UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2011/2012

COURSE NAME	: CONTROL SYSTEMS
COURSE CODE	: BEE 3143/BEX 31603
PROGRAMME	: BEE
EXAMINATION DATE	: JUNE 2012
DURATION	: 2 ½ HOURS
INSTRUCTION	: ANSWER **FOUR** (4) QUESTIONS ONLY

THIS PAPER CONSISTS OF **SEVEN** (7) PAGES

Q1 (a) What components are required to convert an open loop system into a closed loop system?

(2 marks)

(b) Draw the general block diagram of a closed loop control system.

(3 marks)

(c) Figure Q1(c) shows a schematic diagram of an armature-controlled direct current motor. This motor is assumed to have a constant magnetic field. Explain clearly with the aid of a suitable schematic diagram, how the motor angular displacement $\theta_m(t)$, can be controlled in a closed-loop manner.

(20 marks)

Q2 By using the general rules for sketching root locus, sketch the root locus for a control system with the open loop transfer function given by:

$$G(s)H(s) = \frac{K}{s^2 + 10s + 9}$$

(16 marks)

From the root locus

(a) Determine the range of K so that the system response will be over-damped.

(3 marks)

(b) Obtain the value of K so that the response is critically damped.

(3 marks)

(c) Determine the range of K so that the response is under-damped

(3 marks)

Q3 Figure Q3 shows a block diagram for a control system.

(a) Determine the damping ratio ζ and the undamped natural frequency ω_n and explain qualitatively the nature of response that can be expected be obtained from this system.

(10 marks)

(b) Derive and sketch the system response c(t) for a unit step input.

(15 marks)

Q4 (a) Design a closed-loop speed control regulator that will produce a regulation 0.1% when the no load speed is 1000 rpm and the load torque is 10 Nm. A tachogenerator is available as a speed transducer and this has a sensitivity of 10 V per 1000 rpm. The direct current motor that is used in the regulator has the following properties:

(i) On no load, its speed increase linearly with input voltage with a sensitivity at 10 rpm per input volt; and

(ii) Its speed falls linearly on a torque load with sensitivity of 10 rpm per Nm of load torque.

(18 marks)

(b) Calculate the percentage regulation for the same values of no load speed and load torque if the speed control regulator is on open loop. Give your comment on the value obtained.

(7 marks)

Q5 (a) Figure Q5(a) shows a phase lead compensator circuit. Show that the transfer function of this circuit is given by:

$$\frac{E_o(s)}{E_i(s)} = \frac{R_2}{R_1 + R_2}\left(\frac{1 + R_1Cs}{1 + \frac{R_2}{R_1 + R_2}R_1Cs}\right)$$

(5 marks)

(b) Design a phase lead compensator by giving the components' values of the compensator circuit used, for a control system with a unity feedback such that the dominant closed loop poles have the damping ratio ζ=0.5 and the undamped natural frequency ω_n=3 rad/s. The open loop transfer function of the control system is given by:

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

(20 marks)

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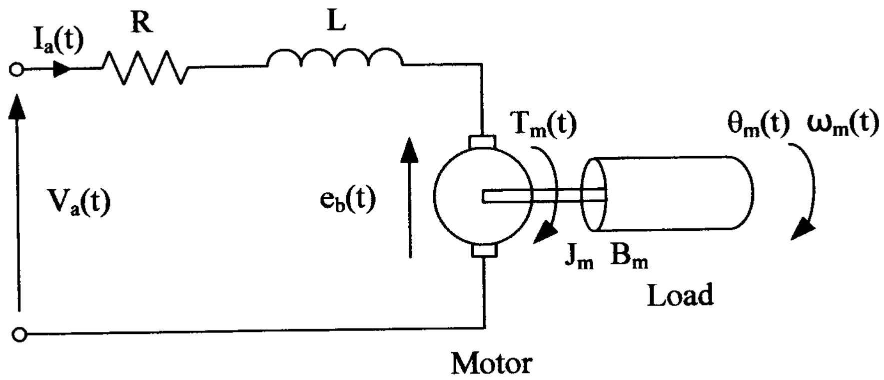

Figure Q1(c)

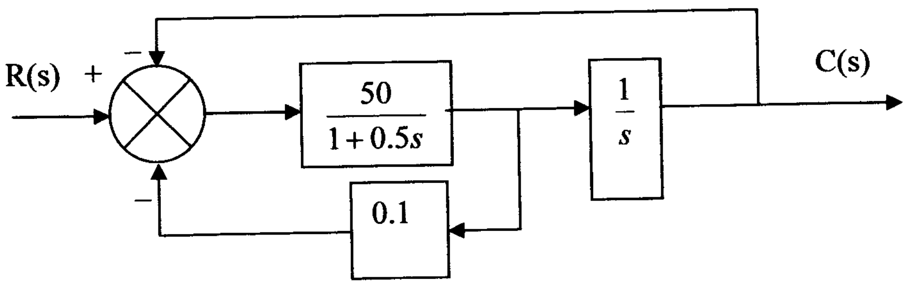

Figure Q3

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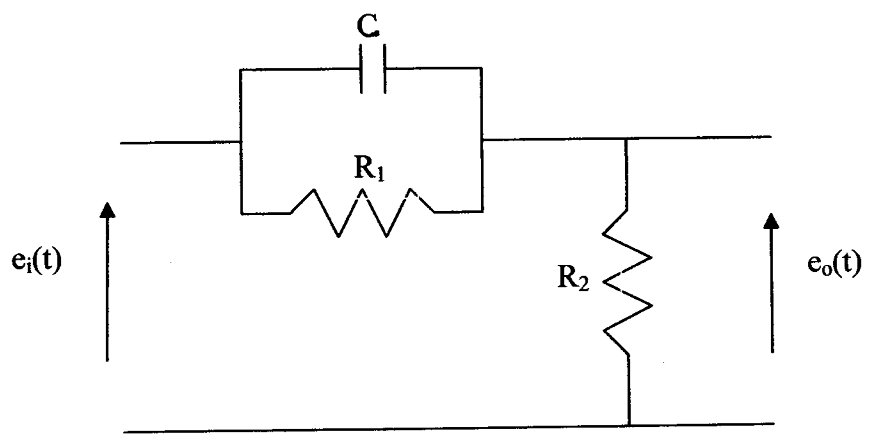

