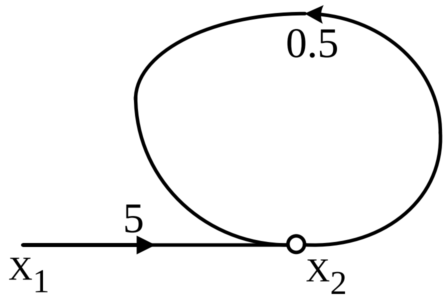
Signal Flow Graph

1. In the signal flow graph shown in figure $X_2 = TX_1$ where T, is equal to



(a) 2.5
(b) 5
(c) 5.5
(d) 10

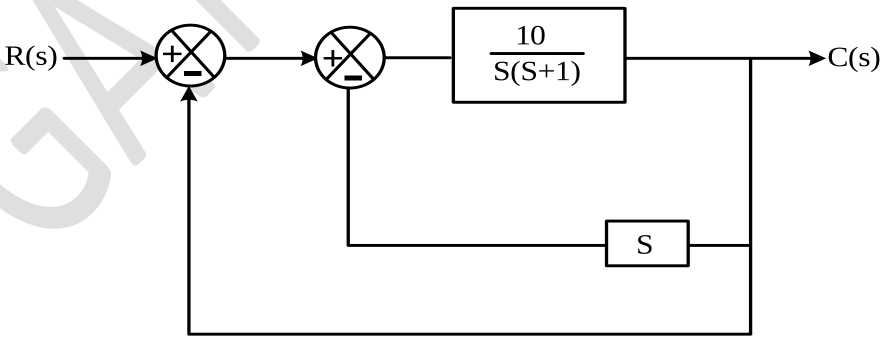
[GATE 1987: 2 Marks]

Soln. $X_2 = TX_1$

$$\frac{X_2}{X_1} = \frac{5}{\Delta} = \frac{5}{1-0.5} = 10$$

Option (d)

2. For the system shown in figure the transfer function $\frac{C(s)}{R(s)}$ *is equal to*



(a) $\frac{10}{S^2+S+10}$
(b) $\frac{10}{S^2+11S+10}$
(c) $\frac{10}{S^2+9S+10}$
(d) $\frac{10}{S^2+2S+10}$

[GATE 1987: 2 Marks]

Soln. The forward path transmittance $= \frac{10}{S(S+1)}$

The two closed loop are $L_1 = \frac{-10}{S(S+1)}$

$$L_2 = \frac{-10S}{S(S+1)}$$

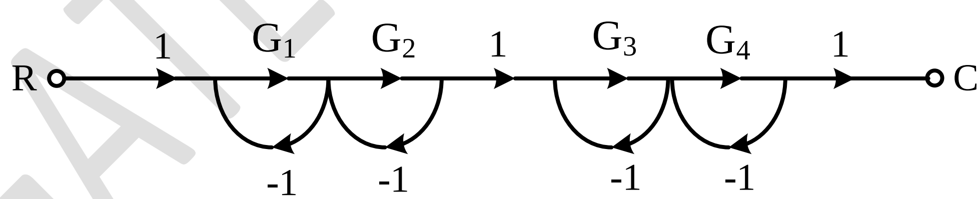
$$\frac{C(S)}{R(S)} = \frac{10/S(S+1)}{1 - \left\{\frac{-10}{S(S+1)} \frac{-10}{S+1}\right\}}$$

$$= \frac{10}{S(S+1)\left[1 + \frac{10}{S(S+1)} + \frac{10}{(S+1)}\right]} = \frac{10\ \ S(S+1)}{S(S+1)[S(S+1) + 10 + 10S]}$$

$$= \frac{10}{S^2 + S + 10S + 10} = \frac{10}{S^2 + 11S + 10}$$

Option (b)

3. The C/R for the signal flow graph in figure is



(a) $\frac{G_1 G_2 G_3 4}{(1+G_1 G_2)(1+G_3 G_4)}$

(b) $\frac{G_1 G_2 G_3 G_4}{(1+G_1+G_2+G_1 G_2)(1+G_3+G_4+G_3 G_4)}$

(c) $\frac{G_1 G_2 G_3 G_4}{(1+G_1+G_2)(1+G_3+G_4)}$

(d) $\frac{G_1 G_2 G_3 G_4}{(1+G_1+G_2+G_3+G_4)}$

[GATE 1989: 2 Marks]

Soln. The forward path transmittance = $G_1\ G_2\ G_3\ G_4$

Individual loops are, $-G_1$, $-G_2$, $-G_3$, $-G_4$.

