{\sqrt{\epsilon_r}} = \lambda f$$

$$\frac{3\times10^8}{\sqrt{\epsilon_r}} = 12 \times 10^{-3} \times 10 \times 10^9$$

$$\Rightarrow \quad \sqrt{\epsilon_r} = 2.5$$

$$\Rightarrow \quad \epsilon_r = 6.25$$

2.9 (c)

By Snell's law

$$n_1 \sin\theta_i = n_2 \sin\theta_r$$

But $\quad n_2 = \sqrt{\epsilon_r}$

So, $\quad \sin 30 = \sqrt{2.7}\cdot\sin\theta_r$

$$\Rightarrow \quad \sin\theta_r = 0.3$$

$$\Rightarrow \quad \theta_r = 17.7$$

$$\Rightarrow \quad \theta_r \approx 18^\circ$$

2.11 (a)

Dimension of $\vec{E}$ = Volt/m

Dimension of $\vec{H}$ = Ampere/m

Dimension of $\vec{P} = \vec{E}\times\vec{H}$ is

$$\frac{\text{Volt}}{\text{m}}\cdot\frac{\text{Ampere}}{\text{m}} = \frac{\text{Watt}}{\text{m}^2}$$

or dimension of $\vec{P}$ = Power/Unit area

2.13 (a)

Velocity, $\quad v = \dfrac{c}{\sqrt{\mu_r\,\epsilon_r}}$

$$= \frac{3\times10^8}{\sqrt{4.5\times2}} = 1\times10^8 \text{ m/s}$$

2.14 (b)

Magnitude of time average Poynting vector

$$|\vec{P}| = \frac{1}{2}\eta H^2 = \frac{1}{2}\times120\pi\times(0.1)^2$$

$$|\vec{P}| = 0.6\pi$$

The direction of propagation is $-y$ direction.

So, $\quad \vec{P} = -0.6\pi\,\hat{a}_y \text{ W/m}^2$

3. Transmission Lines

3.1 (b)

Load, $\quad Z_L = Z_o\left(\dfrac{1+|\Gamma|}{1-|\Gamma|}\right) = 50\left(\dfrac{1+0.268}{1-0.268}\right)$

$$\Rightarrow \quad Z_L = 86.612\ \Omega$$

Reflected voltage,

$$V_r = |\Gamma|\,V_{in} = 0.268\times15 = 4.02\text{ V}$$

Voltage across load,

$$V_L = V_{in} - V_r = 15 - 4.02$$

$$\Rightarrow \quad V_L = 10.98\text{ V}$$

Net power delivered to the load,

$$P_L = \frac{V_L^2}{R_L} = \frac{(10.98)^2}{86.612} = 1.39\text{ W}$$

3.2 (c)

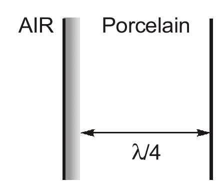
$$\frac{v}{\sqrt{\epsilon_r}} = \frac{1}{\sqrt{LC}} \quad \text{...(i)}$$

$$Z_o = \sqrt{\frac{L}{C}} \quad \text{...(ii)}$$

$$\frac{vZ_o}{\sqrt{\epsilon_r}} = \frac{1}{C}$$

$$\Rightarrow \quad Z_o = \frac{\sqrt{\epsilon_r}}{vC}$$

3.3 (c)

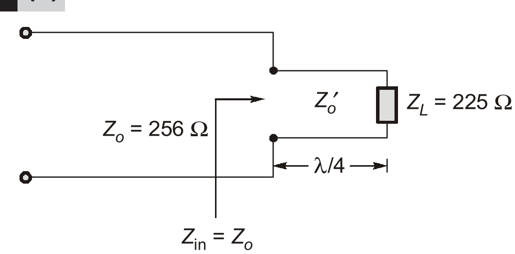


The porcelain plate of λ/4 thickness reduces reflections similar to a quarterwave transformer.

$$\text{Thickness} = \frac{\lambda}{4} = \frac{3\times10^8}{\sqrt{\epsilon_R}\times10\times10^9}\times\frac{1}{4}$$

$$= 0.53\text{ cm}$$

3.4 (b)



Characteristic impedance of QWT

$$Z_o' = \sqrt{Z_o Z_L}$$

$$= \sqrt{256\times225} = 16\times15 = 240\ \Omega$$

3.5 (b)

Distortionless when $LG = RC$

or $\alpha = \sqrt{RG}$ and $\beta = \omega\sqrt{LC}$

when calculated from γ.

α is constant and independent of frequency.

β is linear function of frequency.

3.6 (c)

Reflection coefficient

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

$$\Rightarrow \quad |\Gamma| = \frac{3-1}{3+1}$$

$$\Rightarrow \quad |\Gamma| = \frac{2}{4} = \frac{1}{2}$$

3.7 (c)

Characteristic impedance

$$Z_o = \sqrt{\frac{L}{C}}$$

$$\Rightarrow \quad L = CZ_0^2$$

$$\Rightarrow \quad L = 40 \times 10^{-12} \times (50)^2$$

$$\Rightarrow \quad L = 0.1\ \mu\text{H/m}$$

3.8 (d)

Propagation constant,

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

In a lossless line,

$$R = 0$$

and $G = 0$

For a lossless line,

$$\gamma = \sqrt{(j\omega L)(j\omega C)}$$

or $\gamma = j\omega\sqrt{LC}$

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

So, $\alpha = 0$

$$\beta = \omega\sqrt{LC}$$

So, $\beta = |\gamma|$

3.9 (d)

Reflection coefficient

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$\Gamma = \frac{40 + j30 - 50}{40 + j30 + 50}$$

$$\Gamma = \frac{-10 + j30}{90 + j30}$$

$$|\Gamma| = \frac{\sqrt{(10)^2 + (30)^2}}{\sqrt{(90)^2 + (30)^2}}$$

$$\rho = \frac{1}{3}$$

$$\text{VSWR} = \frac{1+\rho}{1-\rho}$$

$$\Rightarrow \quad \text{VSWR} = \frac{1+\frac{1}{3}}{1-\frac{1}{3}}$$

$$\Rightarrow \quad \text{VSWR} = 2$$

3.10 (c)

The best way for the impedance matching is to use a short-circuited stub at a specific distance from the load.

3.11 (c)

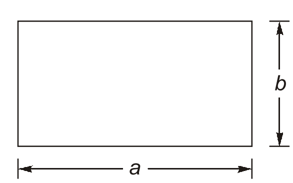
Characteristic impedance of quarter-wave transformer is

$$Z_o = \sqrt{Z_S Z_L} = \sqrt{75 \times 300} = 150\ \Omega$$

4. Waveguides

4.1 (c)

$$f_c = \frac{3 \times 10^{10}}{2 \times 2.29} = 6.55\ \text{GHz}$$



Maximum power handling capacity of the waveguide for the TE mode is

$$P = \frac{E_m^2}{4\eta} \cdot ab\ \text{W}$$

(Maximum power when voltage is half of input)

$$= \frac{E_m^2}{4\left(\dfrac{\eta_o}{\sqrt{1-(f_c/f)^2}}\right)} \cdot ab$$

$$= \frac{\sqrt{1-(f_c/f)^2}}{4\eta_o} \cdot E_m^2 \cdot ab$$

$$= \frac{\sqrt{1-\left(\frac{6.55}{11}\right)^2}}{4\times 120\pi} \times (5\times 10^5)^2 \times 2.29 \times 1.02 \times 10^{-4}$$

$$= 31.11 \text{ kW}$$

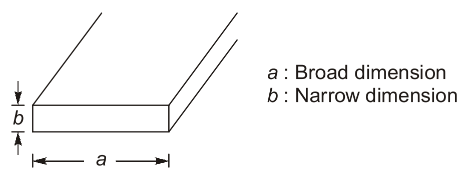
4.2 (d)

V_p depends on ω means

β depends on ω^2

i.e. non-linear function of $\beta(\omega)$

4.3 (b)



Cut-off frequency of rectangular waveguide, for dominant mode (TE_{10})

$$f_c = \frac{c}{2a}$$

Wave impedance for dominant mode in rectangular waveguide,

$$\eta_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

Guided wavelength in rectangular waveguide for dominant mode,

$$\lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

When narrow side dimension decrease neither η_{TE} nor λ_g changes.

