INTI International College Penang

FINAL
Examination Paper

(COVER PAGE)

Session	:	**August 2019**
Programme	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2108: Modern Control Systems Engineering**
Date of Examination	:	11 December 2019 (Wednesday)
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
Linear Graph Paper (× 2)
Worksheet for Question 5(b)

Examiner(s)	:	**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 EXAMINATION: AUGUST 2019 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. Convert the block diagram in Figure-Q1(a)(i) to the one shown in Figure-Q1(a)(ii) using **ONLY** rule-based block diagram reduction method. Show all conversion steps clearly. [10]

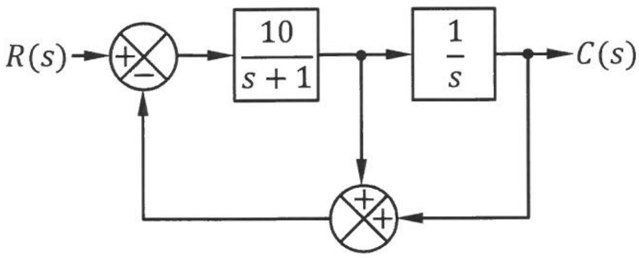

Figure-Q1(a)(i)

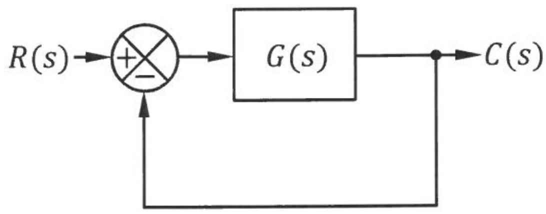

Figure-Q1(a)(ii)

b. Determine the expression of $C(s)/R(s)$ in Figure-Q1(b) using Mason's gain formula. Show all your workings clearly. [15]

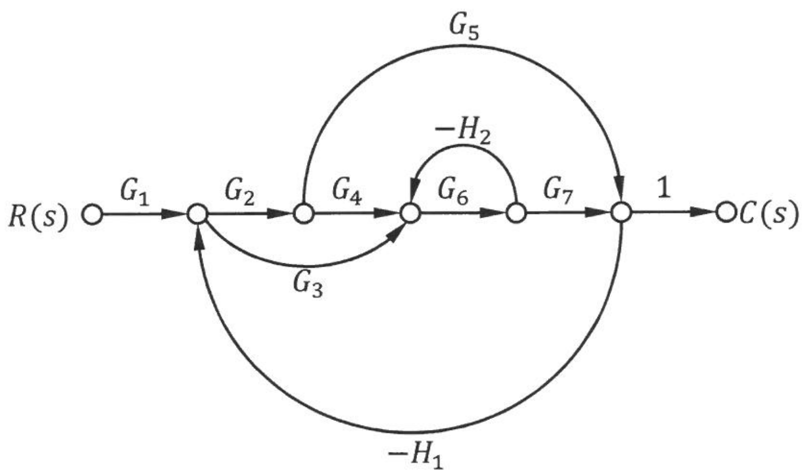

Figure-Q1(b)

Question 2

a. An electronic system is modeled by the equations,

$$0.00125\frac{d^2 i_o(t)}{dt^2} + 19.5\frac{di_o(t)}{dt} + 211250 i_o(t) = 10^6 v_i(t)$$

where, $i_o(t)$ is the instantaneous output current while $v_i(t)$ is the instantaneous input voltage. The initial output current of the system is 0 A.

