UNIVERSITI TUN HUSSEIN ONN MALAYSIA

PEPERIKSAAN AKHIR
SEMESTER II
SESI 2008/2009

NAMA MATA PELAJARAN	:	SISTEM KAWALAN
KOD MATA PELAJARAN	:	BEE 3143
KURSUS	:	3 BEE
TARIKH PEPERIKSAAN	:	APRIL 2009
JANGKA MASA	:	3 JAM
ARAHAN	:	JAWAB EMPAT (4) SOALAN SAHAJA DARIPADA ENAM (6) SOALAN

KERTAS SOALAN INI MENGANDUNGI DUA BELAS (12) MUKA SURAT

Q1 An electric train uses a pantograph to draw power from electrical line. A feedback control system is used in order to avoid loss of contact of the pantograph to the power line. The components of the pantograph system are shown in Figure Q1. A motor applies upward force to the pantograph frame. A force sensor measures the force applied by the pantograph to the power line and produces a voltage proportional to the measured force. The desired force is set by the train engineer through a potentiometer as an input transducer which produces an input voltage. A PID controller is used to control the system.

(a) Draw a functional block diagram showing the feedback control system of the pantograph and identify all signals in the block diagram.

(10 marks)

(b) The model of the pantograph system is shown in Figure Q1(b). The parameters of the system are:

(i)	mass of pantograph frame, m_f:	17.2 kg
(ii)	mass of pantograph head, m_h:	9.1 kg
(iii)	spring constant of power line, k_l:	1.535×10^6 N/m
(iv)	spring constant of pantograph shoe , k_s:	82.3×10^3 N/m
(v)	spring constant of pantograph head, k_h:	7×10^3 N/m
(vi)	damping coefficient of pantograph head, b_h:	130 N-s/m
(vii)	damping coefficient of pantograph frame, b_f:	30 N-s/m

Calculate the transfer function

$$G_p(s) = \frac{Y_1(s)}{F(s)}.$$

(15 marks)

Q2 (a) The location of poles in the s-plane indicates the resulting transient response for the system. Give 3 condition of poles location that can determine whether the system is stable, unstable or marginally stable.

(2 marks)

(b) A unity feedback system has an open loop transfer function as follows:

$$G(s) = \frac{K(s+2)}{s(s+5)(s^2+2s+5)}.$$

Determine:

(i) The range of value of K for stable system.

(9 marks)

(ii) The value of K that will result in the system being marginally stable.

(2 marks)

(iii) The location of the roots of the characteristic equation for the value of K found in Q2(b)(ii).

(5 marks)

(c) The unity feedback of the system with the following forward transfer function:

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

is to be designed to meet the following specifications:

(i) The steady state error for unit step input is 0.1.
(ii) The damping ratio for the system is 0.5.
(iii) The natural frequency is $\sqrt{10}$ rad/s.

Find the values of K, α, and β in order to meet the specifications using second order prototype approximation.

(7 marks)

Q3 (a) A linear feedback control system has a block diagram shown in Figure Q3(a). Using block diagram reduction rules, obtain the closed-loop transfer function $Y(s)/R(s)$.

(11 marks)

(b) Given the transfer function:

$$G(s) = \frac{Y(s)}{R(s)} = \frac{1}{s^2+3s+2}.$$

Find the respond $y(t)$ to the input $r(t) = 5t\ u(t)$.

(7 marks)

(c) Obtain the inverse Laplace transform of $F(s)$, where

$$F(s) = \frac{0.4s+1}{s(s^2+s+1)}.$$

(7 marks)

Q4 (a) A simplified block diagram for a space telescope is shown in Figure Q4(a)(i). The output response to $r(t) = 4u(t)$ input when $K = 2$ is shown in Figure Q4(a)(ii). Given that $T_p = 2$ seconds.

(i) Based on Figure Q4(a)(i) and Figure Q4(a)(ii) generate the closed loop transfer function of the system.

(9.5 marks)

(ii) Calculate the rise time, T_r.

(1 marks)

(iii) Calculate the settling time, T_s.

(1 marks)

(iv) If the system is designed to have a 10% overshoot from the final value, $c(\infty)$, calculate the new damping ratio, ζ.

(3.5 marks)

(b) Given the system shown in Figure Q4(b)(i).

(i) Determine the system type.

(3 marks)

(ii) Calculate the steady-sate error for an input of $4u(t)$.

(2 marks)

(iii) Calculate steady-sate error for an input of $4tu(t)$.