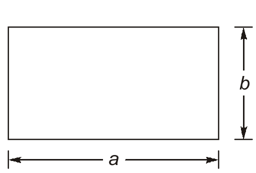
Therefore statement (1) and statement (3) is wrong

Narrow side dimension determine attenuation with inverse dependency as $\alpha = k/b$. Attenuation increases with narrow side dimension.

Power handling = Density × ab (area)

This decreases with narrow side dimension.

4.4 (c)



Cutoff wavelength in a rectangular waveguide for TE_{mn} mode is

$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

For TE_{20}, $$\lambda_c = \frac{2}{\sqrt{\left(\frac{2}{a}\right)^2 + 0}} = \frac{2a}{2} = a$$

4.5 (a)

$$v_p = \frac{c}{\cos\theta} \qquad v_g = c\cdot\cos\theta$$

where θ = path angle inside the guide.

$$v_p \cdot v_g = c^2$$

5. Antennas and Radar

5.1 (c)

$$E_\theta = \frac{I_m}{2}\frac{dl}{\lambda}\frac{\sin\theta}{r}\eta$$

$$H_\phi = \frac{I_m}{2}\frac{dl}{\lambda}\frac{\sin\theta}{r}$$

$$\text{Power} \propto \frac{\eta}{\lambda^2}$$

$$\eta = \sqrt{\frac{\mu}{\in}} \; ; \; \beta = \omega\sqrt{\mu\in} = \frac{2\pi}{\lambda}$$

$$\text{Power} \propto \in$$

5.2 (c)

Radiation resistance of half-wave dipole

$$R_{rad} = 73 \ \Omega$$

Radiated power,

$$P_r = I_{rms}^2 \cdot R_{rad}$$

$$P_r = 4\times\left(\frac{0.5}{\sqrt{2}}\right)^2 \times 73 = 36.5 \text{ W}$$

5.3 (b)

$$\text{Gain} = \frac{4\pi}{\theta_{HPBW}\times\phi_{HPBW}} = \frac{4\pi}{(\theta_{HPBW})^2}$$

$$\text{Gain} = 44 \text{ dB} = 10^{4.4}$$

In degrees $4\pi = 4 \times 3.14 \times 57° \times 57°$

$$\text{Gain} = 10^{4.4} = \frac{40800}{(\theta_{HPBW})^2}$$

$$\theta_{HPBW} = 1.42°$$

5.4 (c)

$$\text{Efficiency} = \frac{W_r}{W_{in}} = \frac{\text{Out power radiated}}{\text{Input power}}$$

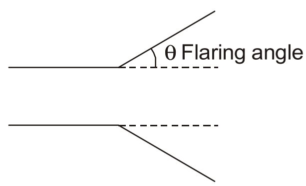
$$= \frac{I^2R_r}{I^2R_r + I^2R_l} = \frac{R_r}{R_r + R_l}$$

$\lambda/8$ antenna $R_r = 18.25\ \Omega$

$$\text{Efficiency} = \frac{18.25}{19.75} \cong 92\%$$

5.5 (a)

Flare angle is mouth angle of the horn.



Smaller flare angle means lesser dispersion and scattering and hence field is most likely to be TE_{10}.

Mode filter means eliminating other modes other than given input mode TE_{10}. Narrow flare angle is therefore a mode filter.

5.6 (b)

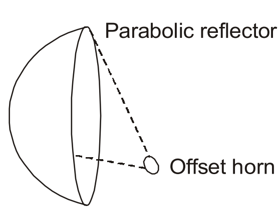
To measure the antennas performance in any aspect the near field or $\frac{1}{r^2}$ and $\frac{1}{r^3}$ have to be neglected. The radiation field $\frac{1}{r}$ term should be strong enough ignoring $\frac{1}{r^2}$ and $\frac{1}{r^3}$.

This distance is called as Fraunhofer zone where measurements are carried.

$$r > \frac{2D^2}{\lambda}$$

Where D is the biggest dimension of the antenna.

5.7 (a)



Offset feed is a mechanism where the feed horn placed below the conductor and focussed on the parabolic reflector.

It is used to reduce aperture blocking and use of two polarizations from two sides.

5.8 (c)

$$R_{max} = \left[\frac{P_t A_e^2 \sigma}{4\pi\lambda^2 S_{min}}\right]^{1/4}$$

$$\Rightarrow \quad R_{max} \propto [P_t \cdot A_e^{\,2}]^{1/4}$$

$$\Rightarrow \quad R_{max} \propto [P_t \cdot D^4]^{1/4}$$

$$\Rightarrow \quad R'_{max} = [16 \times (2)^4]^{1/4} R_{max}$$

$$\Rightarrow \quad R'_{max} = 4\ R_{max}$$

5.9 (b)

$$P \propto E^2$$

$$\Rightarrow \quad E \propto \sqrt{P}$$

$$\Rightarrow \quad \frac{E_2}{E_1} = \sqrt{\frac{P_2}{P_1}} = \sqrt{2}$$

$$\Rightarrow \quad E_2 = 2.5 \times \sqrt{2}$$

$$\Rightarrow \quad E_2 = 3.5 \text{ mV/m}$$

5.11 (d)

$$P_t \propto (R)^4$$

$$P_r = \frac{P_t\, G_t\, A_e\, \sigma}{(4\pi)^2\, R^4}$$

$$\Rightarrow \quad P_t \propto R^4$$

5.12 (a)

The FM-CW radar principle is used in the aircraft radio altimeter to measure height above the surface of the earth. Since the relative motion between the aircraft and ground is small, the effect of the Doppler frequency shift may usually be neglected.

5.13 (d)

Radiation resistance,

$$R_{rad} = 60\ \Omega$$

Antenna resistance,

$$R_{ant} = 40\ \Omega$$

Efficiency of the antenna,

$$\eta = \frac{R_{rad}}{R_{rad} + R_{ant}} \times 100$$

$$\Rightarrow \quad \eta = \frac{60}{60 + 40} \times 100 = 60\%$$

5.14 (b)

Radiation pattern is a function of field or power strength.

Every ray is a source of secondary emissions-Huygen's wave principle.

5.15 (b)

Simple dipole is vertically sinθ dependent.

Omin-directional antenna has spherical pattern.

Loop antenna is for direction finding on horizontal earth.