Product of non touching loops, G_1G_3, G_1G_4, G_2G_3, G_2G_4

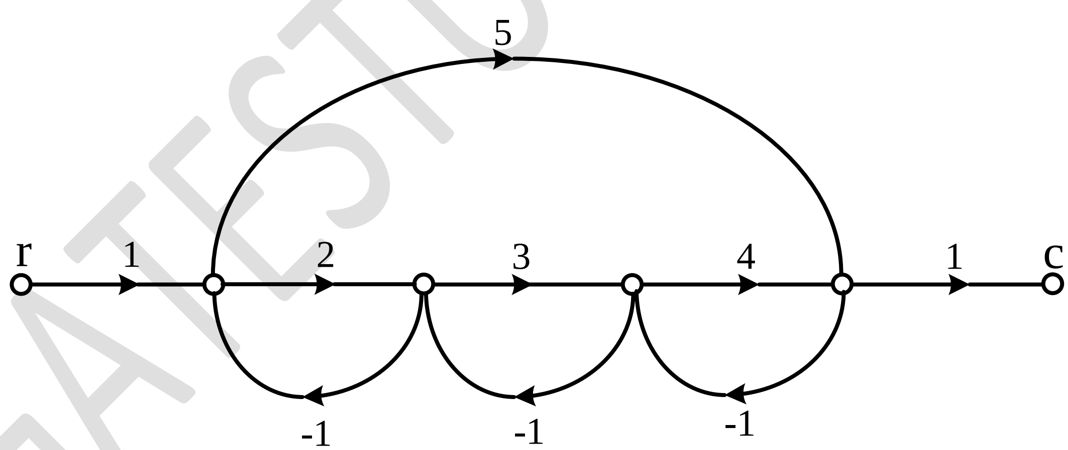
$$\Delta = 1 - [-G_1 - G_2 - G_3 - G_4] + [G_1G_3 + G_1G_4 + G_2G_3 + G_2G_4]$$

$$\frac{S}{R} = \frac{G_1G_2G_3G_4}{(1 + G_1 + G_2 + G_3 + G_4) + (G_1G_3 + G_1G_4 + G_2G_3 + G_2G_4)}$$

$$= \frac{G_1G_2G_3G_4}{(1 + G_1 + G_2)(1 + G_3 + G_4)}$$

Option (c)

4. In the signal flow graph of figure the gain c/r will be



(a) 11/9 (c) 24/23

(b) 22/15 (d) 44/23

[GATE 1991: 2 Marks]

Soln. The forward path $P_1 = 1 \times 2 \times 3 \times 4 = 24$

The forward path $P_2 = 5$

$$\Delta_1 = 1$$

$$L_1 = -2,\ \ L_2 = -3,\ \ L_3 = -4$$

Non touching loops $\rightarrow L_1 L_3$

The loop $L_2 = -3$ does not touch the path P_2

So, $\Delta_2 = (1 - L_2)$

$= 1 + 3$

$= 4$

$$\frac{S}{R} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

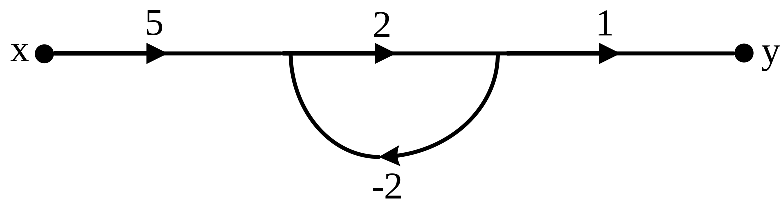
$$= \frac{24 \times 1 + 5 \times 4}{1 — (-2 - 3 - 4 - 5) + (-2) \times (-4)}$$

$$= \frac{24 + 20}{(1 + 14) + 8}$$

$$= \frac{44}{23}$$

Option (d)

5. In the signal flow graph of figure y/x equals



(a) 3
(b) 5/2
(c) 2
(d) None of the above

[GATE 1997: 2 Marks]

