



POSTAL BOOK PACKAGE 2024

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INSTRUMENTATION ENGINEERING

Objective Practice Sets

Control Systems and Process Control

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Block Diagram and Transfer Function

MCQ and NAT Questions

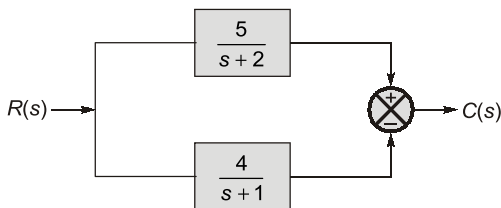
Q.1 Consider the following open-loop transfer function:

$$G = \frac{K(s+2)}{(s+1)(s+4)}$$

The characteristic equation of the unity negative feedback will be

- (a) $(s+1)(s+4) + K(s+2) = 0$
 (b) $(s+2)(s+1) + K(s+4) = 0$
 (c) $(s+1)(s-2) + K(s+4) = 0$
 (d) $(s+2)(s+4) + K(s+1) = 0$

Q.2 For the given figure,



- (a) $\frac{4(s+2)}{(s+2)(s+1)}$ (b) $\frac{(s-3)}{(s+2)(s+1)}$
 (c) $\frac{9s+13}{(s+2)(s+1)}$ (d) $\frac{1}{(s+2)(s+1)}$

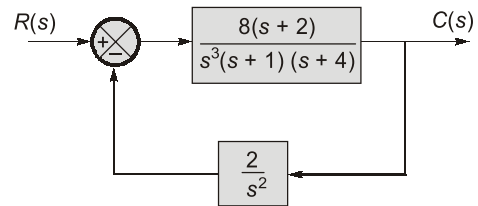
Q.3 The transfer function of three blocks connected in cascade is given by $\frac{(s+1)}{s(s+2)(s+3)}$. If block 1

has transfer function of $\frac{1}{s(s+2)}$ and block 2 has

transfer function of $\frac{(s+2)}{(s+3)}$ then the transfer function of the 3rd block is

- (a) $(s+1)(s+2)$ (b) $\frac{(s+1)}{(s+2)}$
 (c) $\frac{(s+1)}{s(s+3)}$ (d) $\frac{(s+1)^2}{(s+2)^2}$

Q.4 The type of the control system represented by the block diagram shown below is



- (a) Type-2 (b) Type-3
 (c) Type-4 (d) Type-5

Q.5 Match List-I (Transfer Function of the System) with List-II (Type and Order of the System) and select the correct answer using the codes given below the lists:

List-I

List-II

- | | |
|-------------------------------------|-------------------------|
| A. $\frac{2(s+2)}{s(s+5)}$ | 1. Type 0, second order |
| B. $\frac{(s+2)}{(s+3)(s+5)}$ | 2. Type 1, second order |
| C. $\frac{2(s+5)}{s^2(s+2)}$ | 3. Type 0, third order |
| D. $\frac{5(s+2)}{(s+1)(s+3)(s+5)}$ | 4. Type 2, third order |

Codes:

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

Q.6 The closed-loop transfer function of a unity feedback control system is $\frac{25}{s^2 + 10s + 25}$. What is the open loop transfer function of the system?

- (a) $\frac{25}{s^2 + 10s}$ (b) $\frac{25}{s^2 + 25}$
 (c) $\frac{25}{s + 25}$ (d) $\frac{25}{s + 10}$

- Q.7** For a transfer function $H(s) = \frac{P(s)}{Q(s)}$, where $P(s)$ and $Q(s)$ are polynomials in s .

Then:

- (a) the degree of $P(s)$ is always greater than the $Q(s)$.
 - (b) the degree of $P(s)$ and $Q(s)$ are same.
 - (c) degree of $P(s)$ is independent of degree of $Q(s)$.
 - (d) the maximum degree of $P(s)$ and $Q(s)$ differ at most by one.
- Q.8** The transfer function is applicable to
- (a) linear and time variant system
 - (b) non-linear and time variant system
 - (c) linear and time invariant system
 - (d) non-linear and time invariant system
- Q.9** The transfer function, $G(s) = \frac{10(s-5)}{s(s+1)(s+2)}$ represents
- (a) A non-minimum phase transfer function
 - (b) A minimum phase transfer function
 - (c) An all pass transfer function
 - (d) None of these
- Q.10** Consider the following statement and choose the correct option:

Statement 1: The transfer function is said to be strictly proper if the order of the denominator polynomial is greater than that of numerator polynomial.

Statement 2: The transfer function is said to be proper if the order of the denominator polynomial is equal to that of numerator polynomial.

Statement 3: The function is called improper if the order of the denominator polynomial is greater than that of numerator polynomial.