Therefore strictly uni-directional pattern.

5.16 (b)

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{10\times10^6} = 30 \text{ m}$$

Radiation resistance,

$$R_{rad} = 80\pi^2\left(\frac{dl}{\lambda}\right)^2$$

$$= 80\pi^2\left(\frac{1}{30}\right)^2 = 0.88\ \Omega$$

Total radiated power,

$$P_r = I^2 R_{rad} = (1)^2 \times 0.88 = 0.88 \text{ W}$$

5.17 (d)

Single reflector for uni-directional beam and multiple directors for increasing gain and decreasing beam angle.

■■■

4 Computer Organization and Architecture

2. I/O Organisation and Pipelining

2.1 The method used to transfer data from I/O units to memory by suspending the memory-CPU data transfer for one memory cycle is called
(a) I/O spooling (b) cycle stealing
(c) line conditioning (d) demand paging
[ESE-1999]

2.2 Consider the following statements:
The horizontal microinstruction has
1. longer control word than vertical microinstruction.
2. high degree of parallelism.
3. slower execution than vertical microinstruction.
Which of these statements is/are correct?
(a) 1 alone (b) 2 alone
(c) 1 and 2 (d) 2 and 3 [ESE-2000]

3. Memory Organisation

3.1 The principle of locality of reference justifies the use of
(a) interrupts (b) DMA
(c) virtual memory (d) cache memory
[ESE-1999]

3.2 The access time of a word in a 4 MB main memory is 100 ns. The access time of a word in a 32 kB data cache memory is 10 ns. The average data cache hit ratio is 0.95. The effective memory access time is
(a) 9.5 ns (b) 14.5 ns
(c) 20 ns (d) 95 ns
[ESE-1999]

3.3 If a RAM has 34 bits in its MAR and 16 bits in its MDR, then its capacity will be
(a) 32 GB (b) 16 GB
(c) 32 MB (d) 16 MB
[ESE-2000]

3.4 **Assertion (A):** LRU (Least Recently Used) replacement policy is not applicable to direct mapped caches.
Reason (R): A unique memory page is associated with every cache page in direct mapped caches.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

3.5 **Assertion (A):** Most personal computers use static RAMs for their main memory.
Reason (R): Static RAMs are much faster than dynamic RAMs.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE-2000]

4. Data Representation and Programming

4.1 Consider the following features:
1. Negative operands cannot be used.
2. When immediate operand changes, the program should be reassembled.
3. The program is difficult to read.
4. The size of operand is restricted by word length of the computer.
Disadvantages of immediate addressing include
(a) 1 and 2 (b) 2 and 4
(c) 2 and 3 (d) 1 and 4
[ESE-1999]

4.2 **Assertion (A):** The top down structured programming should be used for developing programs.

Reason (R): The top down structured programming methodology enables us to get readable and easily provable programs.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-1999]**

4.3 Consider the following statements:
1. An assembly language program runs faster than a high level language program to produce the desired result.
2. An assembler which runs on a computer for which it produces object codes is called a resident assembler.
3. A cross-assembler is an assembler that runs on a computer than that for which it provides machine codes.
4. A one-pass assembler reads the assembly language programs only once.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1 and 4 (d) 1, 2, 3 and 4
[ESE-1999]

4.4 The software that transfers the object program from secondary memory to the main memory is called

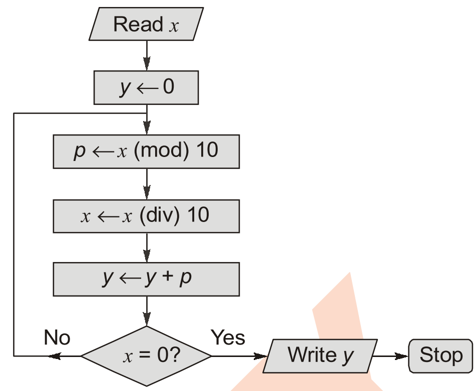
(a) assembler (b) loader
(c) linker (d) task builder
[ESE-1999]

4.5 **Assertion (A):** The 'do-while' statements is used less frequently than the 'while' statement.

Reason (R): For most applications, it is more natural to test for continuation of a loop at the beginning rather than at the end of the loop.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-1999]**

4.6 If the value of x in decimal number 3954, the value of y in decimal number computed by the given flow chart is



(a) 20 (b) 22
(c) 21 (d) 3954
[ESE-2000]

4.7 In *C* language, *f*– = 9 is equivalent to

(a) $f = -9$ (b) $f = f - 9$
(c) $f = 9 - 1$ (d) $-f = 9$ **[ESE-2000]**

4.8 A primitive computer uses a single register. The following fragment of assembly code is written for the machine

```
LOAD X
MULT Y
STORE T1
MULT T1
STORE T1
LOAD Z
ADD Y
ADD T1
STORE R
```

Which one of the following expressions is evaluated?

(a) $R := (XY) + Y + Z$
(b) $R := (XY)^2 + Y + Z$
(c) $R := (XY)^2 \pm Y + Z$
(d) $R : XY^2 + (Y + Z)$ **[ESE-2000]**

6. Operating Systems and Data Bases

6.1 Which one of the following is loaded in the main memory by the bootstrap loader?

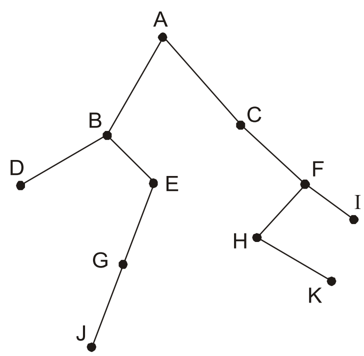
(a) System data (b) User program
(c) BIOS (d) Parts of DOS
[ESE-2000]

5. Data Structures

5.1 The expression for the infix equivalent of the prefix form of + – * ↑ *ABCD*/*E*/*F* + *GH* will be

(a) $A^{B*C} - D + E / F / G + H$
(b) $A^{B} * C - D + E / F / G + H$
(c) $A^{B} * C - D + E / F / (G + H)$
(d) $A^{B} * C - D + E / (F / (G + H))$ [ESE-1999]

5.2 If the given binary tree is traversed in post-order



then the order of nodes visited is
(a) J G E D B K H I F C A
(b) D B J G E A K H F I C
(c) D J G E B K H I F C A
(d) A B D E G J C F H K I [ESE-1999]

5.3 A single edge is added to a tree without increasing the number of nodes. The number of cycles in the resulting graph is equal to
(a) zero (b) one
(c) two (d) indeterminate
[ESE-2000]

5.4 The prefix form of the expression $X + Y - Z$ is
(a) $- + XYZ$ (b) $+ - XYZ$
(c) $XYZ - +$ (d) $XYZ + -$
[ESE-2000]

7. Miscellaneous

7.1 A PASCAL function is defined as calc (var *A*: real; *B*: real): real; begin
X : = 3.0;
Y : = 3.0;
calc: = 5.0*A+(B – A);
end;
If this function was called
X : = 7.0;
Y : = 1.0;
R : = calc (*X*, *Y*);
the value of R would be
(a) 15 (b) 29
(c) 13 (d) 31
[ESE-1999]

■■■

Answers Computer Organization and Architecture

2.1	(b)	2.2	(c)	3.1	(d)	3.2	(b)	3.3	(a)	3.4	(d)	3.5	(d)				
4.1	(b)	4.2	(d)	4.3	(d)	4.4	(b)	4.5	(a)	4.6	(c)	4.7	(b)	4.8	(b)	5.1	(d)
5.2	(c)	5.3	(b)	5.4	(a)	6.1	(c)	7.1	(b)								

Explanations Computer Organization and Architecture

2. I/O Organisation and Pipelining

2.1 (b)

One memory cycle is used to transfer data from I/O to memory when DMA is operating in cycle stealing mode.