Soln. Transfer function

$$\frac{Y}{X} = \frac{P_K \Delta_K}{\Delta}$$

$P_K = 5 \times 2 \times 1 = 10$

$\Delta_K = 1$

$\Delta_K = 1$

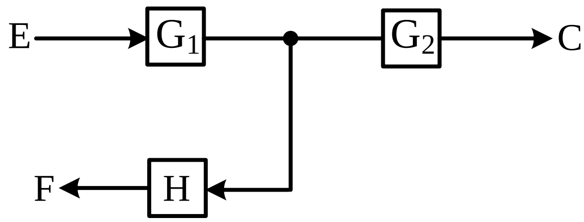
$\Delta = 1 - (-4) = 5$

$\frac{Y}{X} = \frac{10}{5}$

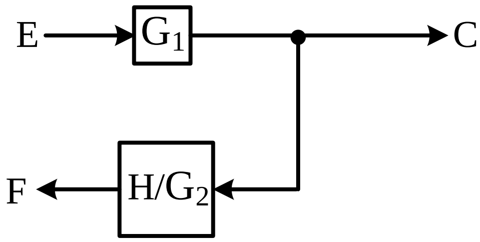
= 2

Option (c)

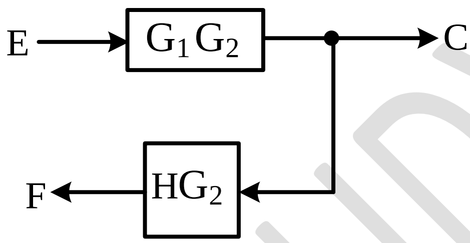
6. The equivalent of the block diagram in the figure is given as



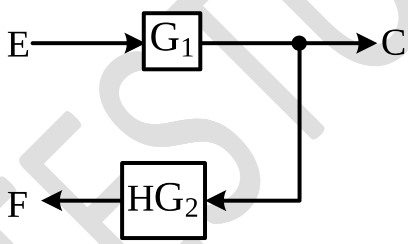
(a)



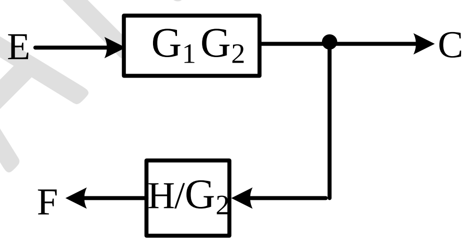
(b)



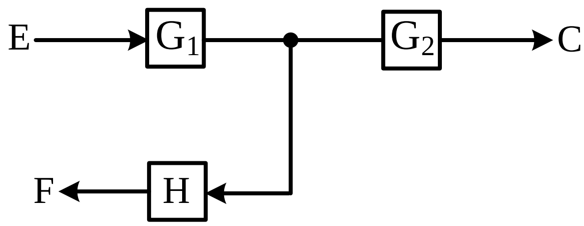
(c)



(d)

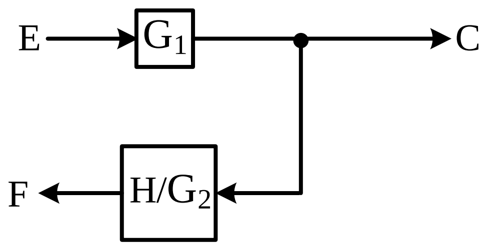


Soln.



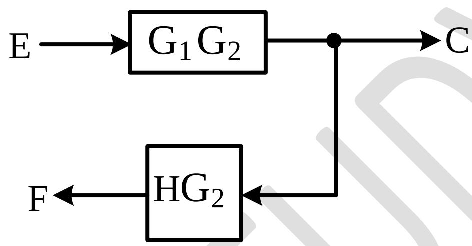
$$F = E\,G_1 H$$

(a)



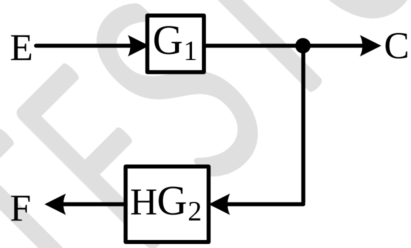
$$F = \frac{E\,G_1 H}{G_2}$$

(b)



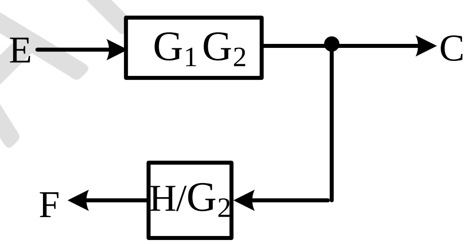
$$F = \frac{E\,G_1 G_2}{H\,G_2}$$

(c)