- (a) Statement 1 and 2 are correct
 - (b) Statement 2 and 3 are correct
 - (c) Only statement 1 is correct
 - (d) All the statements are correct
- Q.11** The impulse response of an initially relaxed linear system is $e^{-2t} u(t)$. To produce a response of $te^{-2t} u(t)$, the input must be equal to
- (a) $e^{-t} u(t)$
 - (b) $e^{-2t} u(t)$
 - (c) $2e^{-t} u(t)$
 - (d) $\frac{1}{2} e^{-2t} u(t)$

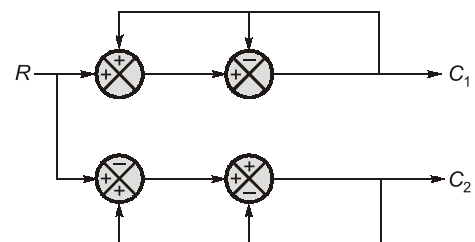
- Q.12** The unit step response of a linear time invariant system is $y(t) = 5e^{-10t} u(t)$, where $u(t)$ is the unit step function. If the output of the system corresponding to an unit impulse input $\delta(t)$ is $h(t)$, then $h(t)$ is

- (a) $-50 e^{-10t} u(t)$
- (b) $5 u(t) - 50 e^{-10t} \delta(t)$
- (c) $5 e^{-10t} \delta(t)$
- (d) $5 \delta(t) - 50 e^{-10t} u(t)$

- Q.13** A control system whose step response is $-0.5(1 + e^{-2t})$ is cascaded to another control block whose impulse response is e^{-t} . What is the transfer function of the cascaded combination?

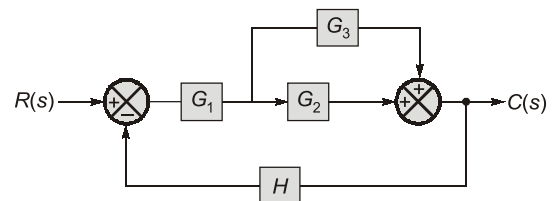
- (a) $\frac{1}{(s+1)(s+2)}$
- (b) $\frac{1}{s(s+1)}$
- (c) $\frac{-1}{s+2}$
- (d) $\frac{0.5}{(s+1)(s+2)}$

- Q.14** Determine C_1/R and C_2/R for the block diagram.



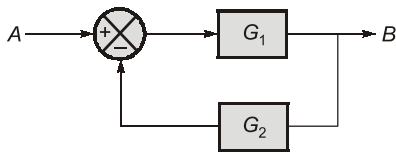
- (a) 0 and 1
- (b) 1 and 1
- (c) 0 and 0
- (d) 1 and 0

- Q.15** The transfer function of the block diagram of figure is

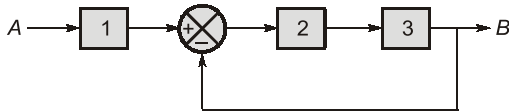


- (a) $\frac{G_2(G_1 + G_3)}{1 + G_1 G_2 H + G_1 G_3 H}$
- (b) $\frac{G_1(G_2 + G_3)}{1 + G_1 G_2 H + G_1 G_3 H}$
- (c) $\frac{G_1(G_2 - G_3)}{1 + G_1 H + G_2 H}$
- (d) $\frac{G_1(G_2 + G_3)}{1 + G_1 H + G_3 H}$

Q.16 Original block diagram

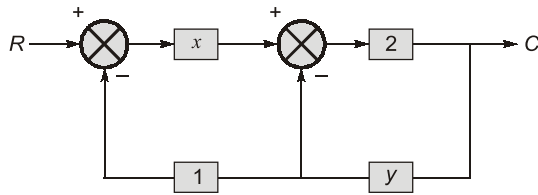


Equivalent block diagram blocks 1, 2, 3 are respectively.



- (a) G_1, G_2, G_3 (b) $1/G_1, 1/G_2, 1/G_3$
(c) $1/G_1, G_2, G_3$ (d) $1/G_2, G_1, G_2$

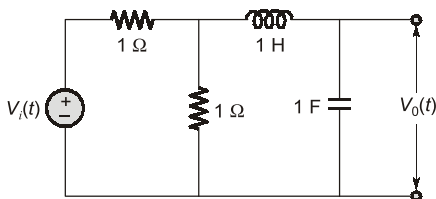
Q.17 Consider the diagram shown,



If $\frac{C}{R} = 1$, then

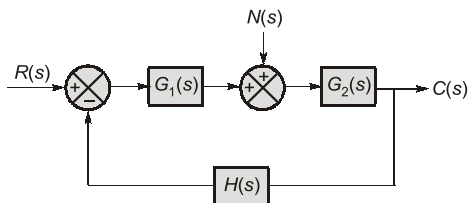
- (a) $x - y - xy = 1$ (b) $x - y + xy = 1$
(c) $x - y - xy = \frac{1}{2}$ (d) $x - y + xy = \frac{1}{2}$

Q.18 Find the transfer function $\frac{V_o(s)}{V_i(s)}$ for the network shown in figure.