2.2 (c)

Horizontal microstructure has:
(a) 1 bit/control signal (longer control word)
(b) little encoding (faster)
(c) high degree of parallelism (more than 1 control signal enabled at a time).

3. Memory Organisation

3.1 (d)

Cache memory works on the principle of locality of reference. The principle of locality of reference states that "the references to memory at any given interval of time tends to be confined to within localized areas of memory". In cache, by placing most frequently used data and instructions in a small cache the average access time can be minimized.

3.2 (b)

Effective memory access time
= Hit ratio × access time in cache memory + (1 – Hit ratio) × access time in main memory
= 0.95 × 10 + (1 – 0.95) × 100
= 9.5 + 5 = 14.5 ns

3.3 (a)

MAR stores address-bits
⇒ 34 bits of address bus.
MDR stores data
⇒ 16-bits of data,
Capacity of RAM = $2^{34} * 16$ bits = 32 GB

3.4 (d)

Direct mapped cache forces to use a specific block only, inspite other are free because of (KMODN) rule i.e. K^{th} main memory block in $(KMODN)^{th}$ cache location.
Where N = number of blocks in cache.
Thus, LRU replacement policy is not applicable and Reason (R) is also false.
Every main memory block has fixed location in cache i.e. the i^{th} block of a page must be mapped to i^{th} block of cache.

3.5 (d)

Dynamic RAMs are used in the main memory, whereas Static RAMs are used in cache memory. Cache memory is faster than main memory because Static RAMs are much faster than Dynamic RAMs.

4. Data Representation and Programming

4.1 (b)

Immediate addressing:
Ex: MOV A, 10;

- Negative operands can used;
  MOV A, –10;
- When immediate operand changes, the program should be reassembled by changing data of instruction.
  MOV A, 10; ⇒ MOV A, 20;
- The program is easier to read when we use immediate addressing.
- The size of the operand is restricted by word length of the computer.

∴ Option (b) is correct.

4.2 (d)

Top down structured programming need not be used for developing programs.
Top down approach is readable and easy to prove.

4.4 (b)

A loader is a program which loads object code from secondary memory to main memory.

4.5 (a)

'do-while' statement is used less frequently compared to while. Most applications depend on the condition (test) at loop beginning, to execute the loop instead at the end of loop.

4.6 (c)

$x = 3954$
$y = 0$
$p =$ remainder of 3954/10
$\Rightarrow$ $p = 4$
$x =$ greatest integer of 3954/10
$\Rightarrow$ $x = 395$
$y = 0 + 4 = 4$
Since $x \neq 0$, loop will continue.
$p =$ remainder of 395/10
$= 5$
$x =$ greatest integer of 395/10
$= 39$
$y = 4 + 5 = 9$
Since, $x \neq 0$, loop will continue.
So $p =$ remainder of 39/10
$= 9$
$x =$ greatest integer of 39/10
$= 3$
$y = 9 + 9 = 18$
Since $x \neq 0$, loop will continue.
So $p =$ remainder of 3/10
$= 3$
$x =$ greatest integer of 3/10
$= 0$
$y = 18 + 3 = 21$
Since $x = 0$, y has final value.
$y = 21$

4.7 (b)

$f -= q;$	$f *= 9;$	$f /= 9;$
$\Downarrow$	$\Downarrow$	$\Downarrow$
$f = f - 9;$	$f = f * 9;$	$f = f / 9;$

$-=$, $*=$, etc. are called as multi character operator.

4.8 (b)

Assembly code		Operation
LOAD	X	X
MULT	Y	XY
STORE	T1	XY
MULT	T1	$(XY)^2$
STORE	T1	$(XY)^2$
LOAD	Z	Z
ADD	Y	Z + Y
ADD	T1	$Z + Y + (XY)^2$
STORE	R	R: $= (XY)^2 + Y + Z$

5. Data Structures

5.1 (d)

$A^B * C - D + E/(F/(G + H))$: Infix expression

$\Rightarrow$ $A \uparrow B * C - D + E/(F/(G + H))$

Convert it into prefix

$A \uparrow B * C - D + E/(F/+GH)$

$\Rightarrow$ $A \uparrow B * C - D + E// F + GH$

$\Rightarrow$ $\uparrow AB * C - D + E// F + GH$

$\Rightarrow$ $*\uparrow ABC - D + /E/ F + GH$

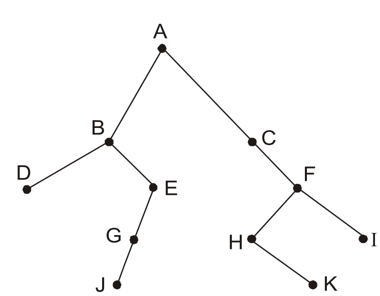
$\Rightarrow$ $- *\uparrow ABCD + /E/ F + GH$

$\Rightarrow$ $+ - *\uparrow ABCD /E/ F + GH$

Note:

Order of precedence	Associativity
Parenthesis ( )	Left to right
Exponential $\uparrow$ or ^	Right to left
Multiplication or Division	Left to right
Addition or Substraction	Left to right

5.2 (c)



Post order traversal in a binary tree follows the order: Left-Right-Root (Recursively)

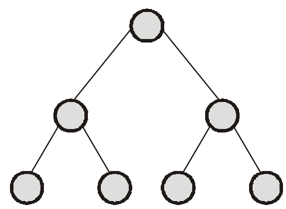
- First traverse the entire left subtree (recursively) and get the port order : DJGEB.
- Now traverse the entire right subtree (recursively) and get the post order : KHIFC

- At last add the root : A

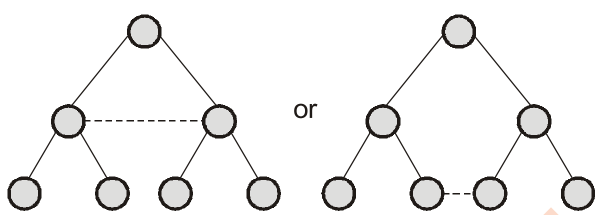
∴ The order of nodes visited in post order form is DJGEBKHIFCA.

5.3 (b)

The diagram shows a complete binary tree.



A tree is a graph with no cycles. If we add a new edge such that it forms a cycle as shown in figure, then we will have only one cycle.



5.4 (a)

Infix : X + Y – Z

Prefix : X + Y – Z

⇒ +X Y – Z

⇒ –+X Y Z

6. Operating Systems and Data Bases

6.1 (c)

BIOS is loaded in the main memory by the bootstrap loader.