$$F = E\,G_1 H\,G_2$$

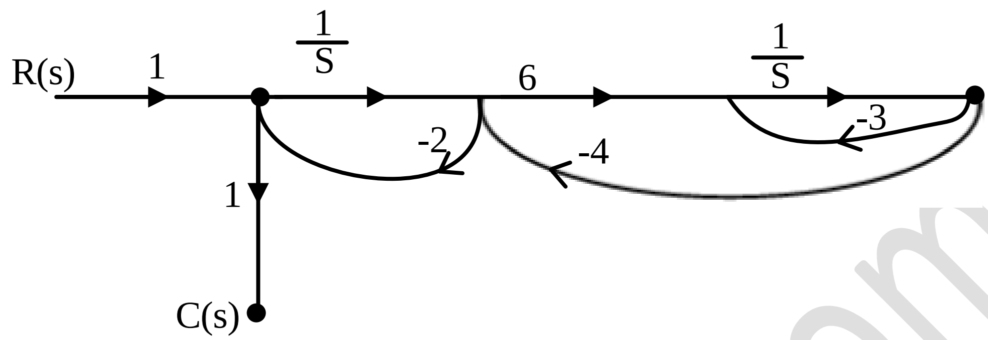
(d)



$$F = \frac{E\,G_1\,G_2\,H}{G_2} = E\,G_1\,H$$

Option (d)

7. The signal flow graph of a system is shown in the figure. The transfer function $\frac{C(s)}{R(s)}$ of the system is



(a) $\frac{6}{S^2+29S+6}$

(b) $\frac{6S}{S^2+29S+6}$

(c) $\frac{S(S+2)}{S^2+29S+6}$

(d) $\frac{S(S+27)}{S^2+29S+6}$

[GATE 2003: 2 Marks]

Soln. The transfer function $\frac{C(S)}{R(S)}$ of the systems?

$$L_1 = \frac{-3}{S}, L_2 = -4 \times \frac{6}{S}, \quad L_3 = \frac{-2}{S}$$

$P_1 = 1$

Loops L_1 and L_3 are not touching the forward path

$$\Delta_1 = 1 - L_1 - L_3$$

$$= 1 + \frac{3}{S} + \frac{24}{S}$$

$$= \frac{S+27}{S}$$

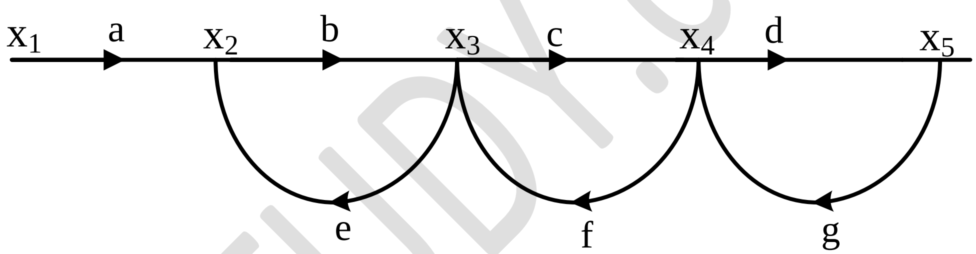
$$\frac{C(S)}{R(S)} = G(s) = \frac{P_1 \Delta_1}{1 - (loop\ gain) + pair\ of\ non\ tuching\ loops}$$

$$\frac{\frac{S+27}{S}}{1-\left(\frac{-3}{S}\frac{-24}{S}\frac{-2}{S}\right)+\frac{-2}{S}\times\frac{-3}{S}}$$

$$\frac{\frac{S+27}{S}}{1+\frac{29}{S}+\frac{6}{S^2}}=\frac{S(S+27)}{S^2+29S+6}$$

Option (d)

8. Consider the signal flow graph shown in the figure. The gain X_5 / X_1 is



(a) $\frac{1-(be+cf+dg)}{abc}$

(b) $\frac{bedg}{1-(be+cf+dg)}$

(c) $\frac{abcd}{1-(be+cf+dg)+bedg}$

(d) $\frac{1-(be+cf+dg)+bedg}{abcd}$

[GATE 2004: 2 Marks]

