Time Response Analysis Questions

MCQ Question 1

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Let Y(s) be the unit-step response of a causal system having a transfer function $G\left(s\right)=\frac{3-s}{(s+1)(s+3)}$

that is, $Y\left(s\right)=\frac{G(s)}{s}$**. The forced response of the system is**

1. $u(t) - 2e^{-t} + e^{-3t}u(t)$
2. $2u(t) - 2e^{-t} + e^{-3t}u(t)$
3. $2u(t)$
4. $u(t)$

Answer (Detailed Solution Below)

Option 4 : u(t)

Time Response Analysis MCQ Question 1 Detailed Solution

<u>Concept:</u>

The output response of a system is equal to the sum of natural response and forced response.

Forced response: The response generated due to the pole of the input function is called the forced response.

Natural response: The response generated due to the pole of system function is called the natural response.

Calculation:

The output y(s) is given as

$$y\left(s\right)=\frac{G(s)}{s}=\frac{3-s}{s(s+1)(s+3)}$$

Converting into partial fractions

$$y\left(s\right)=\frac{3-s}{s(s+1)(s+3)}=\frac{A}{s}+\frac{B}{(s+1)}+\frac{C}{(s+3)}$$

Multiply whole equation LHS and RHS by s and put s = 0

A = 1

Multiply whole equation by (s + 1) and put s = -1

B = -2

Multiply whose equation by (s + 3) and put s = -3

C = 1

$$y\left(s\right)=\frac{1}{s}-\frac{2}{s+1}+\frac{1}{s+3}$$

Taking the ILT, we get:

$$y\left(t\right)=\underbrace{u(t)}_{\substack{\downarrow\\ Forced\ response}}\underbrace{-2e^{-t}u\left(t\right)+e^{-3t}u\left(t\right)}_{\substack{\downarrow\\ Transient\ response}}$$

MCQ Question 2

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The steady-state error due to unit step input to a type-1 system is:

1. 1/ (1 + kp)

2. Zero

3. 1/ Kp

4. Infinity

Answer (Detailed Solution Below)

Option 2 : Zero

Time Response Analysis MCQ Question 2 Detailed Solution

Concept:

K_p = position error constant = $\lim\limits_{s \to 0} G(s)H(s)$

K_v = velocity error constant = $\lim\limits_{s \to 0} sG(s)H(s)$

K_a = acceleration error constant = $\lim\limits_{s \to 0} s^2G(s)H(s)$

Steady-state error for different inputs is given by

Input	Type -0	Type - 1	Type -2
Unit step	$\frac{1}{1+K_p}$	0	0
Unit ramp	∞	$\frac{1}{K_v}$	0
Unit parabolic	∞	∞	$\frac{1}{K_a}$

From the above table, it is clear that for type – 1 system, a **system shows zero steady-state error for step-input.**

MCQ Question 3

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A second-order real system has the following properties:
The damping ratio $\xi = 0.5$ and undamped natural frequency $\omega_n = 10\ rad/s$, the steady state value at zero is 1.02.
The transfer function of the system is

1. $\frac{1.02}{s^2+5s+100}$

2. $\frac{102}{s^2+10s+100}$

3. $\frac{100}{s^2+10s+100}$

4. $\frac{102}{s^2+5s+100}$

Answer (Detailed Solution Below)

Option 2 : $\frac{102}{s^2+10s+100}$

Time Response Analysis MCQ Question 3 Detailed Solution

Standard 2nd order system is $\mathrm{T}(\mathrm{s}) = \frac{\mathrm{K}\omega_\mathrm{n}^2}{\mathrm{s}^2+2\xi\omega_\mathrm{n}\mathrm{s}+\omega_\mathrm{n}^2}$

Given $\xi = 0.5 \text{ and } \omega_\mathrm{n} = 10$

Steady state value $\mathrm{T}(\mathrm{s})|_{\mathrm{s}=0} = \mathrm{K} = 1.02$

$\therefore \mathrm{T}(\mathrm{s}) = \frac{(1.02)(100)}{\mathrm{s}^2+10\mathrm{s}+100} = \frac{102}{\mathrm{s}^2+10\mathrm{s}+100}$

MCQ Question 4

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Settling time is the time required for the system response to settle within a certain percentage of

1. maximum value
2. final value
3. input amplitude value
4. transient error value

Answer (Detailed Solution Below)

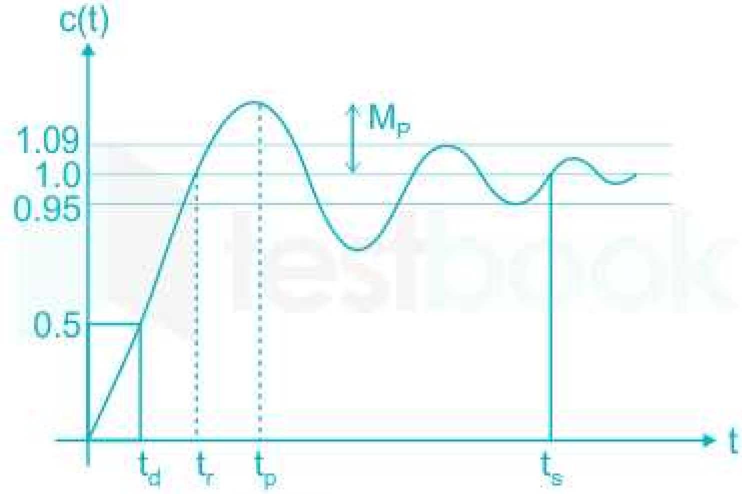
Option 2 : final value

Time Response Analysis MCQ Question 4 Detailed Solution

Settling time:

