UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1996/97

Oktober/November 1996

<u>EEE 350 - Sistem Kawalan</u>

Masa : [3 jam]

ARAHAN KEPADA CALON :

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEMBILAN (9)** muka surat bercetak dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Agihan markah bagi soalan diberikan di sut sebelah kanan soalan berkenaan.

Soalan-soalan boleh dijawab sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.

1. (a) Pertimbangkan sistem kawalan gelung tertutup dalam Rajah 1.1(a) dan diagram simulasinya dalam Rajah 1.1(b).

Consider the closed-loop control system in Figure 1.1(a) and its simulation diagram in part (b) of the figure.

(i) Dapatkan persamaan keadaan untuk sistem kawalan tersebut daripada diagram simulasi.

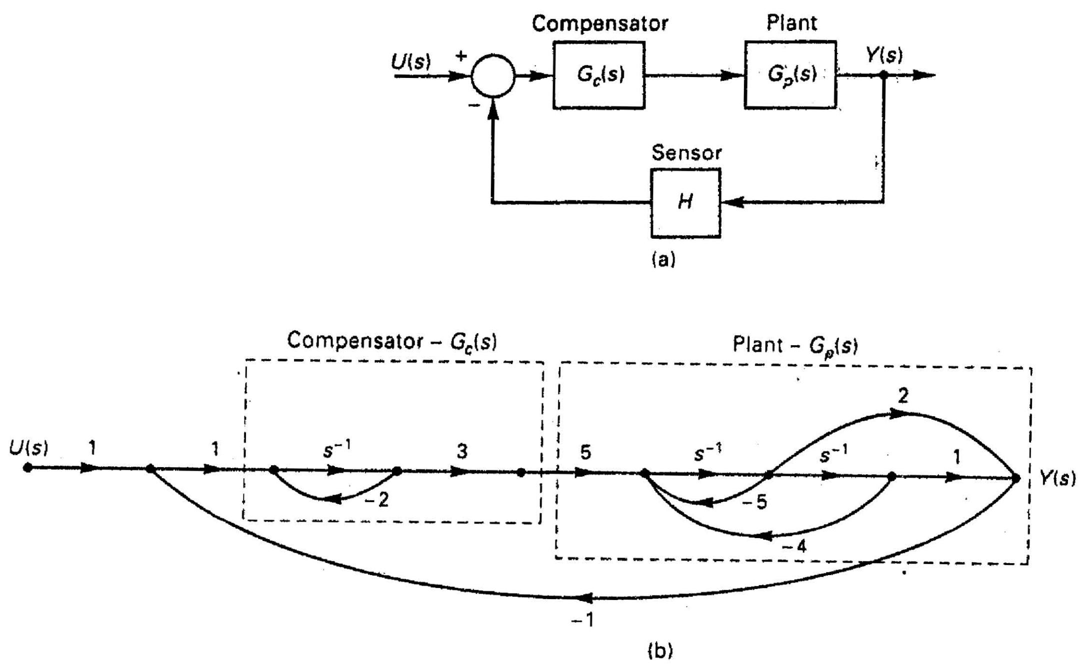
Write the state equations for the control system from the simulation diagram.

(10%)

(ii) Cari $G_c(s)$, fungsi pindah pemampas dan $G_p(s)$, fungsi pindah logi langsung daripada diagram simulasi.

Find $G_c(s)$, the compensator transfer function, and $G_p(s)$, the plant transfer function, directly from the simulation diagram.

(10%)



Rajah 1.1 *Figure 1.1*

(iii) Fungsi pindah gelung tertutup sistem kawalan diberikan oleh

The closed-loop transfer function of the control system is given by

$$\frac{Y(s)}{U(s)} = T(s) = \frac{G_c(s)G_p(s)}{1+G_c(s)G_p(s)H}$$

Nilaikan fungsi pindah ini.

Evaluate this transfer function. (10%)

(iv) Tunjukkan bahawa pembawah fungsi pindah dalam (iii) bersamaan dengan penentu (sI - A), dengan menggunakan A daripada (I).

Show that the denominator of the transfer function in (iii) is equal to det (sI - A), using A from (i).

(10%)

(v) Sahkan hasil bahagian (iv) dengan mencari Δ bagi formula untung Mason.

Verify the results of (iv) by finding the Δ of Mason's gain formula.

(10%)

(b) Pertimbangkan sistem kawalan servo dalam Rajah 1.2 yang menggunakan suapbalik kadaran (K_v).

Consider the servo control system of Figure 1.2 which employs rate feedback (K_v).

(i) Cari fungsi pindah.

Find the system transfer function.

(10%)

(ii) Rekabentuk sistem dengan mencari nilai K_v agar supaya sistem menjadi genting lewati $(\zeta = 1)$.

