INTI
International College Penang
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FINAL
Examination Paper

(COVER PAGE)

Session	:	**April 2016**
Programme	:	Diploma In Electrical And Electronic Engineering (DEEI)
Course	:	**EEE2108: Modern Control Systems Engineering**
Date of Examination	:	30 July 2016, Saturday
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 BY THE STUDENTS.**

Materials Permitted :
Scientific Calculator (Model fx570 Series)

Materials Provided :
Laplace Transform Table (Appendix)
Worksheet-Q5(a)

Examiner(s)	:	**Mr. Chan Tse Wei**
Moderator	:	Dr. Ooi Beng Lee

This paper consists of 6 printed pages, including the cover page.

INTI INTERNATIONAL COLLEGE

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (DEEI)
EEE2108: MODERN CONTROL SYSTEMS ENGINEERING
FINAL EXAMINATIONS: APRIL 2016 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. The assessor reserves the rights to ignore your answers if they are ambiguous.

Question 1

a. Reduce the block diagram shown in Figure-Q1(a) into a block of single-input-single-output (SISO) system using block diagram reduction algebra. [7]

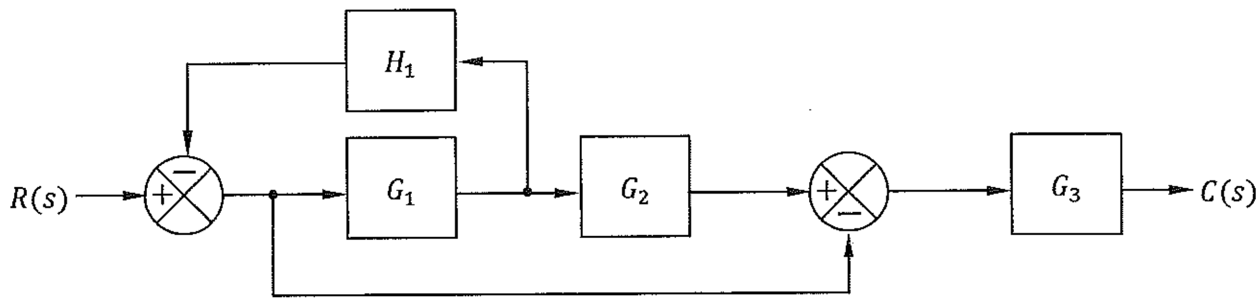


Figure-Q1(a)

b. Convert the block diagram shown in Figure-Q1(a) to a signal flow graph. Verify the answer obtained in part (a) by using Mason's gain formula. [7]

c. Comment on the two methods used in part (a) and (b) in terms of their similarity and their ease of applications. [4]

d. Design single op-amp electronic circuit that implements the comparators in Figure-Q1(a). Quantitatively justify your design. [7]

Question 2

a. i. Explain poles and zeros of a system. [4]

ii. If the closed-loop transfer function of a system is given by,

$$T(s) = \frac{s^2 + 9s + 18}{s^3 + 11s^2 + 38s + 40}$$

Determine the system's closed-loop poles and zeros respectively. [5]

iii. Is the system stable? Explain why. [4]

b. The instantaneous output expression of a closed-loop system, responding to a unit step input, is given by,

$$c(t) = 4 + 3e^{-2t} + 7e^{-5t}$$

i. Determine the closed-loop poles and zeros of the system. [10]

ii. Comment on the impact of closed-loop poles and zeros on the system's output. [2]

Question 3

a. i. The output response of a linear system comprises of natural response and force response. Identify the part of the output response that is responsible for determining the stability of the system. [2]

ii. Describe the response stated in part (a)(i) that creates instability. [2]

iii. Describe the behavior of a physical system that has become unstable. [2]

iv. Explain Routh-Hurwitz stability criterion. [2]

v. State the condition in which the Routh-Hurwitz criterion can be utilized to determine the actual locations of a system's closed-loop poles. [2]

b. The characteristic equation of a closed-loop system is given by,

$$s^5 + 6s^3 + 5s^2 + 8s + 20 = 0$$

Determine the respective quantity of the system's closed-loop poles that are in the right half s-plane, in the left-half and on the $j\omega$ axis. [9]

c. Determine the range of K in the system of Figure-Q3(c) that ensures system absolute stability.

