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UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI, GHANA

SCHOOL OF ENGINEERING

DEPARTMENT OF COMPUTER AND ELECTRICAL ENGINEERING

LEVEL 300 END OF FIRST SEMESTER EXAMINATIONS, 2018/2019

Bachelor of Science (Electrical and Electronic Engineering)
Bachelor of Science (Computer Engineering)

ELNG 305: CLASSICAL CONTROL SYSTEMS

December, 2018 | **Time: 3 hours**

Material (s) Required:
Table of common Laplace transforms pairs (given on page 7).

Instruction (s):

Answer ALL questions in Section A and TWO (2) questions in Section B.

Section A: Answer All Questions.

Question 1

(a) State two(2) advantages of closed-loop systems over open loop systems. **[2 marks]**

(b) State two(2) conditions or applications where open loop systems are preferrable to closed-loop systems. **[2 marks]**

(c) The loop transfer function of unity feedback system is

$$\frac{s+1}{s^n(s+2)(s+3)},$$

where n is an integer. The steady-state error is 0 for a unity step input and 6 for a unity ramp input. What is the value of n? **[2 marks]**

(d) The open loop transfer function of a closed loop system is

$$\frac{K}{s^2+2s}.$$

Find the value of K such that the step response has the minimum settling time at no overshoot.

[2 marks]

$-\pi\xi/\sqrt{1-\xi^2}$

$\left(\frac{O}{\pi}\right)^2 = \left(\frac{\xi}{\sqrt{1-\xi^2}}\right)^2$

$0 = \frac{\xi^2}{1-\xi^2}$

$0 =$

 S. Osei Fobi

(e) The forward path transfer function of a negative feedback system with unity feedback is given as

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

Find the unit step response. What is the steady-state value? [4 ma

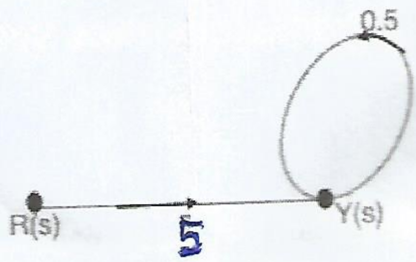
(f) State the condition(s) for a point, s_0, to belong to the root locus plot of a system. [1 m

(g) A plant, with a PI controller, is described by transfer function

$$G(s) = \left(K_p + \frac{K_i}{s}\right)\frac{1}{s(s+2)}.$$

If the plant is connected in a unity feedback configuration, determine the relation between the gains K_p and K_i for the system to be stable. [2 ma

(h) For the signal flow shown in Figure 1, $Y(s) = TR(s)$. Find T. [2 ma



0.6 (1 - 8

Figure 1: Signal flow for Question 1(h).

Total for Question 1:

Question 2

(a) The equations for a filter, shown in Figure 2 are expressed as

$$v_i = \frac{1}{C}\int (i_1 - i_2)dt + Ri_1$$

$$\frac{1}{C}\int (i_1 - i_2)dt = Ri_2 + \frac{1}{C}\int i_2 dt$$

$$v_0 = \frac{1}{C}\int i_2 dt$$

i. Show that the transfer function from v_1 to v_0 is given by

$$\frac{V_0(s)}{V_1(s)} = \frac{\frac{1}{(RC)^2}}{s^2 + \frac{3}{RC}s + \frac{1}{(RC)^2}}$$

ii. Express the damping ratio and undamped natural frequency in terms of R and C.

$-1-\sqrt{3}i$

Index Number:..

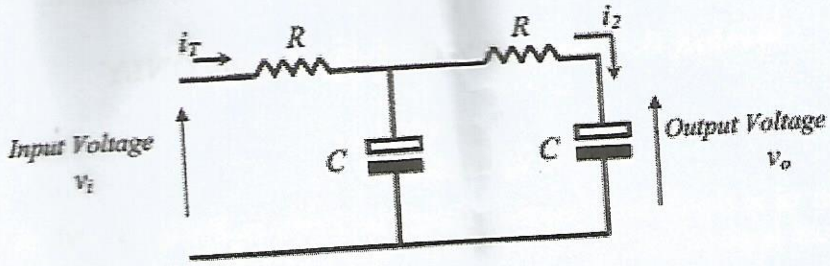
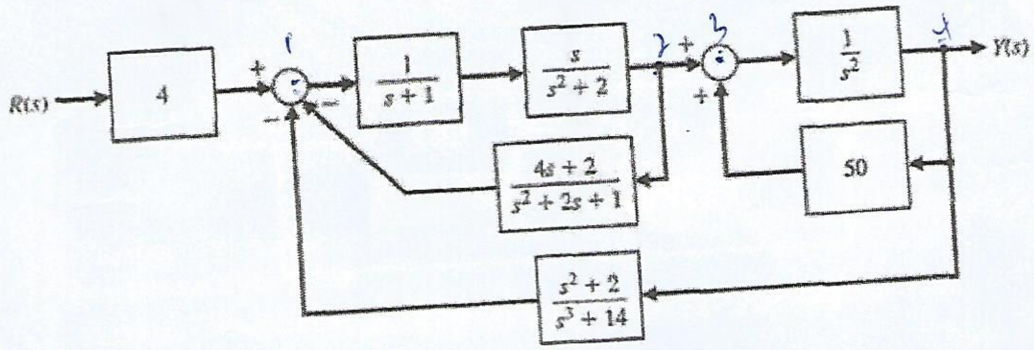