(2 marks)

(iv) Calculate steady-sate error for an input of $4t2u(t)$.

(2 marks)

(v) Based on the results of Q4(b)(ii), Q4(b)(iii), and Q4(b)(iv), select the suitable input to produce zero steady-state error for the system.

(1 marks)

Q5 (a) Based on the characteristic equation of the forward path of a system, the starting points (poles) and ending points (zeros) of the root locus of the system are plotted on the *s*-plane as shown in Figure Q5(a). Calculate the angle of departure from the complex poles.

(3 marks)

(b) Consider the simplified form of the transfer function for position servomechanism used in an antenna tracking system as shown in Figure Q5(b). By using root locus technique:

(i) Construct its root locus.

(15.5 marks)

(ii) Calculate the value of K so that the damping ratio is $\zeta = 0.5$, and give the value of all closed loop poles for the value of K.

(6.5 marks)

Q6 Given a unity feedback system with open-loop transfer function as follows:

$$G(s) = \frac{1}{(s+1)(s+3)}$$

A lead compensator

$$G_c(s) = K_c \frac{s+z_c}{s+p_c},$$

where K_c, z_c, p_c are the gain, zero, and pole of the compensator respectively, is designed to yield the following specifications:

(i) settling time: 1.333 seconds (2% criterion)
(ii) percent overshoot: 4.290 %

(a) The root locus of the system is given in Figure Q6(a). Redraw the root locus in a graph paper and obtain the desired poles location if the lead compensator has been added.

(7 marks)

(b) Obtain the angle which will be contributed by the compensator to the system.

(4 marks)

(c) Obtain the pole and zero of the compensator using bisect angle method.

(7 marks)

(d) Obtain the gain of the compensator and hence give the transfer function of the compensator.

(4 marks)

(e) The Phase-Lead compensator circuit with an amplifier is shown in Q6(e). Its transfer function related to the values of its electronic components is

$$G_c(s) = K_c\left(\frac{s+\frac{1}{T}}{s+\frac{1}{\alpha T}}\right)$$

where $T = R_1C$ and $\frac{R_2}{R_1+R_2} = \alpha$.

Calculate the values of R_1 and R_2, if $C=1\mu F$.

(3 marks)

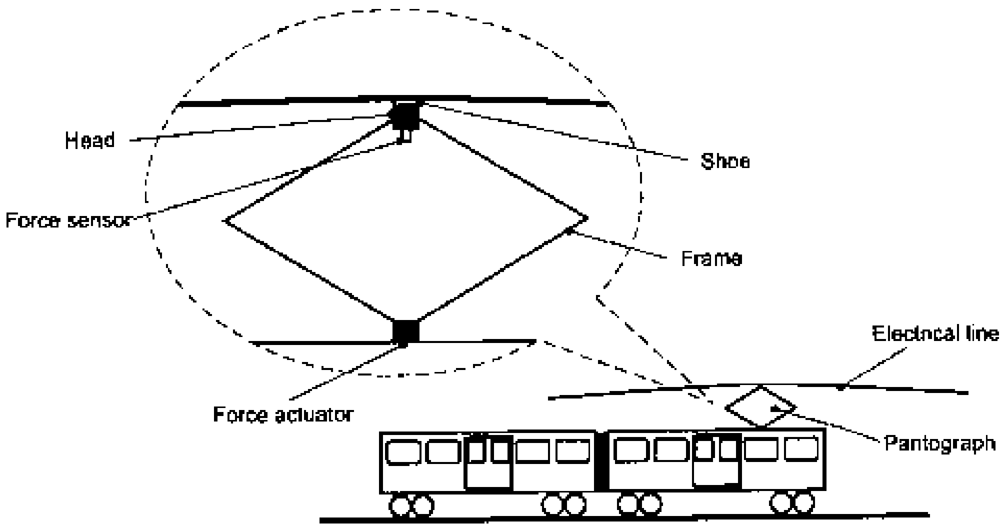

FIGURE Q1

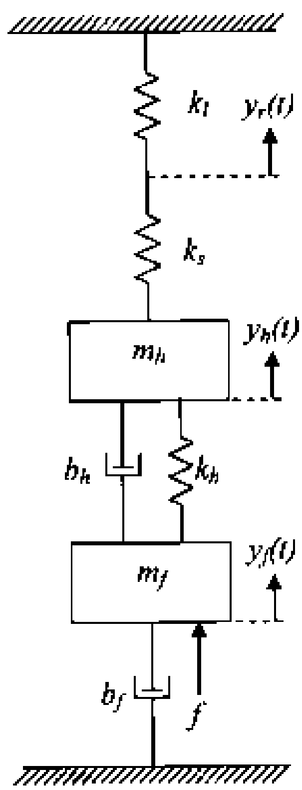

FIGURE Q1(b)