Soln. The forward path transmittance P_1 = abcd

All the loops touch the forward path $\Delta_1 = 1$

$$L_1 = be, \qquad L_2 = Cf, L_3 = dg$$

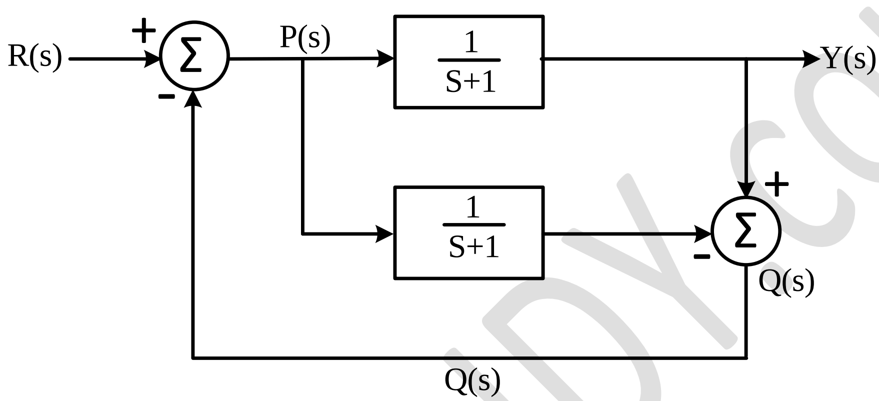
Non touching loops are $L_1,\ \ L_3$

$$L_1 L_3 = be\ dg$$

$$\frac{X_5}{X_1} = \frac{abcd}{1 - (be + cf + dg) + be\,dg}$$

Option (c)

9. The transfer function Y(s) / R(s) of the system shown is



(a) 0

(b) $\frac{1}{S+1}$

(c) $\frac{2}{S+1}$

(d) $\frac{2}{S+3}$

[GATE 2010: 1 Mark]

Soln. $Q(s) = P(s)\left[\frac{1}{S+1} - \frac{1}{S+1}\right]$

$= 0$

$P(s) = R(s) - 0$

$= R(s)$

$$Y(s) = \frac{P(s)}{S+1}$$

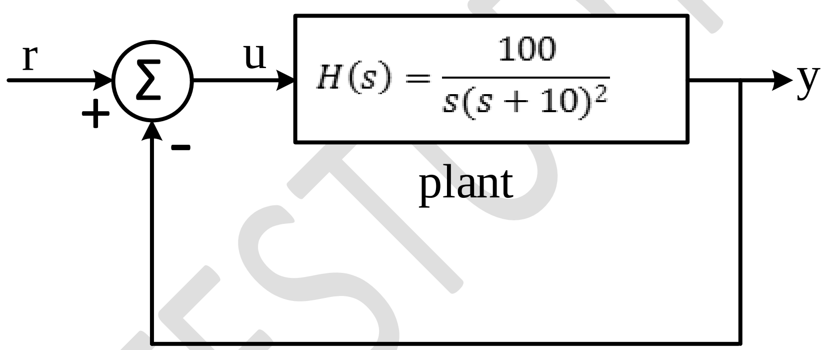
$$= \frac{R(s)}{S+1}$$

$$\frac{Y(S)}{R(S)} = \frac{1}{S+1}$$

Option (b)

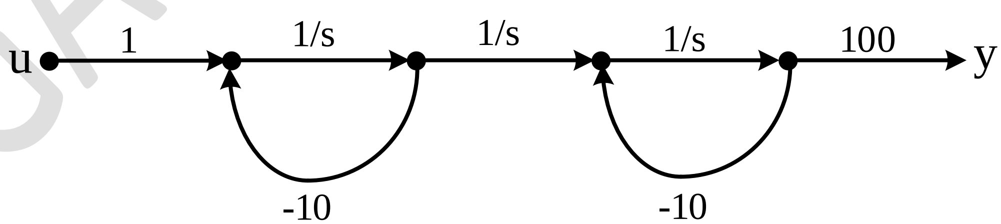
Common Data for Question 10 and Question 11

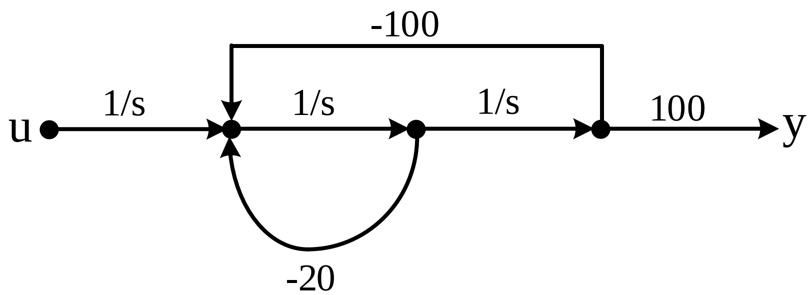
The input-output transfer function of a plant $H(s) = \frac{100}{S(S+10)^2}$.The plant is placed in unity negative feedback configuration as shown in the figure below.

