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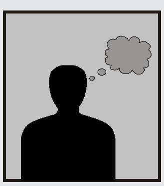
Workbook 2024



Detailed Explanations of Try Yourself *Questions*

Chemical Engineering

Instrumentation and Process Control

MADE EASY PUBLICATIONS

1 Introduction

Detailed Explanation *of* Try Yourself Questions

T1 : Solution

[Ans : (c)]

$$f(t) = t\,u(t) - (t-1)\,u(t-1) - (t-2)\,u(t-2) + (t-3)\,u(t-3)$$

$$f(s) = \frac{1}{s^2} - \frac{1}{s^2}e^{-s} - \frac{1}{s^2}e^{-2s} + \frac{1}{s^2}e^{-3s}$$

$$f(s) = \frac{1}{s^2}\left[1 - e^{-s} - e^{-2s} + e^{-3s}\right]$$

T2 : Solution

[Ans : (c)]

$$f(t) = t\,u(t) - 2(t-1)\,u(t-1) + (t-2)\,u(t-2)$$

$$f(s) = \frac{1}{s^2} - \frac{2}{s^2}e^{-s} + \frac{1}{s^2}e^{-2s}$$

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

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2 First Order System

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans : (c)]

Unsteady state component balance

$$V\frac{dC_A}{dt} = FC_{Ao} - FC_A - (kc_A)V \qquad \text{...(i)}$$

At steady state (t = 0)

$$0 = FC_{Ao,s} - FC_{As} - kc_{as}V \text{... (ii)}$$

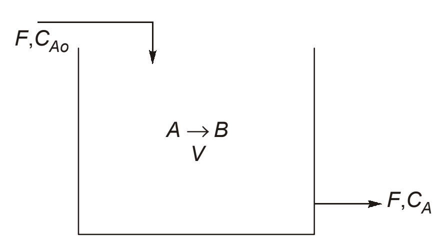
Equation (i) - (ii)

$$V\frac{dC_A}{dt} = F(c_{Ao} - c_{Aos}) - F(c_A - c_{As}) - kV(c_A - c_{As})$$

Let $x(t) = C_{Ao} - C_{Ao,\,s}$ and $y(t) = c_A - c_{As}$

$$V\frac{dy(t)}{dt} = Fx(t) - Fy(t) - kVy(t) = Fx\,(t) - y(t)\,(F + kV)$$

Taking Laplace transform



$$VsY(s) = F \times (s) - Y(s)\,(F + kV)$$

$$\frac{C_A(s)}{C_{A_O}(s)} = \frac{Y(s)}{X(s)} = \frac{\frac{F}{(F+kV)}}{1 + s\left(\frac{V}{F+kV}\right)}$$

$$\frac{Y(s)}{X(s)} = \frac{A}{1+\tau_p s} \text{ where } A = \frac{F}{F+kV}$$

$$\tau_p = \frac{V}{F+kV}$$

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3 Second Order System, Transportation Lag and Inverse Response

Detailed Explanation *of* Try Yourself Questions

T1 : Solution

[Ans : (b)]

$$\text{Gain } 'k' = \frac{11.2-8}{31-15} = 0.20 \text{ mm/ psi}$$

$$\text{Overshoot} = \frac{12.7-11.2}{11.2-8} = 0.47$$

$$\text{Overshoot} = \exp\left[\frac{-\pi\xi}{\sqrt{1-\xi^2}}\right] = 0.47$$

$$\frac{\pi\xi}{\sqrt{1-\xi^2}} = 0.755$$

$$17.31\xi^2 = 1-\xi^2$$

$$\xi = 0.234$$

$$\text{Period of oscillation } (T) = \frac{2\pi\tau}{\sqrt{1-\xi^2}} = 2.3 \text{ sec}$$

$$\tau = \frac{2.3\sqrt{1-0.234^2}}{2\pi} = 0.356 \text{ sec}$$

$$\frac{R'(s)}{P'(s)} = \frac{0.2}{0.127s^2+0.167s+1}$$

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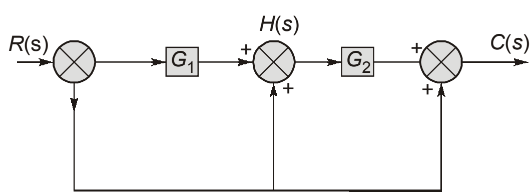
4 Closed Loop Transfer Function

