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FINAL
Examination Paper

(COVER PAGE)

Session	:	AUGUST 2014
Programmes	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2108 : MODERN CONTROL SYSTEMS ENGINEERING**
Date of Examination	:	December 11, 2014 (Thursday)
Time	:	8.00am -10.00am Reading Time: Nil
Duration	:	2 Hours
Special Instructions	:	

This is a supplementary exam paper. 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)
Worksheet for Question 4(b)
Worksheet for Question 4(c)

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 (DEE/I)

EEE2108 : MODERN CONTROL SYSTEMS ENGINEERING
FINAL EXAMINATION : AUGUST 2014 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. Reduce the block diagram in Figure-Q1(a) to a single transfer function $T(s) = C(s)/R(s)$ using the following methods:

   i. Block diagram algebra. [6]

   ii. Signal flow graph. [8]

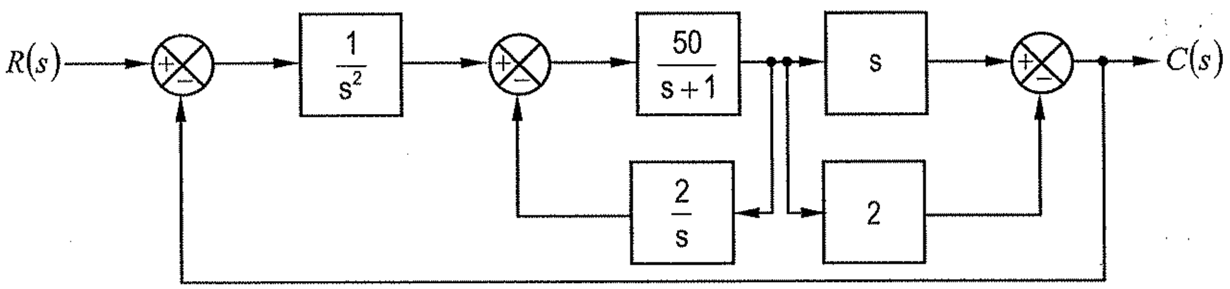


Figure-Q1(a)

b. i. Is the system in Figure-Q1(a) stable? [1]

   ii. Qualitatively justify your answer given in part (b)(i). [2]

c. i. Derive the error signal expression, $E(s)$ of the system in Figure-Q1(a), in terms of its input signal, $R(s)$ and the system's transfer function, $T(s)$. [3]

   ii. Hence, determine the system's steady-state error in response to a unit step input. [5]

Question 2

a. For the system shown in Figure-Q2(a), calculate,

i. The percent overshoot [7]

ii. The peak time [3]

iii. The settling time [3]

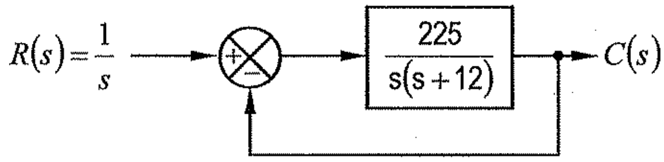


Figure-Q2(a)

Figure-Q2(b)(i) shows the step response of the system in Figure-Q2(b)(ii). Base on the step response, approximate the respective value of *a* and *b*. [12]