Calculate the circuit's,

i. undamped natural frequency, ω_n [4]

ii. damping ratio, ζ [2]

iii. damped natural frequency, ω_d [2]

iv. the system's DC gain. [2]

b. When tested with a unit step input, the closed-loop system in Figure-Q2(b) exhibited,

- a maximum overshoot of 25%
- a peak time of 2 seconds

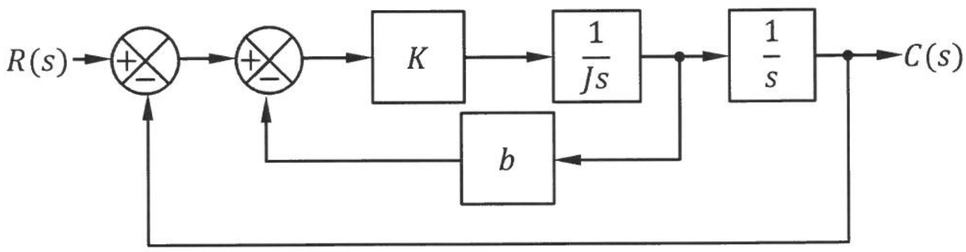

Figure-Q2(b)

i. Determine the value of b of the closed-loop system. Show all workings clearly. [10]

ii. Quantitatively comment on the significance of value b on the system's steady-state error when the system is responding to a unit ramp input. [5]

Question 3

a. Figure-Q3(a) shows a root locus plot of a negative unity feedback system, which have a characteristic equation given by,

$$1 + KG(s) = 0$$

K is the system's DC gain and is always positive, while $G(s)$ is the system's feed-forward path transfer function.

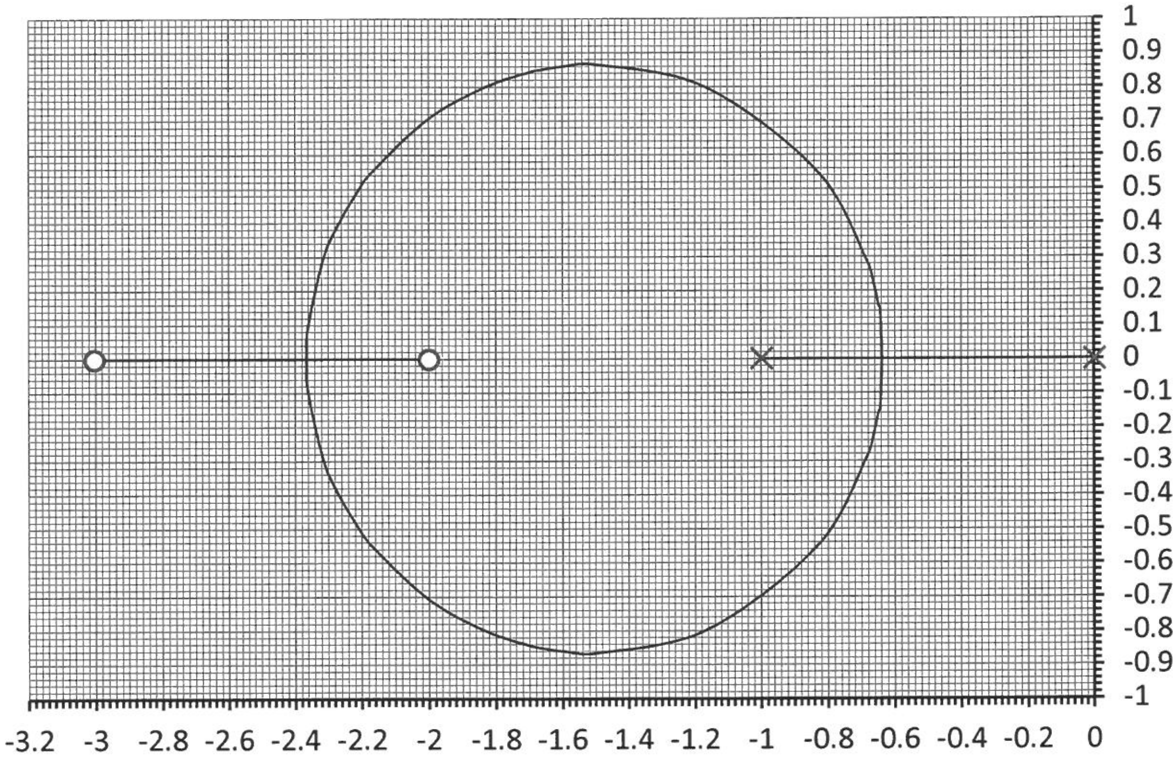

Figure-Q3(a)