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans : (c)]



From the above system, we can write following two equation:

$$C(s) = H(s).\, G_2 + R(s) \quad ...(i)$$

$$H(s) = R(s).\, G_1 + R(s) \quad ...(ii)$$

Putting value of $H(s)$ from equation (ii) to equation (i), we get

$$C(s) = R(s)[G_1 + 1] \times G_2 + R(s)$$

$$= R(s)[G_1G_2 + G_2 + 1]$$

$$\frac{C(s)}{R(s)} = \left[G_1G_2 + G_2 + 1\right]$$

T2 : Solution

[Ans : (c)]

$$\frac{Y(s)}{U(s)} = \frac{\frac{4}{s(s+4)}}{1+\frac{4}{s(s+4)}} = \frac{4}{s^2+4s+4} = \frac{1}{\frac{s^2}{4}+s+1}$$

Here, $\tau = \frac{1}{2}$ so natural frequency $(\omega_n) = \frac{1}{\tau}$

$$\omega_n = \frac{1}{\tau} = 2 \text{ rad/sec}$$

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5 Stability and Frequency Response

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans : (c)]

Characteristic equation is $1 + G(s) = 0$

$$1+\frac{(s+8)}{(s^2+\alpha s-4)} = 0$$

$$s^2 + s(\alpha + 1) + 4 = 0$$

Routh table

s^2	1	4
s	$\alpha + 1$	
s^0	4	

For given to be stable

$(\alpha + 1) > 0$

$[\alpha > -1]$

For all positive value of α, system will be stable.

T2 : Solution

[Ans : (b)]

Characteristic equation become $1 + G(s) = 0$

$$1+\frac{1}{(s^3+\alpha s^2+ks+3)} = 0$$

$$s^3 + \alpha s^2 + ks + 4 = 0$$

Routh table

s^3	1	k
s^2	α	4
s^1	$\frac{\alpha k-4}{\alpha}$	0
s^0	4	

For system to be stable $\alpha > 0$, $(\alpha k - 4) > 0$

$[\alpha > 0]$, $[\alpha k > 4]$

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6 Controller and Valves

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans : (d)]

For PI controller

$$p(t) = p(s) + k_c e(t) + \frac{1}{\tau_I}\int_0^t e(t)\,dt$$

$p(t)$ = Output current from controller (mA)

$p(s)$ = Output current for zero error = 10 mA

k_c = Proportional gain of the controller = 1 mA/mA

$e(t)$ = Error (input to controller)

τ_I = 1 min

$e(t)$ = Changed by unit step function = 1 mA

$$p(t) = 10 + 1\left[1 + \frac{1}{1}\int_o^t 1 \times dt\right] = 10 + [1 + (t)]$$

$p(t)$ = 11 + t

So, $p(t)$ jumps to 11 mA and than increases linearly at the rate of 1 mA/min.

T2 : Solution

[Ans : (b)]

$$p = p_s + k_c\left[\varepsilon(t) + \tau_D \frac{d\varepsilon(t)}{dt} + \frac{1}{\tau_I}\int_o^t \varepsilon(t)dt\right]$$

$$\frac{d\varepsilon(t)}{dt} = 4$$

$$\varepsilon(t) = 4t$$

$$p = 1 + 0.1\left[4t + 2.4 + \frac{2t^2}{\tau_I}\right]$$

$$p = 1 + 0.1\left[4t + 2.4 + \frac{2t^2}{1.4}\right]$$

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7 Advance Control Strategies and Measurement of Process Variables

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans : (d)]

$$G_p(s) = \frac{2}{(3s+1)(5s+1)}$$

$$G_d(s) = \frac{5}{(5s+1)(2s+1)}$$

$$G_{ffc}(s) = \frac{G_d(s)}{G_p(s)}$$

$$= \frac{5(3s+1)}{(2s+1)\times 2} = \frac{5}{2}\frac{(3s+1)}{(2s+1)}$$

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