INTI International College Penang

FINAL
Examination Paper

(COVER PAGE)

Session	:	**April 2018**
Programme	:	Diploma In Electrical And Electronic Engineering (DEEI)
Course	:	**EEE2108: Modern Control Systems Engineering**
Date of Examination	:	26 July 2018 (Thursday)
Time	:	11:00am - 1:00pm
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 :

Non-programmable Calculator (e.g. Model fx570 Series)

Materials Provided :

Laplace Transform Table

Formula Sheet

Examiner(s) : **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 EXAMINATION: APRIL 2018 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. Present your answers neatly and clearly. The assessor reserves the rights to ignore your answers if they are ambiguous.

Question 1

a. State an example of open-loop electrical/electronic system and an example of a closed-loop electrical/electronic system. [2]

b. Illustrate the block diagram of a single-input, single-output (SISO) closed-loop system comprising of a single feedback loop. Clearly label the blocks using generic terms in control system engineering. [3]

c. Figure-Q1(c) shows a non-inverting direct-coupled voltage amplifier utilizing an operational amplifier. Calculate the transfer function of its feedback network, $H(s)$. [3]

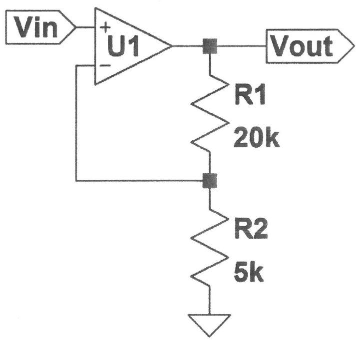

Figure-Q1(c)

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

$$\frac{C(s)}{R(s)} = \frac{6s}{(s+3)(s+9)}$$

$C(s)$ is the system's controlled variable while $R(s)$ is its reference variable. Solve the system's time domain controlled variable, $c(t)$ if the system is subjected to a unit impulse input. [9]

e. The transfer function of a control system is given by,

$$T(s) = \frac{5s + 45}{s^3 + 40s^2 + 389s + 2670}$$

Determine the system's poles and zeros and thus illustrate the system's unit step response, emphasizing on the response nature and it's steady-state value. [8]

Question 2

a. Use block diagram algebra technique to reduce the block diagram in Figure-Q2(a) into a single block. [10]

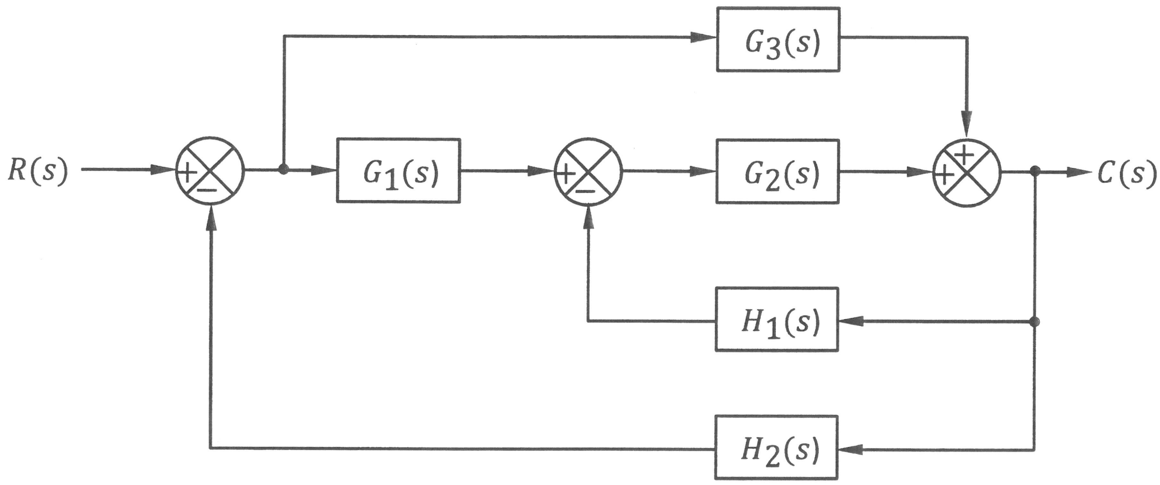

Figure-Q2(a)

b. Illustrate the block diagram in Figure-Q2(a) as a signal flow graph and hence determine its transfer function using Mason's gain formula. [15]

Question 3

a. State two type of inputs which are commonly used to evaluate a system's transient response. [2]

b. Explain the Routh-Hurwitz's stability criterion in the context of the system's characteristic equation. [3]

c. Explain the usage of Final Value Theorem to evaluate the steady-state error of a control system. [7]

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

$$s^7 + s^6 + 2s^5 + 2s^4 - s^3 - s^2 - 2s - 2 = 0$$

Determine all the closed-loop poles of the system. [13]

Question 4

a. Sketch the root locus for a negative unity feedback control system which has an open-loop transfer function, $G(s)$ given by,

