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CONTENTS

INSTRUMENTATION ENGINEERING

Objective Practice Sets

Control Systems and Process Control

1 CHAPTER

Introduction

MCQ and NAT Questions

Q.1 A control system is represented by $y(t) = x(t + T)$ with $T > 0$. Is the system causal?
(a) Yes (b) No
(c) Not necessarily (d) None of these

Q.2 $s(t)$ is step response and $h(t)$ is impulse response of a system. Its response $y(t)$ for any input $u(t)$ is given by

(a) $\frac{d}{dt}\int_0^t s(t-\tau)\, u(\tau)\, d\tau$

(b) $\int_0^t s(t-\tau)\, u(\tau)\, d\tau$

(c) $\int_0^t \int_0^t s(t-\tau_1)\, u(\tau_1) d\tau_1\, d\tau$

(d) $\int_0^t h(t-\tau)u(\tau)d\tau$

Q.3 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

Q.4 Which one of the following is an example of open loop system
(a) Washing machine
(b) Respiratory system of animal
(c) Stablisation of air pressure entering into mask
(d) Execution of program by computer

Q.5 Which is not an example of closed loop system?
(a) Radar tracking system
(b) Electric iron
(c) Missile launching system
(d) Traffic light controller

Q.6 Consider the following statements:
Statement 1: The difference between the output response and the reference signal is called actuating signal.
Statement 2: If the initial conditions for a system are inherently zero, it means system is at rest or no energy stored in any of its parts.
(a) Statement 1 is wrong, 2 is correct
(b) Statement 1 is correct, 2 is wrong
(c) Both the statement are correct
(d) Both the statements are wrong

Q.7 The Laplace transform at a transportation lag of 2 seconds is given as :
(a) $\frac{1}{s+2}$ (b) e^{2s}
(c) e^{-2s} (d) $e^{2/s}$

Q.8 A certain LTI system has input $r(t)$ and output $c(t)$. If the input is first passed through a block whose T.F. is e^{-s} and then applied to system. The modified output will be
(a) $c(t)\, u(t-1)$ (b) $c(t-1)\, u(t)$
(c) $c(t-1)\, u(t-1)$ (d) none of these

Q.9 Let $F(s)$ be the Laplace transform of a signal $f(t)$.
If $F(s) = \frac{K}{(s+1)(s^2+4)}$, then $\lim_{t\to\infty} f(t)$ is given by
(a) $K/4$ (b) zero
(c) infinite (d) undefined

Q.10 For the given transfer function what will be the initial value $F(s) = \frac{(2s+1)}{s(4s+3)}$?
(a) $\frac{1}{3}$ (b) $\frac{1}{2}$
(c) $\frac{2}{3}$ (d) 0

Q.11 The compensator $G(s) = \dfrac{16(1+30s)}{(1+5s)}$ would provide gain at high frequency,

(a) 24.08 dB (b) 55.45 dB
(c) 91.28 dB (d) 39.65 dB

Q.12 The final value of the function $F(s) = \dfrac{5}{s(s^2+s+2)}$ is equal to ________.

Q.13 The voltage across an element in a circuit is given by $V(s) = \dfrac{1}{s(s+\alpha)}$. If $v(\infty)$ is equal to 4 V then the value of $v(t)$ at t = 1 sec is ____________ V.

Q.14 Assertion (A): A linear system gives a bounded output if the input is bounded.

Reason (R): The roots of the characteristic equation have all negative real parts and response due to initial conditions decay to zero as time t tends to infinity.

(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

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Answers Introduction

1. (b)	2. (d)	3. (b)	4. (a)	5. (d)	6. (d)	7. (c)	8. (c)	9. (b)
10. (b)	11. (d)	12. (2.5)	13. (0.885)	14. (d)				

Explanations Introduction

1. (b)

$$y(t) = x(t+T)$$

Taking Laplace transform,

$$Y(s) = X(s)e^{sT}$$

$$H(s) = \frac{Y(s)}{X(s)} = e^{sT}$$

Taking inverse Laplace transform

$$h(t) = \delta(t+T),\ T > 0$$

Thus, $h(t) \neq 0$, $t < 0$, its an impulse at $t = -T$.
System is causal if $h(t) = 0$, $t < 0$.

