GATE 2026 TEST SERIES

Control Systems

Test 1

1. The open loop transfer function of closed loop system is given by

$G(s)H(s)=\dfrac{K}{s^2(s^2+2s+2)}$. The angle of departure of the root locus at

$s=-1+j$ is

A) -180^0

B) 90^0

C) -90^0

D) Zero

Angle of Departure, $\phi_D = 180 - \phi$

$\phi_{p1} = \phi_{p2} = 135^0$, $\phi_{p3}=90^0$

$\phi = 270° + 90° = 360^0$

$\phi_D = 180° - 360^0 = -180^0$

Correct Answer: **A**

Not Attempted : !

Marks : 2 / 0.66 (-Ve)

2. Which of the following statements is/are correct?

A) Transfer function can't be obtained from the signal flow graph of the system

B) Transfer function typically characterizes to linear time invariant systems

C) Transfer function gives the ratio of output to input in frequency domain of the system.

D) Transfer function can be obtained from the signal flow graph of the system

Correct Answer: **B,C,D** *Not Attempted :* Marks : 1 / 0 (-Ve)

Correct Statements are

(i) Transfer function can be obtained from signal flow graph of the system.

(ii) Transfer function typically characterizes to LTI systems.

(iii) Transfer function gives the ratio of output to input in s- domain of system.

$$TF = \left.\frac{L[\text{Output}]}{L[\text{Input}]}\right|_{\text{Initial conditions}=0}$$

3. An electrical system and its signal-flow graph representation are shown in figure (a) and (b) respectively. The values of G_2 and H, respectively, are

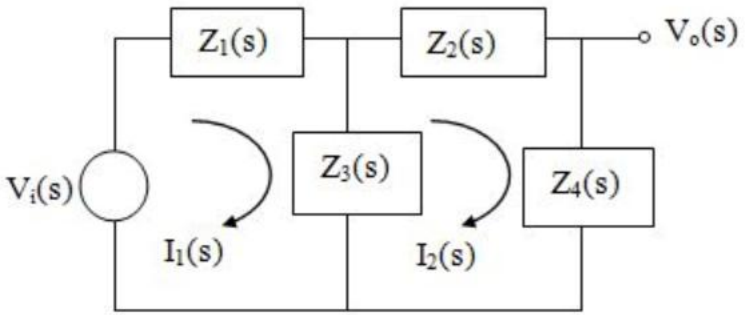


Fig a

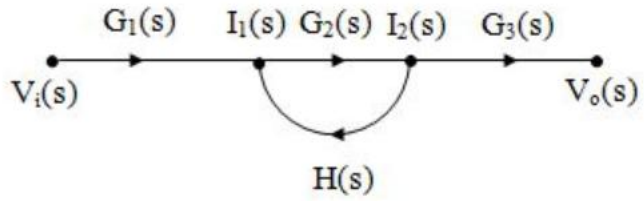


Fig (b)

A) $\dfrac{Z_3(s)}{Z_2(s)+Z_3(s)+Z_4(s)}, \dfrac{-Z_3(s)}{Z_1(s)+Z_3(s)}$

B) $\dfrac{Z_3(s)}{Z_2(s)+Z_3(s)+Z_4(s)}, \dfrac{Z_3(s)}{Z_1(s)+Z_3(s)}$

C) $\dfrac{-Z_3(s)}{Z_2(s)-Z_3(s)+Z_4(s)}, \dfrac{-Z_3(s)}{Z_1(s)+Z_3(s)}$

D) $\dfrac{-Z_3(s)}{Z_2(s)-Z_3(s)+Z_4(s)}, \dfrac{Z_3(s)}{Z_1(s)+Z_3(s)}$

Correct Answer: **B** *Not Attempted :* Marks : 2 / 0.66 (-Ve)

Apply KVL in 1st loop

$$V_i(s) = I_1(s)[Z_1(s) + Z_3(s)] - I_2(s)Z_3(s)$$

$$I_1(s) = \frac{V_i(s)}{Z_1(s) + Z_3(s)} + \frac{I_2(s)Z_3(s)}{Z_1(s) + Z_3(s)} \;\ldots.\; (1)$$