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

Give the values for all critical points (if any) such as, break-away point(s), break-in point(s), angles of departure, angles of arrival, imaginary axis intersections, asymptote centroid and angles. [15]

b. Figure-Q4(b) shows the root locus plot of a closed-loop control system.

i. Examine if the system is stable for all values of gain K. [2]

ii. Calculate the system damping factor if two of its closed-loop poles are positioned approximately at $s = -1 \pm j2.5$. [3]

iii. Calculate the system's gain value to position two of its closed-loop poles approximately at $s = -1 \pm j2.5$. [5]

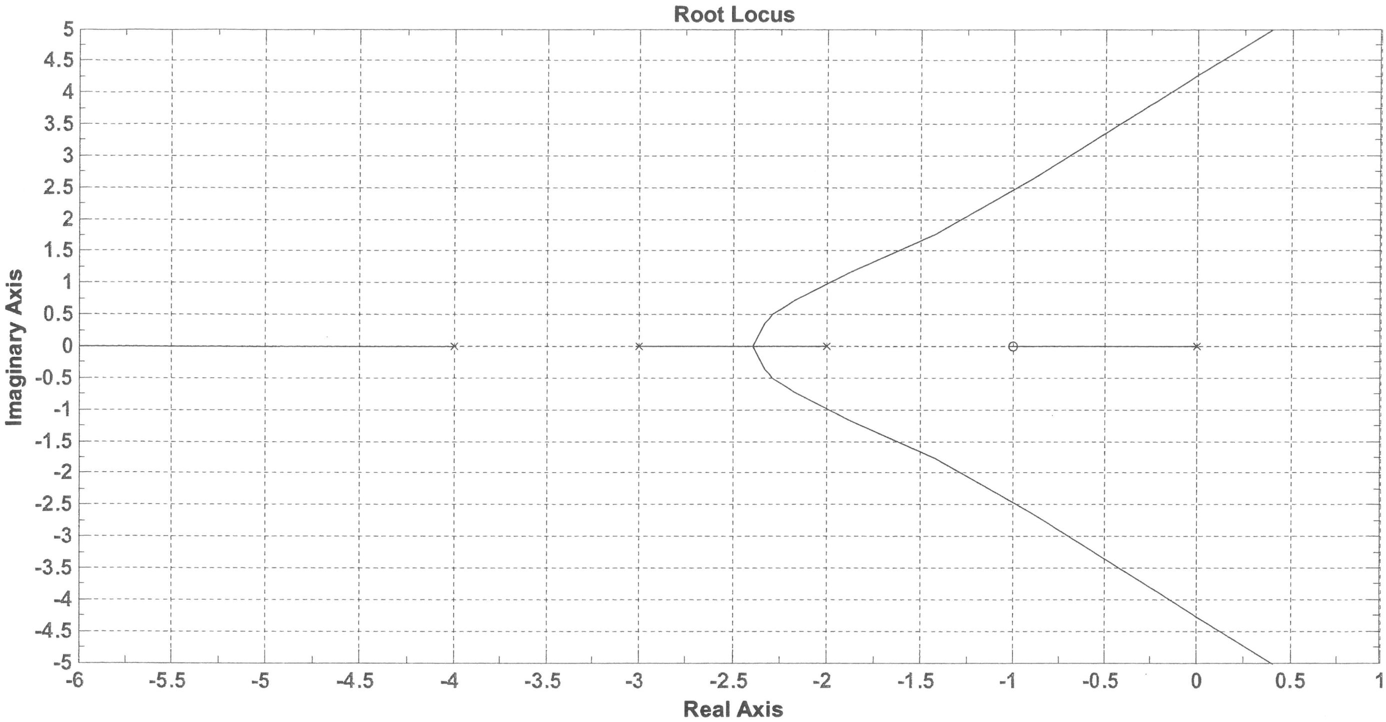

Figure-Q4(b)

Question 5

a. Explain frequency response of a physical system and list three commonly used plots for frequency response analysis. [7]

b. Describe the approach to manually obtain a frequency response plot from a given transfer function. [6]

c. Calculate the steady-state error value of the system in Figure-Q5(c) for an input of $r(t) = 0.1t$. [12]

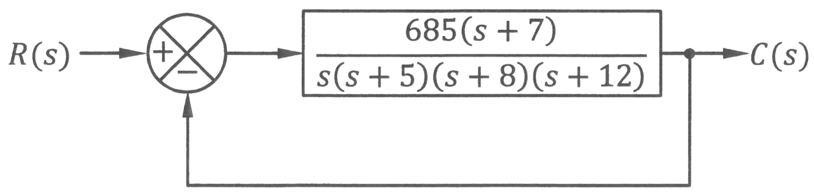

Figure-Q5(c)

Question 6

a. Figure-Q6(a) shows a Nichols chart of a control system. Solve for the system's gain margin and phase margin. Hence, comment on the system's stability. [10]

