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FINAL
Examination Paper

(COVER PAGE)

Session	:	JANUARY 2012
Programmes	:	Diploma in Electrical and Electronic Engineering (DEE/I)
Course	:	**EEE2108 : MODERN CONTROL SYSTEMS ENGINEERING**
Date of Examination	:	8 March 2012
Time	:	11a.m. – 1p.m. Reading Time : Nil
Duration	:	2 Hours

Special Instructions :

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)

Examiner(s) : **Chan Tse Wei**

Moderator : Johnny Wong

This paper consists of 6 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 : JANUARY 2012 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. Use block diagram reduction method to show that the overall transfer function of the system in Figure-Q1 is given by,

$$\frac{C}{R}=\frac{G_1G_2G_3G_4}{(1+G_1G_2H_1)(1+G_3G_4H_2)+G_2G_3H_3}$$ [10]

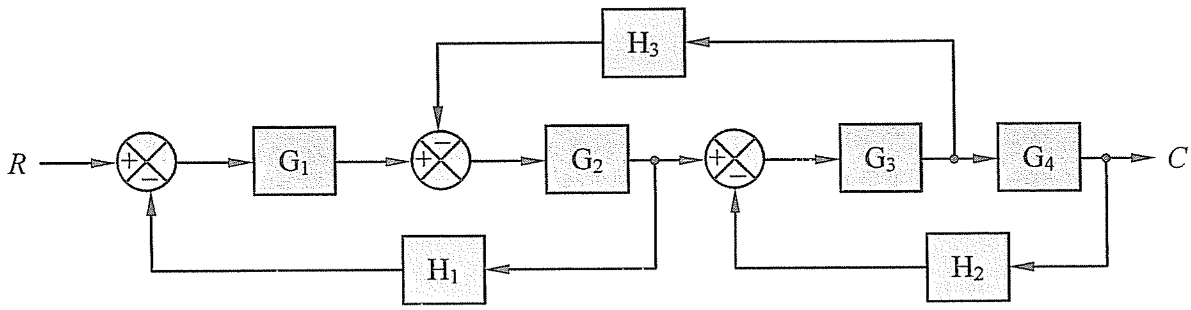

Figure-Q1

b. i. Convert the system shown in Figure-Q1 to a signal flow graph. [5]

ii. Use Mason's gain formula to verify the transfer function shown in part (a). [10]

Question 2

a. Figure-Q2(a) shows the locations of the closed-loop poles of a system on an s-plane when its gain K is adjusted to 100.

i. Briefly describe the nature of response of the system. [2]

ii. Determine the undamped natural frequency of the system. [3]

iii. Determine the damping factor of the system. [3]

iv. Determine the settling time of the system. Assume 2% accuracy is to be observed. [3]

v. Determine the rise time of the system. [3]

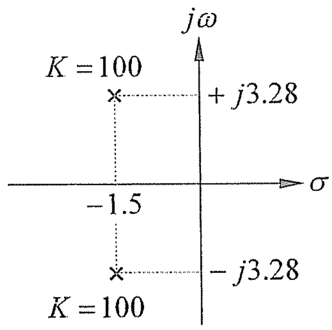

Figure-Q2(a)

b. The block diagram in Figure-Q2(b) represents the system described in part (a).

i. Derive the possible transfer function for block $G(s)$ expressed in polynomial form. [5]

ii. Determine the value of gain K, so that repeating poles exist in the system and it exhibits critically damped response when applied with an impulse input. State the location of the repeating poles on the s-plane. [6]

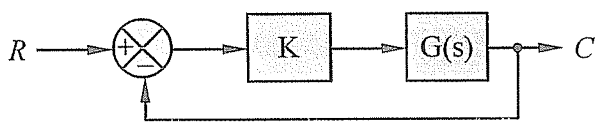

Figure-Q2(b)

Question 3

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

$$G(s) = \frac{\mu}{(1 + 10\tau s)^3}$$

Where τ is the time constant and μ is the dimensionless gain.