Apply KVL in 2nd Loop

$$[I_2(s)-I_1(s)]Z_3(s) + I_2(s)Z_2(s)+I_2(s)Z_4(s)= 0$$

$$I_2(s)[Z_2(s)+Z_3(s)+Z_4(s)] = I_1(s)\, Z_3(s)$$

$$I_2(s) = \frac{Z_3(s)}{Z_2(s) + Z_3(s) + Z_4(s)} I_1(s) \;\ldots.(2)$$

From signal flow graph

$$I_1(s) = V_i\, G_1(s) + I_2(s)\, H(s) \;\ldots\ldots\ldots\; (3)$$

$$I_2(s) = G_2(s)\, I_1(s) \;\ldots\ldots\ldots\; (4)$$

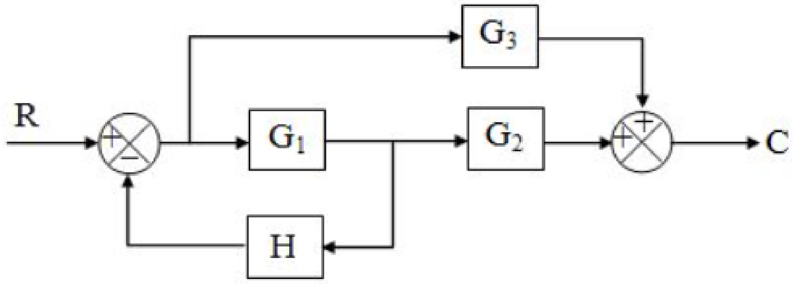
Comparing equation (1) and (3)

$$\therefore H(s) = \frac{Z_3(s)}{Z_1(s) + Z_3(s)}$$

Comparing equation (2) and (4)

$$G_2(s) = \frac{Z_3(s)}{Z_2(s) + Z_3(s) + Z_4(s)}$$

4. The overall transfer function (C/R) for the block diagram shown in figure is.



A) $\frac{C}{R}=\frac{G_1G_2+G_3}{1-G_1H}$

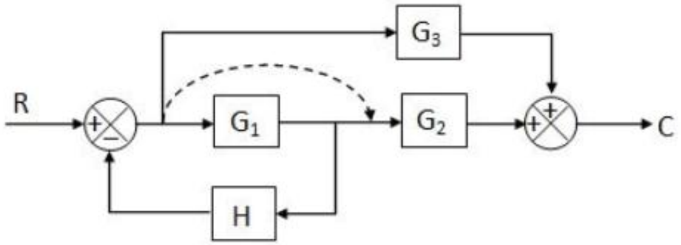
B) $\frac{C}{R}=\frac{G_3}{1+G_1H}$

C) $\frac{C}{R}=\frac{G_1G_2G_3}{1+G_1H}$

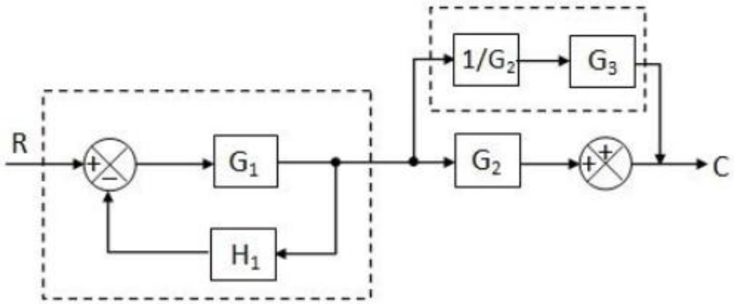
D) $\frac{C}{R}=\frac{G_1G_2+G_3}{1+G_1H}$

Correct Answer: **D** *Not Attempted :* Marks : 2 / 0.66 (-Ve)

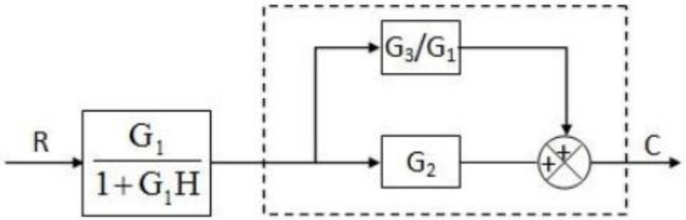
Step-1: Move the branch point after the block