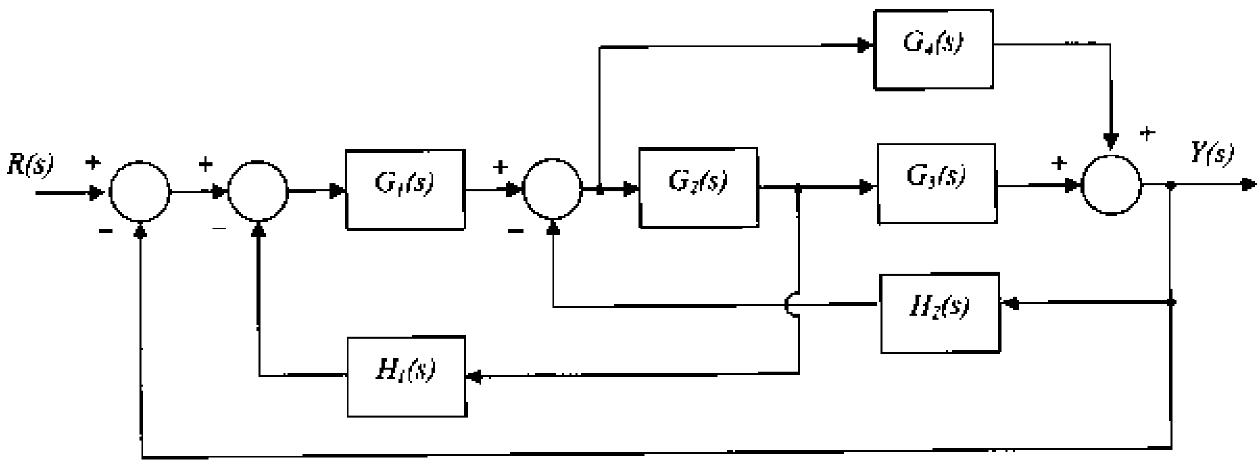

Figure Q3(a)

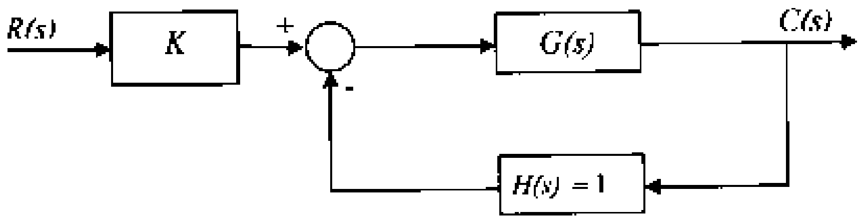

FIGURE Q4(a)(i)

