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FINAL
Examination Paper

(COVER PAGE)

Session	:	APRIL 2013
Programmes	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2108 : MODERN CONTROL SYSTEMS ENGINEERING**
Date of Examination	:	1 August 2013
Time	:	2p.m. – 4p.m. Reading Time : Nil
Duration	:	2 Hours
Special Instructions	:	

This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks.

Students are not allowed to remove this question paper from the examination venue.

Materials permitted :

Non-programmable scientific calculator

Materials provided :

Laplace Transform Table (Appendix)

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Moderator	:	Chai Yoon Yik

This paper consists of 7 printed pages, including the cover page.

INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEE/I)

EEE2108 : MODERN CONTROL SYSTEMS ENGINEERING
FINAL EXAMINATION : APRIL 2013 SESSION

Instructions: This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks. Marks for each sub-question are shown in square brackets.

Question 1

a. The behavior of a system can be mathematically described by the following differential equations:

$$r(t) = 2\frac{dx_1(t)}{dt} + 3x_2(t) \quad \ldots(1)$$

$$c(t) = 3x_2(t) = 5\int x_3(t)dt \quad \ldots(2)$$

And, $x_1(t) = x_2(t) + x_3(t) \quad \ldots(3)$

Where $r(t)$ = input function, $c(t)$ = output function, and

x_1, x_2 and x_3 = state variables

i. Rewrite equations (1) and (2) in Laplace transformed format. Assume all the state variables' initial values are zero. [4]

ii. Determine the system's transfer function $C(s)/R(s)$ by eliminating all the state variables. [6]

iii. If $r(t)$ is a unit impulse function, determine the time domain expression for $c(t)$. [5]

iv. Use Routh-Hurwitz method to justify that the system is stable. [5]

b. Derive the transfer function $V_o(s)/V_i(s)$ of the circuit in Figure-Q1(b). State your answer in polynomial form. [5]

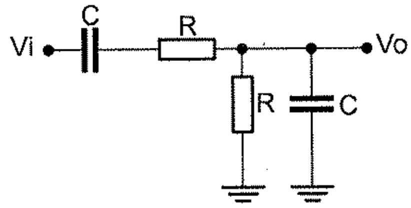
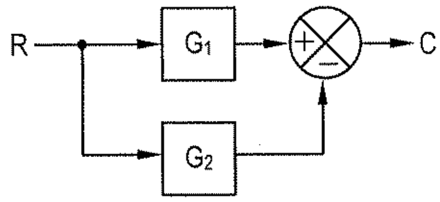


Figure-Q1(b)

Question 2

a. Produce equivalent block diagrams for each of the followings according to the required modification.

i. Original Diagram

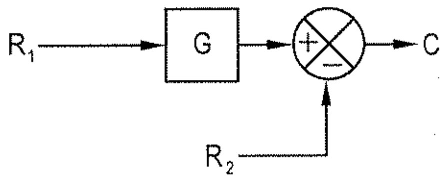


Modification (i):

Combine G1 and G2 to become one block

[3]

ii. Original Diagram

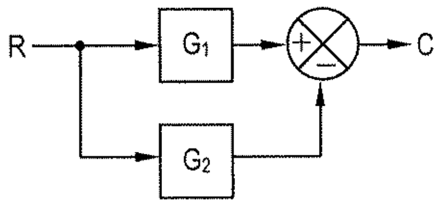


Modification (ii):

Move the summing junction ahead of block G

[4]

iii. Original Diagram

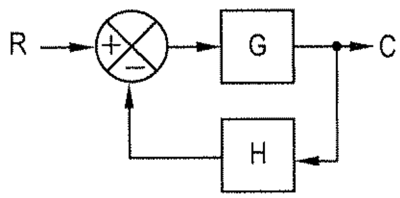


Modification (iii):

Remove block G2 from the feed forward path so that the path possesses unity gain.

[4]

iv. Original Diagram



Modification (iv):

Remove block H from a feedback path so that the feedback path possesses unity gain.

[4]

b. i. Convert the block diagram in Figure-Q2(b) into its equivalent signal flow graph. [4]

ii. Hence, determine the transfer function of the system using Mason's gain formula. [6]

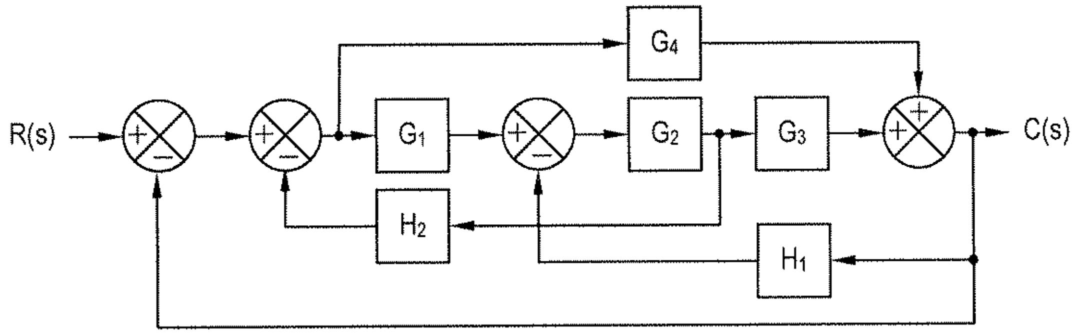


Figure-Q2(b)

