

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination November 2018
B. Tech. in Electrical Engineering, Semester V

Roll No.....

Course Code : EE 501 Linear Control System

Time: 3 hours

Max. Marks: 80

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark) 10

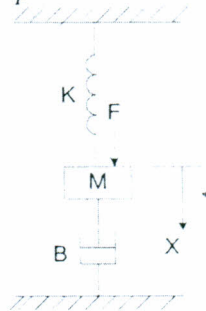
- i. If $X(s)$ is Laplace transform of $x(t)$ and $x(0) = 0$, then $sX(s)$ is Laplace transform of
a) $x(-t)$ b) $x^{-1}(t)$ c) $sx(t)$ d) $\frac{dx}{dt}(t)$
- ii. The intersection of the Root Locus branches with the imaginary axis may be calculated by
a) Nyquist criterion b) Routh criterion c) Nyquist plot d) Bode plot
- iii. A decade frequency range (ω_1, ω_2) is specified by
a) $\frac{\omega_2}{\omega_1} = 10$ b) $\frac{\omega_2}{\omega_1} = 2$ c) $\frac{\omega_2}{\omega_1} = 20$ d) $\frac{\omega_2}{\omega_1} = 100$
- iv. A system having a transfer function $G(s) = \frac{4}{s+3}$ is subjected to a unit step input. The steady state value of the output is
a) 4 b) 3 c) $\frac{4}{3}$ d) $\frac{1}{3}$
- v. The time constant of a system having a transfer function $G(s) = \frac{4}{s+3}$ is
a) 4 b) 3 c) $\frac{4}{3}$ d) $\frac{1}{3}$
- vi. A second order standard system having damping ratio $\frac{1}{2}$ is subjected to a unit step input. The corresponding output overshoot is
a) less than 5% b) less than 20% c) greater than 20% d) greater than 100%
- vii. If the root locus branches cross the imaginary axis in the direction of the right hand complex plane, the system becomes
a) Non linear b) Time variant c) BIBO-stable d) BIBO-unstable
- viii. Assume we have a closed-loop system with unity negative feed-back and open-loop transfer function $G(s) = \frac{4}{s-2}$. The Nyquist plot makes one counterclockwise encirclement of $(-1,0)$. The closed loop system is:
a) Non linear b) Time variant c) BIBO-stable d) BIBO-unstable
- ix. Assume that none of the poles of a LTI system lies in the right hand complex plane (including the imaginary axis). For a bounded input, the output of this system is
a) Nonlinear b) Time variant c) Unbounded d) Bounded
- x. Assume we have an open-loop system with $G(j\omega) = \frac{1}{j\omega+1}$. If $\omega = 1$ then $\angle G(j\omega)$ is
a) 0° b) -45° c) $+45^\circ$ d) -180°

- Q.2 Short answer type questions (4 questions @ 2.5 marks) 10
 Discuss open loop control system
 Discuss settling time
 Discuss lead compensator
 Discuss PI controller

- Q.3A Sketch the Bode plot for $G(s) = \frac{10}{s^2}$ 05

- Q.3B Sketch the Root Locus for $G(s) = \frac{K(s^2-1)}{s^2}$ 05

- Q.4A Determine the transfer function $\frac{x}{F}$ for the mechanical system given below 05

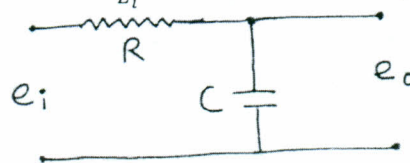


- Q.4B Assume we have a closed-loop system with unity negative feed-back and open-loop transfer function 05

$$G(s) = \frac{K(s+1)}{(s+4)(s+7)}$$

Determine K such that we have a closed-loop pole in $s = -3$ or show that it is impossible to have a closed-loop pole in that position

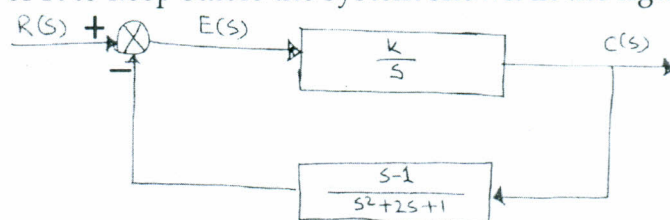
- Q.5A Determine the transfer function $\frac{E_o}{E_i}$ for the electrical system given below 05



- Q.5B Obtain a state-space representation of the system: 05

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

- Q.6A Find the range of K to keep stable the system shown in the figure below 05



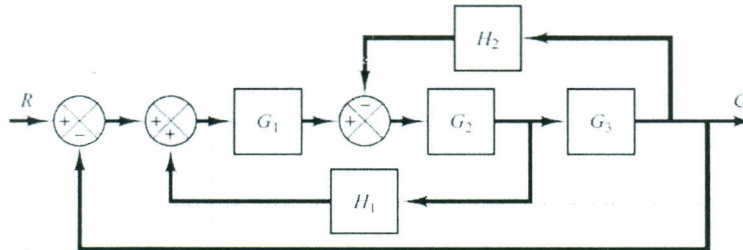
Q.6B Assume we have a stable closed-loop system with unity negative feed-back and open-loop transfer function given below: 05

$$G(s) = \frac{K(s+1)}{(s+4)(s+7)}$$

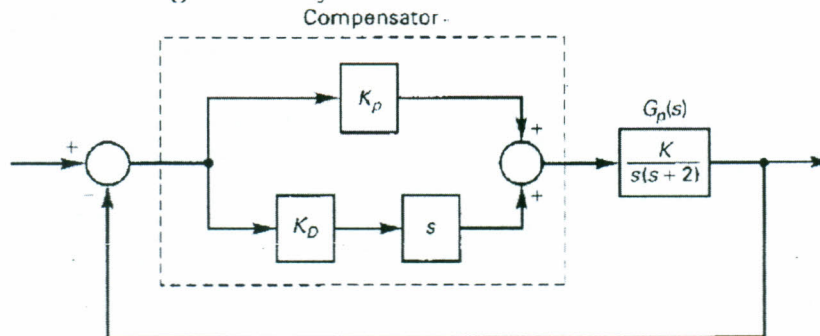
Determine the steady state error if the reference signal is a unit step, as a function of K

OR

Q.6B Determine the transfer function $\frac{C}{R}$ for the system given below 05



Q.7 Consider the following control system 10



and three different cases

i) $\frac{K_p}{K_D} < 0$

ii) $0 < \frac{K_p}{K_D} < 2$

iii) $\frac{K_p}{K_D} > 2$

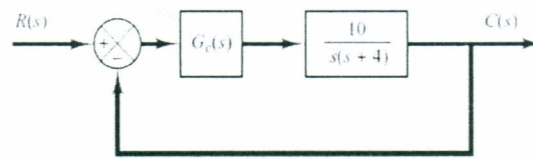
Which of the three cases can result in the system with the fastest settling time?

Which of the three cases can result in an unstable system?

Which of the three cases can result in a critically damped system?

Q.8 Consider the system

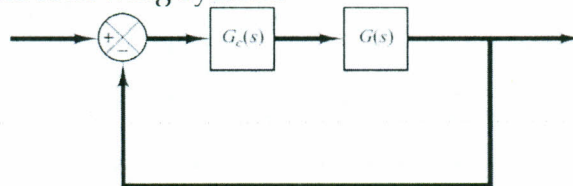
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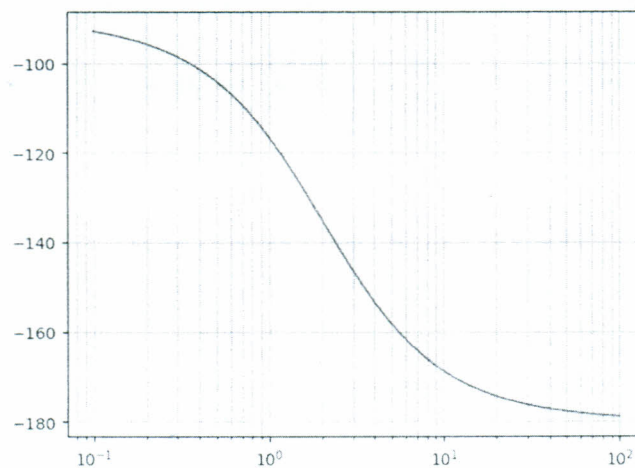
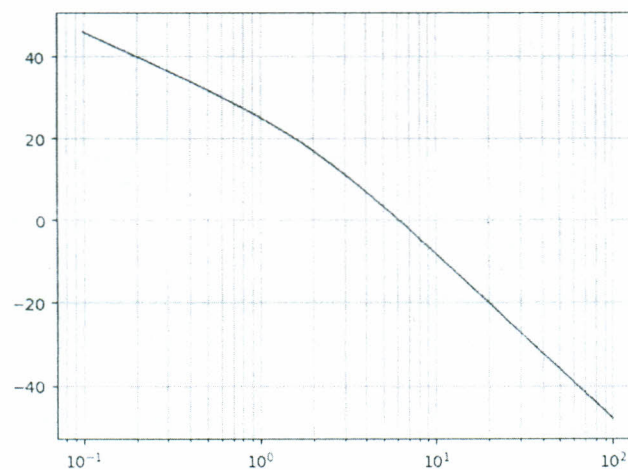
Design a controller such that we have closed-loop poles in $-3 \pm 3j$
OR

Q.8 Assume we have the following system:

10



Design a lead compensator such that Phase Margin = 40° . The Bode Plot for $G(s)$ is given below



Formulae:

Standard First Order System: $\frac{K}{1+\tau s}$, settling time (2%) $\approx 4\tau$

Standard Second Order System: $\frac{K\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$, settling time (2%) $\approx \frac{4}{\xi\omega_n}$

PD design: $T_d = \left[\sigma_{des} + \frac{\omega_{des}}{\tan(\varphi_{des})} \right]^{-1} K_p = \frac{K}{K_G} \quad K = \left[|G(p_{des})|_{K=1} T_d \sqrt{\left(\sigma_{des} - \frac{1}{T_d} \right)^2 + \omega_{des}^2} \right]^{-1}$

PI design: $T_i = \left[\sigma_{des} + \frac{\omega_{des}}{\tan(\varphi_{des})} \right]^{-1} K_p = \frac{K}{K_G} \quad K = \left[|G(p_{des})|_{K=1} \sqrt{\left(\sigma_{des} - \frac{1}{T_i} \right)^2 + \omega_{des}^2} \right]^{-1}$

PID design: $T = \frac{1}{2} \left[\sigma_{des} + \frac{\omega_{des}}{\tan\left(\frac{\varphi_{des}}{2}\right)} \right]^{-1} K_p = \frac{K}{K_G} \quad K = \left[|G(p_{des})|_{K=1} T \sqrt{\left(\sigma_{des} - \frac{1}{T} \right)^2 + \omega_{des}^2} \right]^{-1}$

Lead design:

$$\begin{aligned} G_{c_lead}(s) &= K_c \left[\frac{1}{\alpha} \cdot \frac{(s + z_c)}{(s + p_c)} \right] \\ &= K_c \frac{(s/z_c + 1)}{(s/p_c + 1)} = K_c \frac{(\tau s + 1)}{(\alpha \tau s + 1)} \end{aligned}$$

$$z_c > 0, \quad p_c > 0, \quad \alpha \triangleq \frac{z_c}{p_c} < 1, \quad \tau = \frac{1}{z_c} = \frac{1}{\alpha p_c}$$

$$\phi_{\max} = PM_{spec} - PM_{uncomp} + 10^\circ$$

$$\alpha = \arcsin \left(\frac{1 - \sin(\phi_{\max})}{1 + \sin(\phi_{\max})} \right)$$

$$|G(j\omega_{max})|_{dB} = 10 \log(\alpha)$$

$$\tau = \frac{1}{\omega_{max} \sqrt{\alpha}}$$

$$z_c = \frac{1}{\tau}$$

$$p_c = \frac{1}{\alpha \tau}$$