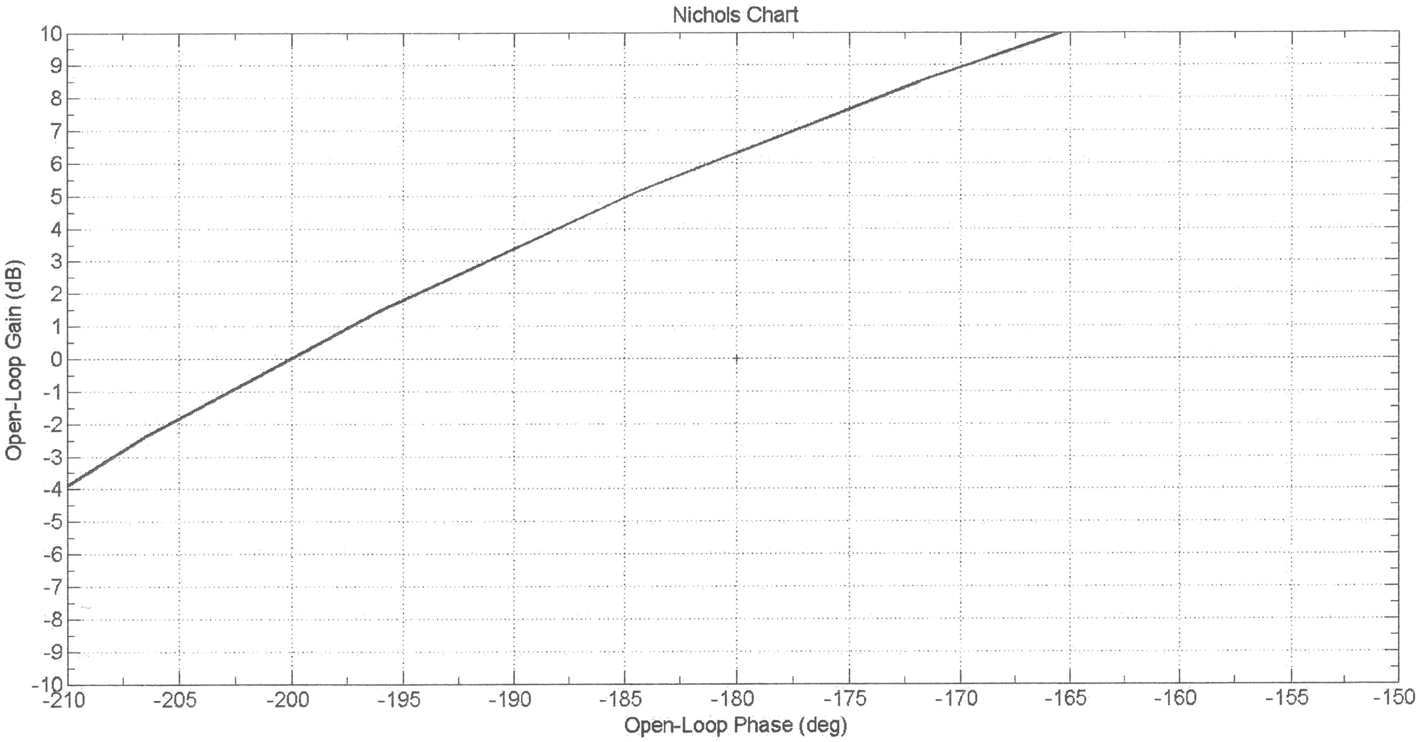

Figure-Q6(a)

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

$$G(s) = \frac{10000}{(s+5)(s+20)(s+50)}$$

Calculate,

i. the gain crossover frequency, ω_{gc} [5]

ii. the phase crossover frequency, ω_{pc} [4]

iii. the gain margin, GM [3]

iv. the phase margin PM. [3]

~ The End ~

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 $t>0$	$F(s)=\mathcal{L}\left[f(t)\right]=\int_0^{\infty} f(t)e^{-st}dt$
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 × 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	$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$

Step Response Performance Criteria of 2nd Order System

$$Overshoot, OS = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}}$$

$$Peak\ Time, t_p = \frac{\pi}{\omega_d}$$

$$Rise\ Time, t_r = \frac{\pi - \cos^{-1}(\zeta)}{\omega_d}$$

$$Settling\ Time, t_s = -\frac{1}{\zeta\omega_n}\ln\left(\frac{P}{100}\right)$$

Formulas for Root Locus Construction

$$Asymptote\ Centroid, \sigma_A = \frac{\Sigma(poles) - \Sigma(zeros)}{n - m}$$

$$Asymptote\ Angle, \phi_A = \frac{2q+1}{n-m} \times 180°, \qquad q = \{0,1,2,\ldots,(n-m-1)\}$$

$$Angle\ of\ Departure, \phi = -\Sigma(other\ GH\ pole\ angles) + \Sigma(GH\ zero\ angle) + 180°$$

$$Angle\ of\ Arrival, \phi' = \Sigma(GH\ pole\ angles) - \Sigma(other\ GH\ zero\ angle) - 180°$$