- (a) $\frac{1}{s^2 + s + 2}$ (b) $\frac{1}{2s^2 + s + 2}$
(c) $\frac{1}{s^2 + 2s + 2}$ (d) $\frac{1}{2s^2 + 2s + 2}$

Q.19 The closed-loop system shown in the figure is subjected to a disturbance $N(s)$. The transfer function $C(s)/N(s)$ is given by



- (a) $\frac{G_1(s) G_2(s)}{1 + G_1(s) G_2(s) H(s)}$ (b) $\frac{G_1(s)}{1 + G_1(s) H(s)}$
(c) $\frac{G_2(s)}{1 + G_2(s) H(s)}$ (d) $\frac{G_2(s)}{1 + G_1(s) G_2(s) H(s)}$

Q.20 Consider the following statements and choose the correct option:

Statement 1: Non minimum phase functions are the functions which have poles or zeros on the right hand side of s-plane.

Statement 2: Minimum phase systems are systems which have no poles or zeros with positive real parts.

Statement 3: A system having the transfer

function as $F(s) = \frac{1-sT}{1+sT}$ represents an all pass

system.

- (a) Statements 1 and 2 are correct
(b) Statements 2 and 3 are correct
(c) Statements 1 and 3 are correct
(d) All the statements are correct

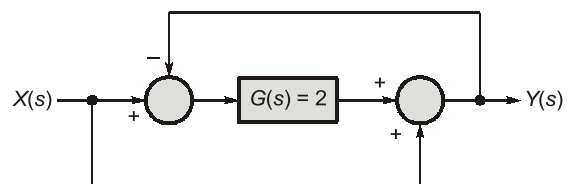
Q.21 Statement (I): The eigen values of the linear system explain about the stability of the system.

Statement (II): Eigen values of linear system give the location of zeros of closed loop transfer function.

Codes:

- (a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

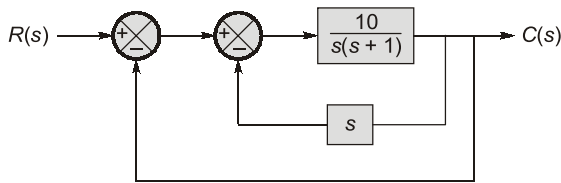
Q.22 For the system shown in the figure, $Y(s)/X(s) =$ _____.



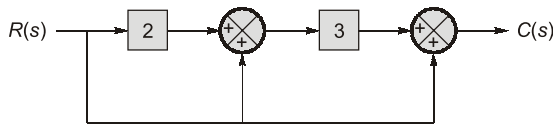
Q.23 For the system in figure the transfer function $\frac{C(s)}{R(s)}$

is given as $\frac{C(s)}{R(s)} = \frac{P}{s^2 + Rs + Q}$.

Then value of $P + R + Q$ will be _____.



Q.24 For the given block diagram, the value of $\frac{C(s)}{R(s)}$ will be _____.

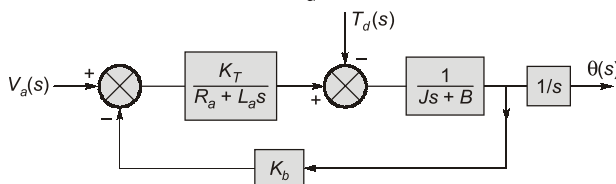


Q.25 The step response of a system is given by,

$$c(t) = \left[1 - \frac{1}{15}e^{-3t} + 7e^{-5t} \right]$$

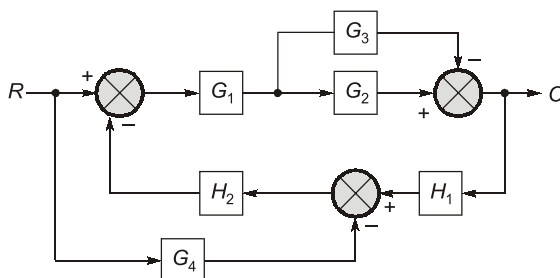
The DC gain of the system is _____.

Q.26 The position control of a DC servo-motor is given in the figure. The values of the parameters are $K_T = 1$ N-m/A, $R_a = 1$ W, $L_a = 0.1$ H. $J = 5$ kg-m², $B = 1$ N-m/(rad/sec) and $K_b = 1$ V/(rad/sec). The steady-state position response (in radians) due to unit impulse disturbance torque T_d is _____.