Question 3

a. When a control system is being designed, its performance is being evaluated in the laboratory using typical input signals because the exact nature of inputs to the system in an actual working environment is not known.

   i. List four most commonly used test input signals meant for such purposes. [2]

   ii. Explain the specific system performance that is being evaluated for each type of test input signal stated in part (a)(i). [5]

   iii. Regardless of the type of test signal being used, the response of a system is broadly distinguished as the transient response and steady-state response. Explain these two responses. [4]

   iv. List four transient response specifications. [2]

b. The output of a system subjected to a specific test signal has an output function, $C(s)$, expressed mathematically as,

$$C(s) = \frac{s(s+10)}{(s+2)(s+4)(s+6)}$$

   i. Determine the output function in time domain, $c(t)$ [6]

   ii. Determine the initial value of $c(t)$ using initial value theorem. [3]

   iii. Determine the final value of $c(t)$ using final value theorem. [3]

Question 4

Figure-Q4 shows the block diagram of a mechanical system. K represents an adjustable gain which is always positive.

a. State the characteristic equation of the system. [2]

b. Identify all the open-loop poles and zeros of the system. [2]

c. Determine the root-locus break-in or break-away point (whichever applies). [5]

d. Sketch the root-locus of the system. [2]

e. Determine the value of gain K when the roots are both equal. [4]

f. Find the settling time (allowing 2% tolerance) of the system when the roots are equal. [5]

g. Determine the closed-loop pole position where the system exhibits a damping factor of 0.5. [5]

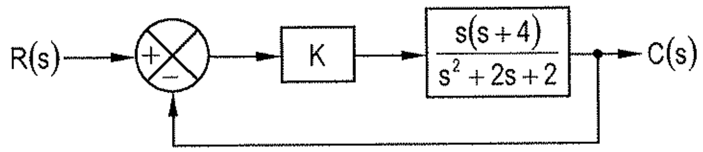


Figure-Q4

Question 5

a. The open-loop transfer function of a closed-loop control system with unity gain feedback is given by,

$$G(s) = \frac{5000}{(s+70)(s+500)}$$

i. Sketch an asymptotic Bode magnitude graph $|G(j\omega)|$ for the system. [5]

ii. Calculate the value of $|G(j200)|$. [4]

iii. Calculate the value of ω for which $\angle G(j\omega) = -138.7°$ [5]

b. Figure-Q5(b) shows Bode plots of a process given by $G(s)=\dfrac{Ks}{(s+a)(s^2+20s+100)}$. By examining the frequency response plot in Figure-Q5(b) as accurate as possible, determine the values of a and K. [11]

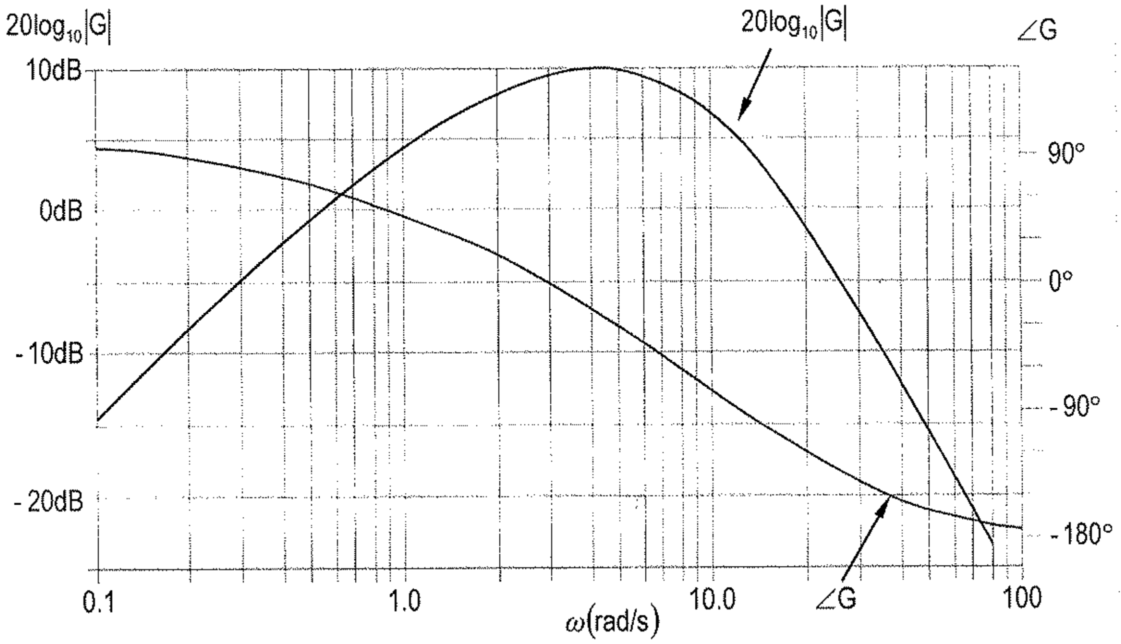


Figure-Q5(b)

