INTI
International College Penang
LAUREATE INTERNATIONAL UNIVERSITIES®

FINAL
Examination Paper

(COVER PAGE)

Session	:	**January 2016**
Programme	:	Diploma In Electrical And Electronic Engineering (DEEI)
Course	:	**EEE2108: Modern Control Systems Engineering**
Date of Examination	:	10 March 2016 (Thursday)
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)
Linear Graph Paper (× 1)

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 PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEEI)
EEE2108: MODERN CONTROL SYSTEMS ENGINEERING
FINAL EXAMINATIONS: JANUARY 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. [7]

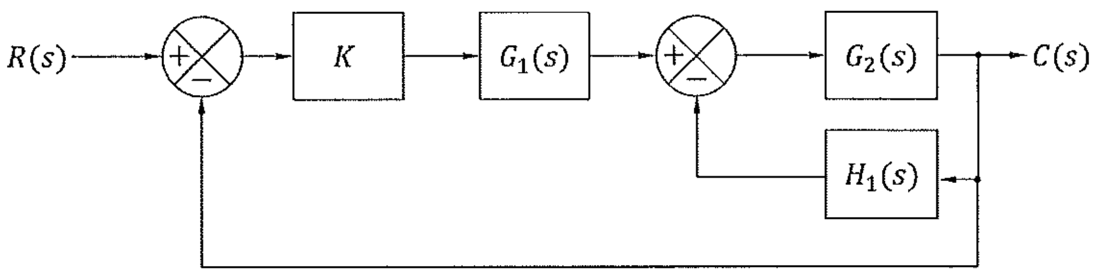

Figure-Q1(a)

b. For the block diagram shown in Figure-Q1(a), blocks K, $G_1(s)$, $G_2(s)$ and $H_1(s)$ are given by,

$$K = 10$$

$$G_1(s) = \frac{1}{s+2}$$

$$G_2(s) = \frac{1}{s+10}$$

$$H_1(s) = \frac{1}{s}$$

By using the answer obtained in part (a), derive the transfer function expression of the system in factor form. [7]

c. Figure-Q1(c) shows an op-amp based analog circuit. Derive the expression of the output function, $V_{out}(s)$, in terms of the input functions, $V_{in1}(s)$ and $V_{in2}(s)$, and the associating components. [7]

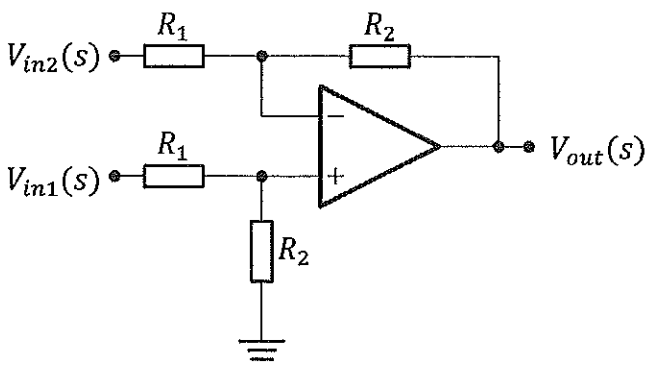

Figure-Q1(c)

d. From the answer obtained in part (c), clearly explain the part of the block diagram in Figure-Q1(a) that can be implemented using the circuit shown in Figure-Q1(c). [4]

Question 2

The transfer function of a control system is given by,

$$T(s) = \frac{1000(s+4)}{s^3 + 33s^2 + 332s + 1020}$$

a. Determine the poles and zeros of the system. [4]

b. Determine the DC gain of the system. [4]

c. By using the answers obtained in part (a)(i), justify if the system is stable. [2]

d. Plot the system's output response on the given graph paper when it is subjected to a unit impulse input. Make use of the table shown in Table-Q2(d). [15]

t (ms)	0	5	10	50	80	100	150	200	400	600	800	1000
$c(t)$												

Table-Q2(d)

Question 3

a. The characteristic equation of a control system is given by,

$$s^6 + 3s^5 + 5s^4 + 9s^3 + 8s^2 + 6s + 4 = 0$$

Verify if the system is stable. [8]

b. Determine the value of gain K, for the feedback control system shown in Figure-Q3(b) so that the system will respond with a 15% overshoot when subjected to a unit step input. [8]