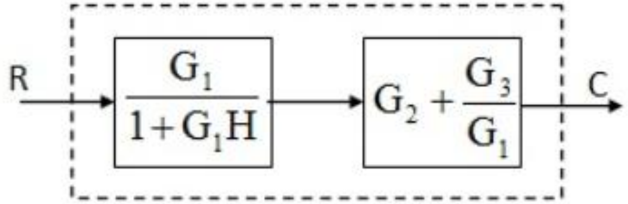
Step-2: Eliminate the feedback path and combining blocks in cascade



Step-3: Combining parallel blocks



Step-4: Combining blocks in cascade



$$\frac{C}{R} = \left(\frac{G_1}{1+G_1H}\right)\left(G_2 + \frac{G_3}{G_1}\right) = \left(\frac{G_1}{1+G_1H}\right)\left(\frac{G_1G_2 + G_3}{G_1}\right) = \frac{G_1G_2 + G_3}{1+G_1H}$$

Result:

The overall transfer function of the system, $\frac{C}{R} = \frac{G_1G_2 + G_3}{1+G_1H}$

5. The equivalent of the block diagram in Fig-1 is given as

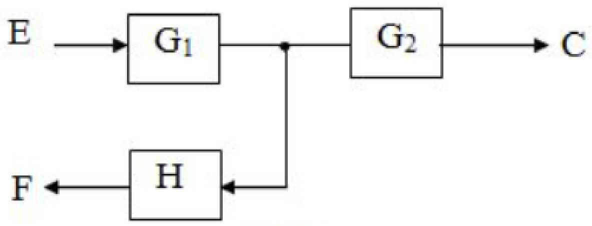


Fig-1

A)

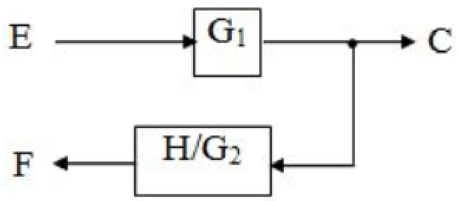


Fig-A

B)

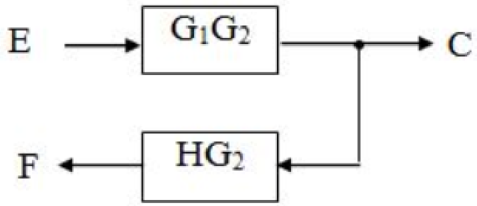


Fig-B

C)

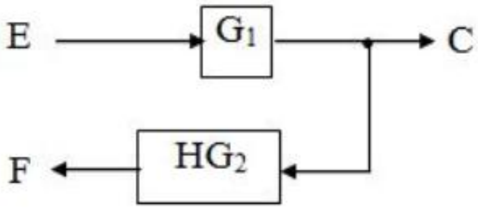


Fig-C

D)

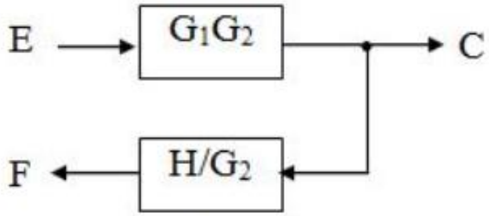


Fig-D

Correct Answer: **D** *Not Attempted :* Marks : 1 / 0.33 (-Ve)

In the options, the take-off point shifted after the block gain G_2. For this the equivalent Block Diagram, is option D.

6. A unity feedback system has the forward loop transfer function

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

A) The range of K for stable operation is < 2

B) The range of K for stable operation is > 2

C) The RLD imaginary axis crossover points are $s = \pm j2\sqrt{2}$

D) The RLD imaginary axis crossover points are $s = \pm j\sqrt{2}$

Correct Answer: **B,C** *Not Attempted :* ! Marks : 2 / 0 (-Ve)

i. Characteristic equation is

$$1+\frac{K(s+2)^2}{s^2(s-1)}=0$$

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

$$s^3-s^2+Ks^2+4Ks+4K=0$$

$$s^3+(K-1)s^2+4Ks+4K=0$$

$$\begin{array}{c|ll} s^3 & 1 & 4K \\ s^2 & (K-1) & 4K \\ s^1 & \left(\dfrac{(K-1)(4K)-4K}{K-1}\right) & 0 \\ s^0 & 4K & \end{array}$$