Figure Q5(a)

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Table 1: Table of z Transform

	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
1.	—	—	Kronecker delta $\delta_0(k)$ 1, $k = 0$ 0, $k \neq 0$	1
2.	—	—	$\delta_0(n-k)$ 1, $n = k$ 0, $n \neq k$	z^{-k}
3.	$\frac{1}{s}$	$1(t)$	$1(k)$	$\frac{1}{1-z^{-1}}$
4.	$\frac{1}{s+a}$	e^{-at}	e^{-akT}	$\frac{1}{1-e^{-aT}z^{-1}}$
5.	$\frac{1}{s^2}$	t	kT	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
6.	$\frac{2}{s^3}$	t^2	$(kT)^2$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
7.	$\frac{6}{s^4}$	t^3	$(kT)^3$	$\frac{T^3z^{-1}(1+4z^{-1}+z^{-2})}{(1-z^{-1})^4}$
8.	$\frac{a}{s(s+a)}$	$1-e^{-at}$	$1-e^{-akT}$	$\frac{(1-e^{-aT})z^{-1}}{(1-z^{-1})(1-e^{-aT}z^{-1})}$
9.	$\frac{b-a}{(s+a)(s+b)}$	$e^{-at}-e^{-bt}$	$e^{-akT}-e^{-bkT}$	$\frac{(e^{-aT}-e^{-bT})z^{-1}}{(1-e^{-aT}z^{-1})(1-e^{-bT}z^{-1})}$
10.	$\frac{1}{(s+a)^2}$	te^{-at}	kTe^{-akT}	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$
11.	$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$	$(1-akT)e^{-akT}$	$\frac{1-(1+aT)e^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

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	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
12.	$\frac{2}{(s+a)^3}$	$t^2 e^{-at}$	$(kT)^2 e^{-akT}$	$\frac{T^2 e^{-aT}(1+e^{-aT}z^{-1})z^{-1}}{(1-e^{-aT}z^{-1})^3}$
13.	$\frac{a^2}{s^2(s+a)}$	$at - 1 + e^{-at}$	$akT - 1 + e^{-akT}$	$\frac{[(aT-1+e^{-aT})+(1-e^{-aT}-aTe^{-aT})z^{-1}]z^{-1}}{(1-z^{-1})^2(1-e^{-aT}z^{-1})}$
14.	$\frac{\omega}{s^2+\omega^2}$	$\sin \omega t$	$\sin \omega kT$	$\frac{z^{-1}\sin \omega T}{1-2z^{-1}\cos \omega T + z^{-2}}$
15.	$\frac{s}{s^2+\omega^2}$	$\cos \omega t$	$\cos \omega kT$	$\frac{1-z^{-1}\cos \omega T}{1-2z^{-1}\cos \omega T + z^{-2}}$
16.	$\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin \omega t$	$e^{-akT}\sin \omega kT$	$\frac{e^{-aT}z^{-1}\sin \omega T}{1-2e^{-aT}z^{-1}\cos \omega T + e^{-2aT}z^{-2}}$
17.	$\frac{s+a}{(s+a)^2+\omega^2}$	$e^{-at}\cos \omega t$	$e^{-akT}\cos \omega kT$	$\frac{1-e^{-aT}z^{-1}\cos \omega T}{1-2e^{-aT}z^{-1}\cos \omega T + e^{-2aT}z^{-2}}$
18.			a^k	$\frac{1}{1-az^{-1}}$
19.			a^{k-1} $k = 1, 2, 3, \ldots$	$\frac{z^{-1}}{1-az^{-1}}$
20.			ka^{k-1}	$\frac{z^{-1}}{(1-az^{-1})^2}$
21.			$k^2 a^{k-1}$	$\frac{z^{-1}(1+az^{-1})}{(1-az^{-1})^3}$
22.			$k^3 a^{k-1}$	$\frac{z^{-1}(1+4az^{-1}+a^2z^{-2})}{(1-az^{-1})^4}$
23.			$k^4 a^{k-1}$	$\frac{z^{-1}(1+11az^{-1}+11a^2z^{-2}+a^3z^{-3})}{(1-az^{-1})^5}$
24.			$a^k \cos k\pi$	$\frac{1}{1+az^{-1}}$
25.			$\frac{k(k-1)}{2!}$	$\frac{z^{-2}}{(1-z^{-1})^3}$
26.		$\frac{k(k-1)\cdots(k-m+2)}{(m-1)!}$		$\frac{z^{-m+1}}{(1-z^{-1})^m}$
27.			$\frac{k(k-1)}{2!}a^{k-2}$	$\frac{z^{-2}}{(1-az^{-1})^3}$
28.	$\frac{k(k-1)\cdots(k-m+2)}{(m-1)!}a^{k-m+1}$			$\frac{z^{-m+1}}{(1-az^{-1})^m}$