Figure 2: Filter for Question 2(a)



start

46.02

$199.97\angle -90$

$\sqrt{10}\angle -108.43$

10

Figure 3: Block diagram for Question 2b

[6 marks]

$\angle -108.41$

(b) Consider Figure 3.

i. Reduce the block diagram in Figure 3, and determine the transfer function $Y(s)/R(s)$. $\frac{2\sqrt{10}}{5}$

OR

2.541

ii. Convert the block diagram in Figure 3 to signal flow and find the transfer function $Y(s)/R(s)$.

[6 marks]

(c) A unity feedback control system has the open loop transfer function

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

s(

excited with an input $r(t) = t$.

i. Write an expression for the error, as a function of time. t

[4 marks]

ii. Determine the steady-state error.

$\delta'(t) =$

(d) A closed loop system has a loop transfer function:

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

[3 marks]

Sketch the magnitude plot of the Bode plot.

Total for Question 2: 19

$\frac{(4s+2)}{s^2+2s+1}$, 50, $-\frac{s^2+2}{s^3+14}$

S. Osei Fobi

Index Number:..

Section B: Answer TWO (2) Questions ONLY

Question 3

The block diagram of a closed loop control system is shown in Figure 4 , where the transfer function of the plant is given by

$$G(s) = \frac{0.1}{s(s+1)^2(s+2)}$$

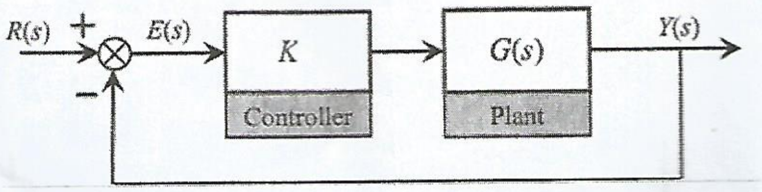


Figure 4: Block diagram for Question 3

(a) Sketch the root locus plot of the closed loop system defined in Figure 4. [4 marks

(b) Find the range of K values for which the closed loop system is stable, marginally stable and unstable. [6 marks

(c) For marginally stability, determine the frequency of oscillations. [2 marks

Total for Question 3: 1

Question 4

(a) Consider a closed-loop system whose open-loop transfer function is given by

$$G(s)H(s) = \frac{K}{(0.25s+1)(0.5s+1)}$$

The nyquist plot is given in Figure 5. Comment on the stability of the system. Determine the gain margin. [4 mark

(b) Given the uncompensated unity feedback system of Figure 4 with

$$\frac{11.2 - 0.1K}{5.6}$$

$$G(s) = \frac{K}{s(s+1)(s+3)},$$

do the following:

i. Design a compensator to yield the following specifications: settling time = 2.86 seconds; percent overshoot = 4.32%; the steady-state error is to be improved by a factor of 2 over the uncompensated system.
(Assume the compensator zero is placed at -1). The uncompensated dominant poles are at $-0.419 \pm j0.419$ with K = 1.11.

 S. Osei Fobi

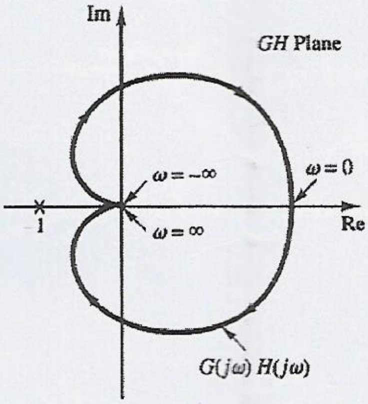


Figure 5: Nyquist plot for Question 4(a)

ii. Compare the transient and steady-state error specifications of the uncompensated and compensated systems.

iii. Compare the gains of the uncompensated and compensated systems.

Total for Question 4: 12

Question 5

(a) Define system **type** and system **order**.

(b) Figure 6 shows the closed-loop control for an anti-lock braking system (ABS). The ABS shown in Figure 6 has the transfer function

$$G(s) = \frac{4}{s(5s+1)}$$

and it is regulated by a dynamic controller having the transfer function of K(s). Its Bode diagrams are shown in figure 7.