$K-1>0, K>1$

$4K>0, K>0$

$(K-1)(4K)-4K>0$

$4K(K-1-1)>0$

$K-2>0, K>2$

$\therefore$ Range of K for stability is $K>2$

ii. Imaginary axis cross over points can be calculated from the above RH tabulation.

s^1 row = 0 ie $(K-1)(4K)-4K=0$

$K=2$

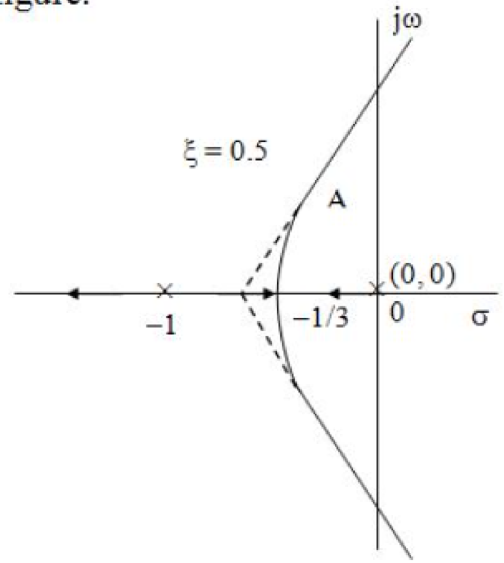
Auxiliary equation s^2 row =0

$(K-1)s^2+4K=0$ substituting K=2

$s^2+8=0$ gives $s=\pm j2\sqrt{2}$

$\therefore$ RLD crosses the imaginary axis at $s=\pm j2\sqrt{2}$

7. The characteristic equation of a unity negative feedback system is $1+KG(s)=0$. The open loop transfer function $G(s)$ has one pole at 0 and two poles at -1. The root locus of the system for varying K is shown in the figure.



The constant damping ratio line, for $\xi = 0.5$, intersects the root locus at point A. The distance from the origin to point A is given as 0.5. The value of K at point A is ________.

Correct Answer: **0.375** Answer Range: **(0.36 , 0.38)** *Not Attempted :* Marks : 2 / 0 (-Ve)

Given $\text{T.F} = \dfrac{K}{s(s+1)^2}$

Given $\xi = 0.5 \Rightarrow \theta = \cos^{-1}(\xi) = \cos^{-1}(0.5) = 60° \Rightarrow \theta = 60°$

Origin to point distance = 0.5

Now co-ordinates of point (A) = $r\angle\theta = 0.5\angle 60°$

$$r\angle\theta = r\cos\theta + j\, r\sin\theta = 0.5\cos 60° + j(0.5)\sin 60°$$

$$= 0.5 \times 0.5 + j(0.5) \times \frac{\sqrt{3}}{2} = 0.25 + j0.433$$

Point A co-ordinates = $0.25 + j0.433$

Magnitude $\Rightarrow |A| = \sqrt{(0.25)^2 + (0.433)^2} = 0.5$

Now pole [at $s = -1$] to point A distance = $\sqrt{1^2 - 0.5^2}$

$$= \sqrt{1 - 0.25} = \sqrt{0.75}$$

For two poles [$s = -1$, $s = -1$] $\Rightarrow$ distance = $\sqrt{0.75}$, $\sqrt{0.75}$

Formula: $K = \dfrac{\text{Product of distances from point A to poles}}{\text{Product of distances from point A to zeros}}$

$$K = \frac{0.5 \times \sqrt{0.75} \times \sqrt{0.75}}{1} \text{ [No zeros hence distance = 1]}$$

$$K = 0.375$$

8. 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

Correct Answer: **C** *Not Attempted :* ! Marks : 1 / 0.33 (-Ve)

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

Centroid =

$$\frac{\Sigma \text{real parts of poles of } G(s)H(s) - \Sigma \text{real parts of zeros of } G(s)H(s)}{(P-Z)}$$

