INTI International College Penang
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FINAL
Examination Paper

(COVER PAGE)

Session : **August 2015**

Programme : Diploma In Electrical And Electronic Engineering (DEEI)

Course : **EEE2108: Modern Control Systems Engineering**

Date of Examination : 7th December 2015 (Monday)

Time : 2:00pm – 4:00pm

Duration : 2 Hours Reading Time : Nil

Special Instructions :

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

IMPORTANT NOTE : THIS PAPER SHOULD NOT BE TAKEN OUT OF THE EXAMINATION HALL

Materials Permitted : Non-programmable scientific calculator

Materials Provided : Laplace Transform Table (Appendix)

Examiner(s) : **Mr. Chan Tse Wei**

Moderator : Dr. Ooi Beng Lee

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

INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEEI)
EEE2108: MODERN CONTROL SYSTEMS ENGINEERING
FINAL EXAMINATIONS: AUGUST 2015 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. Figure-Q1(a) shows a passive electronic system whose components are normalized for analysis purposes. Determine the transfer function, $G(s) = V_{out}(s)/V_{in}(s)$ of the system. [6]

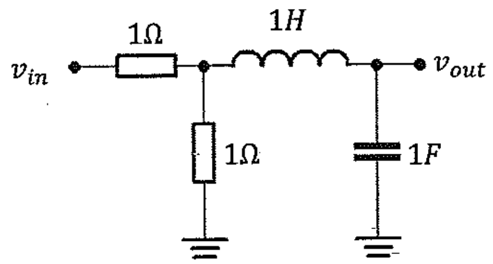

Figure-Q1(a)

b. Reduce the block diagram shown in Figure-Q1(b)(i) into the one shown in Figure-Q1(b)(ii). [8]

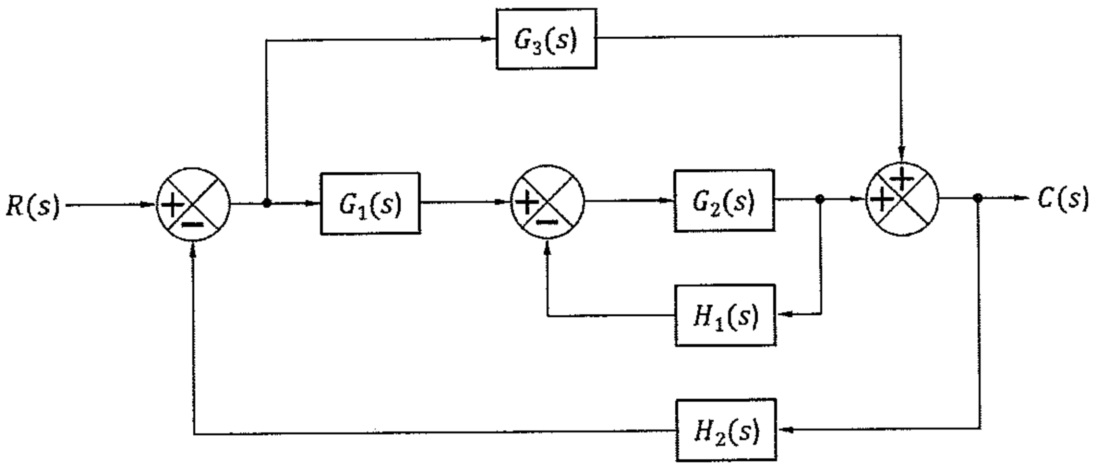

Figure-Q1(b)(i)

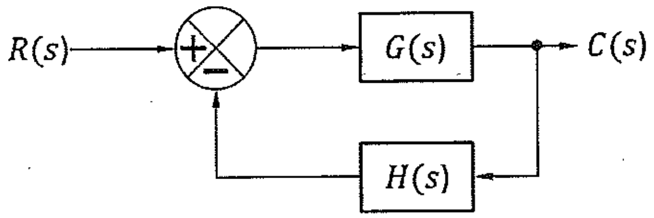

Figure-Q1(b)(ii)

c. Using Mason's gain formula, find the transfer function $T(s) = C(s)/R(s)$, for the system represented in Figure-Q1(c). [11]