It is the time required for the response to reach the **steady-state (or) final value** and stay within the specific tolerance bands around the **final value.**

This is explained with the help of the following:



The settling time for 5% tolerance band is given by:

$t_s = \frac{3}{\zeta\omega_n} = 3T$

Similarly, for 2% tolerance, the settling time is given by:

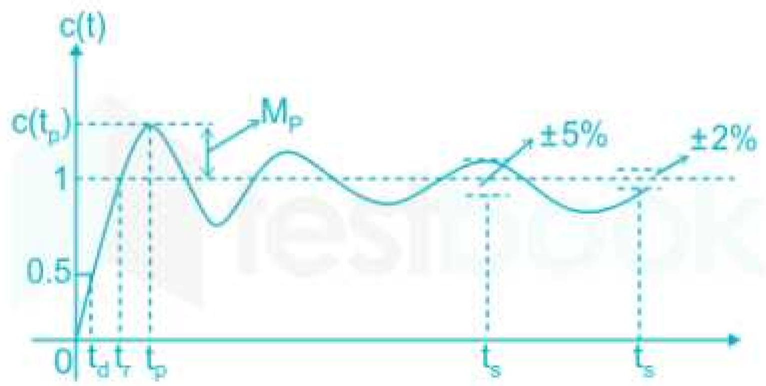
$t_s = \frac{4}{\zeta\omega_n} = 4T$

ζ = Damping ratio

ω_n = Natural frequency

Important Point

Time-domain specification (or) transient response parameters:



Rise time (t_r): It is the time taken by the response to reach from 0% to 100% Generally 10% to 9% for overdamped and 5% to 95% for the critically damped system is defined.

$c\left(t\right)|_{t=t_r} = 1 = 1 - \frac{e^{-\xi\omega_n t_r}}{\sqrt{1-\xi^2}} \sin\left(\omega_n t_r + \varphi\right)$

$t_r = \frac{\pi-\varphi}{\omega_d}$

Peak Time (t_p): It is the time taken by the response to reach the maximum value.

$\frac{dc(t)}{dt}\Big|_{t=t_p} = 0, t_p = \frac{\pi}{\omega_d}$

Delay time (t_d): It is the time taken by the response to change from 0 to 50% of its final or steady-state value.

$$c(t)|_{t=t_d} = 0.5$$

$$t_d \simeq \frac{1+0.7\xi}{\omega_n}$$

Maximum (or) Peak overshoot (M_p): It is the maximum error at the output.

$$M_p = c(t_p) - 1,\ M_p = e^{\left(\frac{-\xi\pi}{\sqrt{1-\xi^2}}\right)}$$

$$\%M_p = \frac{c(t_p)-c(\infty)}{c(\infty)} \times 100\%$$

If the magnitude of the input is doubled, then the steady-state value doubles, therefore M_p doubles, but % M_p, t_r, t_p remains constant.

MCQ Question 5

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Consider a unity feedback system with forward transfer function given by $G(S) = \frac{1}{(s+1)(s+2)}$

The steady-state error in the output of the system for a unit-step input is ________ (up to 2 decimal places).

Answer (Detailed Solution Below) **0.65 - 0.69**

Time Response Analysis MCQ Question 5 Detailed Solution

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

Steady-state error for the Unit step input is,

$$E_{ss} = \frac{A}{1+k_p}$$

$$k_p = \lim_{s \to 0} G(s)\ H(s)$$

$$k_p = \lim_{s \to 0} \frac{1}{(s+1)(s+2)}$$

= $\frac{1}{2}$

$$E_{ss} = \frac{1}{1+\frac{1}{2}} = \frac{2}{3} = 0.67$$

MCQ Question 6

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Match the transfer functions of the second-order systems with the nature of the systems given below.

Transfer functions	Nature of system
P: $\frac{15}{s^2+5s+15}$ Q: $\frac{25}{s^2+10s+25}$ R: $\frac{35}{s^2+18s+35}$	I: Overdamped II: Critically damped III: Underdamped

1. P-I, Q-II, R-III
2. P-II, Q-I, R-III
3. P-III, Q-II, R-I
4. P-III, Q-I, R-II

Answer (Detailed Solution Below)

Option 3 : P-III, Q-II, R-I

Time Response Analysis MCQ Question 6 Detailed Solution

The standard second order system is given by $\frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$

Where ξ is damping ratio.

If ξ = 1, then system is critically damped.

If ξ < 1, then system is under damped.

If ξ > 1, then system is order damped.