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

9. For the given following set of algebraic equations which of the following is/are true?

$$y_2 = a\,y_1 - g y_3$$

$$y_3 = e\,y_2 + c\,y_4$$

$$y_4 = b\,y_2 - d\,y_4$$

A) The gain $\frac{y_2}{y_1} = \frac{(1+d)}{1+d+eg+bcg+edg}$

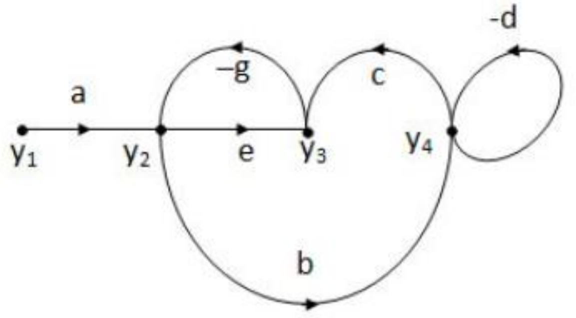
B) The gain $\frac{y_3}{y_1} = \frac{ae(1+d)+abc}{1+d+eg+bcg+edg}$

C) The gain $\frac{y_2}{y_1} = \frac{a(1+d)}{1+d+eg+bcg+edg}$

D) The gain $\frac{y_3}{y_1} = \frac{e(1+d)+abc}{1+d+eg+bcg+edg}$

Correct Answer: **B,C** *Not Attempted :* ! Marks : 2 / 0 (-Ve)

The signal flow graph is drawn below



Numbers of loops = 3

No. of two non-touching loop = 1

No. of forward path from y_1 to y_2 = 1

No. of forward paths from y_1 to y_3 = 2

Applying the Mason's gain formula

$$\frac{y_2}{y_1} = \frac{a(1+d)}{1+d+eg+bcg+edg}$$

$$\frac{y_3}{y_1} = \frac{ae(1+d)+abc}{1+d+eg+bcg+edg}$$

10. A causal system having the transfer function $G(s) = \dfrac{1}{s+2}$ is excited with 10u(t). The time at which the output reaches 99% of its steady state value is

A) 2.1 sec

B) 2.3 sec

C) 2.8 sec

D) 2.9 sec

Correct Answer: **B** *Not Attempted :* ! Marks : 2 / 0.66 (-Ve)

Given T.F is $G(s) = \dfrac{1}{s+2}$

$r(t) = 10\ u(t)$

$R(s) = \dfrac{10}{s}$

$C(s) = G(s)R(s)$

$$= \frac{1}{s+2} \times \frac{10}{s} = \frac{10}{s(s+2)}$$

$$\Rightarrow \frac{10}{s(s+2)} = \frac{A}{s} + \frac{B}{s+2}$$

$A = 5,\ \ B = -5$

$$\therefore C(s) = \frac{5}{s} - \frac{5}{s+2}$$

Apply Inverse Laplace Transform

$c(t) = 5\ [1 - e^{-2t}]$

If $t \to \infty$ the steady state value = 5

99% of steady state value is

$5[1 - e^{-2t}] = 5 \times 0.99$

$1 - e^{-2t} = 0.99$

$-e^{-2t} = 1 - 0.99 = 0.01$

$-2t = ln(0.01)$

$-2t = -4.60$

$t = 2.3$ sec

11. The characteristic equation of an LTI system is given by $F(s) = s^5 + 2s^4 + 3s^3 + 6s^2 - 4s - 8 = 0$. The number of roots that lie strictly in the left half of s-plane is ______.

Correct Answer: **2** Answer Range: **(2 , 2)** *Not Attempted :* Marks : 1 / 0 (-Ve)

$$\begin{array}{c|ccc} s^5 & 1 & 3 & -4 \\ s^4 & 2 & 6 & -8 \\ s^3 & 0 & 0 & \end{array}$$

$$AE = 2s^4 + 6s^2 - 8 = 0$$

$$\frac{dAE}{ds} = 8s^3 + 12s = 0$$

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

$$\begin{array}{c|cc} s^3 & 0(2) & 0(3) \\ s^2 & 3 & -8 \\ s^1 & \frac{25}{3} & \\ s^0 & -8 & \end{array}$$

No. of RHS roots = 1

No. of $j\omega$ roots = 2

No. of LHS roots = 2

12. A unity feedback control system has an amplifier with gain $K_A = 10$ and gain ratio, $G(s) = 1/s(s+2)$ in the feed forward path. A derivative feedback, $H(s) = sK_0$ is introduced as a mirror loop around G(s). Find the derivative feedback constant, K_0 so that the system damping factor is 0.6.