Show that the root locus branches are coincident with the asymptotes. [10]

b. Find a value of μ in part (a) and all the three associated closed-loop pole locations for which the system exhibits an underdamped response with damping ratio ζ = 0.5. [15]

Question 4

a. A robotic arm and camera is designed to pick fruit as shown in Figure-Q4(a)(i). The camera is used to closed the feedback loop to a microcomputer, which controls the arm. The system is represented by the block diagram in Figure-Q4(a)(ii).

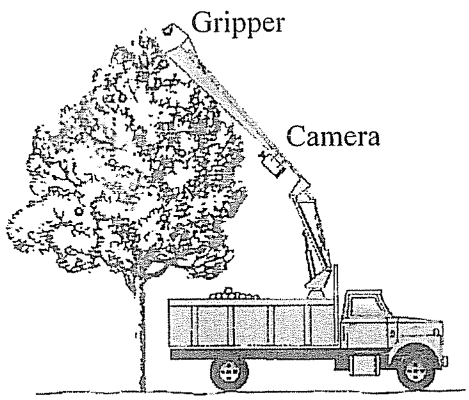

Figure-Q4(a)(i)

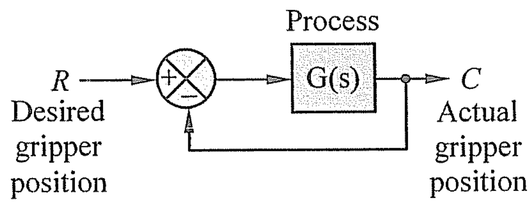

Figure-Q4(a)(ii)

i. If the transfer function of the process is $G(s)=\frac{K}{(s+3)^2}$, calculate the expected steady-state error of the gripper, as a function of K, for a step input $R(s)=\frac{A}{s}$. [6]

ii. State a possible disturbance for this system. [2]

b. The linear model of a phase detector system can be represented by Figure-Q4(b). The steady-state error of the system for a ramp change in the phase signal is to be minimized.

i. Determine the limiting value of the gain K_aK, in order to maintain a stable system. [8]

ii. A steady-state error equal to 1° is acceptable for a ramp signal of 100 rad/s. For that value of gain K_aK, determine the location of the roots of the system. [9]

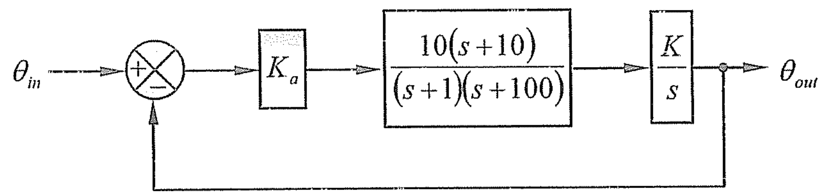

Figure-Q4(b)

Question 5

a. A robotic arm has a joint-control loop transfer function given by $G_C(s)G(s) = \dfrac{300(s+100)}{s(s+10)(s+40)}$

i. Determine the frequency value when $\angle G_C(j\omega)G(j\omega) = -180°$. [8]

ii. Find $|G_C(j\omega)G(j\omega)|$ at the frequency obtained in part (a)(i). Express your answer in dB. [5]

iii. Determine the gain margin of the system. [3]

b. The Bode magnitude plot of a transfer function $G(s)$ is shown in Figure-Q5. If $G(s) = \dfrac{K(1+0.5s)(1+as)}{s\left(1+\frac{s}{8}\right)(1+bs)\left(1+\frac{s}{36}\right)}$, determine K, a and b from the plot. [9]