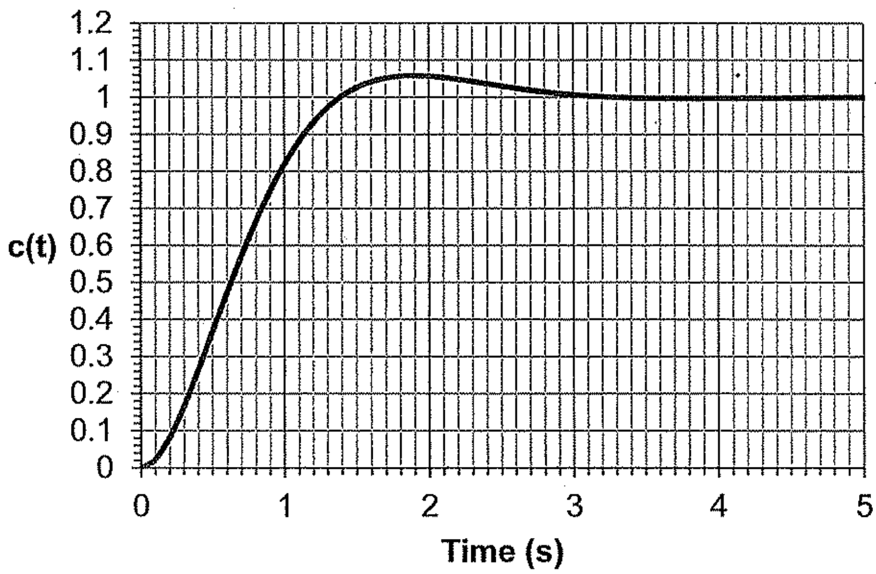


Figure-Q2(b)(i)

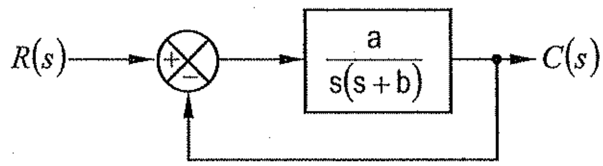


Figure-Q2(b)(ii)

Question 3

a. State if the following statements are true or false.

i. A system is stable if the natural response approaches zero as time approaches infinity. [1]

ii. A system is stable if the natural response approaches infinity at the initial condition. [1]

iii. A system is marginally stable if the natural response neither decays or grows but remains constant or oscillates. [1]

iv. A system is stable if every bounded input yields a bounded output. [1]

v. A system is unstable if any bounded input yields an unbounded output. [1]

vi. System with positive real closed-loop poles is unstable. [1]

vii. Repeated poles located along the imaginary axis of the s-plane denote system stability. [1]

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

$$G(s)=\frac{1000}{(s+2)(s+3)(s+5)}$$

i. Set up the Routh array table for the system. [5]

ii. Hence, determine if the system is stable. Justify your answer. [3]

iii. Without calculation, determine the number of closed-loop poles of the system that are located at the left side of the s-plane? [2]

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

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

i. Sketch the Nyquist diagram for the system's open-loop transfer function by setting K to unity and replacing $s=j\omega$, where ω ranges from 0 to infinity. [5]

ii. From the Nyquist diagram drawn in part (c)(i), justify that when K = 20, the system is marginally stable. [3]

Question 4

a. For each of the root loci shown in Figure-Q4(a), explain why the root loci is incorrect. [6]

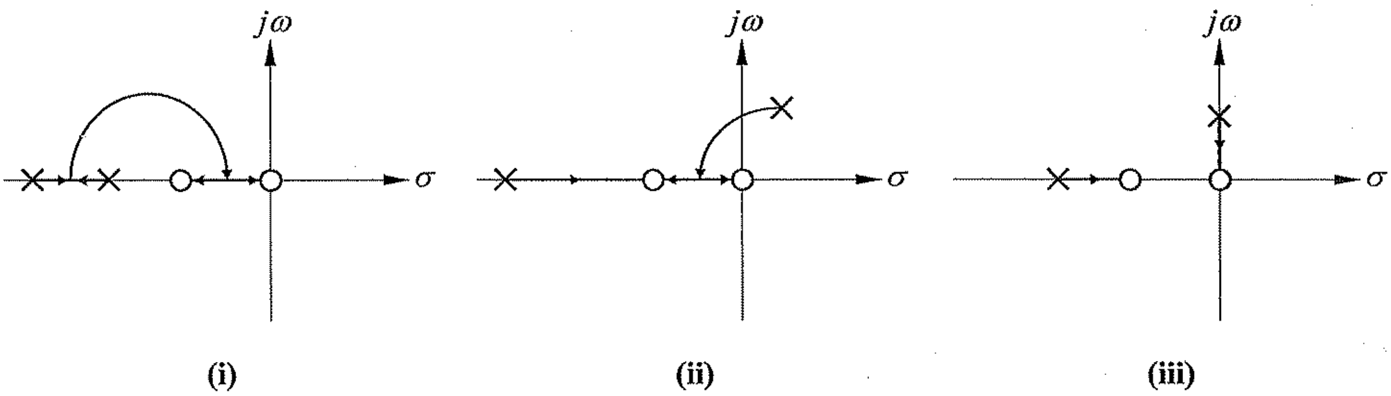


Figure-Q4(a)