Multiple Select Questions (MSQs)

Q.27 Which of the following statement(s) is/are correct about the control system whose block diagram is shown below:



- (a) For the above block diagram, the signal flow graph has four forward paths.
(b) For the above block diagram, the signal flow graph has two loops.
(c) Transfer function

$$\frac{C}{R} = \frac{G_1 G_2 - G_1 G_3 + G_1 G_2 G_4 H_2 - G_1 G_3 G_4 H_2}{1 + G_1 G_2 H_1 H_2 - G_1 G_3 H_1 H_2}$$

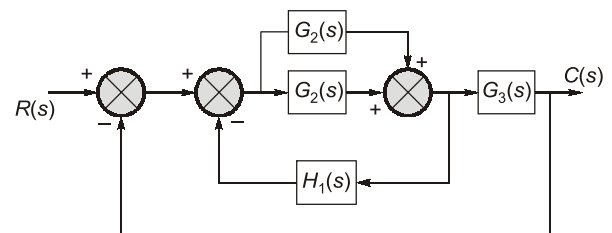
- (d) Transfer function

$$\frac{C}{R} = \frac{G_1 G_2 + G_1 G_3 + G_1 G_2 G_4 H_2 + G_1 G_3 G_4 H_2}{1 + G_1 G_2 H_1 H_2 + G_1 G_3 H_1 H_2}$$

Q.28 Which of the following statements are correct regarding transfer function.

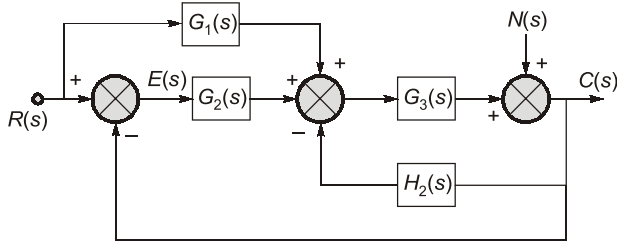
- (a) The transfer function is defined only for a linear time-invariant system.
(b) The transfer function is defined for both linear and nonlinear systems.
(c) The transfer function is independent of the input of the system.
(d) The transfer function of a linear time-invariant system is Laplace transform of the impulse response with all the initial conditions set to zero.

Q.29 The overall closed loop transfer function $\frac{C(s)}{R(s)}$ represented in the figure will be



- (a) $\frac{C(s)}{R(s)} = \frac{(G_1(s) + G_2(s))G_3(s)}{1 + (G_1(s) + G_2(s))(H_1(s) + G_3(s))}$
(b) $\frac{C(s)}{R(s)} = \frac{(G_1(s) + G_2(s))G_3(s)}{1 + G_1(s)H_1(s) + G_2(s)G_3(s)}$
(c) $\frac{C(s)}{R(s)} = \frac{G_1(s) + G_2(s)}{1 + G_1(s)H_1(s) + G_2(s)H_1(s)}$
(d) $\frac{C(s)}{R(s)} = \frac{G_1(s)G_3(s) + G_2(s)G_3(s)}{1 + G_1(s)H_1(s) + G_2(s)H_1(s) + G_1(s)G_3(s) + G_2(s)G_3(s)}$

Q.30 The block diagram of a control system is shown in figure.



Which of the following statements is/are true?

- (a) $\left. \frac{C(s)}{R(s)} \right|_{N(s)=0} = \frac{G_1 G_3 + G_2 G_3}{1 + G_3 H_1 + G_2 G_3}$
- (b) $\left. \frac{C(s)}{N(s)} \right|_{R(s)=0} = \frac{G_1 G_3 + G_2 G_3}{1 + G_3 H_1 + G_2 G_3}$
- (c) $\left. \frac{C(s)}{N(s)} \right|_{R(s)=0} = \frac{1}{1 + G_3 H_1 + G_2 G_3}$
- (d) $\left. \frac{C(s)}{R(s)} \right|_{N(s)=0} = \frac{1}{1 + G_3 H_1 + G_2 G_3}$

■■■■

Answers		Block Diagram and Transfer Function											
1.	(a)	2.	(b)	3.	(b)	4.	(d)	5.	(a)	6.	(a)	7.	(c)
8.	(c)	9.	(a)	10.	(a)	11.	(b)	12.	(d)	13.	(c)	14.	(b)
15.	(b)	16.	(d)	17.	(c)	18.	(b)	19.	(d)	20.	(d)	21.	(c)
22.	(1)	23.	(31)	24.	(10)	25.	(1)	26.	(−0.5)	27.	(a, b, c)	28.	(a, c, d)
29.	(a, d)	30.	(a, c)										

Explanations **Block Diagram and Transfer Function**

1. (a)

$$q(s) = 1 + G(s)H(s) = 0$$

$$q(s) = 1 + \frac{K(s+2)}{(s+1)(s+4)} = 0$$

$$q(s) = (s+1)(s+4) + K(s+2) = 0$$

2. (b)