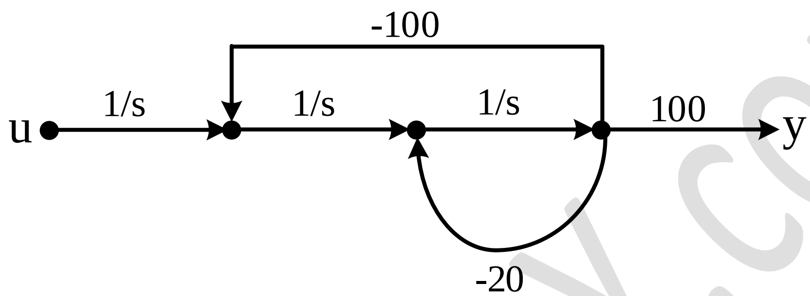


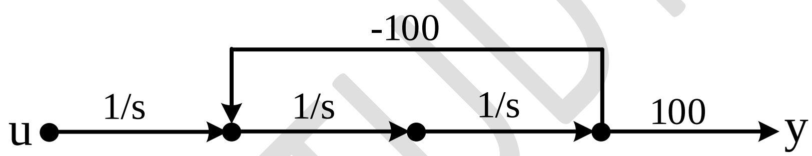
10. The signal flow graph that DOES NOT model the plant transfer function H(s) is

(a)



(b) 

(c) 

(d) 

Soln. The transfer function of a plant $H(s) = \frac{100}{S(S+10)^2}$

For the figure (a) $P_1 = \frac{100}{S^3}$, $\Delta_1 = 1$

$(all\ the\ loops\ touch\ the\ forward\ path)$

$$\frac{Y}{U} = \frac{100/S^3}{1 - \left(\frac{-10}{S}\frac{-10}{S}\right) + \frac{10}{S} \times \frac{10}{S}}$$

$$= \frac{\frac{100}{S^2}}{1 + \frac{20}{S} + \frac{100}{S^2}} = \frac{100}{S(S+10)^2}$$

For figure (b) $P_1 = \frac{100}{S^3}$, $\Delta_1 = 1$

$$\frac{Y}{U} = \frac{\frac{100}{S^3}}{1 - \left(\frac{-100}{S^2}\frac{-20}{S}\right)} = \frac{\frac{100}{S^3}}{1 + \frac{100}{S^2} + \frac{20}{S}} = \frac{100}{S(S+10)^2}$$

For Figure (c)

$$P_1 = \frac{100}{S^3}, \quad \Delta_1 = 1$$

$$\frac{Y}{U} = \frac{\frac{100}{S^3}}{1 - \left(\frac{-100}{S^2}\frac{-20}{S}\right)} = \frac{100}{S(S+10)^2}$$

For Figure (d),

$$\frac{Y}{U} = \frac{\frac{100}{S^3}}{1 - \left(\frac{-100}{S^2}\right)} = \frac{\frac{100}{S^3}}{1 + \frac{100}{S^2}} = \frac{100\ S^2}{S^3(S^2+100)} = \frac{100}{S(S^2+100)}$$

Which is not a transfer function of H(S)

Option (d)

11. The gain margin of the system under closed loop unity negative feedback is

$G(s)H(s) = \frac{100}{S(S+10)^2}$

(a) 0 dB

(b) 20 dB

(c) 26 dB

(d) 46 dB

[GATE 2011: 2 Marks]