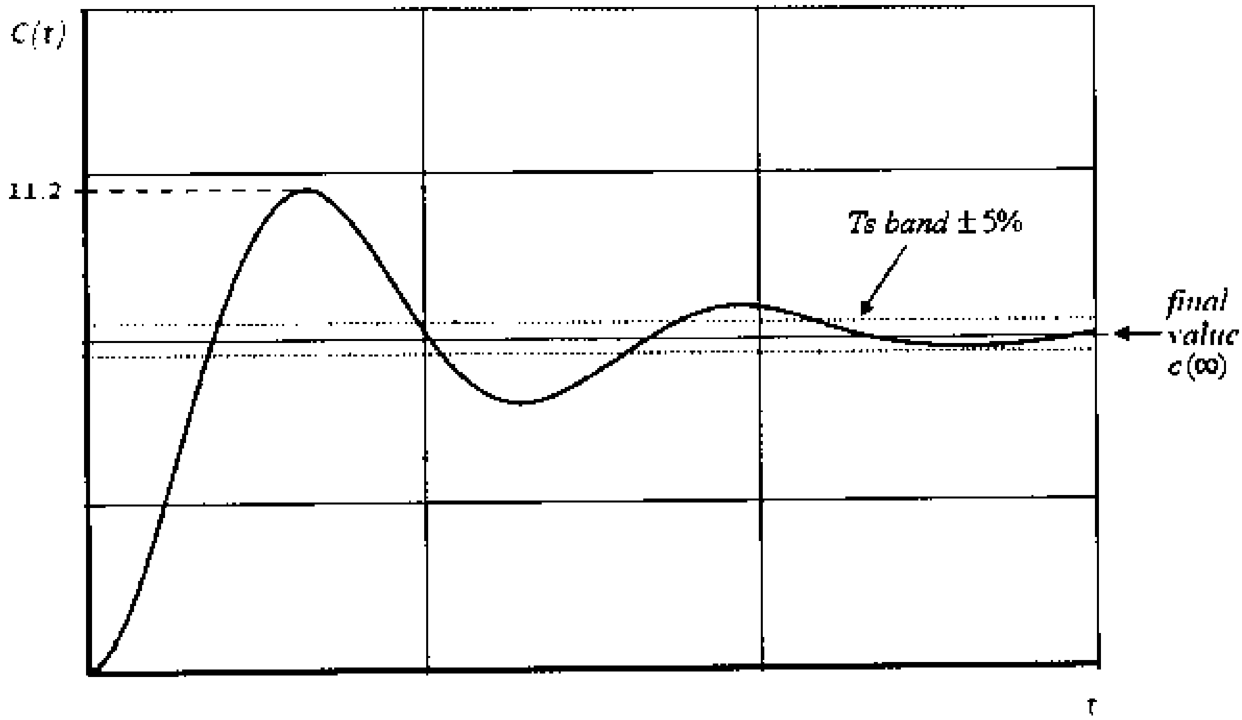

FIGURE Q4(a)(ii)

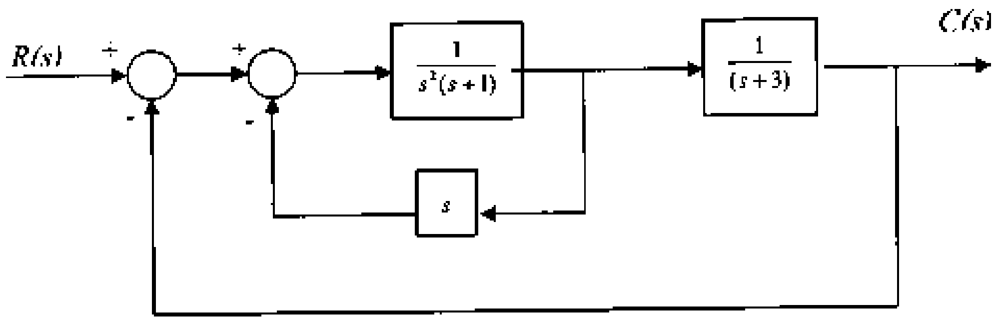

FIGURE Q4(b)(i)

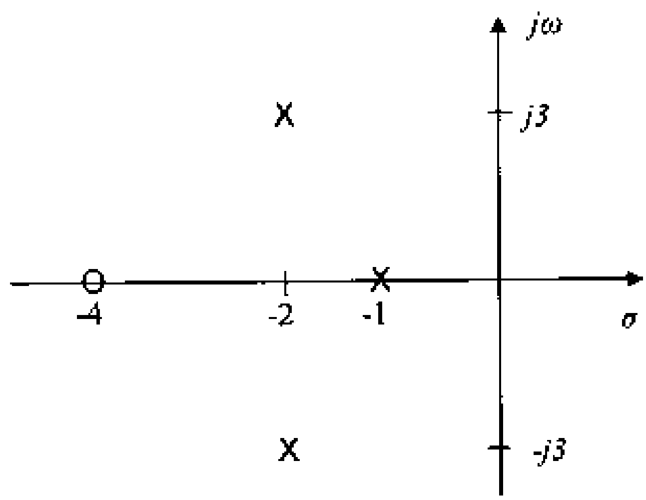

FIGURE Q5(a)

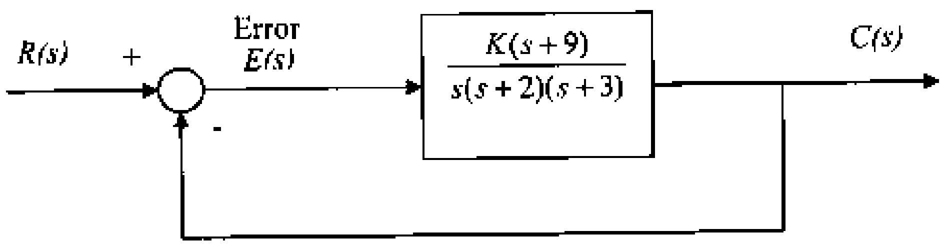

FIGURE Q5(b)