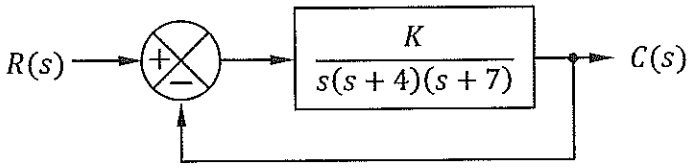


Figure-Q3(c) [6]

Question 4

a. Determine the value of K in the system of Figure-Q4(a)(i) that will positioned the closed-loop poles as shown in Figure-Q4(a)(ii). Hence determine the position of the poles. [15]

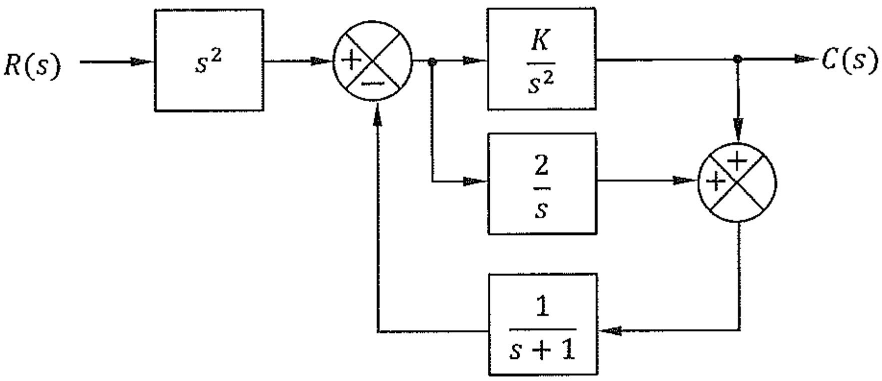


Figure-Q4(a)(i)

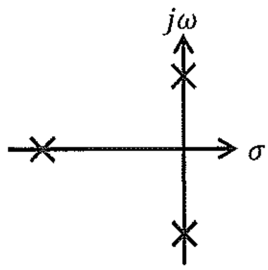


Figure-Q4(a)(ii)

b. i. Explain the steady-state error of a control system. [2]

ii. State the three most common inputs to test the steady-state error of a control system. [3]

iii. Give one example of control system that can be tested by each of the input stated in part (b)(ii). [3]

iv. The error signal of a control system is expressed as,

$$E(s) = 5s + \frac{7}{s}$$

Calculate the steady-state error of the system. [2]

Question 5

a. For each of the root loci shown in Worksheet-Q5(a), tell whether or not the sketch can be a root locus. Justify each answer. [15]

b. The characteristic equation of a closed-loop control system is given by,

$$s^3 + 2s^2 + (20K + 7)s + 100K = 0$$

Sketch the root locus for this system by clearly showing all its open-loop pole(s) and open-loop finite zero(s), and the infinite-extending asymptotic lines. [10]

Question 6

a. Find the analytical expression for the magnitude and phase responses for each $G(s)$ below:

i. $G(s) = \dfrac{1}{s(s+2)(s+4)}$ [6]

ii. $G(s) = \dfrac{s+5}{s^2(s+3)(s+7)}$ [6]

b. The open-loop transfer function of a non-unity feedback system is given by,

$$G(s)H(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

i. Show that the phase shift of the open-loop transfer function is $-90°$ when $\omega = \omega_n$. [4]

ii. If ω_r is the resonant frequency of the open-loop transfer function, show that $\omega_r = \omega_n\sqrt{1 - 2\zeta^2}$. [6]

iii. Figure-Q6(b)(i)&(ii) show the Bode plots of the given system. Determine the values of ζ and ω_n of the system respectively. [3]