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)} \quad \dots \text{For negative feedback}$$

$$\frac{C(s)}{R(s)} = G_1(s) + G_2(s) \quad \dots \text{For parallel feedback}$$

$$G_1(s) = \frac{5}{s+2}$$

$$G_2(s) = -\frac{4}{s+1}$$

$$\frac{C(s)}{R(s)} = \frac{5}{s+2} - \frac{4}{s+1} = \frac{s-3}{(s+1)(s+2)}$$

3. (b)

As the three blocks are connected in cascade the overall transfer function is given by the multiplication of individual blocks.

$$\therefore x_1 \times x_2 \times x_3 = \frac{(s+1)}{s(s+2)(s+3)}$$

$$\frac{1}{s(s+2)} \times \frac{(s+2)}{(s+3)} \times x_3 = \frac{(s+1)}{s(s+2)(s+3)}$$

$$x_3 = \frac{(s+1)}{(s+2)}$$

4. (d)

The type of the system = Number of open loop poles at origin

$$\therefore G(s)H(s) = \frac{8(s+2)}{s^3(s+1)(s+4)} \times \frac{2}{s^2} = \frac{16(s+2)}{s^5(s+1)(s+4)}$$

$$\therefore \text{Type-5.}$$

5. (a)

Type of system: Number of poles at origin**Order of system:** Degree of denominator polynomial or number of total poles

A : Type-1, order 2

B : Type-0, order 2

C : Type-2, order 3

D : Type-0, order 3

6. (a)

Transfer function of unity feedback system with forward path,

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

$$\frac{G(s)}{1+G(s)} = \frac{25}{s^2 + 10s + 25}$$

$$G(s)(s^2 + 10s + 25) = 25(1 + G(s))$$

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

$$\Rightarrow G(s) = \frac{25}{s^2 + 10s}$$

7. (c)

$$\text{Transfer function} = H(s) = \frac{P(s)}{Q(s)}$$

For positive real function, the degree of $P(s)$ and $Q(s)$ must differ by one, but here nothing is mentioned, for transfer function to exist, only initial conditions must be made zero, degree of $P(s)$ and $Q(s)$ are not of importance.

8. (c)

Transfer function only applicable to LTI systems.

9. (a)

The given transfer function has one zero on RHS of s -plane. Hence it is a non-minimum phase transfer function.

10. (a)

Let, Order of denominator polynomial = n Order of numerator polynomial = m

Transfer function is said to be

(i) Strictly proper if $m < n$ (ii) Proper if $m = n$ (iii) Improper if $m > n$

11. (b)

$$h(t) = e^{-2t} u(t)$$

$$y(t) = te^{-2t} u(t)$$

Taking Laplace transform:

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

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

$$Y(s) = H(s) \cdot X(s)$$

$$\Rightarrow \frac{Y(s)}{H(s)} = X(s)$$

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

$$x(t) = e^{-2t} u(t)$$

12. (d)

$$h(t) = \frac{d}{dt}(s(t)) = \frac{d}{dt}(5e^{-10t}u(t))$$

$$h(t) = 5[e^{-10t}\delta(t) - 10e^{-10t}u(t)]$$

$$h(t) = 5e^{-0} \cdot \delta(t) - 50e^{-10t}u(t) \\ = 5\delta(t) - 50e^{-10t}u(t)$$

13. (c)

$$TF_1 = sL[sR]$$

$$= s \left[\frac{-0.5}{s} - \frac{0.5}{s+2} \right] = \frac{-(s+1)}{s+2}$$

$$TF_2 = L[IR] = \frac{1}{s+1}$$

$$\therefore TF = TF_1 \times TF_2 = \frac{-1}{s+2}$$

14. (b)

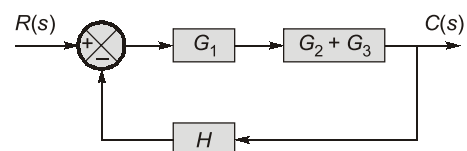
We have, $C_1 = R + C_1 - C_1 = R$

$$\Rightarrow \frac{C_1}{R} = 1$$

Also, $C_2 = R + C_2 - C_2$

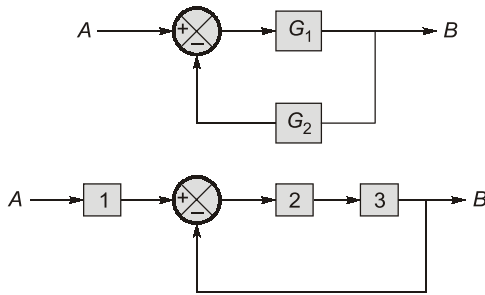
$$\Rightarrow \frac{C_2}{R} = 1$$

15. (b)



$$\frac{C(s)}{R(s)} = \frac{G_1(G_2 + G_3)}{1 + G_1H(G_2 + G_3)}$$

16. (d)