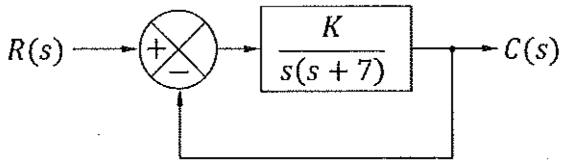

Figure-Q3(b)

c. Find the range of gain K for the system shown in Figure-Q3(c) that will cause the system to be stable, unstable, and marginally stable. Assume $K \geq 0$. [9]

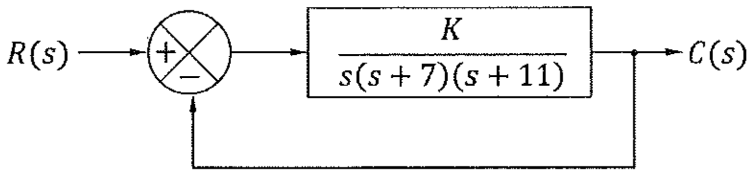

Figure-Q3(c)

Question 4

a. The system shown in Figure-Q4(a) is a unity-feedback control system.

i. Determine the peak magnitude, M_p of the system when responding to a unit step input. [5]

ii. Determine the steady-state error of the system resulting from a unit ramp input. [5]

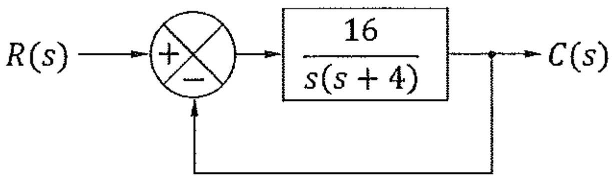

Figure-Q4(a)

b. The system in Figure-Q4(a) is being modified as shown in Figure-Q4(b).

   i. Determine the value of α which will decrease the peak overshoot of the system to 1.5% when responding to a unit step input. [8]

   ii. With the value of α obtained in part (b)(i), determine the steady-state error of the system resulting from a unit ramp input. [5]

   iii. Base on the results obtained in part (a), (b)(i) and (b)(ii), comment on the impact of the system's modification. [2]

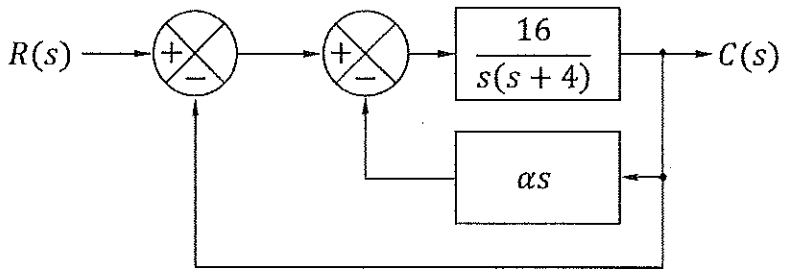

Figure-Q4(b)

Question 5

Figure-Q5 shows a unity feedback system. K is the system's forward path gain and it's always positive.

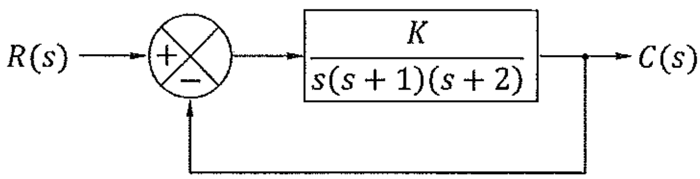

Figure-Q5

a. Identify the system open-loop poles and zeros (if any). [4]

b. By using relevant root locus theory, explain why $s = -1.5$ will not be one of the system closed-loop poles. [2]

c. Determine the locations where two of the system's dominating closed-loop poles are overlapping. [5]

d. Determine the value of K that causes the conditioning described in part (c). [4]

e. By using relevant root locus theory, determine the range of K, that will cause the system to be unstable. [5]

f. By using relevant root locus theory, verify if there is a value of gain K that can position the system's closed-loop poles at $s = -0.5 \pm j0.5$. [5]

Question 6

a. Explain the meaning of "gain crossover frequency" and "phase crossover frequency". [4]

b. Explain the meaning of "gain margin" and "phase margin". [4]

c. Figure-Q6(c) shows the Bode magnitude and phase plots of the open-loop gain of a control system. Determine the phase margin and gain margin of the system. [6]

