

2:00

LECTURE 13 - PowerPoint (Product Activation Failed)

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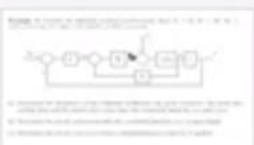
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First order system
Step response
2nd order system
Step response

Typically any 1st
order system will have a
time constant. The time
constant is the time taken
for the response to reach
63.2% of its final value.

EE 250: Control Systems Analysis
Module III: s-plane analysis
Lecture 16: Time Response – An
Example





EE 250: Control Systems Analysis
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Lecture 16: Time Response – An
Example

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SLIDE 23 OF 28

ENGLISH (INDIA)

NOTES

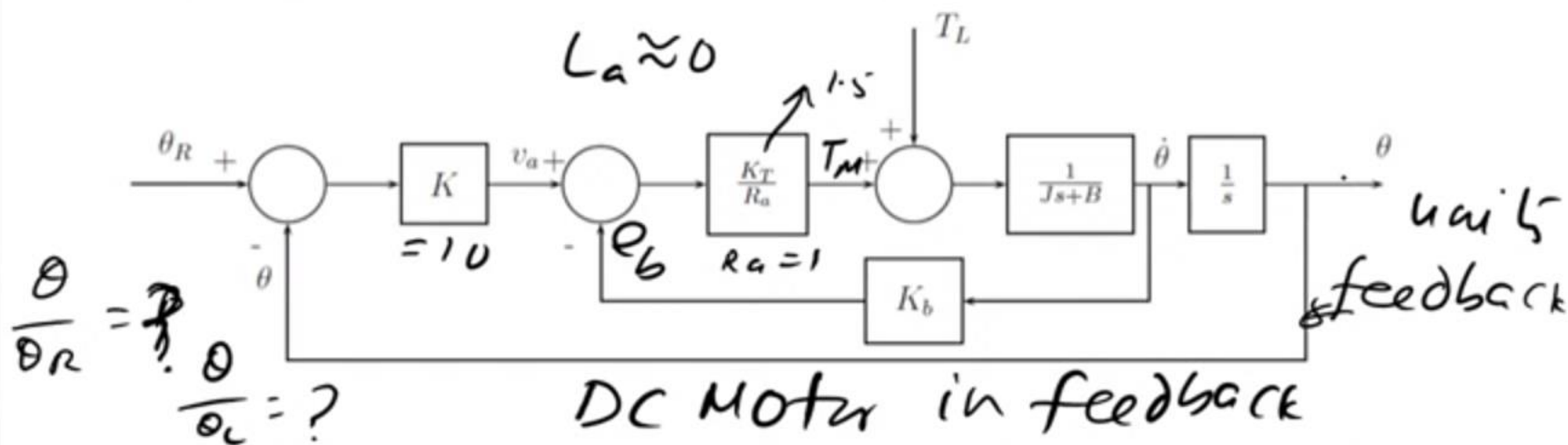
COMMENTS

70%

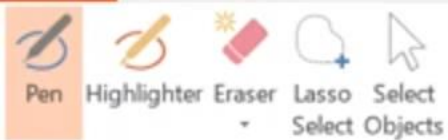




Example 5. Consider the following position control system where $K = 10$, $R_a = 1\Omega$, $K_T = 1.5N - m/amp$, $J = 5Kg - m^2$ and $B = 1.75N - ms/rad$.



- Determine the frequency of the transient oscillation, the peak overshoot, the peak time, settling time and the steady state error when the command signal θ_R is a unity step.
- Determine the steady state error when the command signal $\theta_R = t$, a ramp signal.
- Determine the steady state error when a step disturbance torque T_L is applied.



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21 First order System
Step response
2nd order System
Step response

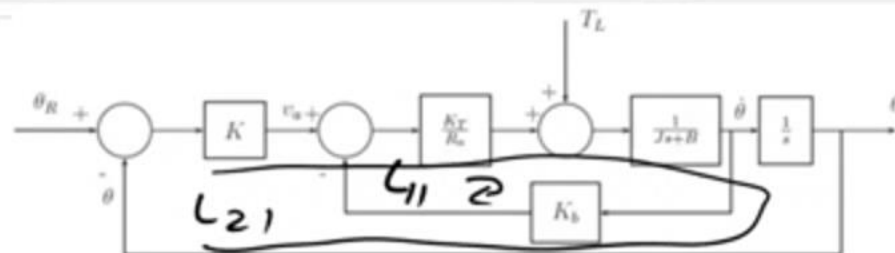
22 Typically any 1st
order system will have a
time constant of 1/σ
where σ is the real part of the pole

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24 Block diagram of a control system with feedback and disturbance.

25 Block diagram of a control system with feedback and disturbance.

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The forward gain between $\theta(s)$ and $\theta_R(s)$ is

$$M_1 = \frac{15}{s(5s + 1.75)}$$

The forward gain between $\theta(s)$ and $T_L(s)$ is

$$M_2 = \frac{1}{s(5s + 1.75)}$$

The loop gains are as follows :

$$L_{11} = \frac{-2.25}{(5s + 1.75)}$$

$$L_{21} = \frac{-15}{s(5s + 1.75)}$$

$$1 + \frac{2.25}{5s + 1.75} + \frac{15}{s(5s + 1.75)}$$

$$\frac{M_1 \times 1}{1 - L_{11} - L_{21}}$$

$$\frac{\theta(s)}{\theta_R(s)} = \frac{15}{(5s^2 + 4s + 15)}$$

$$= \frac{3}{s^2 + 0.8s + 3}$$

$$\frac{\theta(s)}{T_L(s)} = \frac{1}{(5s^2 + 4s + 15)}$$



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$$\frac{\theta(s)}{\theta_R(s)} = \frac{3}{s^2 + 0.8s + 3}$$

$$= \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

where the parameter $\omega_n = \sqrt{3} = 1.732$ and $2\zeta\omega_n = 0.8$ which gives $\zeta = 0.2309$.