Soln. The gain margin of the system under closed loop unity negative feedback is

$G(s)H(s) = \frac{100}{S(S+10)^2}$

$\emptyset = -90^0 - 2tan^{-1}\left(\frac{\omega}{10}\right)$

Flow phase cross aver frequency $\emptyset = -180^0$

$$-180 = -90^0 - 2tan^{-1}\left(\frac{\omega}{10}\right)$$

$$\omega = 10\, rad/sec$$

$$G(j\omega)H(j\omega) = \frac{100}{j\omega\,(j\omega + 10)^2}$$

$$|G(j\omega)H(j\omega)| = \frac{100}{\omega(\omega^2 + 100)}$$

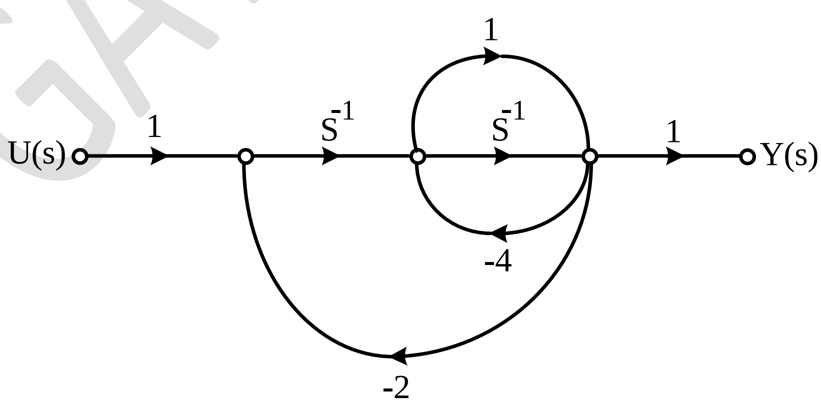
$$= \frac{100}{10(100 + 100)} = \frac{1}{20}$$

$$Gain\ margin\ (G.M) = \frac{1}{|G(j\omega)H(j\omega)|} = 20$$

$$G.M\ in\ dB = 20log_{10}^{20} = 26\ dB$$

Option (c)

12. The signal flow graph for a system is given below. The transfer function $\frac{Y(s)}{U(s)}\ for\ this\ system\ is$



(a) $\frac{s+1}{5s^2+6s+2}$

(b) $\frac{s+1}{s^2+6s+2}$

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

(d) $\frac{1}{5s^2+6s+2}$

[GATE 2013: 2 Marks]

Soln. The forward path transmittance $P_1 = S^{-1} \times S^1 = \frac{1}{S^2}$

The forward path transmittance $P_2 = S^{-1} = \frac{1}{S}$

$\Delta_1 = 1, \Delta_2 = 1$

$\Delta = 1 - (-2S^{-2} - 2S^{-1} - 4S^{-1} - 4)$

$$= 1 + \frac{2}{S^2} + \frac{2}{S} + \frac{4}{S} + 4$$

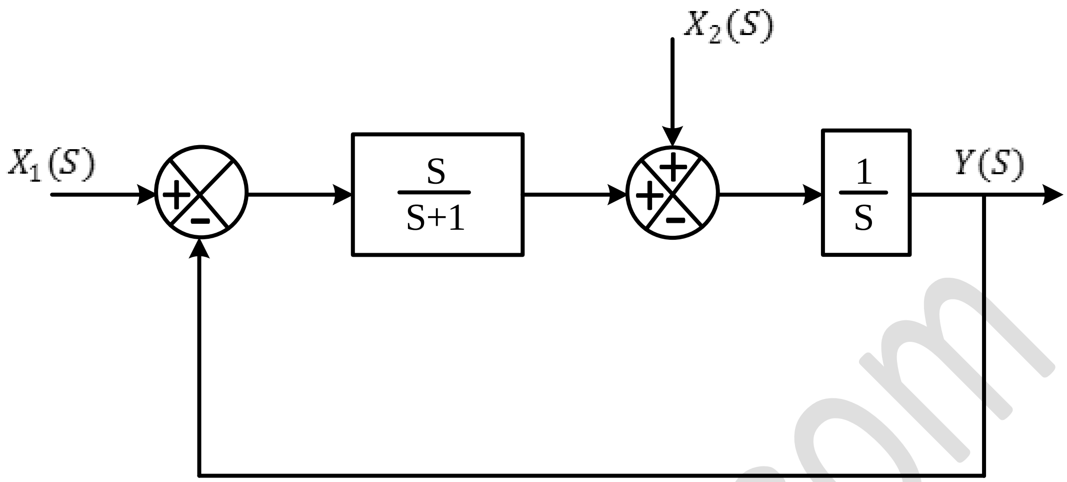
$$= 1 + \frac{2}{S^2} + \frac{2}{S} + \frac{4}{S} + 4$$

$= (5S^2 + 6S + 2)/S^2$

$$\frac{Y(S)}{U(S)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta} = \frac{\frac{1}{S^2} + \frac{1}{S}}{(5S^2 + 6S + 2)/S^2} = \frac{(S+1)}{5S^2 + 6S + 2}$$

Option (a)