2. (d)

$$y(t) = x(t) \otimes h(t)$$

$$y(t) = u(t) \otimes h(t)$$

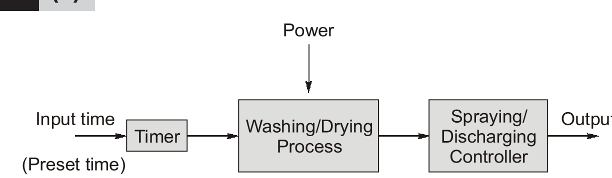
$$y(t) = \int_{-\infty}^{\infty} h(t-\tau)\, u(\tau) dt$$

$$y(t) = \int_{0}^{t} h(t-\tau)\, u(\tau) d\tau$$

3. (b)

When a human being tries to approach an object, his brain acts as a controller because his brain controls the activity of the human.

4. (a)

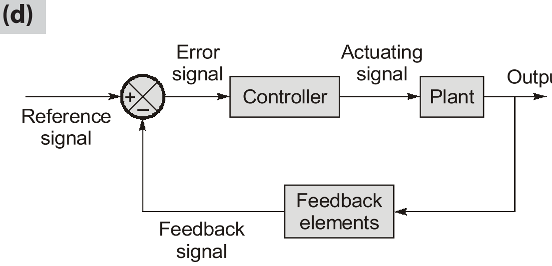


In the block diagram of a washing machine, input and output are unrelated, in the above. Thus washing machine is an example of open loop system.

5. (d)

Since all the system except (d) depend on the target or output.
Hence, output/target provides feedback to the system. While traffic light controller does not take any output consideration.

6. (d)



$$\text{Error signal} = \text{Reference} - \text{Output}$$

7. (c)

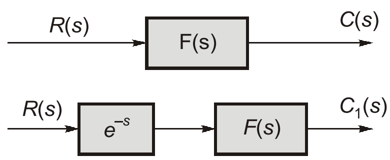
Transportation lag = e^{-st_d}

where t_d is time delay

Here, $t_d = 2$ sec

Thus, lag $= e^{-2s}$

8. (c)



$$C(s) = F(s)\,R(s)$$

$$C_1(s) = R(s)\cdot e^{-s}\cdot F(s)$$

$$C_1(s) = C(s)\,e^{-s}$$

$$\because \quad L^{-1}[F(s)\,e^{-as}] = f(t-a)\,u(t-a)$$

$$\therefore \quad c_1(t) = c(t-1)\,u(t-1)$$

9. (b)

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

We know by Final value theorem

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$$

$$= \lim_{s\to 0} \frac{sK}{(s+1)(s^2+4)} = 0$$

10. (b)

By initial value theorem $\lim_{t\to 0} f(t) = \lim_{s\to\infty} sF(s)$

where $F(s)$ is Laplace transform of $f(t)$.

So, Initial value $= \lim_{s\to\infty} \frac{s(2s+1)}{s(4s+3)}$

$$= \lim_{s\to\infty} \frac{2\left(1+\frac{1}{s}\right)}{4\left(1+\frac{3}{4s}\right)} = \frac{2}{4}\frac{(1+0)}{(1+0)}$$

$$= \frac{1}{2}$$

11. (d)

Sinusoidal transfer function is given by

$$G(j\omega) = \frac{16(1+j30\omega)}{(1+j5\omega)}$$

Solving, we get

$$G(j\omega) = \frac{16\times j\omega\left(\frac{1}{j\omega}+30\right)}{j\omega\left(\frac{1}{j\omega}+5\right)}$$

At $\omega\to\infty$ (high frequency)

$$G(j\omega)_{\omega\to\infty} = \frac{16\times\left(\frac{1}{\infty}+30\right)}{\left(\frac{1}{\infty}+5\right)} = 96$$

Gain in dB = 20 log 96

gain = 39.65 dB

12. (2.5)

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

$$\text{Final value} = \lim_{s\to 0} s\,F(s)$$

$$= \lim_{s\to 0} \frac{5s}{s(s^2+s+2)} = \frac{5}{2}$$

13. (0.885)

$$V(s) = \frac{1}{s(s+\alpha)}$$

By $v(\infty) = \lim_{t\to\infty} v(t) = \lim_{s\to 0} sV(s)$

By final value theorem

$$v(\infty) = \frac{1}{\alpha} = 4$$

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

Now, $$V(s) = \frac{1}{s(s+\alpha)}$$

By partial fraction

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

$$V(s) = 4\left[\frac{1}{s}-\frac{1}{s+\alpha}\right]$$

By inverse Laplace transform

$$v(t) = 4[1-e^{-\alpha t}] = 4[1-e^{-t/4}]$$

$$v(t = 1\text{ sec}) = 4[1-e^{-1/4}]$$

$$= 0.885\text{ V}$$

14. (d)

Assertion is wrong as it is applicable only for the BIBO (Bounded Input Bounded Output) stable system.