Design the system by finding the value of K_v such that the system is critically damped $(\zeta = 1)$.

(10%)

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(iii) Rekabentuk semula sistem dengan mencari nilai K_v agar supaya $\zeta = 0.707$ (suatu nilai yang lazim dalam rekabentuk)

Redesign the system by finding the value of K_v such that $\zeta = 0.707$ (a commonly used value in design).

(10%)

(iv) Cari nilai K_v agar supaya bila input merupakan suatu pemalar bernilai 10, output juga merupakan nilai pemalar 10.

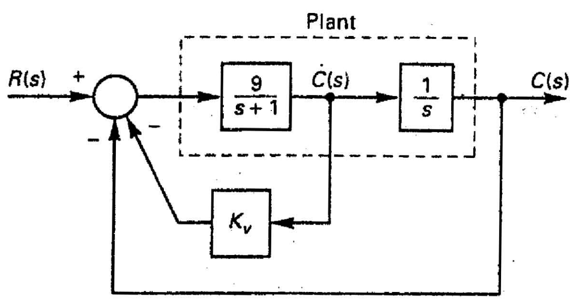
Find the value of K_v such that when the input is a constant value of 10, the output is also a constant value of 10.

(10%)

(v) Adakah nilai K_v yang didapat dalam (iv) menasabah, dengan mempertimbangkan bahawa isyarat suapbalik ialah dc(t)/dt?.

Is the value of K_v found in (iv) reasonable, considering that the fed-back signal is dc(t)/dt?.

(10%)



Rajah 1.2 *Figure 1.2*

2. Pertimbangkan sistem kawalan Rajah 2.1. Dalam sistem gelung tertutup ini, suapbalik halaju atau kadaran digunakan. Untung sensor kadaran ialah a. Rekabentuk sistem ini mengandungi pencarian untung a untuk memenuhi kriteria tertentu.

Consider the control system of Figure 2.1. In this closed-loop system, velocity or rate feed-back is employed. The gain of the rate sensor is a. The design of this system consists of determining the gain a to satisfy certain criteria.

...5/-

(i) Tentukan sama ada logi $G_p(s)$ stabil?
Determine if the plant $G_p(s)$ is stable. (20%)

(ii) Untung sensor kadar ialah a. Untuk masalah bahagian ini biarkan a=0; iaitu sensor kadar disingkirkan. Tentukan sama ada hasilan sistem gelung tertutup stabil.

The gain of the rate sensor is a. For this part of the problem, let a=0; that is, the rate sensor is removed. Determine if the resulting closed-loop system is stable.
(20%)

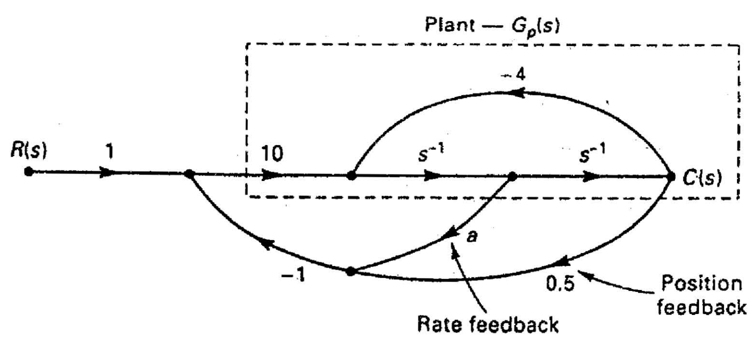
(iii) Ulang bahagian (ii) untuk suapbalik kadaran dalam sistem bernilai a=1.
Repeat (ii) for rate feedback in the system, with a=1. (20%)

(iv) Suatu sistem takstabil adalah tidak memberi manfaat, oleh itu cari julat a agar sistem gelung tertutup stabil.

An unstable system is useless; hence, find the range of a for which the closed-loop system is stable.

(20%)

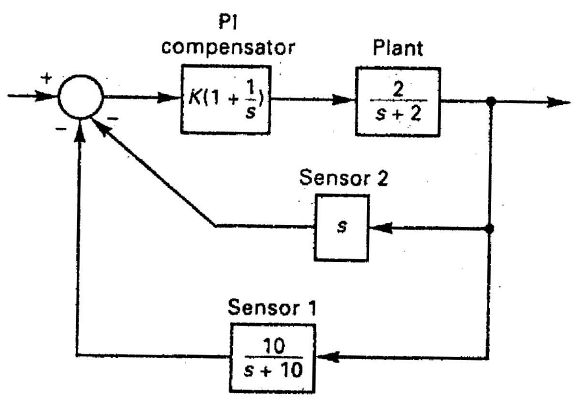
(v) Rekabentuk sistem agar menghasilkan pelematian yang genting.
Design the system such that the system is incritical damping. (20%)



Rajah 2.1
Figure 2.1

3. Suatu sistem kawalan suhu yang tertera dalam Rajah 3.1. Lihat pemampas PI dan sensor kadar (sensor 2). Sensor 1 menyukat suhu dan sensor ini lambat jika dibandingkan dengan kadar pada mana suhu boleh berubah. Sensor 2 menyukat kadar perubahan suhu adalah merupakan litar amplifier operasi yang berfungsi sebagai pembeza.