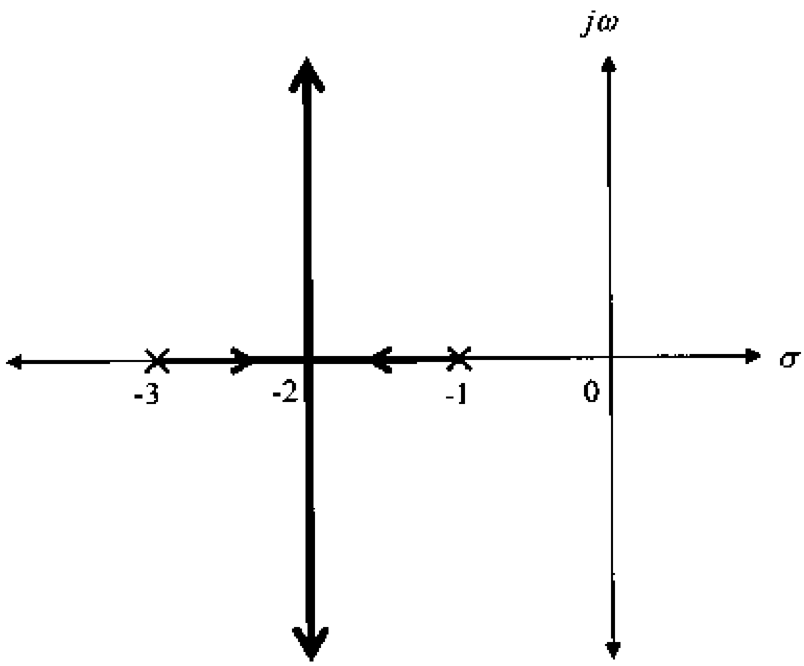

FIGURE Q6(a)

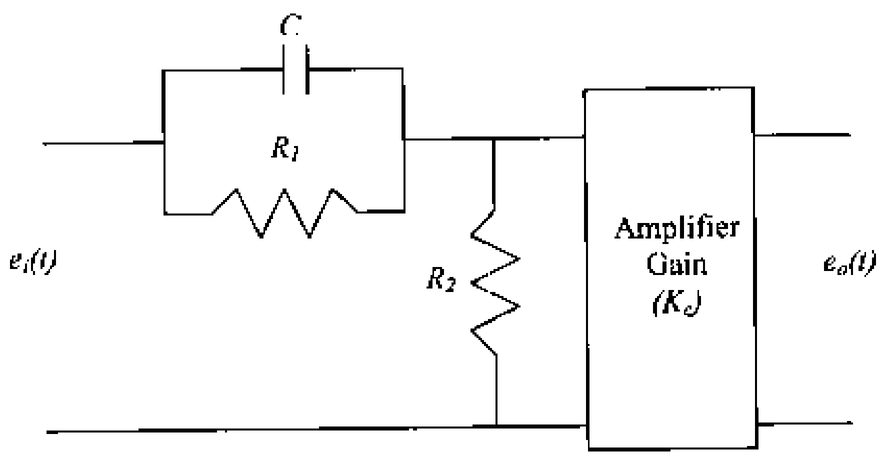

FIGURE Q6(e)

TABLE 1

Laplace transform table

$f(t)$	$F(s)$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{-at}u(t)$	$\frac{1}{s+a}$
$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$

TABLE 2

Laplace transform theorems

Name	Theorem
Frequency shift	$\mathcal{L}\left[e^{-at} f(t)\right] = F(s+a)$
Time shift	$\mathcal{L}\left[f(t-T)\right] = e^{-sT} F(s)$
Differentiation	$\mathcal{L}\left[\frac{d^n f}{dt^n}\right] = s^n F(s) - \sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$
Integration	$\mathcal{L}\left[\int_{0^-} f(\tau)d\tau\right] = \frac{F(s)}{s}$
Initial value	$\lim_{t\to 0} f(t) = \lim_{s\to\infty} sF(s)$
Final value	$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$

TABLE 3

2nd Order prototype system equations

$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$	$T_r = \frac{\pi - \cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$
$\mu_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$	$T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$
$T_s = \frac{4}{\zeta\omega_n}$ (2% criterion)	$T_s = \frac{3}{\zeta\omega_n}$ (5% criterion)