Moreover if the system is unbounded then assertion will be wrong.

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2 CHAPTER Block Diagram and Transfer Function

MCQ and NAT Questions

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

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

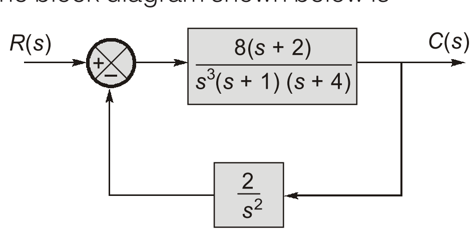
The characteristic equation of the unity negative feedback will be

(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 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.3 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.4 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.5 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.6 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.7 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 than that 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.8 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.9 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) $5\,u(t) - 50\,e^{-10t}\,\delta(t)$

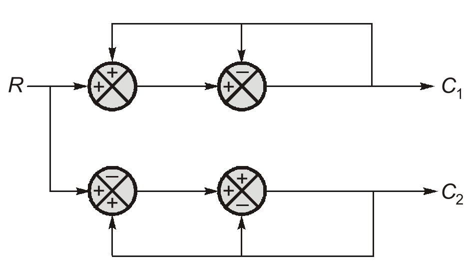
(c) $5\,e^{-10t}\,\delta(t)$ (d) $5\,\delta(t) - 50\,e^{-10t}\,u(t)$

Q.10 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) $\frac{1}{s(s+1)}$

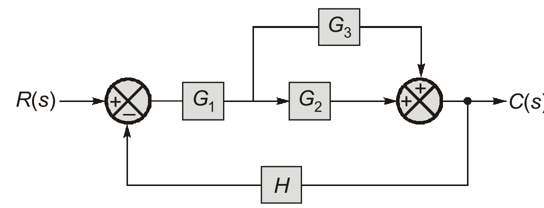
(c) $\frac{-1}{s+2}$ (d) $\frac{0.5}{(s+1)(s+2)}$

Q.11 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.12 The transfer function of the block diagram of figure is



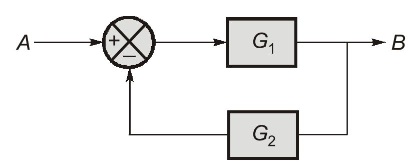
(a) $\frac{G_2(G_1+G_3)}{1+G_1G_2H+G_1G_3H}$

(b) $\frac{G_1(G_2+G_3)}{1+G_1G_2H+G_1G_3H}$

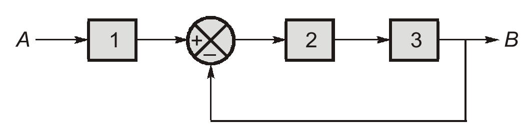
(c) $\frac{G_1(G_2-G_3)}{1+G_1H+G_2H}$

(d) $\frac{G_1(G_2+G_3)}{1+G_1H+G_3H}$

Q.13 Original block diagram

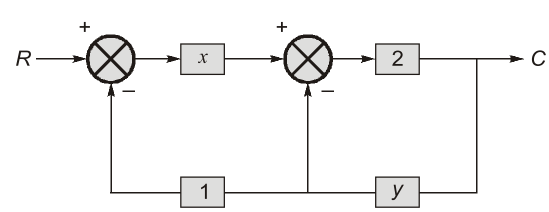


Equivalent block diagram blocks 1, 2, 3 are respectively.



(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.14 Consider the diagram shown,

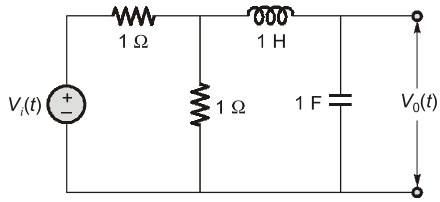


If $\frac{C}{R} = 1$, then

(a) $x - y - xy = 1$ (b) $x - y + xy = 1$

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

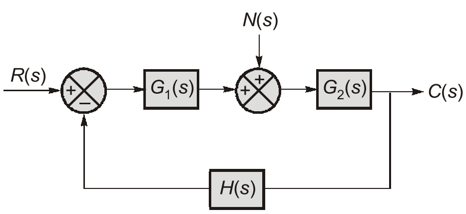
Q.15 Find the transfer function $\frac{V_0(s)}{V_i(s)}$ for the network shown in figure.