13.For the following system,



When $X_1(S) = 0$, the transfer function $\frac{Y(S)}{X_2(S)}$ is

(a) $\frac{S+1}{S^2}$

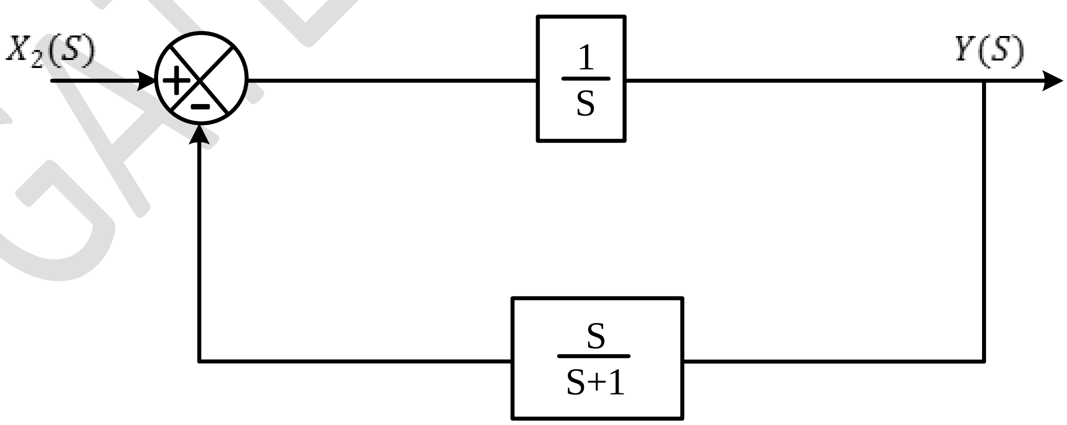
(b) $\frac{1}{S+1}$

(c) $\frac{S+2}{S(S+1)}$

(d) $\frac{S+1}{S(S+2)}$

[GATE: 2014: 1 Mark]

Soln. With $X_1(s) = 0$, the block diagram is redrawn as

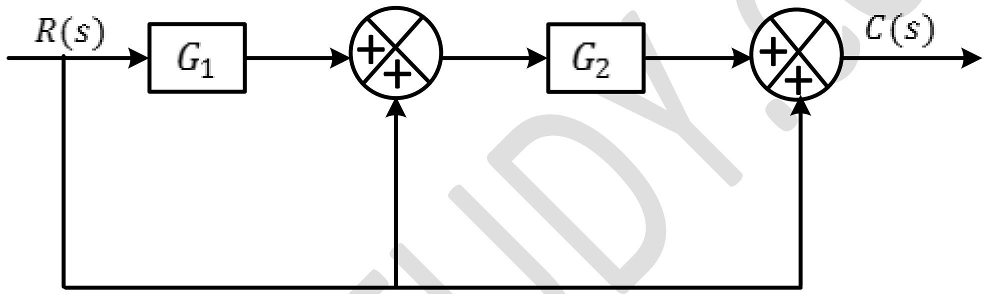


$$T(s) = \frac{Y(S)}{X_2(S)} = \frac{G(S)}{1 + G(S)H(S)}$$

$$G(s) = \frac{1}{S}, H(s) = \frac{S}{S+1} = \frac{1/S}{1 + \frac{1}{S} \times \frac{S}{S+1}} = \frac{1(S+1)}{S(S+1+1)} = \frac{(S+1)}{S(S+2)}$$

Option (d)

14.Consider the following block diagram in the figure



the transfer function $\frac{C(S)}{R(S)}$ is

(a) $\frac{G_1G_2}{1+G_1G_2}$

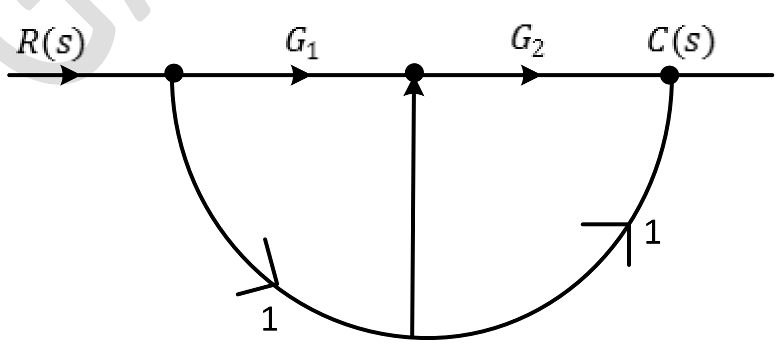
(b) $G_1G_2 + G_1 + 1$

(c) $G_1G_2 + G_2 + 1$

(d) $\frac{G_1}{1+G_1G_2}$

[GATE 2014: 1 Mark]

Soln. Converting the block diagram into signal flow graph as:



The forward paths

$$P_1 = G_1 G_2$$

$$P_2 = G_2$$

$$P_3 = 1.1 = 1$$

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

Option (c)