7. Miscellaneous

7.1 (b)

$= 5 \times 7 + (1 - 7) = 35 - 6 = 29$

■■■

5 Microprocessors and Microcontrollers

1. 8085 Microprocessors

1.1 Match **List-I** (Pre terminals) with **List-II** (Applications) and select the correct answer using the code given below the lists:

List-I		List-II	
A.	SID, SOD	1.	Wait state
B.	Ready	2.	Interrupt
C.	TRAP	3.	Serial data transfer
D.	ALE	4.	Memory or I/O read/ write
		5.	Address latch control

Codes:

	A	B	C	D
(a)	3	1	5	2
(b)	3	1	2	5
(c)	4	3	2	5
(d)	4	3	1	2

[ESE-1999]

2. 8086 Microprocessors

2.1 In 8086 microprocessor, if the code segment register contains 1FAB and IP register contains 10A1, the effective memory address is

(a) 20B51 (b) 304C
(c) FBC0 (d) FDB5

[ESE-1999]

2.2 To have the multiprocessing capabilities of the 8086 microprocessor, the pin connected to the ground is

(a) $\overline{DEN}$ (b) ALE
(c) INTR (d) $MN/\overline{MX}$

[ESE-1999]

2.3 In 8086, if the content of the code segment register is 1FAB and the content of the IP register is 10A1, then the effective memory address is

(a) 1FBC0 (b) 304C
(c) FDB5 (d) 20B51

[ESE-2000]

2.4 Consider the following instructions executed in 8086.

PUSH AX; AX has 20 Hex in it
PUSH BX; BX has 34 Hex in it
POP AX;
ADD AX, BX;
POP G

The value stored in G would be

(a) 20 Hex (b) 34 Hex
(c) 54 Hex (d) 68 Hex

[ESE-2000]

■■■

Answers Microprocessors and Microcontrollers

1.1 (b) 2.1 (a) 2.2 (d) 2.3 (d) 2.4 (a)

Explanations Microprocessors and Microcontrollers

1. 8085 Microprocessors

1.1 (b)

A. SID - Serial input data
SOD - Serial output data } Serial data transfer

B. Ready - Wait state

C. TRAP - Hardware interrupt

D. ALE - Address latch enable control

2. 8086 Microprocessors

2.1 (a)

Effective memory address

= 1 FAB0 + 10A1 = 20 B51

2.2 (d)

To have the multiprocessing capabilities, 8086 microprocessor has to operate in the maximum mode which happens when pin $MN/\overline{MX}$ is low.

2.3 (d)

Effective memory address

= 1 FAB0 + 10 A1 = 20 B51

2.4 (a)

PUSH AX ; AX has 20H and pushed onto stack.
PUSH BX ; BX has 34H and pushed onto stack.
POP AX ; 34 H stored in AX from top of stack.
ADD AX, BX ; AX contains sum of 34H and 34H.
POP G ; 20H stored in G from top of stack.

The value stored in G is 20H.

■■■

6 Analog and Digital Communication Systems

1. Analog Communication Systems

1.1 A 10 kW carrier is sinusoidally modulated by two carriers corresponding to a modulation index of 30% and 40% respectively. The total radiated power is
(a) 11.25 kW (b) 12.5 kW
(c) 15 kW (d) 17 kW [ESE-1999]

1.2 In phase modulation, the frequency deviation is
(a) independent of the modulating signal frequency
(b) inversely proportional to the modulating signal frequency
(c) directly proportional to the modulating signal frequency
(d) inversely proportional to the square root of the modulating frequency
[ESE-1999]

1.3 An arbitrary signal $m(t)$ has zero average value and it is band-limited to 3.2 kHz. It is sampled at the rate of 8 k samples/s. The samples are passed through an ideal band-pass filter with centre frequency of 32 kHz and bandwidth of 6.4 kHz. The output of the band-pass filter is
(a) AM-DSB signal with suppressed carrier
(b) AM-DSB signal with carrier
(c) AM-SSB signal with carrier
(d) a sequence of exponentially decaying sine waves
[ESE-1999]

1.4 The correct sequence of subsystems in an FM receiver is
(a) mixer, RF amplifier, limiter, IF amplifier, discriminator, audio amplifier
(b) RF amplifier, mixer, IF amplifier, limiter, discriminator audio amplifier
(c) RF amplifier, mixer, limiter, discriminator, IF amplifier, audio amplifier
(d) mixer, IF amplifier, limiter, audio amplifier, discriminator
[ESE-1999]

1.5 In a superheterodyne receiver, the IF is 455 kHz, if it is tuned to 1200 kHz, the image frequency will be
(a) 1655 kHz (b) 745 kHz
(c) 2110 kHz (d) 910 kHz
[ESE-1999]

1.6 **Assertion (A):** Square law detectors are not particular satisfactory for the detection of modulated signals.
Reason (R): With square law detectors, harmonic distortion of as high as 25% occurs for a completely modulated signal.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-1999]

1.7 The signal $(1 + M\cos 4\pi t)\cos(2\pi \times 10^3\, t)$ contains the frequency component (in Hz)
(a) 998, 1000 and 1002
(b) 1000 and 2000
(c) dc, 2 and 1000
(d) ..., 996, 998, 1000, 1002, 1004, ...
[ESE-1999]

1.8 In an amplitude modulated system, if the total power is 600 W and the power in carrier is 400 W, then the modulation index is
(a) 0.5 (b) 0.75
(c) 0.9 (d) 1 [ESE-2000]

1.9 Which one of the following statements regarding the threshold effect in demodulators is correct?
(a) It is exhibited by all demodulators when the input signal to noise ratio is low
(b) It is the rapid fall in output signal to noise ratio when the input signal to noise ratio falls below a particular value

(c) It is the property exhibited by all AM suppressed carrier coherent demodulators
(d) It is the property exhibited by correlation receivers

[ESE-2000]

1.10 A band-pass signal has significant frequency components in the range of 1.5 MHz to 2 MHz. If the signal is to be reconstructed from its samples, the minimum sampling frequency will be
(a) 1 MHz (b) 2 MHz
(c) 3.5 MHz (d) 4 MHz

[ESE-2000]

1.11 A signal $m(t) = 5\cos(2\pi 100t)$ frequency modulates a carrier. The resulting FM signal is $10\cos\{(2\pi 10^5 t) + 15\sin(2\pi 100t)\}$
The approximate bandwidth of the FM signal would be
(a) 0.1 kHz (b) 1 kHz
(c) 3.2 kHz (d) 100 kHz

[ESE-2000]

1.12 The essential blocks of a phase lock loop (PLL) are phase detector, amplifier,
(a) high-pass filter and crystal controlled oscillator
(b) low-pass filter and crystal controlled oscillator
(c) high-pass filter and voltage controlled oscillator
(d) low-pass filter and voltage controlled oscillator

[ESE-2000]

2. Random Variables, Random Process & Noise

2.1 Consider a random sinusoidal signal $x(t) = \sin(\omega_0 t + \phi)$ where a random variable 'ϕ' is uniformly distributed in the range $\pm\pi/2$. The mean value of $x(t)$ is
(a) zero (b) $(2/\pi)\sin(\omega_0 t)$
(c) $2/\pi\cos(\omega_0 t)$ (d) $2/\pi$

[ESE-1999]

2.2 A system has a receiver noise resistance of 50 Ω. It is connected to an antenna with an input resistance of 50 Ω. The noise figure of the system is
(a) 1 (b) 2
(c) 50 (d) 101

[ESE-1999]