A temperature-control system is depicted in Figure 3.1. Note the PI compensator and the rate sensor (sensor 2). Sensor 1 measures temperature, and this sensor is slow compared to the rate at which the temperature can change. The sensor that measures the rate of change of temperature, sensor 2, is an operational amplifier circuit that differentiates.



Rajah 3.1
Figure 3.1

(a) Apakah untung frekuensi-rendah $(s = j\omega \approx j0)$ sensor kedudukan (sensor 1)?
What is the low-frequency $(s = j\omega \approx j0)$ gain of the position sensor (sensor 1)?
(20%)

(b) Apakah untung frekuensi-rendah $(s = j\omega \approx j0)$ sensor kadar (sensor 2)?
What is the low-frequency $(s = j\omega \approx j0)$ gain of the rate sensor (sensor 2)?
(20%)

(c) Daripada (a) dan (b) kita lihat bahawa pada frekuensi rendah sistem ialah suapbalik uniti. Apakah number jenis sistem ini?

From (a) and (b) we see that at low frequencies the system is a unity feedback system. What is the type number of this system?

(30%)

(d) Daripada (c) kita lihat bahawa ralat keadaan mantap untuk input pemalar ialah sifar, asalkan sistem stabil. Apakah julat K agar sistem stabil?

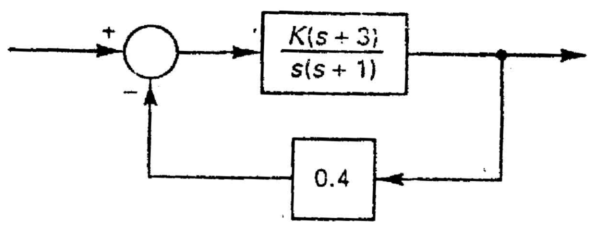
From (c) we see that the steady-state error for a constant input is zero, provided that the system is stable. For what range of K is the system stable?

(30%)

4. (a) Lakarkan secara tepat londar punca untuk sistem yang tertera dalam Rajah 4.1. Cari julat K, $0 < K < \infty$ untuk mana sistem stabil dengan menggunakan londar punca.

Accurately sketch the root locus for the system shown in Figure 4.1. Find the range of K, $0 < K < \infty$, for which the system is stable, using the root locus.

(40%)



Rajah 4.1
Figure 4.1

(b) Gunakan kriteria Routh-Hurwitz untuk mengesahkan keputusan dalam (a).
Use the Routh-Hurwitz criterion to verify the results in (a). (30%)

(c) Cari julat K, K>0 untuk mana punca-punca persamaan ciri sistem semuanya nyata.

Find the ranges of K, K>0, for which the roots of the system characteristic equation are all real.

(30%)

5. Pertimbangkan sistem dengan fungsi pindah.
Consider the system with the transfer function

$$G(s)=\frac{2(s+10)}{(s+1)(s+2)}$$

(a) Lakarkan sambutan garis-lurus amplitud dan fasa bagi diagram Bode.
Plot the straight-line amplitude and phase response of the Bode diagram.

(50%)

(b) Cari sambutan keadaan mantap untuk isyarat input cos t. Gunakan keputusan 2 dalam (a) jangan gunakan perhitungan.

Find the steady-state response for the input signal cos t. Use the results in (a) and do no calculations.

(25%)

(c) Hitung keputusan dalam (b).
Calculate the result in (b). (25%)

6. Untuk suatu sistem suapbalik uniti, biarkan.
For a unity feedback system, let

$$G(s)=\frac{0.707(s+1)}{s^2}$$

(a) Lakarkan diagram Nyquist.
Sketch the Nyquist diagram. (40%)

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(b) Catatan bahawa frekuensi pada mana $|G(j\omega)| = 1$ mudah dicari. Cari sut fasa yang tepat.

Note that the frequency at which $|G(j\omega)| = 1$ *is easily found. Find the exact phase margin.*

(20%)

(c) Cari sut untung.
Find the gain margin. (20%)

(d) Sahkan hasil dalam (c) melalui kriteria Routh-Hurwitz.
Verify the results in (c) with the Routh-Hurwitz criterion. (20%)

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