We know, $\frac{B}{A} = \frac{G_1}{1 + G_1 G_2}$

$$\frac{B}{A} = \left[\frac{2.3}{1 + 2.3} \right] 1$$

Now, option (a)

$$TF = \frac{G_1 G_2 G_3}{1 + G_2 G_3}$$

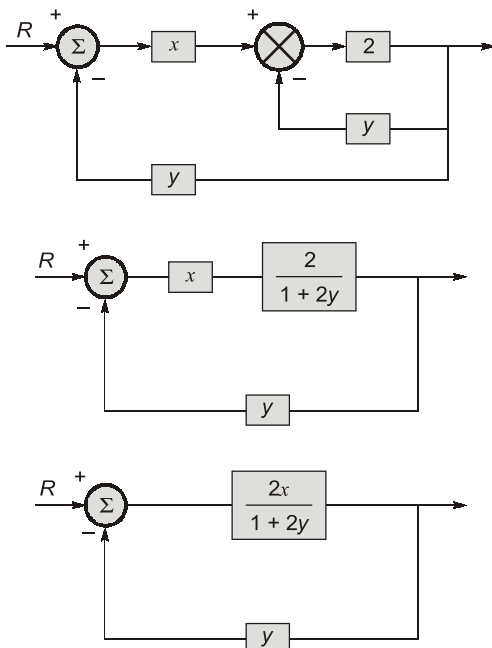
Option (b), $TF = \frac{\frac{1}{G_1} \cdot \frac{1}{G_2} \cdot \frac{1}{G_3}}{1 + \frac{1}{G_2} \cdot \frac{1}{G_3}} = \frac{1}{G_1(1 + G_2 G_3)}$

Option (c), $TF = \frac{\frac{1}{G_1} \cdot G_2 \cdot G_3}{1 + G_2 G_3} = \frac{G_2 G_3}{G_1(1 + G_2 G_3)}$

Option (d), $TF = \frac{\frac{1}{G_2} \cdot G_1 G_2}{1 + G_1 G_2} = \frac{G_1}{1 + G_1 G_2}$

Hence option (d) is correct.

17. (c)



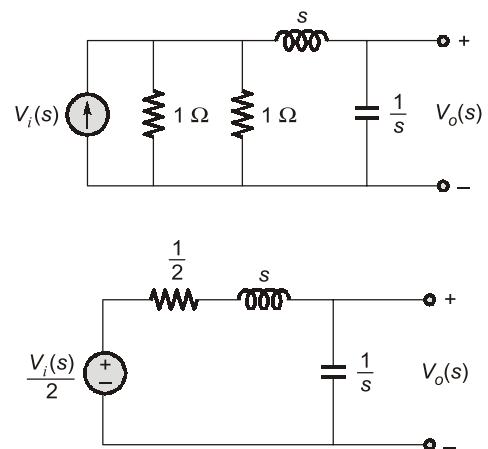
$$\frac{C}{R} = \frac{\frac{2x}{1+2y}}{1 + \frac{2x \cdot y}{1+2y}} = \frac{2x}{1+2y+2xy}$$

$$\frac{C}{R} = \frac{2x}{1+2y+2xy} = 1$$

$$2x = 1 + 2y + 2xy$$

$$\Rightarrow x - y - xy = \frac{1}{2}$$

18. (b)



Applying voltage division

$$\frac{V_o(s)}{\frac{V_i(s)}{2}} = \frac{\frac{1}{s}}{\frac{1}{2} + s + \frac{1}{s}} = \frac{2}{2s^2 + 2 + s}$$

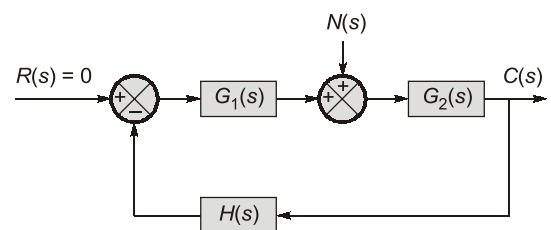
$$2 \frac{V_o(s)}{V_i(s)} = \frac{2}{2s^2 + s + 2}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{2s^2 + s + 2} = \frac{1}{2s^2 + s + 2}$$

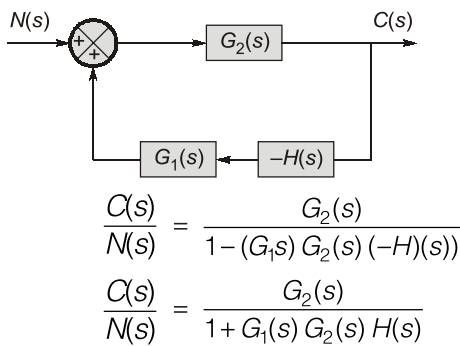
19. (d)

To calculate, $\frac{C(s)}{N(s)}$, input $R(s)$ is set to zero.