b. Sketch the general shape of the root locus for each of the open-loop pole-zero plots shown in Figure-Q4(b). Submit your answer using the accompanying worksheet. [6]

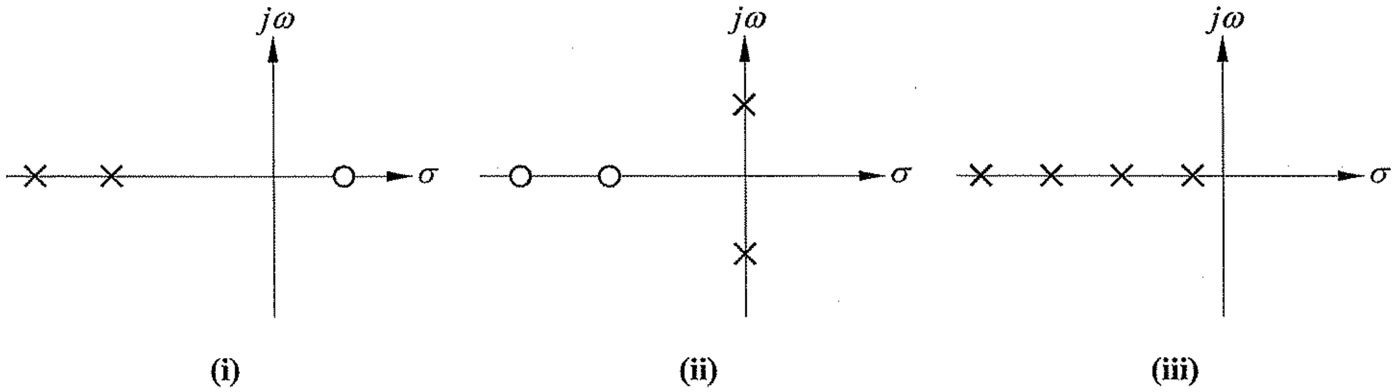


Figure-Q4(b)

c. Figure-Q4(c) shows open-loop poles and zeros drawn on an s-plane. There are two possibilities for the sketch of the root locus. Sketch each of the two possibilities in the accompanying worksheet. [6]

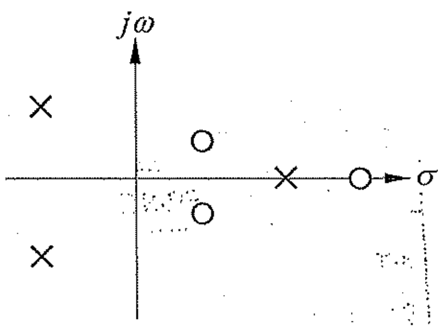


Figure-Q4(c)

d. Figure-Q4(d) shows a root locus plot of a unity negative feedback system.