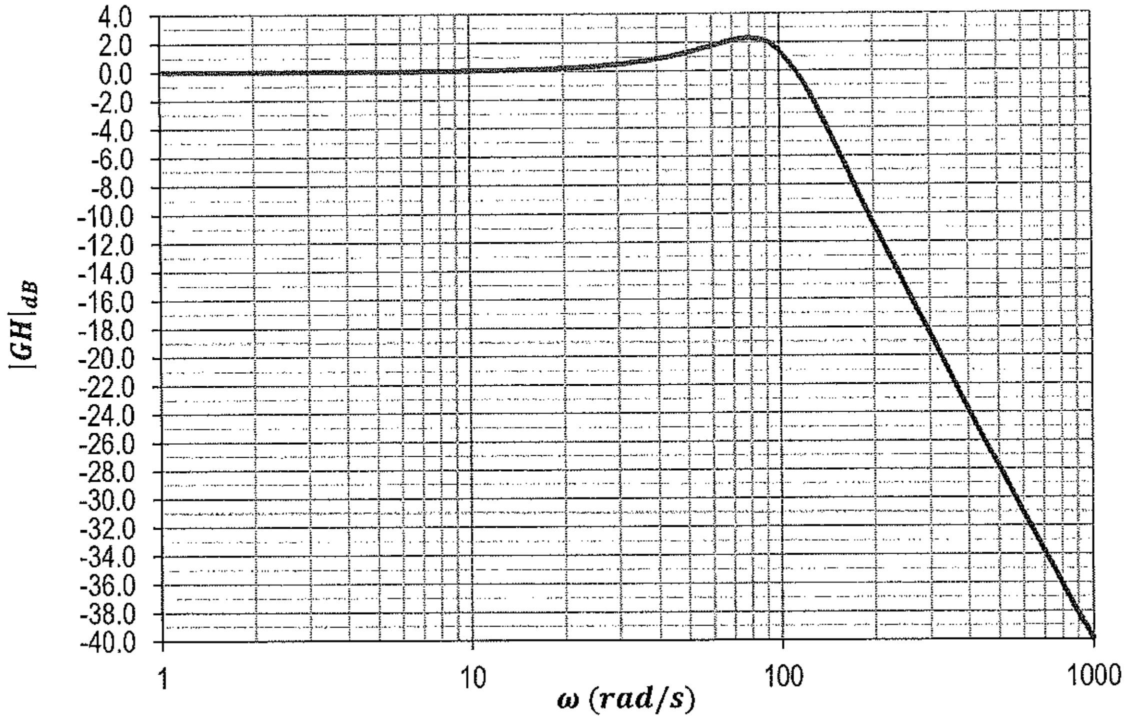


Figure-Q6(b)(i)

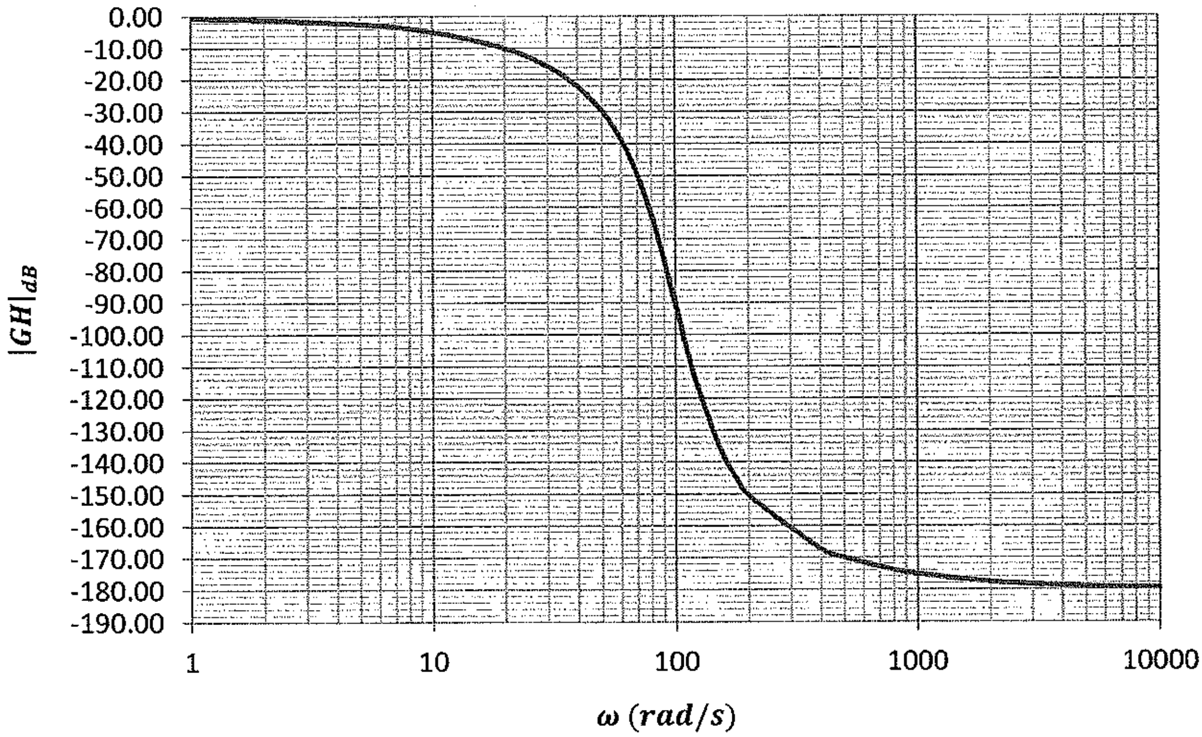


Figure-Q6(b)(ii)