Block diagram can be redrawn as,



Redrawing:

**20. (d)**

Minimum phase system:

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

Non-minimum phase system:

$$F(s) = \frac{s-1}{(s+2)(s+3)}$$

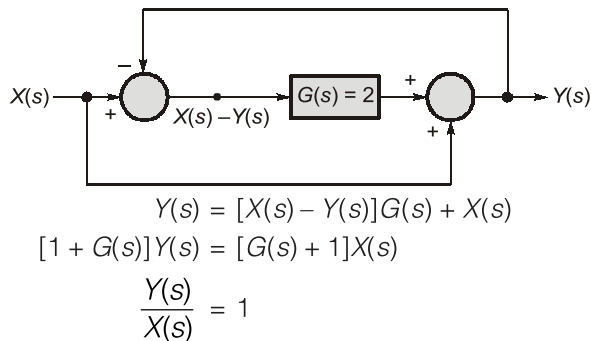
All pass system:

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

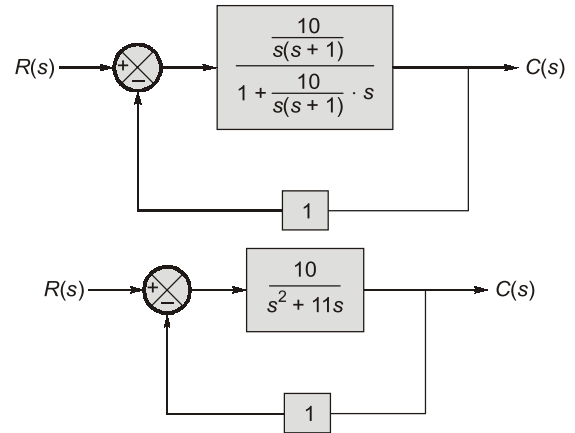
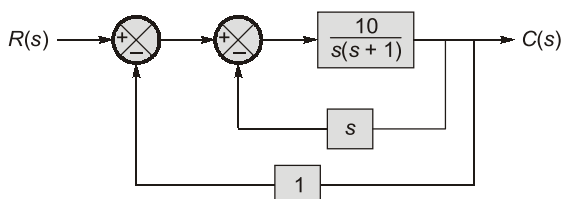
All pass system also have gain = 1 for all the frequencies.

21. (c)

Eigen values of the system are closed loop poles. And location of these poles describes the stability of system.

22. (1)**23. (31)**

The above block diagram can be rewrite as



$$\frac{C(s)}{R(s)} = \frac{10}{s^2 + 11s} = \frac{10}{s^2 + 11s + 10}$$

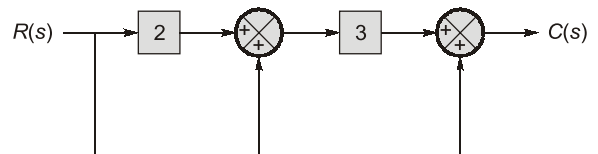
By comparing with $\frac{P}{s^2 + Rs + Q}$

$P = 10$
 $Q = 10$
 $R = 11$

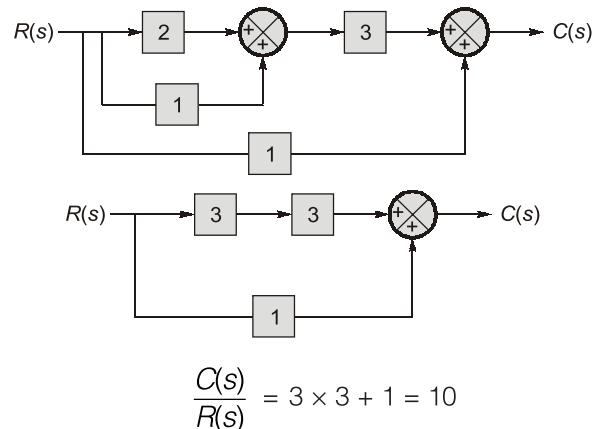
$$\text{Hence, } P + Q + R = 10 + 11 + 10 = 31$$

24. (10)

For the given block diagram



We can rewrite it as below:

**25. (1)**

Using Laplace transform of given response function, we get,

$$C(s) = \frac{1}{s} - \frac{1}{15(s+3)} + \frac{7}{(s+5)}$$

$$= \frac{15(s^2 + 8s + 15) - s^2 - 5s + 105s^2 + 315s}{15s(s+3)(s+5)}$$

$$= \frac{119s^2 + 430s + 225}{15s(s+3)(s+5)}$$

∴ Transfer function,

$$T(s) = \frac{C(s)}{R(s)} = sC(s)$$

$$= \frac{119s^2 + 430s + 225}{15(s+3)(s+5)}$$

$$\text{DC gain} = \lim_{s \rightarrow 0} T(s) = \frac{225}{15 \times 3 \times 5} = 1$$