A) The value of constant, $K_0 = 1.79$

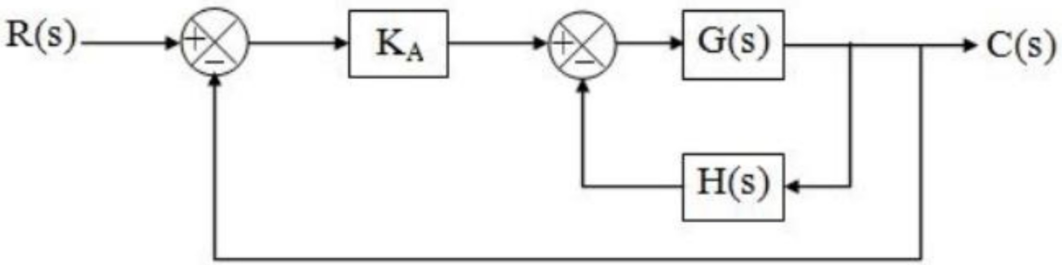
B) The value of constant, $K_0 = 2.94$

C) The value of constant, $K_0 = 2.79$

D) The value of constant, $K_0 = 1.94$

Correct Answer: **A** *Not Attempted :* ! Marks : 2 / 0.66 (-Ve)

The given system can be represented by the block diagram shown in figure.

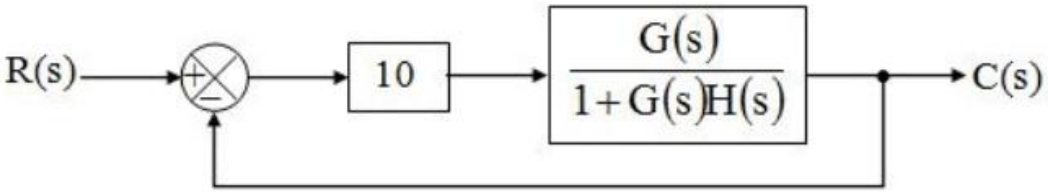


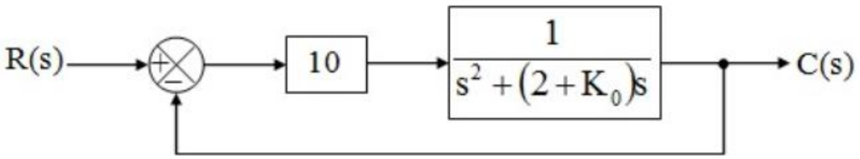
Here, $K_A = 10$; $G(s) = \dfrac{1}{s(s+2)}$ and $H(s) = sK_0$

The closed loop transfer function of the system can be obtained by block diagram reduction techniques.

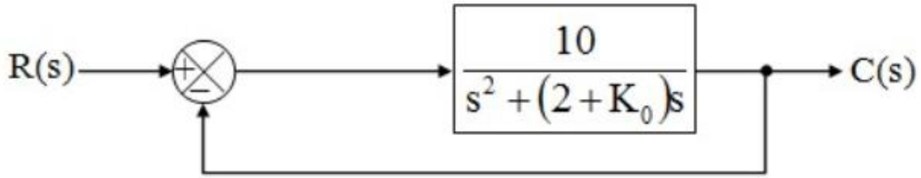
Step-1: Reducing the inner feedback loop.

$$\frac{G(s)}{1+G(s)H(s)} = \frac{\dfrac{1}{s(s+2)}}{1+\dfrac{1}{s(s+2)}sK_0} = \frac{1}{s(s+2)+sK_0} = \frac{1}{s^2+2s+sK_0} = \frac{1}{s^2+(2+K_0)s}$$

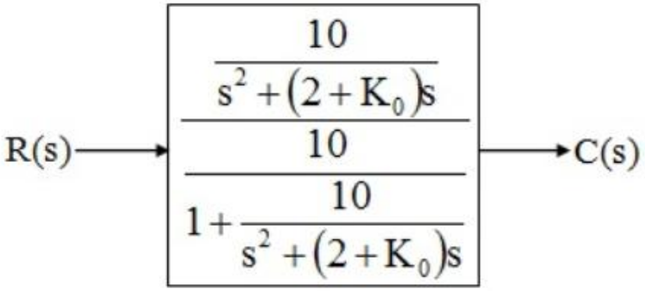


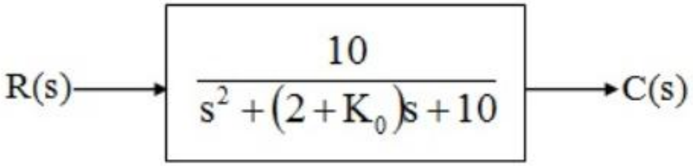


Step-2: Combining blocks in cascade



Step-3: Reducing the unity feedback path





The closed loop transfer function, $\frac{C(s)}{R(s)} = \frac{10}{s^2+(2+K_0)s+10}$ ……..(1)