(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.16 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.17 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.

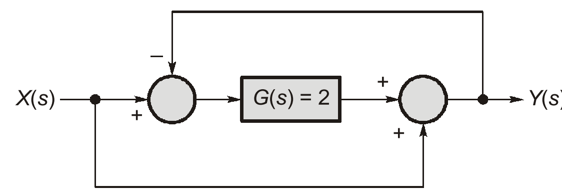
(a) Statements 1 and 2 are correct
(b) Statements 2 and 3 are correct
(c) Statements 1 and 3 are correct
(d) All the statements are correct

Q.18 **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.

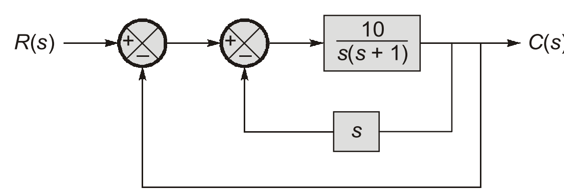
Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement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

Q.19 For the system shown in the figure, $Y(s)/X(s)$ = _______.

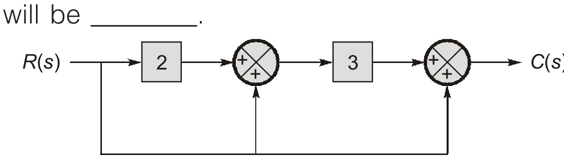


Q.20 For the system in figure the transfer function $\frac{C(s)}{R(s)}$ is given as $\frac{C(s)}{R(s)}=\frac{P}{s^2+Rs+Q}$.

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



Q.21 For the given block diagram, the value of $\frac{C(s)}{R(s)}$ will be ________.

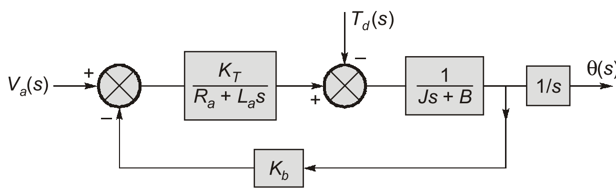


Q.22 The step response of a system is given by,

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

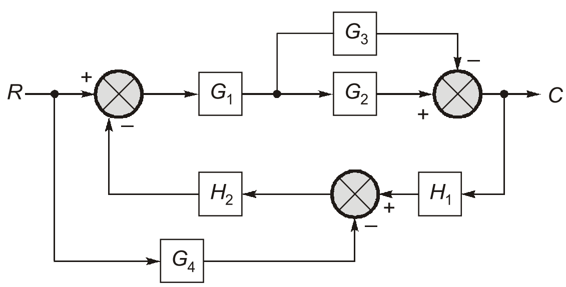
The DC gain of the system is __________.

Q.23 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-m^2, 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.24 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

$$\frac{C}{R} = \frac{G_1G_2 - G_1G_3 + G_1G_2G_4H_2 - G_1G_3G_4H_2}{1 + G_1G_2H_1H_2 - G_1G_3H_1H_2}$$

(d) Transfer function

$$\frac{C}{R} = \frac{G_1G_2 + G_1G_3 + G_1G_2G_4H_2 + G_1G_3G_4H_2}{1 + G_1G_2H_1H_2 + G_1G_3H_1H_2}$$

Q.25 Which of the following statements are correct regarding transfer function.

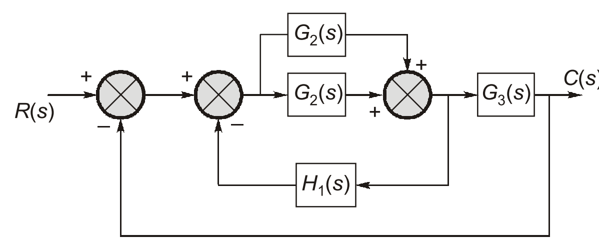
(a) The transfer function is defined only for a linear time-invariant system.

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

■■■■

Answers Block Diagram and Transfer Function

1.	(a)	2.	(b)	3.	(d)	4.	(a)	5.	(c)	6.	(a)	7.	(a)
8.	(b)	9.	(d)	10.	(c)	11.	(b)	12.	(b)	13.	(d)	14.	(c)
15.	(b)	16.	(d)	17.	(d)	18.	(c)	19.	(1)	20.	(31)	21.	(10)
22.	(1)	23.	(–0.5)	24.	(a, b, c)	25.	(a, c, d)	26.	(a, d)				

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)

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

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