26. (-0.5)

The transfer function due to the disturbance torque $T_d(s)$ is

$$\frac{\theta(s)}{T_d(s)} = \frac{-\frac{1}{(Js+B)} \times \frac{1}{s}}{1 + \left(\frac{1}{Js+B} \right) \left(\frac{K_b K_T}{R_a + L_a s} \right)}$$

$$= \frac{-(R_a + L_a s) \cdot \frac{1}{s}}{(R_a + L_a s)(Js+B) + K_b K_T}$$

The steady value of response for unit impulse input

$$\theta(0) = \lim_{s \rightarrow 0} \frac{-s(R_a + L_a s) \cdot \frac{1}{s}}{(R_a + L_a s)(Js+B) + K_b K_T} \cdot T_d$$

$$= -\frac{R_a}{R_a B + K_b K_T} \cdot 1$$

Given:

$$K_T = 1 \text{ N-m/A } R_a = 1 \Omega,$$

$$B = 1 \text{ N-m/rad/sec}$$

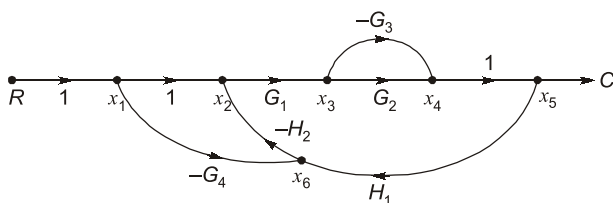
$$\text{and } K_b = 1 \text{ V/rad/sec}$$

Substituting the given values into above equation, we get

$$\theta(0) = -\frac{1}{2} = -0.5 \text{ rad}$$

27. (a, b, c)

The signal flow graph corresponding to the block diagram.



The signal flow graph has four forward paths and two loops. There are no combinations of two non-touching loops.

Both the loops are touching all the four forward paths.

Forward path $R - x_1 - x_2 - x_3 - x_4 - x_5 - C$

$$M_1 = (1)(1)(G_1)(G_2)(1) = G_1 G_2 \Delta_1 = 1$$

Forward path $R - x_1 - x_2 - x_3 - x_4 - x_5 - C$

$$M_2 = (1)(1)(G_1)(-G_3)(1) = -G_1 G_3 \Delta_2 = 1$$

Forward path $R - x_1 - x_6 - x_2 - x_3 - x_4 - x_5 - C$

$$M_3 = (1)(-G_4)(-H_2)(G_1)(-G_2)(1) = G_1 G_2 G_4 H_2 \Delta_3 = 1$$

Forward path $R - x_1 - x_6 - x_2 - x_3 - x_4 - x_5 - C$

$$M_4 = (1)(-G_4)(-H_2)(G_1)(-G_3)(1) = -G_1 G_3 G_4 H_2 \Delta_4 = 1$$

Loops and the gains associated with them are as follows:

Loop $x_2 - x_3 - x_4 - x_5 - x_6 - x_2$

$$L_1 = (G_1)(G_2)(H_1)(H_2) = -G_1 G_2 H_1 H_2$$

Loop $x_2 - x_3 - x_4 - x_5 - x_6 - x_2$

$$L_2 = (G_1)(-G_3)(1)(H_1)(-H_2) = G_1 G_3 H_1 H_2$$

The determinant of the signal flow graph is

$$\Delta = 1 - (L_1 + L_2)$$

$$\therefore 1 - (-G_1 G_2 H_1 H_2 + G_1 G_3 H_1 H_2)$$

Applying Mason's gain formula, the transfer function is

$$\frac{C}{R} = \frac{G_1 G_2 - G_1 G_3 + G_1 G_2 G_4 H_2 - G_1 G_3 G_4 H_2}{1 + G_1 G_2 H_1 H_2 - G_1 G_3 H_1 H_2}$$

28. (a, c, d)

The transfer function is defined only for a linear time-invariant system. It is not defined for nonlinear systems.

29. (a, d)

Blocks G_1 and G_2 are in parallel

$$\therefore G_1 + G_2$$

To the above result H_1 is in negative feedback.

$$\therefore \frac{(G_1 + G_2)}{1 + (G_1 + G_2)H_1}$$

To the above result feedback G_3 is in series

$$\therefore \frac{(G_1 + G_2)G_3}{1 + (G_1 + G_2)H_1}$$

To the above result feedback is '1'.

$$\therefore \frac{C(s)}{R(s)} = \frac{(G_1 + G_2)G_3}{1 + (G_1 + G_2)(H_1 + G_3)}$$