The given system is a second order system. The value of K_0 can be determined by comparing the system transfer function with standard form of second order transfer function given below.

$$\left.\begin{array}{l}\text{S tan dard form of} \\ \text{Second order transfer function}\end{array}\right\} \frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

………..(2)

On comparing equation (1) & (2) we get,

$$\omega_n^2 = 10$$

$$\therefore \omega_n = \sqrt{10} = 3.162 \text{ rad/sec}$$

$$2 + K_0 = 2\zeta\omega_n$$

$$\therefore K_0 = 2\zeta\omega_n - 2$$

$$= 2 \times 0.6 \times 3.162 - 2 = 1.7944$$

13. For servomechanisms with open loop transfer function given below explain what type of input signal give rise to a constant steady state error and calculate the value.

$$G(s) = \frac{10}{(s+2)(s+3)}$$

A) Steady state error, $e_{ss} = 0.075$

B) Steady state error, $e_{ss} = 0.375$

C) Steady state error, $e_{ss} = 0.095$

D) Steady state error, $e_{ss} = 0.65$

Correct Answer: **B** *Not Attempted :* ! Marks : 2 / 0.66 (-Ve)

$$G(s) = \frac{10}{(s+2)(s+3)}$$

Let us assume unity feedback system, $\therefore H(s) = 1$

The open loop system has no pole at origin. Hence it is a type-0 system.

In systems with type number-0, the step input will give a constant steady state error.

The steady state error with unit step input, $e_{ss} = \dfrac{1}{1+K_p}$;

Position error constant,

$$K_p = \underset{s\to 0}{\mathrm{Lt}}\, G(s)H(s) = \underset{s\to 0}{\mathrm{Lt}}\, G(s) = \underset{s\to 0}{\mathrm{Lt}}\, \frac{10}{(s+2)(s+3)} = \frac{10}{2\times 3} = \frac{5}{3}$$

Steady state error, $$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+\frac{5}{3}} = \frac{3}{3+5} = \frac{3}{8} = 0.375$$

14. A system has open-loop transfer function $G(s) = \frac{10}{s(s+1)(s+2)}$, what is the steady state error when it is subjected to the input $r(t) = 10+2t + 3/2\ t^2$?

A) Zero

B) 0.4

C) 4

D) Infinity

Correct Answer: **D** *Not Attempted :* ! Marks : 1 / 0.33 (-Ve)

Given $r(t) = 1 + 2t + \frac{3}{2}t^2$

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

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

$$e_{ss} = \underset{s \to 0}{Lt} \frac{s.R(s)}{1 + G(s)H(s)}$$

$$= \underset{s \to 0}{Lt} \frac{s\left(.\frac{s^2 + 2s + 3}{s^3}\right)}{1 + \frac{10}{s(s+1)(s+2)}}$$

$$= \underset{s \to 0}{Lt} \frac{(s^2 + 2s + 3)(s+1)(s+2)}{s^2(s+1)(s+2) + 10s} = \infty$$

15. Which of the following are the dis-advantages of Open loop control systems?

1. The open loop systems are simple and economical
2. The open loop systems are easier to construct
3. Generally the open loop systems are stable
4. The open loop systems are inaccurate and unreliable
5. The changes in the output due to external disturbances are not corrected automatically.

A) 1, 3 and 5

B) 1, 2 and 3

C) 1, 4 and 5

D) 4 and 5

Correct Answer: **D** *Not Attempted :* ! Marks : 2 / 0.66 (-Ve)

Advantages of Open loop systems:

1. The open loop systems are simple and economical
2. The open loop systems are easier to construct
3. Generally the open loop systems are stable

Disadvantage of Open loop systems:

1. The open loop systems are inaccurate and unreliable
2. The changes in the output due to external disturbances are not corrected automatically.