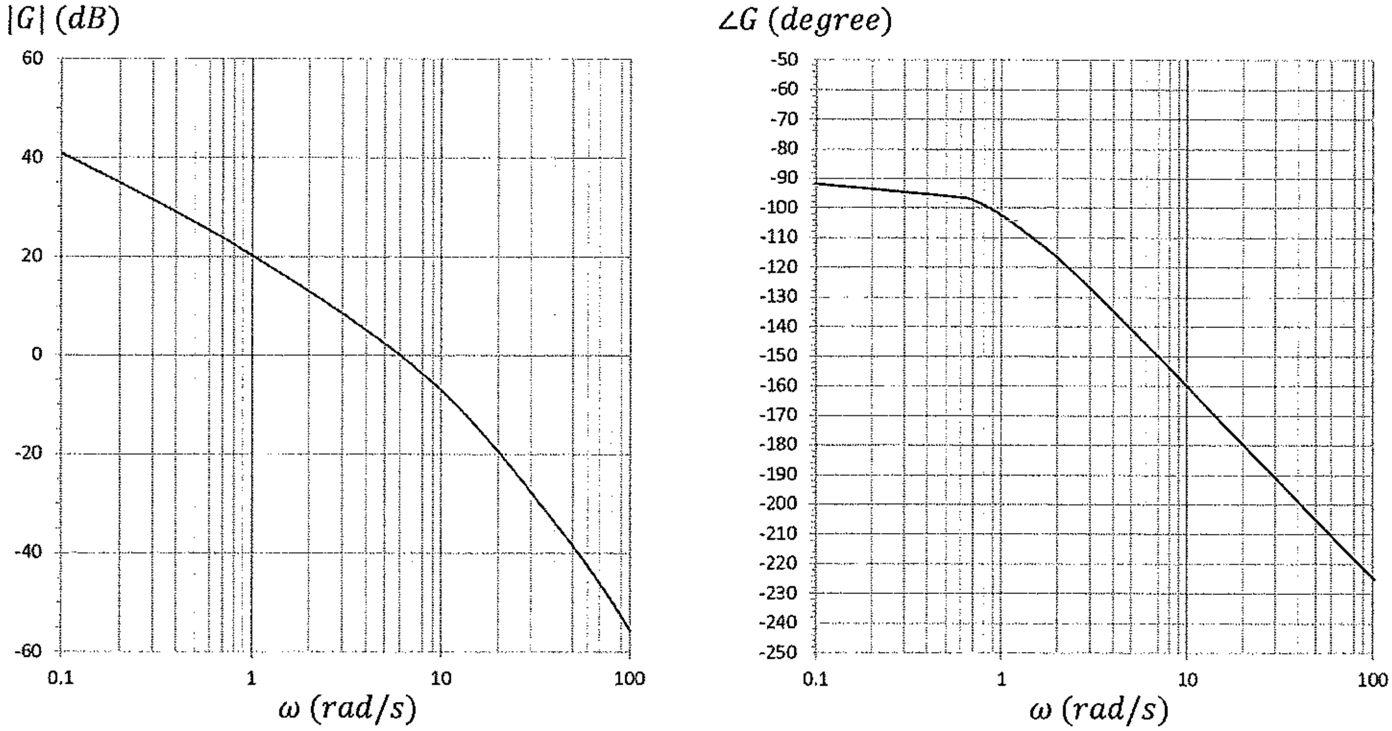

Figure-Q6(c)

d. The open-loop transfer function of a control system is given by,

$$G(s)H(s) = \frac{10(s+2)}{(s+3)(s+8)}$$

Determine the gain margin and phase margin of the system. [11]

~ The End ~

Appendix-1: THE LAPLACE TRANSFORM TABLE

	Definition	$f(t)$ from $t > 0$	$F(s) = \mathcal{L}\left[f(t)\right] = \int_0^\infty f(t)e^{-st}dt$
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 $t = \mathrm{kT}$	$\delta(t - kT)$	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 $t > 0$	$F(s) = \mathcal{L}\left[f(t)\right] = \int_0^\infty f(t)e^{-st}\,dt$
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 $\times t$	te^{-at}	$\frac{1}{(s+a)^2}$
21.	Exponential $\times t^n$	$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$
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 $\times t$	$t \sin \omega t$	$\frac{2\omega s}{\left(s^2+\omega^2\right)^2}$
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 $\times t$	$t\cos\omega t$	$\frac{s^2-\omega^2}{\left(s^2+\omega^2\right)^2}$
31.	Exponentially decaying cosine	$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$