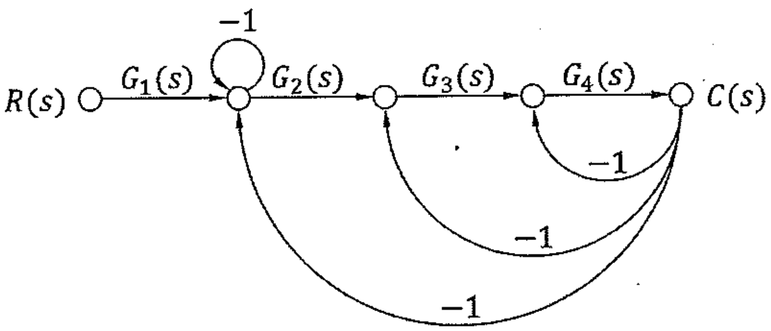

Figure-Q1(c)

Question 2

a. i. System-A has closed loop poles at $s = -7$ and $s = -10$, while system-B's closed loop poles are overlapping at $s = -0.5$. If both systems are exposed to the same unit impulse input simultaneously, qualitatively describe the difference in their respective output responses. [3]

ii. Two stable second order systems have complex conjugate closed-loop poles. Their closed-loop poles have the same real part but differ only in the imaginary term. If both systems are exposed to the same unit impulse input simultaneously, qualitatively describe the difference in their respective output responses. [3]

iii. Explain why a system with closed-loop poles having positive real part will be unstable. [4]

b. Determine if the system shown in Figure-Q2(b) is stable. [5]

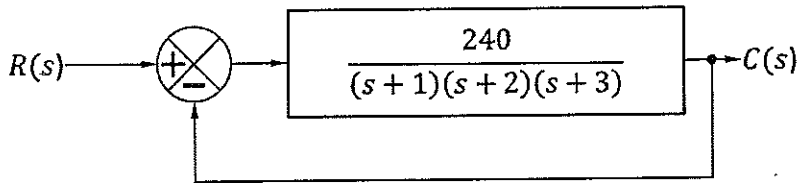

Figure-Q2(b)

c. Determine the range of K for which the system shown in Figure-Q2(c) is stable. Given that K is always positive. [10]

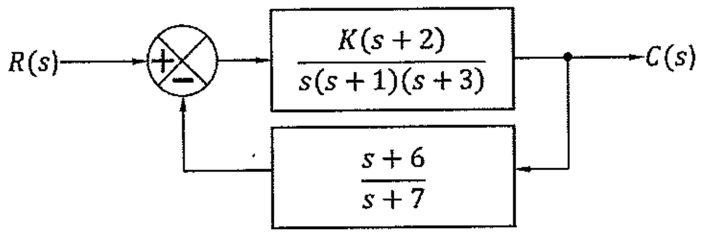

Figure-Q2(c)

Question 3

a. Determine the closed-loop pole locations of the system which has the following transfer function,

$$\frac{C(s)}{R(s)} = \frac{s^2 + 4s - 3}{s^4 + 4s^3 + 8s^2 + 20s + 15}$$ [8]

b. A second order system has a damping ratio of 0.5, a natural frequency of 100 rad/s, and a DC gain of 1. Determine the time response of the system to a unit step input. [10]

c. When a second order system respond to a unit step input, it exhibits a percent of overshoot as much as 12% and settles down, with 2% accuracy, 0.6 s after the input is applied. Find the system's closed-loop poles. [7]

Question 4

a. A unity negative feedback control system has a loop transfer function given as,

$$G(s) = \frac{K}{s(s + \sqrt{2K})}$$

i. Determine the percent overshoot and the 2% accuracy criterion of settling time in terms of K due to a unit step input. [8]

ii. For what range of K is the settling time less than 1 second? [2]

b. For the system shown in Figure-Q4(b), quantitatively explain why the steady-state error signal of the system cannot be zero for the system to have a finite non-zero output. [3]

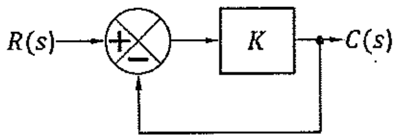

Figure-Q4(b)

c. i. For the system shown in Figure-Q4(c), find the value of K so that there is 10% error in the steady state when responding to a unit ramp input. [4]

ii. Quantitatively justify that the K value found in part (c)(i) will not cause the system to be unstable. [4]

iii. Quantitatively justify that the K value found in part (c)(i) will not affect the steady-state error when the system is responding to a step input. [4]