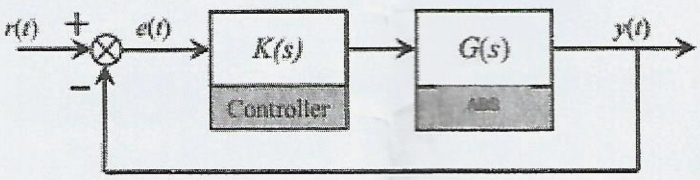


Figure 6: Block diagram for Question 5

i. Determine the values of crossover frequency (in rad/sec) and phase margins of the system if the controller transfer function $K(s) = 1$. **[2 marks]**

ii. For the above defined system, G(s), design a phase-lead compensator K(s) to achieve a closed-loop system with a crossover frequency of 0.5 rad/s and phase margin of 55^0

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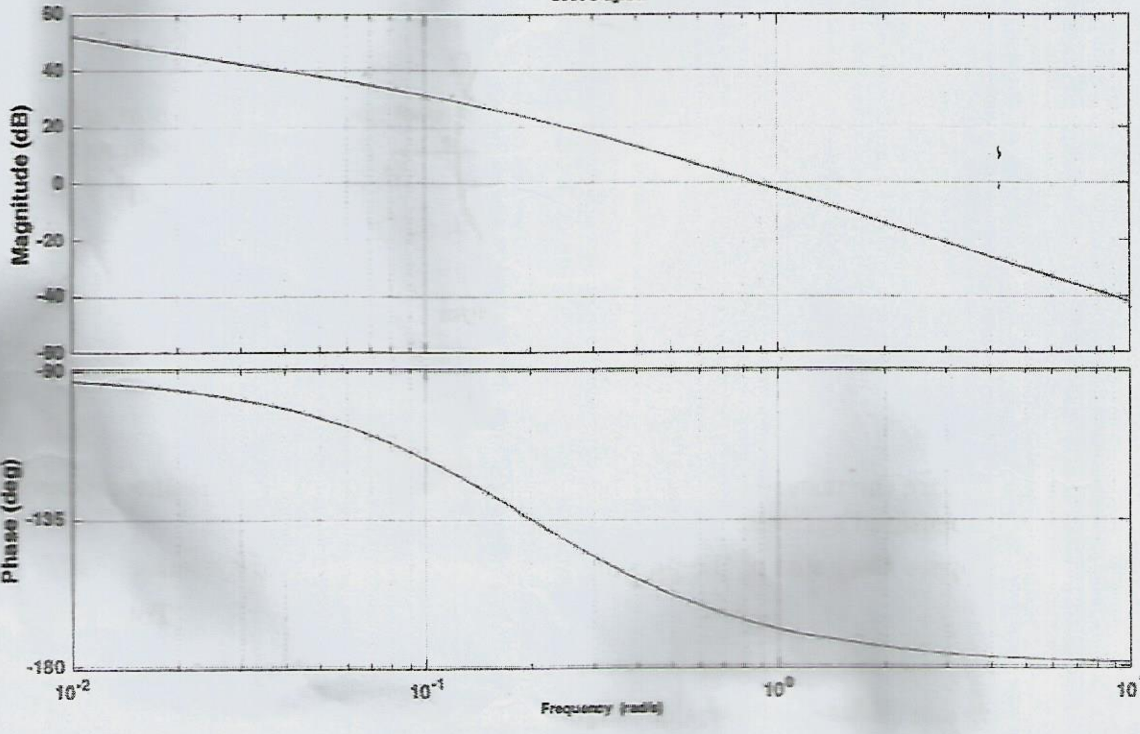

Figure 7: Bode Diagram for Question 5

[Note: you should state clearly any values of gain and phase you have taken from the Bode diagrams. It is recognized that only approximate values can be obtained from these plots.]

[2 marks]

Total for Question 5: 1

Table 1: Laplace Transform Pairs of Selected Signals

$$F(s) = \int_0^{+\infty} f(t)e^{-st}dt$$

Signal f(t)	Laplace Transform F(s)	ROC
$A\delta(t)$	A	All s
Ae^{at}	$\frac{A}{s-a}$	$Re(s) > a$
A	$\frac{A}{s}$	$Re(s) > 0$
$A\cos(kt)$	$\frac{As}{s^2+k^2}$	$Re(s) > 0$
$A\sin(kt)$	$\frac{Ak}{s^2+k^2}$	$Re(s) > 0$
At	$\frac{A}{s^2}$	$Re(s) > 0$
At^n	$\frac{An!}{s^{n+1}}$	$Re(s) > 0$
Ate^{at}	$\frac{A}{(s-a)^2}$	$Re(s) > 0$
$Ae^{at}\cos(kt)$	$\frac{A(s-a)}{(s-a)^2+k^2}$	$Re(s) > 0$
$Ae^{at}\sin(kt)$	$\frac{Ak}{(s-a)^2+k^2}$	$Re(s) > 0$
$A\sinh(kt)$	$A\frac{k}{s^2-k^2}$	$Re(s) > 0$
$A\cosh(kt)$	$A\frac{s}{s^2-k^2}$	$Re(s) > 0$