2.3 A linear system has the transfer function

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

When it is subjected to an input white noise process with a constant spectral density 'A', the spectral density of the output will be
(a) $\frac{1}{(j\omega+1)}$ (b) $\frac{A}{(j\omega+1)^2}$
(c) $\frac{A}{(\omega^2+1)}$ (d) $\frac{A}{\sqrt{(\omega^2+1)}}$

[ESE-2000]

3. Digital Communication Systems

3.1 Consider the following statements comparing delta modulation with PCM systems: DM requires
1. a lower sampling rate
2. a higher sampling rate
3. a large bandwidth
4. simpler hardware

Which of these statements are correct?
(a) 1, 2 and 4 (b) 1, 2, and 3
(c) 1, 3 and 4 (d) 2 and 4

[ESE-1999]

3.2 12 signals each band-limited to 5 kHz are to be transmitted over a single channel by frequency division multiplexing. If AM-SSB modulation guard band of 1 kHz is used, then the bandwidth of the multiplexed signal will be
(a) 51 kHz (b) 61 kHz
(c) 71 kHz (d) 81 kHz

[ESE-1999]

3.3 The bandwidth of a 'N' bit binary coded PCM signal for modulating a signal having bandwidth of 'f' Hz is
(a) $\frac{f}{N}$ Hz (b) $\frac{f}{N^2}$ Hz
(c) Nf Hz (d) $N^2 f$ Hz

[ESE-2000]

3.4 Time division multiplexing requires
(a) constant data transmission
(b) transmission of data samples
(c) transmission of data at random
(d) transmission of data of only one measurand

[ESE-2000]

3.5 A telephone channel has bandwidth B of 3 kHz and SNR ($S/\eta B$) of 30 dB. It is connected to a teletype machine having 32 different symbols. The symbol rate required for errorless transmission is nearly

(a) 1800 symbols/s (b) 3000 symbols/s
(c) 5000 symbols/s (d) 6000 symbols/s

[ESE-2000]

3.6 Quadrature multiplexing is

(a) same as FDM
(b) same as TDM
(c) a combination of FDM and TDM
(d) the scheme where same carrier frequency is used for two different signals

[ESE-2000]

3.7 A 8 kHz communication channel has an SNR of 30 dB. If the channel bandwidth is doubled, keeping the signal power constant, the SNR for the modified channel will be

(a) 27 dB (b) 30 dB
(c) 33 dB (d) 60 dB [ESE-2000]

3.8 The ramp signal $m(t) = at$ is applied to a delta modulator with sampling period T_s and step size δ. Slope overload distortion would occur if

(a) $\delta < a$ (b) $\delta > a$
(c) $\delta < aT_s$ (d) $\delta > aT_s$ [ESE-2000]

3.9 In a PCM system each quantisation level is encoded into 8 bits. The signal to quantisation noise ratio is equal to

(a) 24 dB (b) 48 dB
(c) 64 dB (d) 256 dB [ESE-2000]

3.10 If binary PSK modulation is used for transmission, the required minimum bandwidth is 9600 Hz. To reduce the transmission bandwidth to 2400 Hz, the modulation scheme to be adopted should be

(a) quadrature phase-shift keying
(b) minimum shift keying
(c) 16-ary quadrature amplitude modulation
(d) 8-ary PSK

[ESE-2000]

3.11 Four signals each band-limited to 5 kHz are sampled at twice the Nyquist rate. The resulting PAM samples are transmitted over a single channel after time division multiplexing. The theoretical minimum transmission bandwidth of the channel should be equal to

(a) 5 kHz (b) 20 kHz
(c) 40 kHz (d) 80 kHz [ESE-2000]

3.12 Generally, a transversal type equaliser with 5 taps can take care of distorted signal due to intersymbol interference in the received signal at

(a) 4 sampling instants
(b) 5 sampling instants
(c) 9 sampling instants
(d) 10 sampling instants

[ESE-2000]

3.13 Match **List-I** (Operations) with **List-II** (Functions) and select the correct answer using the codes given below the lists:

List-I
A. Companding
B. Squelch
C. Preemphasis
D. Double conversion

List-II
1. Improving image rejection
2. Variation of step size in quantisation
3. Muting the receiver
4. Boosting of higher modulating frequencies at the transmitter

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	2	1	4	3
(c)	4	3	2	1
(d)	4	1	2	3

[ESE-2000]

4. Information Theory

4.1 A source deliver symbols X_1, X_2, X_3 and X_4 with probabilities 1/2, 1/4, 1/8 and 1/8 respectively. The entropy of the system is

(a) 1.75 bits per second
(b) 1.75 bits per symbol
(c) 1.75 symbols per second
(d) 1.75 symbols per bit

[ESE-1999]

4.2 In a single error correcting Hamming code, the number of message bits in a block is 26. The number of check bits in the block would be

(a) 3 (b) 4
(c) 5 (d) 7 [ESE-2000]

■■■

Answers Analog and Digital Communication Systems

1.1	(a)	1.2	(c)	1.3	(a)	1.4	(b)	1.5	(c)	1.6	(a)	1.7	(a)	1.8	(d)	1.9	(b)
1.10	(a)	1.11	(c)	1.12	(d)	2.1	(b)	2.2	(b)	2.3	(c)	3.1	(d)	3.2	(c)	3.3	(c)
3.4	(b)	3.5	(d)	3.6	(d)	3.7	(a)	3.8	(c)	3.9	(b)	3.10	(c)	3.11	(c)	3.12	(b)
3.13	(a)	4.1	(b)	4.2	(c)												

Explanations Analog and Digital Communication Systems

1. Analog Communication Systems

1.1 (a)

$$m^2 = m_1^2 + m_2^2$$

$\Rightarrow \quad m^2 = (0.3)^2 + (0.4)^2$

$\Rightarrow \quad m^2 = 0.25$

$\Rightarrow \quad m = 0.5$

Total Radiated Power,

$$P_T = P_c\left(1+\frac{m^2}{2}\right) = 10\left(1+\frac{0.25}{2}\right) = 11.25 \text{ kW}$$

1.2 (c)

Let modulating signal, $m(t) = v_m \sin \omega_m t$

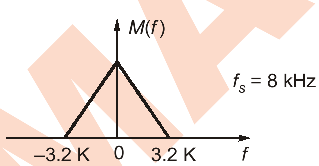
In PM, $\quad \theta_i = \omega_c t = k_p\, m(t)$

$\Rightarrow \quad \omega_i = \frac{d\theta_i}{dt} = \omega_c + k_p\, \dot{m}(t)$

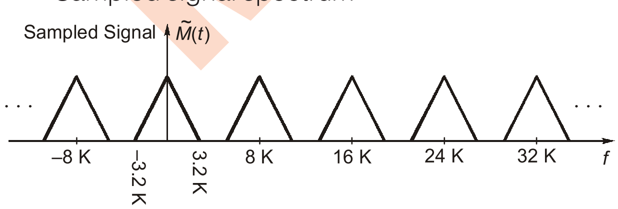
$\Rightarrow \quad \omega_i = \omega_c + k_p\, \omega_m\, v_m \cos \omega_m t$

This frequency deviation is $k_p \omega_m v_m \cos\omega_m t$ which is directly proportional to ω_m.