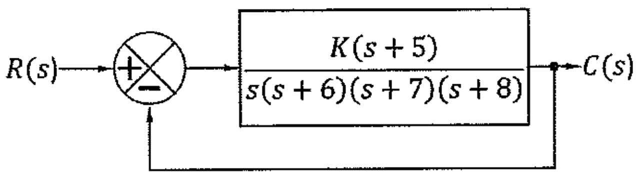

Figure-Q4(c)

Question 5

a. A negative unity feedback system has an open-loop transfer function given as,

$$G(s) = \frac{K(s+1)(s+2)}{(s+5)(s+6)}$$

i. Sketch the root locus of the system clearly. [8]

ii. Determine the value(s) of K which causes the system to have a pair of overlapping poles. [4]

b. A negative unity feedback system has an open-loop transfer function given as,

$$G(s) = \frac{K(s+\alpha)}{s(s+3)(s+6)}$$

Find the most probable values of α and K that will yield a second-order closed-loop pair poles at $-1 \pm j100$. Justify the accuracy of your answer. [13]

Question 6

A negative unity feedback system is being experimented. Figure-Q6(i) shows the open-loop gain Bode magnitude plot of the system, while Figure-Q6(ii) shows its associated Bode phase plot.

a. Estimate the gain margin and phase margin of the system. [8]

b. Approximate the system open-loop transfer function in s-domain. [8]

c. With the transfer function obtained in part (b), quantitatively show that the system is unstable. [3]

d. Comment on the system frequency response analysis in relationship to the system stability. [2]

e. Suggest the appropriate maximum open-loop DC gain value for this system to be stable. [4]