i. Determine the expression for $G(s)$. [2]

ii. Determine two values of K that cause the system to exhibit critically damped response. [6]

iii. Determine the range of K such that the system exhibits overdamped response with relatively short transient period. [2]

b. A negative unity feedback system has a characteristic equation given as,

$$1 + \frac{K}{(s-1)(s^2+4s+7)} = 0$$

i. Use phase criterion to examine if the system's root locus plot comprises of only straight line loci. [7]

ii. Plot the root locus for the system on the given linear graph paper. [8]

Question 4

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

$$G(s) = \frac{1}{s(1 + 0.6s)^2}$$

Calculate the system's,

i. gain margin in dB [5]

ii. phase margin in degree. [5]

b. Figure-Q4(b) shows the true Bode magnitude plot of the open-loop transfer function, $G(s)$ of a system with negative unity feedback.

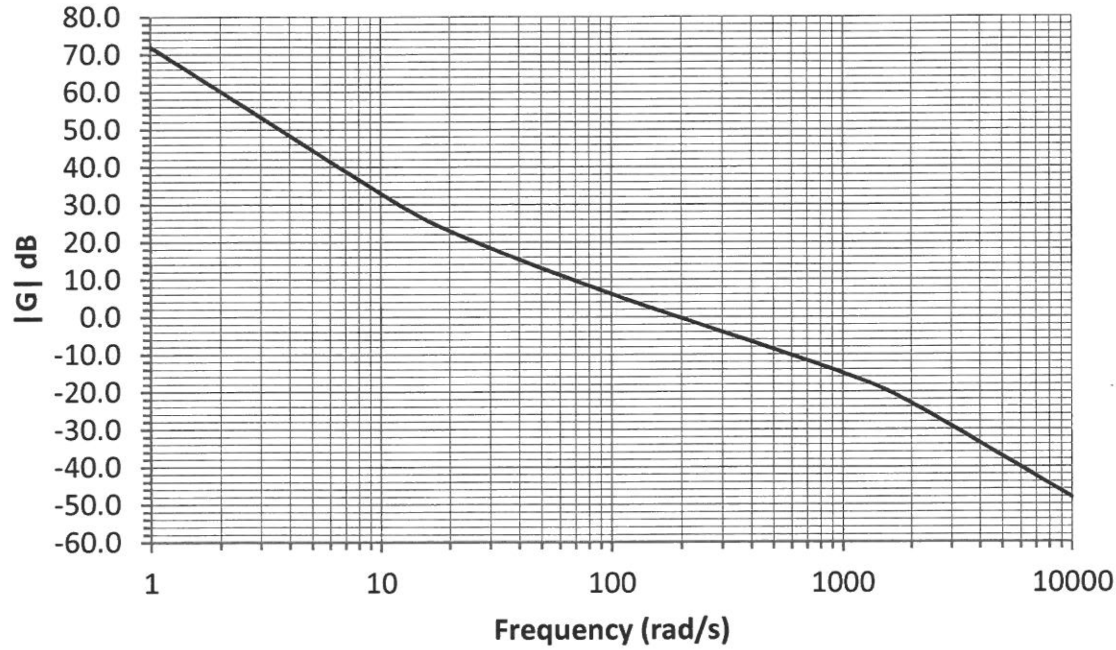

Figure-Q4(b)

i. Utilize the initial slope of the Bode magnitude plot to examine the system type number. [3]

ii. Approximate the asymptotic lines on the Bode magnitude plot to examine the expression for $G(s)$. [6]

iii. Examine the steady-state error of the system responding to an accelerated input of $r(t) = 10t^2$. [6]

Question 5

a. The op-amp in Figure-Q5(a) has a voltage transfer function, A_v, such that $V_{out}(s) = A_v[V^+(s) - V^-(s)]$ and there is no current flowing into its two inputs.