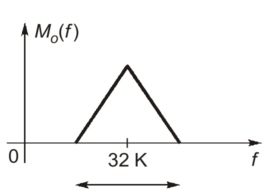
1.3 (a)



Sampled signal spectrum

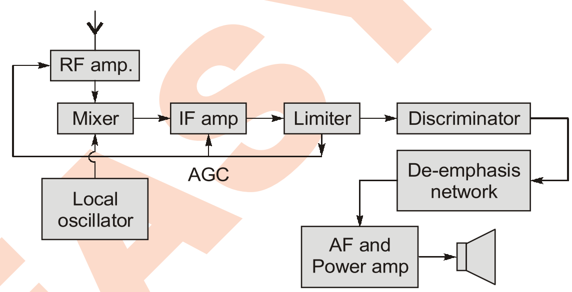


Filter output ⇒



This is DSB-SC signal.

1.4 (b)



FM Receiver Block diagram

1.5 (c)

$$f_{si} = f_s + 2f_i = 1200 + 2 \times 455 = 2110 \text{ kHz}$$

1.7 (a)

$(1 + M \cos 4\pi t) \cos(2\pi \times 10^3\, t)$

$\Rightarrow \cos(2\pi \times 10^3\, t) + M \cos 4\pi t \cos(2\pi \times 10^3\, t)$

$\Rightarrow \cos(2\pi \times 10^3\, t) + M/2\{\cos 2\pi\,(1000 + 2)t$

$\qquad + \cos 2\pi(1000 - 2)t\}$

⇒ Thus the signal contains frequency components of 998, 1000 and 1002 Hz.

1.8 (d)

$$P_t = P_c\left(1+\frac{m^2}{2}\right)$$

$$600 = 400\left(1+\frac{m^2}{2}\right)$$

$\Rightarrow \quad \frac{m^2}{2} = \frac{6}{4} - 1 = \frac{1}{2}$

$\Rightarrow \quad m = 1$

1.9 (b)

The loss of a message in an envelope detector that operates at a low carrier-to-noise ratio is referred to as the threshold effect. By threshold we mean a value of carrier-to-noise ratio below which the noise performance of a detector deteriorates much more rapidly than proportionately to the CNR.

1.10 (a)

Minimum sampling frequency,

$$f_{s_{\min}} = \frac{2f_H}{k} \qquad \text{where, } k = \left\lfloor \frac{f_H}{f_H - f_L} \right\rfloor 1$$

where $\lfloor x \rfloor$ means the greatest integer lower than x

$$k = \left\lfloor \frac{2}{2-1.5} \right\rfloor = \left\lfloor \frac{2}{0.5} \right\rfloor = 4$$

$$f_{s_{\min}} = \frac{2\times 2}{4} = 1 \text{ MHz}$$

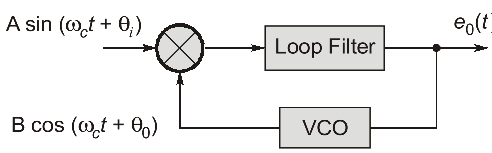
1.11 (c)

$$f_m = 100 \text{ Hz and } m_f = 15$$

$$\text{BW} = 2(m_f + 1)f_m = 2(15+1)\times 100 = 3.2 \text{ kHz}$$

1.12 (d)

The block diagram of a PLL is shown below:



Loop filter is a low pass narrow band filter.

2. Random Variables, Random Process & Noise

2.1 (b)

$$\overline{x(t)} = \overline{\sin(\omega_0 t + \phi)}$$

$$= \int_{-\infty}^{\infty} \sin(\omega_0 t + \phi)\rho_\phi(\phi)d\phi$$

$$= \frac{1}{\pi}\int_{-\pi/2}^{\pi/2} \sin(\omega_0 t + \phi)d\phi$$

$$= \frac{1}{\pi}\left[-\cos(\omega_0 t + \phi)\Big|_{-\pi/2}^{\pi/2}\right]$$

$$= \frac{1}{\pi}\left[-\cos\left(\omega_0 t + \frac{\pi}{2}\right) + \cos\left(\omega_0 t - \frac{\pi}{2}\right)\right]$$

$$= \frac{1}{\pi}[\sin\omega_0 t + \sin\omega_0 t] = \frac{2\sin\omega_0 t}{\pi}$$

2.2 (b)

$R_{eq} \rightarrow$ Receiver noise resistance

$R_a \rightarrow$ Resistance of antenna

$$F = 1 + \frac{R_{eq}}{R_a} = 1 + \frac{50}{50} = 1 + 1 = 2$$

2.3 (c)

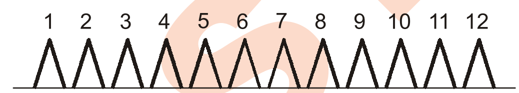
$$S_0(\omega) = |H(\omega)|^2 S_i(\omega)$$

$$\Rightarrow S_0(\omega) = \left(\frac{1}{\omega^2+1}\right)A \qquad \left(\because |H(\omega)| = \frac{1}{\sqrt{\omega^2+1}}\right)$$

$$\Rightarrow S_0(\omega) = \frac{A}{(\omega^2+1)}$$

3. Digital Communication Systems

3.2 (c)



$$\text{BW} = 12\times 5 + (12-1)\times 1$$

$$= 60 + 11 = 71 \text{ kHz}$$

3.3 (c)

$$\text{Bandwidth} = \frac{R_b}{2} = \frac{Wf_s}{2}$$

where, R_b = Bit rate (bits/sec)

f_s = Sampling frequency

and $f_s = 2f$

where, f = Signal bandwidth

$$\therefore \quad \text{B.W.} = \frac{N2f}{2} = Nf \text{ Hz}$$

3.4 (b)

TDM requires transmission of data samples.

3.5 (d)

$$10\log_{10}(\text{SNR}) = 30 \text{ dB}$$

$$\text{SNR} = 10^3 = 1000$$

The source is producing 32 symbols. By assuming equiprobable symbols case (or) fixed length coding,

Bit rate, $R_{b(\max)} = R_s \log_2(32) = 5R_s$

R_s = Symbol rate

For error-free transmission,

$$R_b \le C = B\log_2(1 + \text{SNR})$$

So, $5R_s = 3000 \log_2(1001)$ symbols/sec

$R_s = 5980 \simeq 6000$ symbols/sec

3.6 (d)

Quadrature multiplexing is a scheme where same carrier frequency is used in phase quadrature for two different signals both having the same bandwidths.

3.7 (a)

$B_2 = 2B_1$ and $(SNR)_1 = 30$ dB

$$B_1 (SNR)_1 = B_2 (SNR)_2$$

$$\Rightarrow \quad (SNR)_2 = \frac{B_1}{B_2} \times (SNR)_1 = \frac{1}{2} \times (SNR)_1$$

$\Rightarrow 10 \log (SNR)_2 = -10 \log 2 + 10 \log (SNR)_1$

$\Rightarrow (SNR)_2 \text{ (dB)} = -3 + (SNR)_1 \text{ (dB)}$

$\Rightarrow (SNR)_2 \text{ (dB)} = -3 + 30 = 27$ dB

3.8 (c)

Slope overload distortion would occur if

$$a > \frac{\delta}{T_s} \Rightarrow \delta < aT_s$$

3.9 (b)

$$\frac{S}{N_q}\text{(dB)} \approx 6n$$

where $n \rightarrow$ number of bits

$$\frac{S}{N_q}\text{(dB)} \approx 6 \times 8 \approx 48 \text{ dB}$$

3.10 (c)

$$\text{BW}\big|_{\text{BPSK}} = 2R_b$$

$$\text{BW}\big|_{\text{QPSK}} = R_b$$

$$\text{BW}\big|_{\text{16-QAM}} = \frac{R_b}{2}$$

Bandwidth of 16-ary QAM modulation is one-fourth of the bandwidth required for BPSK.