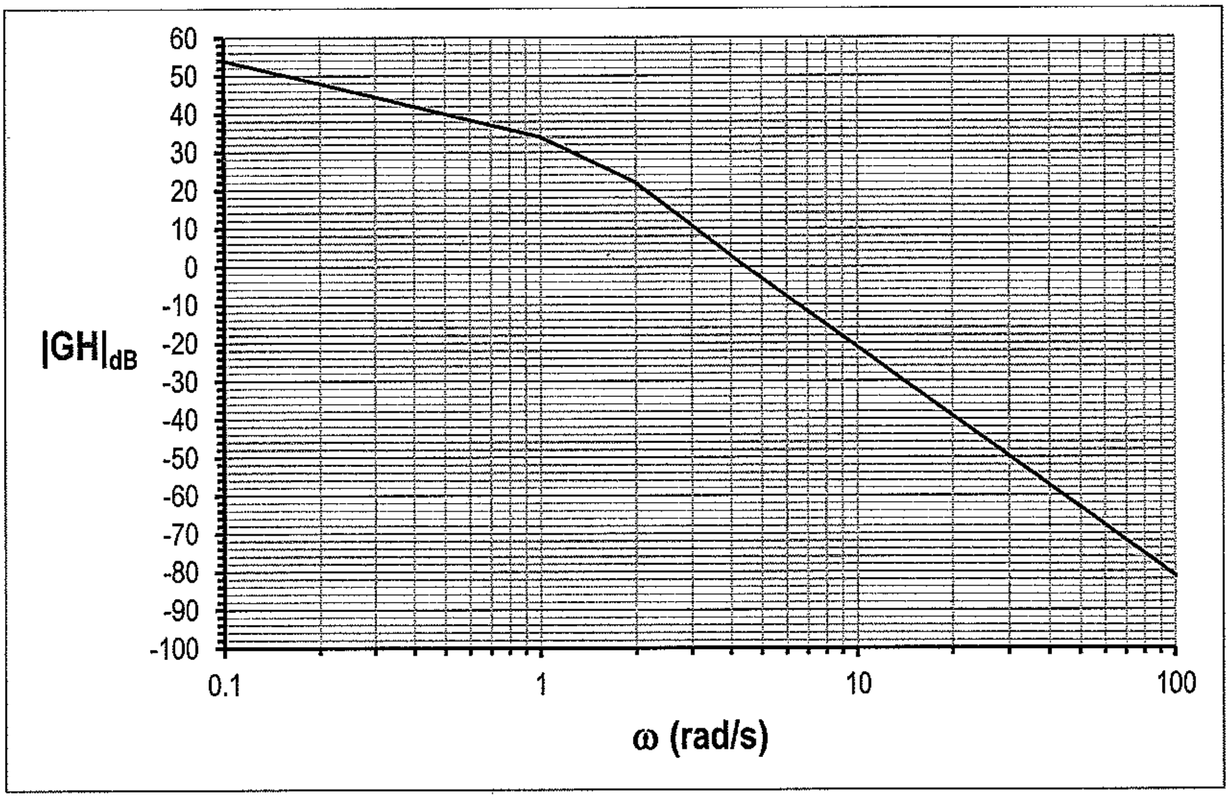

Figure-Q6(i)

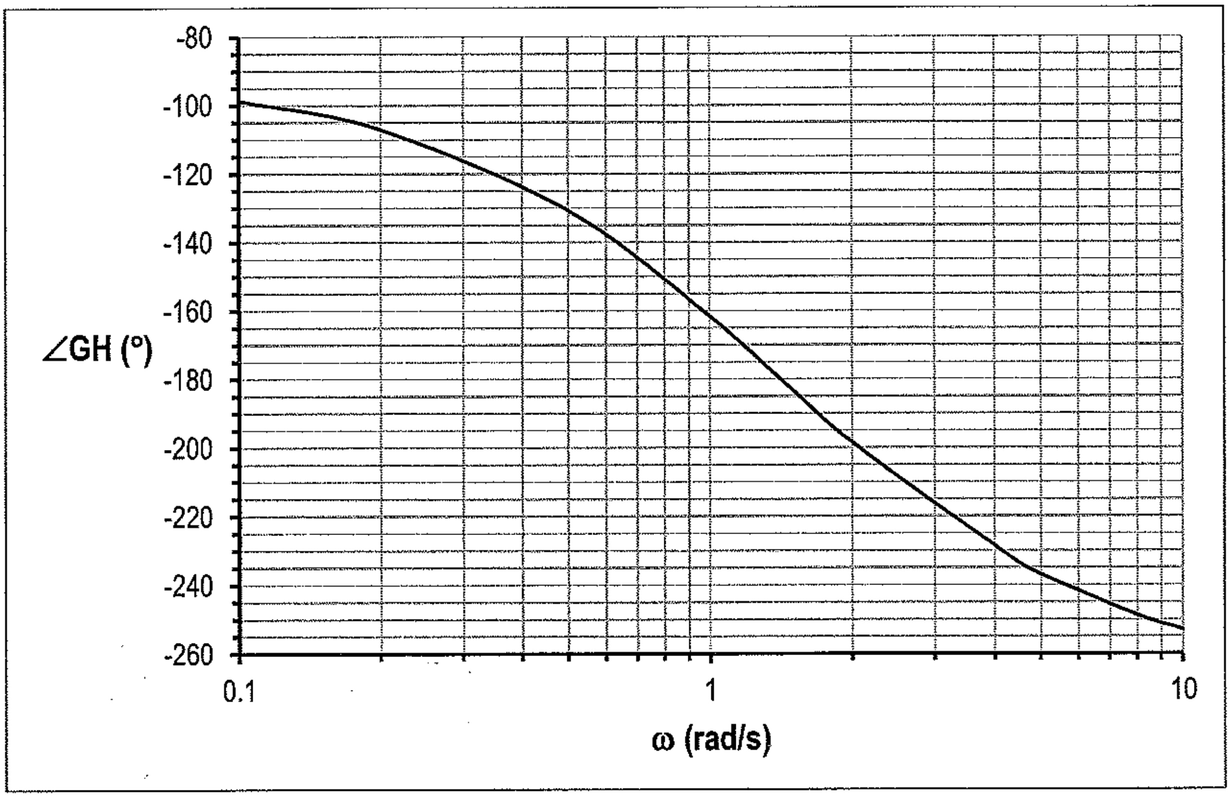

Figure-Q6(ii)

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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	$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$