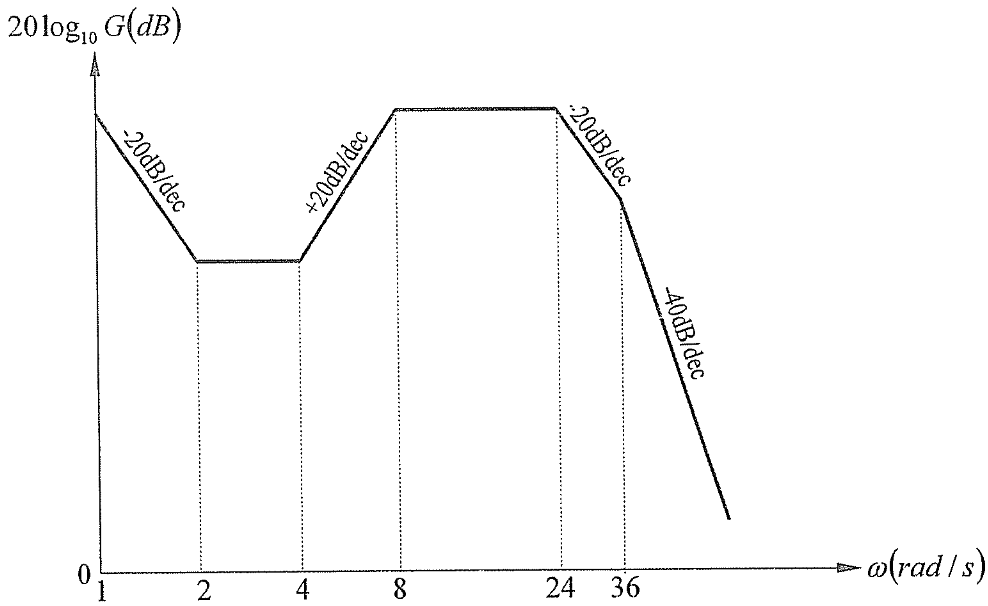

Figure-Q5

Question 6

A feedback control system has an open-loop transfer function given by,

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

Design a suitable compensator for the system such that the response meets the following performance specifications:

- Steady-state error for a ramp input $r(t) = At$ should be less than 5%
- Phase margin should be at least 40° [25]

– 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 $t=\text{kT}$	$\delta(t-kT)$	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	$\dfrac{n!}{s^{n+1}}$
18.	Exponential decay	e^{-at}	$\dfrac{1}{s+a}$
19.	Exponential growth	$1-e^{-at}$	$\dfrac{a}{s(s+a)}$
20.	Exponential × t	te^{-at}	$\dfrac{1}{(s+a)^2}$
21.	Exponential × t^n	$t^n e^{-at}$	$\dfrac{n!}{(s+a)^{n+1}}$
22.	Difference of exponentials	$e^{-at} - e^{-bt}$	$\dfrac{b-a}{(s+a)(s+b)}$
23.	Difference of exponentials	$\dfrac{1}{b-a}\left(be^{-bt} - ae^{-at}\right)$	$\dfrac{s}{(s+a)(s+b)}$
24.	Sine	$\sin \omega t$	$\dfrac{\omega}{s^2+\omega^2}$
25.	Phase-advanced sine	$\sin(\omega t + \phi)$	$\dfrac{\omega\cos\phi + s\sin\phi}{s^2+\omega^2}$
26.	Sine × t	$t\sin\omega t$	$\dfrac{2\omega s}{\left(s^2+\omega^2\right)^2}$
27.	Exponentially decaying sine	$e^{-at}\sin\omega t$	$\dfrac{\omega}{(s+a)^2+\omega^2}$
28.	Cosine	$\cos\omega t$	$\dfrac{s}{s^2+\omega^2}$
29.	Phase-advanced cosine	$\cos(\omega t + \phi)$	$\dfrac{s\cos\phi - \omega\sin\phi}{s^2+\omega^2}$
30.	Cosine × t	$t\cos\omega t$	$\dfrac{s^2-\omega^2}{\left(s^2+\omega^2\right)^2}$
31.	Exponentially decaying cosine	$e^{-at}\cos\omega t$	$\dfrac{s+a}{(s+a)^2+\omega^2}$