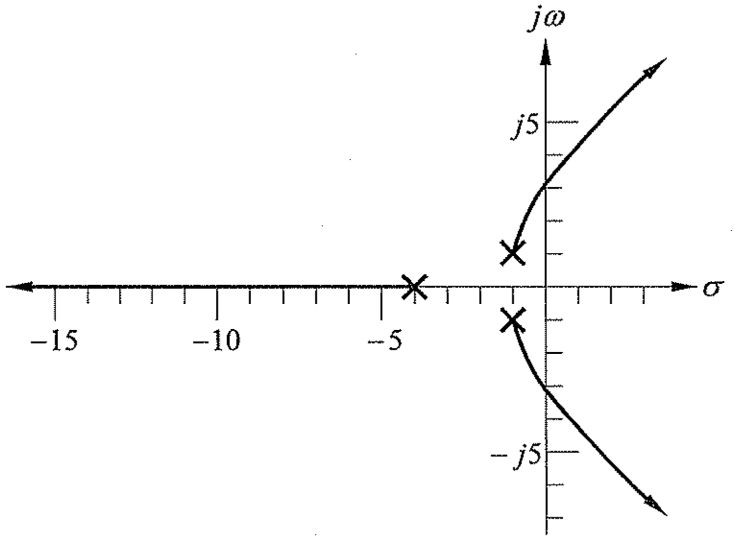


Figure-Q4(d)

i. Find the value of gain that will make the system marginally stable. [5]

ii. Find the value of gain for which the closed-loop transfer function will have a pole on the real axis at –5. [2]

Question 5

The open-loop transfer function of a negative unity feedback system is given as,

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

a. Express the analytical expression for the magnitude and phase response for $G(s)$. [4]

b. Sketch the Bode magnitude response for $G(s)$ ranging from $\omega > 0.1$ rad/s, clearly identify the corner frequencies and the corresponding gain values. [9]

c. Identify the gain crossover frequency of $G(s)$ in rad/s. [4]

d. Calculate the phase margin of $G(s)$. [4]

e. Calculate the phase crossover frequency of $G(s)$. [4]

Question 6

a. The circuit shown in Figure Q6(a) is to implement a compensator. Derive the circuit's transfer function expression and justify that it implement a phase lead compensator. [10]

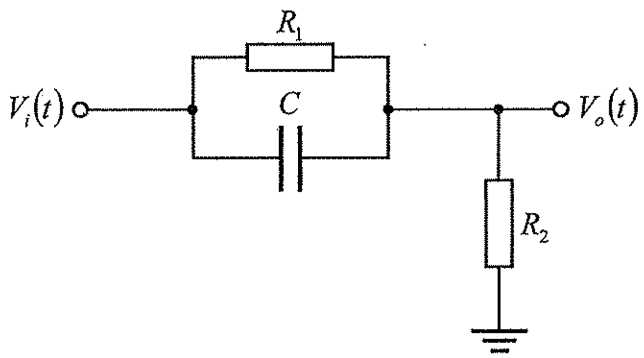


Figure-Q6(a)

b. The open-loop transfer function of an uncompensated second order control system is given by $G(s)=\frac{2}{s(s+4)}$. Design a phase-lead network for the system such that the response has 10% overshoot for a step input and approximately $\frac{4}{3}s$ of settling time at 2% accuracy. [15]

– THE END –

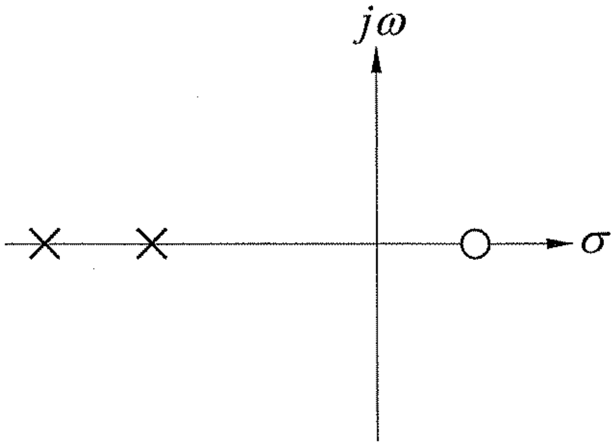
Appendix-1: THE LAPLACE TRANSFORM TABLE

	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	$\frac{d^n}{dt^n}[f(t)]$	$s^nF(s) - s^{n-1}f(0) - s^{n-2}f'(0) \cdots f^{(n-1)}(0)$
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 = $ 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	$r(t - kT)$	$\frac{e^{-skT}}{s^2}$