Complete the block diagram given in "**Worksheet for Question 5(a)**". [8]

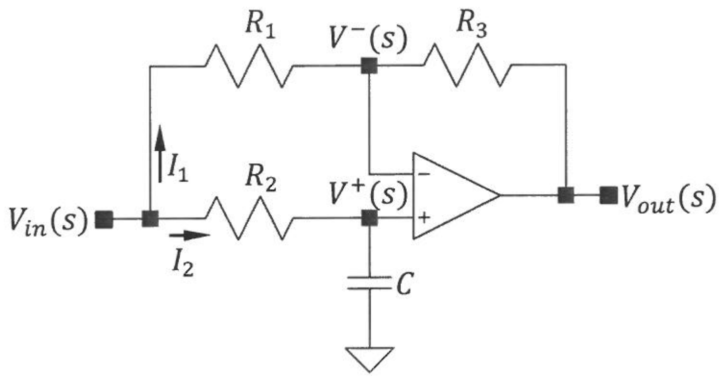

Figure-Q5(a)

b. The system in Figure-Q5(b) is design to eliminate steady-state error when the system is responding to a ramp input, by calibrating the value of k. Examine the needed value of k such that a ramp input of $R(s) = 1/s^2$ does not produce any steady-state error. [8]

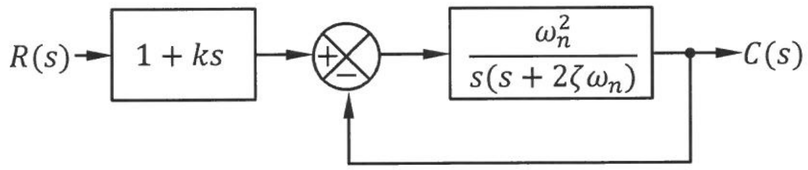

Figure-Q5(b)

c. The characteristic equation of a control system is,

$$s^5 + s^4 + 7s^3 + 2s^2 + 10s + 14 = 0$$

Determine if the system is stable. [4]

d. The system in Figure-Q5(d) has zero steady-state error, i.e. when switch, S is closed, $v_o(t) = v_i(t) = V_{DC}$. Determine the system's steady-state error if an **EXTRA** load resistor, R_{load} is connected directly across capacitor C. [5]

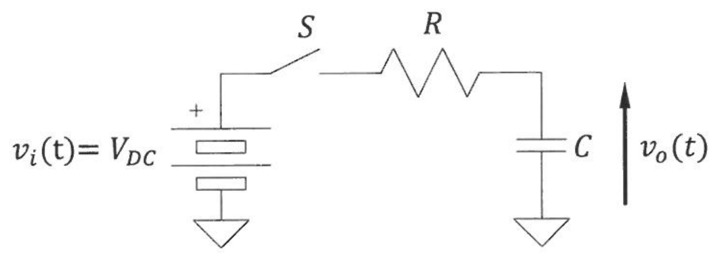

Figure-Q5(d)

Question 6

a. The transfer function of a servo motor system with tachometer feedback is given by,

$$\frac{C(s)}{R(s)} = \frac{20K}{s^3 + 5s^2 + (4 + 20Kb)s + 20K}$$

where, $C(s)$ = system's output

$R(s)$ = system's input

K = proportional gain control

b = tachometer feedback factor (always positive)

Plot the graph of b against K on the given linear graph paper and shade the region where the values of b and K ensure system absolute stability. [12]

b. The open-loop transfer function of a control system with unity negative feedback is,

$$KG(s) = \frac{K}{s(0.08s + 1)(0.36s + 1)}$$

i. By using frequency domain analysis, examine the value of K which will make this system marginally stable. [8]

ii. Verify the answer obtained in part (b)(i) by using another control system theory. [5]

~ The End ~