$P : \frac{15}{s^2+5s+15}$

By comparing with standard second order transfer function,

$\omega_n^2 = 15 \Rightarrow \omega_n = \sqrt{15}$

$2\xi\omega_n = 5 \Rightarrow \xi = \frac{5}{2\sqrt{15}} < 1$

So, it is underdamped system.

$Q : \frac{25}{s^2+10s+25}$

$\omega_n^2 = 25 \Rightarrow \omega_n = 5$

$2\, \xi\, \omega_n = 10 \Rightarrow \xi = 1$

So, it si critically damped system.

$R : \frac{35}{s^2+18s+35}$

$\omega_n^2 = 35 \Rightarrow \omega_n = \sqrt{35}$

$2\xi\omega_n = 18 \Rightarrow \xi = \frac{9}{\sqrt{35}} > 1$

So, it is overdamped system.

MCQ Question 7 View this Question Online >

A unity feedback has an open-loop transfer function $G(s) = \frac{10(s+2)(s+3)}{s(s+3.5)(s+2.5)}$
What will be the steady-state error if it is excited with input x(t) = 15tu(t) unit ramp input?

1. 2.1875
2. 0
3. 4

4. 102.8

Answer (Detailed Solution Below)

Option 1 : 2.1875

Time Response Analysis MCQ Question 7 Detailed Solution

Concept:

K_P = position error constant = $\lim_{s\to 0} G(s)H(s)$

K_v = velocity error constant = $\lim_{s\to 0} sG(s)H(s)$

K_a = acceleration error constant = $\lim_{s\to 0} s^2G(s)H(s)$

Steady state error for different inputs is given by

Input	Type -0	Type - 1	Type -2
Unit step	$\frac{1}{1+K_p}$	0	0
Unit ramp	∞	$\frac{1}{K_v}$	0
Unit parabolic	∞	∞	$\frac{1}{K_a}$

From the above table, it is clear that for type – 1 system, a system shows zero steady-state error for step-input, finite steady-state error for Ramp-input and ∞ steady-state error for parabolic-input.

Calculation:

$G(s) = \frac{10(s+2)(s+3)}{s(s+3.5)(s+2.5)}$

Velocity error coefficient, $K_v = \lim_{s\to 0} s\frac{10(s+2)(s+3)}{s(s+3.5)(s+2.5)} = \frac{60}{8.75}$

$e_{ss} = \frac{15}{\frac{60}{8.75}} = 2.1875$

MCQ Question 8

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For a second order dynamic system, if the damping ratio is 1 then the poles are

1. Imaginary and complex conjugate
2. In the right-half of s-plane
3. Equal, negative and real
4. Negative and real

Answer (Detailed Solution Below)

Option 3 : Equal, negative and real

Time Response Analysis MCQ Question 8 Detailed Solution

Concept:

The transfer function of the standard second-order system is:

$$TF = \frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

ζ is the damping ratio

ω_n is the undamped natural frequency

Characteristic equation: $s^2 + 2\zeta\omega_n + \omega_n^2 = 0$

Roots of the characteristic equation are: $-\zeta\omega_n + j\omega_n\sqrt{1-\zeta^2} = -\alpha \pm j\omega_d$

α is the damping factor

- ζ = 0, the system is undamped
- ζ = 1, the system is critically damped
- ζ < 1, the system is underdamped

- $\zeta > 1$, the system is overdamped

System	Damping ratio	Roots of the Characte-ristic equine.	Root in the 'S' plane
Un-damped	$\xi = 0$	$\xi = 0$ Imaginary; $s = \pm j\omega n$	
Under-damped (Practical system)	$0 \le \xi \le 1$	Complex Conjugate	
Critically damped	$\xi = 1$	$-\omega n$ Real and equal	
Over-damped	$\xi > 1$	Real and unequal	

MCQ Question 9

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How can the steady-state error in a system be reduced?

1. By decreasing the type of system

2. By increasing system gain

3. By decreasing the static error constant

4. By increasing the input

Answer (Detailed Solution Below)

Option 2 : By increasing system gain

Time Response Analysis MCQ Question 9 Detailed Solution

K_p = position error constant = $\lim_{s\to 0} G(s)H(s)$

K_v = velocity error constant = $\lim_{s\to 0} sG(s)H(s)$

K_a = acceleration error constant = $\lim_{s\to 0} s^2G(s)H(s)$

Steady state error for different inputs is given by

Input	Type -0	Type - 1	Type -2
Unit step	$\frac{1}{1+K_p}$	0	0
Unit ramp	∞	$\frac{1}{K_v}$	0
Unit parabolic	∞	∞	$\frac{1}{K_a}$

From the above table, it is clear that for type – 1 system, a system shows zero steady-state error for step-input, finite steady-state error for Ramp-input and ∞ steady-state error for parabolic-input.

As the type of the system increases, the steady-state error decreases.

The steady-state error is inversely proportional to the gain. Therefore, it can be reduced by increasing the system gain.

MCQ Question 10

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A unity feedback system is given by

$G(s) = \frac{10(s+2)}{s^2(s+5)}$

For input, r(t) = 1 + 2t, t > 0 the steady state error e(t) is:

1. infinity
2. zero
3. six
4. five

Answer (Detailed Solution Below)

Option 2 : zero