Question 6

a. Draw block diagrams to illustrate the connections of the following compensation techniques used in single-loop control systems:

i. Cascade-compensation [2]

ii. Parallel compensation [2]

iii. Input compensation [2]

iv. Output compensation [2]

v. Series-parallel compensation [2]

b. The transfer function of a cascade compensator is commonly expressed as, $G_C = K\dfrac{s + a_1}{s + b_1}$. Explain how this compensator can be configured as phase-lead or phase-lag compensator. [4]

c. i. If the compensator described in part (b) is configured as a phase-lead compensator, sketch its Bode magnitude and phase plots respectively. Label all significant points clearly. [6]

ii. Show that the maximum phase lead occurs at a frequency given by $\omega_o = \sqrt{a_1 b_1}$ [5]

– THE END –

Appendix-1: THE LAPLACE TRANSFORM TABLE

	Definition	$f(t)$ from $t > 0$	$F(s) = \mathcal{L}\,[f(t)] = \int_0^\infty f(t)e^{-st}\,dt$
1.	Sum	$af_1(t) + bf_2(t)$	$aF_1(s) + bF_2(s)$
2.	First Derivative	$\frac{d}{dt}[f(t)]$	$sF(s) - f(0)$
3.	n^{th} Derivative	$\frac{d^n}{dt^n}[f(t)]$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f'(0) \cdots f^{(n-1)}(0)$
4.	Definite Integral	$\int_0^t f(u)du$	$\frac{F(s)}{s}$
5.	Shift in t	$f(t - kT)$	$e^{-skT} F(s)$
6.	Exponential multiplier	$e^{-\alpha t} f(t)$	$F(s + \alpha)$
7.	Periodic function (period T)	$f(t)$	$\frac{1}{1 - e^{-sT}} \int_0^T e^{-st} f(t)dt$
8.	Initial Value	$\lim_{t \to 0} f(t)$	$\lim_{s \to \infty} sF(s)$
9.	Final Value	$\lim_{t \to \infty} f(t)$	$\lim_{s \to 0} sF(s)$
10.	Unit impulse at $t = 0$	$\delta(t)$	1
11.	Unit impulse at $t = $ kT	$\delta(t - kT)$	e^{-skT}
12.	Unit step	$u(t)$	$\frac{1}{s}$
13.	Delayed step	$u(t - kT)$	$\frac{e^{-skT}}{s}$
14.	Rectangular pulse (duration kT)	$u(t) - u(t - kT)$	$\frac{1 - e^{-skT}}{s}$
15.	Unit ramp	$r(t) = t$	$\frac{1}{s^2}$
16.	Delayed ramp	$r(t - kT)$	$\frac{e^{-skT}}{s^2}$

	Definition	$f(t)$ from $t > 0$	$F(s) = \mathcal{L}[f(t)] = \int_0^\infty f(t)e^{-st}\,dt$
17.	n^{th} order ramp	t^n	$\frac{n!}{s^{n+1}}$
18.	Exponential decay	e^{-at}	$\frac{1}{s+a}$
19.	Exponential growth	$1-e^{-at}$	$\frac{a}{s(s+a)}$
20.	Exponential × t	te^{-at}	$\frac{1}{(s+a)^2}$
21.	Exponential × t^n	$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$
22.	Difference of exponentials	$e^{-at}-e^{-bt}$	$\frac{b-a}{(s+a)(s+b)}$
23.	Difference of exponentials	$\frac{1}{b-a}\left(be^{-bt}-ae^{-at}\right)$	$\frac{s}{(s+a)(s+b)}$
24.	Sine	$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
25.	Phase-advanced sine	$\sin(\omega t+\phi)$	$\frac{\omega\cos\phi + s\sin\phi}{s^2+\omega^2}$
26.	Sine × t	$t\sin\omega t$	$\frac{2\omega s}{(s^2+\omega^2)^2}$
27.	Exponentially decaying sine	$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
28.	Cosine	$\cos\omega t$	$\frac{s}{s^2+\omega^2}$
29.	Phase-advanced cosine	$\cos(\omega t+\phi)$	$\frac{s\cos\phi - \omega\sin\phi}{s^2+\omega^2}$
30.	Cosine × t	$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
31.	Exponentially decaying cosine	$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$