3.11 (c)

$$\text{Transmission bandwidth} = \text{BW} = \frac{nmf_s}{2}$$

where, $n \rightarrow$ number of bits in a signal

$m \rightarrow$ number of signals

$f_s \rightarrow$ sampling frequency

$m = 4,\ f_s = 2f_{s\,min} = 4f_m$ (Assuming $n = 1$)

$$\Rightarrow \quad \text{BW} = \frac{4 \times 4 \times 5 \text{ kHz}}{2} = 40 \text{ kHz}$$

3.12 (b)

Number of taps = Number of ISI check instances.

3.13 (a)

Companding $\rightarrow$ Variation of step size in quantisation.

Squelch $\rightarrow$ Muting the receiver.

Preemphasis $\rightarrow$ Boosting of higher modulating frequencies at the transmitter.

Double conversion $\rightarrow$ Improving image rejection.

4. Information Theory

4.1 (b)

$$H(x) = \sum_{i=1}^{4} P(i) \log_2 \frac{1}{P(i)}$$

$$= \frac{1}{2}\log_2 2 + \frac{1}{4}\log_2 4 + \frac{1}{8}\log_2 8 + \frac{1}{8}\log_2 8$$

$= 1.75$ bits per symbol

4.2 (c)

In a Hamming code, for k check bits and n message bits,

$$2^k - 1 - k \geq n$$

$$\Rightarrow \quad 2^k - 1 - k \geq 26$$

$$\Rightarrow \quad k = 5$$

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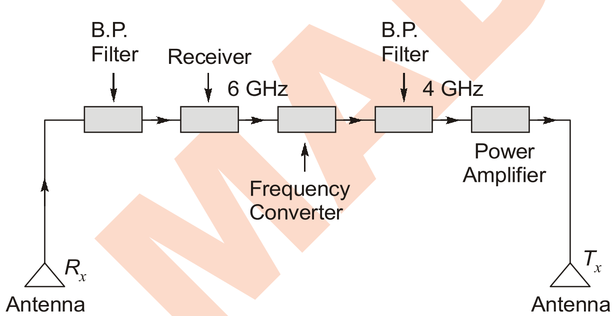
7 Advanced Communication Topics

2. Microwave and Satellite Communication Systems

2.1 13 dBm is equivalent to
(a) 2 mW (b) 20 W
(c) 20 mW (d) 2 MW
[ESE-1999]

2.2 **Assertion (A):** Modern long-distance communication is carried out via satellite.
Reason (R): It covers the entire globe without appreciable fading of signals.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE-1999]

2.3 The system shown in the given figure is



(a) an LOS link
(b) a satellite transponder
(c) a low noise amplifier
(d) a frequency divider
[ESE-1999]

2.4 Antenna elevation angle at the ground station for satellite communication is always kept above 5° to
(a) minimise the sky noise temperature
(b) reduce the effect of oxygen and water vapour absorption on the antenna noise temperature
(c) minimise the slant range
(d) increase the visibility of the satellite
[ESE-2000]

2.5 Random satellite moves in
(a) random paths
(b) polar orbits
(c) geostationary orbits
(d) equatorial plane
[ESE-2000]

2.6 **Assertion (A):** Several satellites have been designed to operate in the Ku-band in spite of higher atmospheric absorption than the *C*-band.
Reason (R): Use of smaller, narrower beam antennas in the Ku-band results in lower interference.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE-2000]

2.7 An earth station employs a 1 kW high power amplifier (HPA) and a 20 m Cassegrain antenna whose transmitted gain is 65 dB at a free space wavelength of 2.1 cm. If the loss of the wavelength that connects HPA to the feed is 1 dBm, then the earth station EIRP is
(a) 29 dB m (b) 59 dB m
(c) 94 dB m (d) 124 dB m
[ESE-2000]

3. Fibre Optic Communication Systems

3.1 A glass fibre has refractive indices n_1 of 1.5 and n_2 of 1. Assuming $c = 3 \times 10^8$ m/s the multipath time dispersion will be
(a) 2.5 ns/m (b) 2.5 μs/m
(c) 5 ns/m (d) 5 μs/m
[ESE-1999]

3.2 **Assertion (A):** Optical fibres have broader bandwidth compared to conventional copper cables.

Reason (R): The information carrying capacity of optical fibres is limited by Rayleigh scattering loss.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE-2000]

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Answers Advanced Communication Topics

2.1 (c) 2.2 (a) 2.3 (b) 2.4 (d) 2.5 (b) 2.6 (a) 2.7 (d) 3.1 (a) 3.2 (b)

Explanations Advanced Communication Topics

2. Microwave and Satellite Communication Systems

2.1 (c)

$$13 = 10\log\left(\frac{P}{10^{-3}}\right)$$

$$\Rightarrow \quad \frac{P}{10^{-3}} = (10)^{1.3} = 20$$

$$\Rightarrow \quad P = 20 \text{ mW}$$

2.7 (d)

$$P_t = 10^3 \text{ W}$$

$$G_t = 65 \text{ dB}$$

$$= (10)^{65/10} = 3162277.66$$

$$\text{EIRP} = P_t G_t = 10^3 \times 3162277.66$$

$$= 3162277660 \text{ W}$$

$$(\text{EIRP})_{\text{dBm}} = 10\log\frac{3162277660}{10^{-3}} = 125 \text{ dBm}$$

Taking the loss into consideration,

$$\text{EIRP} = 125 - 1 = 124 \text{ dBm}$$

3. Fibre Optic Communication Systems

3.1 (a)

We know that,

Multipath time dispersion (MTD)

$$= \frac{\Delta t}{z} = \frac{n_1}{n_2}\cdot\frac{\Delta n}{c} \quad \text{given, } n_1 = 1.5,\ n_2 = 1$$

$$\therefore \quad \Delta n = (1.5 - 1.0) = 0.5$$

$$\text{and} \quad c = 3 \times 10^8 \text{ m/sec}$$

$$\therefore \quad \text{M.T.D.} = \frac{1.5}{1.0} \times \frac{0.5}{(3\times10^8)} \text{m/sec}$$

$$= 2.5 \times 10^{-9} = 2.5 \text{ ns/m}$$

$$\approx 2.5\ \mu \text{ sec/km}$$

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8 Advanced Electronics Topics

1. VLSI Technology

1.1 In an integrated circuit, the SiO_2 layer provides
(a) electrical connection to external circuit
(b) physical strength
(c) isolation
(d) conducting path [ESE-1999]

1.2 Almost all resistors are made in a monolithic integrated circuit
(a) during the emitter diffusion
(b) while growing the epitaxial layer
(c) during the base diffusion
(d) during the collector diffusion [ESE-2000]

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Answers Advanced Electronics Topics

1.1 (c) 1.2 (c)

Explanations Advanced Electronics Topics

1. VLSI Technology

1.1 (c)

SiO_2 has the fundamental property of preventing the diffusion of impurities through it.

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