~ **The End** ~

Appendix: THE LAPLACE TRANSFORM TABLE

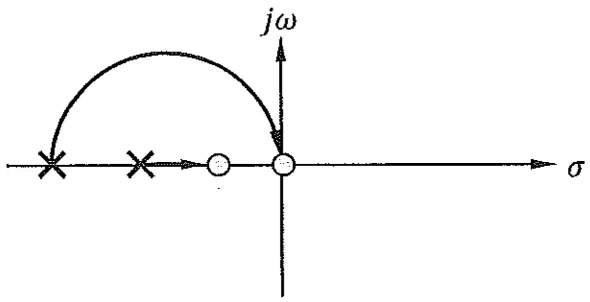
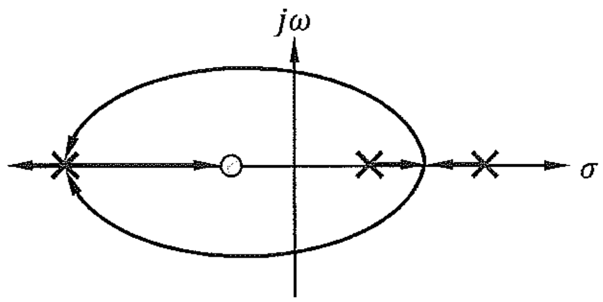
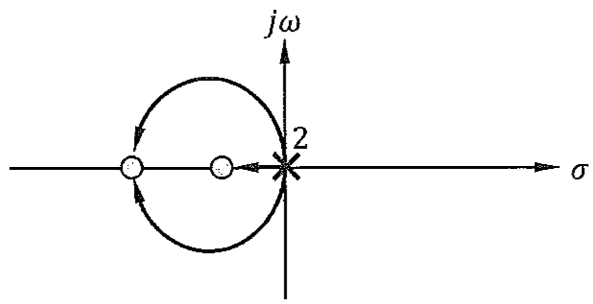
	Definition	$f(t)$ from $t>0$	$F(s)=\mathcal{L}[f(t)]=\int_0^\infty f(t)e^{-st}dt$
1.	Sum	$af_1(t)+bf_2(t)$	$aF_1(s)+bF_2(s)$
2.	First Derivative	$\frac{d}{dt}[f(t)]$	$sF(s)-f(0)$
3.	n^{th} Derivative	$\frac{d^n}{dt^n}[f(t)]$	$s^nF(s)-s^{n-1}f(0)-s^{n-2}f'(0)\cdots f^{(n-1)}(0)$
4.	Definite Integral	$\int_0^t f(u)du$	$\frac{F(s)}{s}$
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 $t=\mathrm{k}T$	$\delta(t-kT)$	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	$r(t-kT)$	$\frac{e^{-skT}}{s^2}$

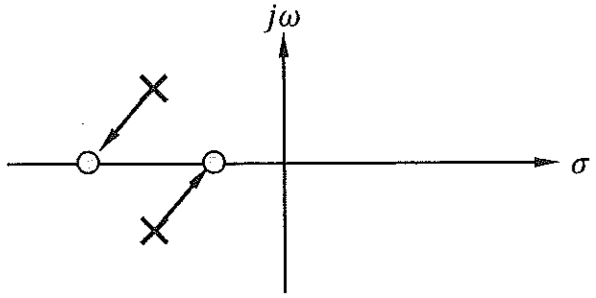
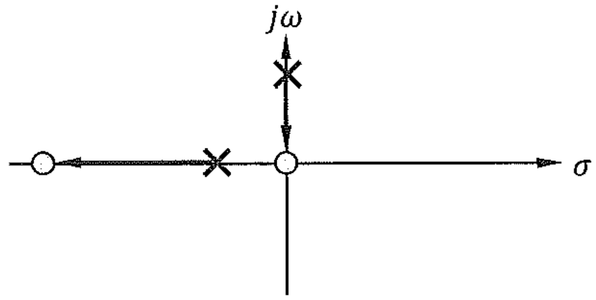
	Definition	$f(t)$ from $t > 0$	$F(s) = \mathcal{L}[f(t)] = \int_0^\infty f(t)e^{-st}\,dt$
17.	n^{th} order ramp	t^n	$\frac{n!}{s^{n+1}}$
18.	Exponential decay	e^{-at}	$\frac{1}{s+a}$
19.	Exponential growth	$1-e^{-at}$	$\frac{a}{s(s+a)}$
20.	Exponential × t	te^{-at}	$\frac{1}{(s+a)^2}$
21.	Exponential × 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	$t \sin \omega t$	$\frac{2\omega s}{\left(s^2+\omega^2\right)^2}$
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	$t\cos\omega t$	$\frac{s^2-\omega^2}{\left(s^2+\omega^2\right)^2}$
31.	Exponentially decaying cosine	$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$

Student Name:	
Matrix Number:	

WORKSHEET-Q5(a)

Instruction: **Attach this worksheet to your answer booklet.**

<table>
<tr><td>i.</td><td>
</td><td>Tick the correct answer:
❑ Is a root locus
❑ Not a root locus
Justification:</td></tr>
<tr><td>ii.</td><td>
</td><td>Tick the correct answer:
❑ Is a root locus
❑ Not a root locus
Justification:</td></tr>
<tr><td>iii.</td><td>
</td><td>Tick the correct answer:
❑ Is a root locus
❑ Not a root locus
Justification:</td></tr>
</table>

iv.		**Tick the correct answer:** ❑ Is a root locus ❑ Not a root locus **Justification:**
v.		**Tick the correct answer:** ❑ Is a root locus ❑ Not a root locus **Justification:**