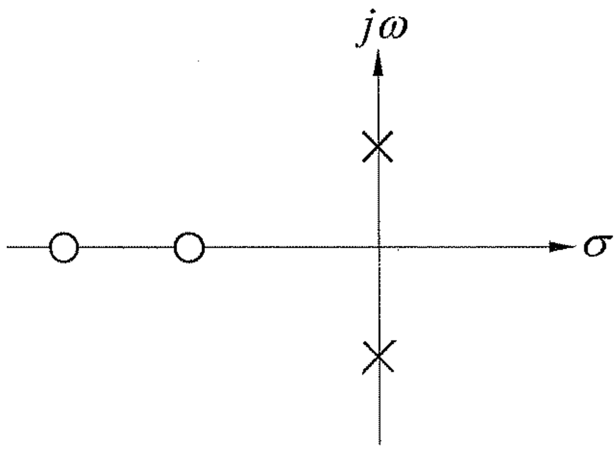
	Definition	$f(t)$ from $t>0$	$F(s)=\mathcal{L}[f(t)]=\int_0^\infty f(t)e^{-st}dt$
17.	n^{th} order ramp	t^n	$\frac{n!}{s^{n+1}}$
18.	Exponential decay	e^{-at}	$\frac{1}{s+a}$
19.	Exponential growth	$1-e^{-at}$	$\frac{a}{s(s+a)}$
20.	Exponential $\times t$	te^{-at}	$\frac{1}{(s+a)^2}$
21.	Exponential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

Worksheet for Question 4(b)

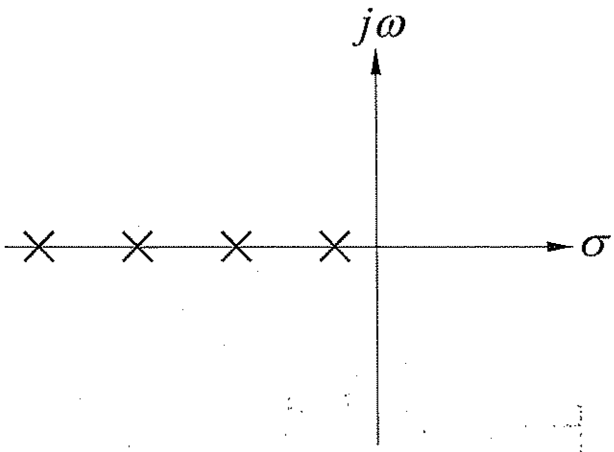
Student Name: ______________________ ID No.: ______________



(i)



(ii)

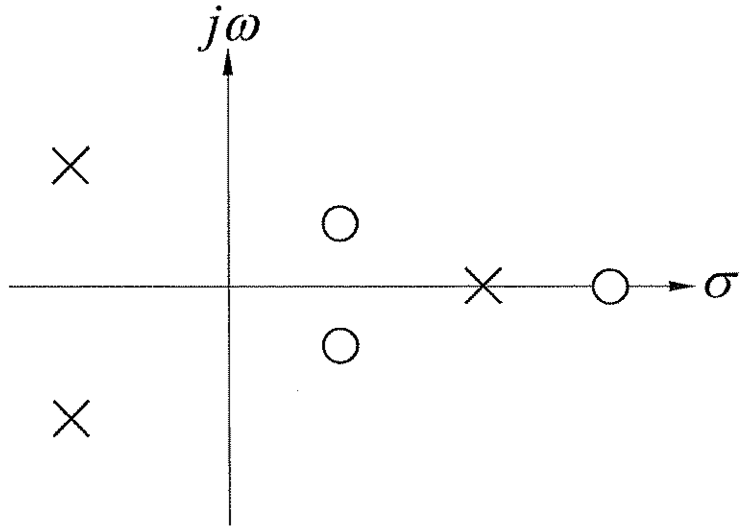


(iii)

Worksheet for Question 4(c)

Student Name: ______________________________ ID No.: ____________________

Possibility 1:



Possibility 2: