National Exams May 2012

07-Mec-A3, SYSTEM ANALYSIS AND CONTROL

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Candidates may use a Casio **or** Sharp approved calculator. This is a **closed book** exam. No aids other than semi-log graph papers are permitted.

3. Any four questions constitute a complete paper. Only the first four (4) questions as they appear in your answer book will be marked.

4. All questions are of equal value.

Question 1

Given:

$$G(s) = \frac{K(s^2 + 0.5s + 100)}{S(s+1)(s+2)}$$

a) Sketch the root Locus

b) If the Loci cross the imaginary axis, determine values of w at the axis intersections.

c) If we want complex roots with $\zeta = 0.707$, what must be the value of K?

Question 2

a) The characteristic equation for a feedback control system is:

$$(s+2)(s^2 + 4s + 8) + K = 0$$

Determine the range of values of K for which the system is stable.

b) Use the Laplace transform method to solve the following differential equations.

- $\frac{dy}{dt} + y = 2 \sin t$
- $\frac{dy}{dt} + y = 2 \cos t$

All the initial conditions are zero.

Question 3

Comment on the stability with the closed-loop transfer function given by each of the following.

a) $$T(s) = \frac{5(s+2)}{(s+1)(s^2+s+1)}$$

b) $$T(s) = \frac{5}{(s-1)(s^2+s+1)}$$

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

Question 4

Given the transfer function

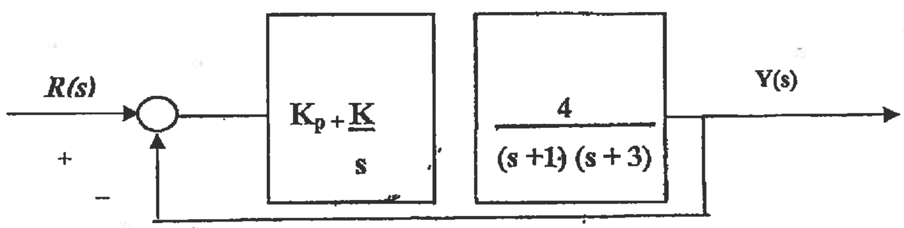
$$G(s) = \frac{10(s+1)}{s(s^2+20\zeta s+100)}$$

a) Sketch the Bode diagram for $\zeta = 1$.

b) Repeat (a) for $\zeta = 0.1$.

Question 5

Consider the control system shown in the figure below with a PI controller. Determine the values of K_p and K_i such that when r(t) = t, i.e., a unit ramp function, the steady-state error is 0.03.



Question 6

The block diagram of a hydraulic machining control system is shown below. Replace the negative feedback with positive feedback. Show that the characteristic equation can be represented in the form:

$$a_4s^4 + a_3s^3 + a_2s^2 + s - K = 0$$

where a_4, a_3, and a_2 are positive constants and are related to the system parameters. Using the Routh-Huwitz criterion, investigate the stability for $K > 0$. Comment on the effect of replacing negative feedback by positive feedback.

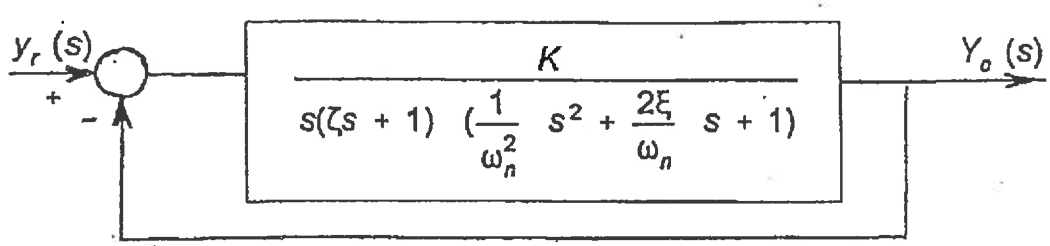


TABLE 6-1
Laplace Transform Pairs

Functions of Time: $f(t)$ for $0 \le t$	Laplace Transforms: $\mathcal{L}[f(t)]$
1. $f(t)$	$\int_0^\infty f(t)e^{-st}\,dt = F(s)$
2. $x(t) + y(t)$	$X(s) + Y(s)$
3. $Kf(t)$	$KF(s)$
4. $\frac{df(t)}{dt}$	$sF(s) - f(0)$
5. $\frac{d^2f(t)}{dt^2}$	$s^2F(s) - sf(0) - \frac{df(0)}{dt}$
6. $\frac{d^nf(t)}{dt^n}$	$s^nF(s) - \sum_{l=1}^{n} s^{n-l}\frac{d^{l-1}f(0)}{dt^{l-1}}$
7. $\int_0^t f(t)dt$	$\frac{1}{s}F(s)$
8. 1 or $u(t)$	$\frac{1}{s}$
9. t	$\frac{1}{s^2}$
10. t^n for $n > -1$	$\frac{n!}{s^{n+1}}$
11. e^{-at}	$\frac{1}{s+a}$
12. te^{-at}	$\frac{1}{(s+a)^2}$
13. t^ne^{-at}	$\frac{n!}{(s+a)^{n+1}}$
14. $1 - e^{-at}$	$\frac{a}{s(s+a)}$
15. $e^{-at} - e^{-bt}$	$\frac{b-a}{(s+a)(s+b)}$
16. $ae^{-at} - be^{-bt}$	$\frac{(a-b)s}{(s+a)(s+b)}$
17. $\sin \alpha t$	$\frac{\alpha}{s^2+\alpha^2}$
18. $\cos \alpha t$	$\frac{s}{s^2+\alpha^2}$
19. $t \sin \alpha t$	$\frac{2\alpha s}{(s^2+\alpha^2)^2}$
20. $t \cos \alpha t$	$\frac{s^2-\alpha^2}{(s^2+\alpha^2)^2}$
21. $e^{-at}\sin \alpha t$	$\frac{\alpha}{(s+a)^2+\alpha^2}$
22. $e^{-at}\cos \alpha t$	$\frac{s+a}{(s+a)^2+\alpha^2}$
23. $e^{-\zeta\omega_n t}\sin \omega_n(1-\zeta^2)^{1/2}t$ for $\zeta < 1$	$\frac{\omega_n(1-\zeta^2)^{1/2}}{s^2+2\zeta\omega_n s+\omega_n^2}$
24. $e^{-\zeta\omega_n t}\sinh \omega_n(\zeta^2-1)^{1/2}t$ for $\zeta > 1$	$\frac{\omega_n(\zeta^2-1)^{1/2}}{s^2+2\zeta\omega_n s+\omega_n^2}$
25. $1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin(\omega_n\sqrt{1-\zeta^2}\,t + \phi)$, $\phi = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$ for $\zeta < 1$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
26. $\begin{Bmatrix} f(t-a) & \text{where } t > a \\ 0 & \text{where } t < a \end{Bmatrix}$	$e^{-as}F(s)$

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