(a) The frequency of transient oscillation

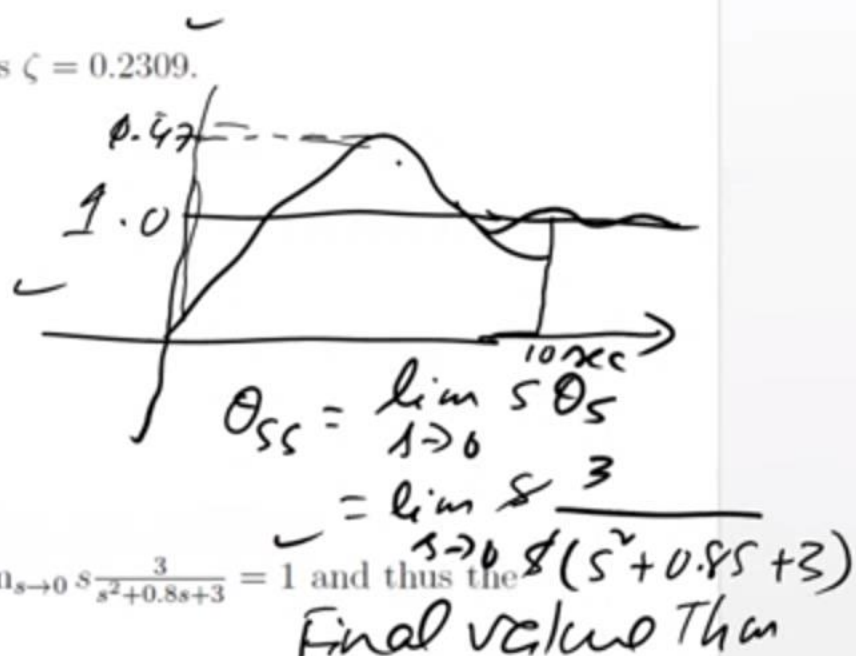
$$\omega_d = \omega_n \sqrt{1 - \zeta^2} = 1.6852$$

The peak time $t_p = \frac{\pi}{\omega_d} = 1.8645$, the peak overshoot

$$M_p = e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}} = 0.4744$$

The steady state value of the output is given to be $\theta_{ss} = \lim_{s \rightarrow 0} s \frac{3}{s^2 + 0.8s + 3} = 1$ and thus the steady state error is $e_{ss} = 1 - \theta_{ss} = 0$.

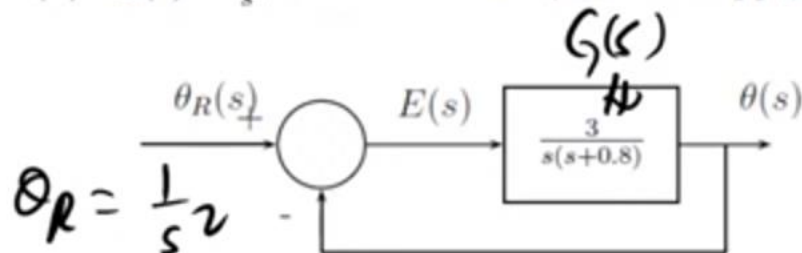
$$\text{The settling time } t_s = \frac{4}{\zeta\omega_n} = \frac{4}{0.2309 * 1.732} = 10\text{sec}$$





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(b) $\theta_R(s) = \frac{1}{s^2}$. Please see that you can't apply the same procedure.



$$e = \theta_R - \theta$$

$$E = \theta_R - \frac{3}{s(s+0.8)} E$$

$$\text{or, } E(s) = \frac{1}{1 + \frac{3}{s(s+0.8)}} \theta_R(s)$$

where $\theta_R(s) = \frac{1}{s^2}$. Therefore, the steady state error

$$\frac{\theta_s}{\theta_R} = \frac{3}{s^2 + 0.8s + 3}$$

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

$$E_{ss} = \lim_{s \rightarrow 0} s E(s)$$

$$= \lim_{s \rightarrow 0} \frac{1}{s + \frac{3}{s+0.8}} = 0.8$$

$$= 0.266 \text{ radian}$$

$$SE(s) = \frac{1}{s + \frac{3}{s+0.8}}$$

$$= \frac{1}{\left(1 + \frac{3}{s(s+0.8)}\right)} \times 1$$

$$= \frac{1}{s^2 + \frac{3s^2}{s(s+0.8)}}$$

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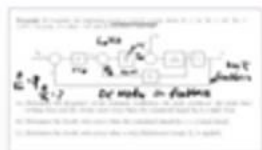
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(c) The transfer function between $\theta(s)$ and $T_L(s)$ is given by

$$T_L = \frac{1}{s}$$

$$\frac{\theta(s)}{T_L(s)} = \frac{1}{5s^2 + 4s + 15}$$

For a unit step disturbance, the steady state value of output is given as

$$\theta_{ss} = \lim_{s \rightarrow 0} s \frac{1}{5s^2 + 4s + 15} \frac{1}{s} = \frac{1}{15} = 0.067$$

$$\theta(s) = \frac{1}{s(5s^2 + 4s + 15)}$$

$$\theta_{ss} = \lim_{s \rightarrow 0} s \theta_s = \lim_{s \rightarrow 0} \frac{1}{5s^2 + 4s + 15} = \frac{1}{15} = 0.067$$