UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003

Februari/Mac 2003

JEE 450 – SISTEM KAWALAN

Masa : 3 jam

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi **LAPAN (8)** muka surat berserta Lampiran (2 muka surat) bercetak dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Agihan markah bagi soalan diberikan disut sebelah kanan soalan berkenaan.

Jawab semua soalan di dalam Bahasa Malaysia.

...2/-

1. Gambarajah blok bagi suatu sistem kawalan adalah seperti di bawah. Tentukan fungsi pindah berikut:

The block diagram of a control system is shown in the following figure. Determine the following transfer functions:

(a) $\left.\dfrac{Y(s)}{R(s)}\right|_{N=0}$ (25%)

(b) $\left.\dfrac{Y(s)}{N(s)}\right|_{R=0}$ (25%)

(c) Tentukan keluaran Y(s) bila U(s) dan N(s) diberikan serentak.

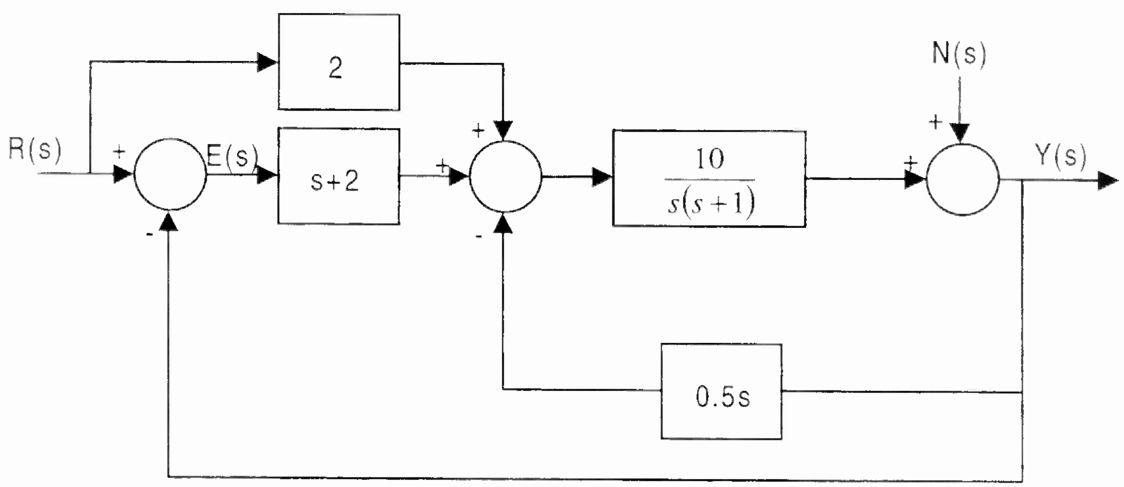
Determine the output Y(s) when U(s) and N(s) are given simultaneously.

(20%)

(d) Gunakan formula untung Mason untuk menyemak jawaban anda dalam bahagian (c).

Check your answer in part (c) using Mason gain formula.

(30%)



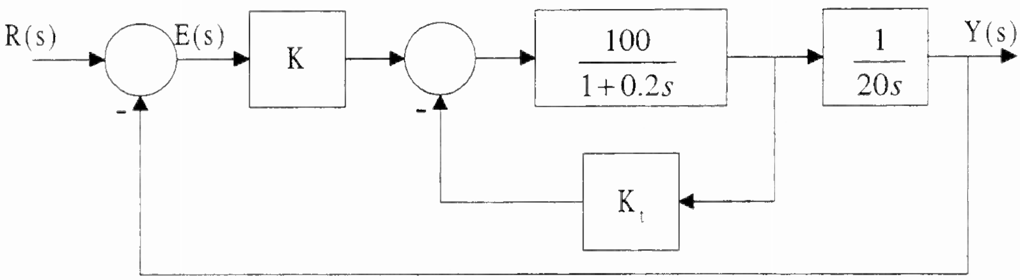
Rajah 1

Figure 1

...3/-

2. Gambarajah blok suatu sistem kawalan diberikan di bawah.

The block diagram of a control system is given below.



Rajah 2
Figure 2

(a) Jika K = 1 dan $K_t = 0.01$, tentukan

If K = 1 and $K_t = 0.01$, determine

(i) Pemalar posisi K_p dan pemalar halaju K_v

The position constant K_p and velocity constant K_v (30%)

(ii) Ralat keadaan mantap sistem tersebut jika $r(t) = 5u_s(t)$

The system steady state error if $r(t) = 5u_s(t)$ (15%)

(iii) Ralat keadaan mantap sistem tersebut jika $r(t) = tu_s(t)$

The system steady state error if $r(t) = tu_s(t)$ (15%)

...4/-

Nota: $u_s(t)$ adalah unit langkah.

Note: $u_s(t)$ is a unit step.

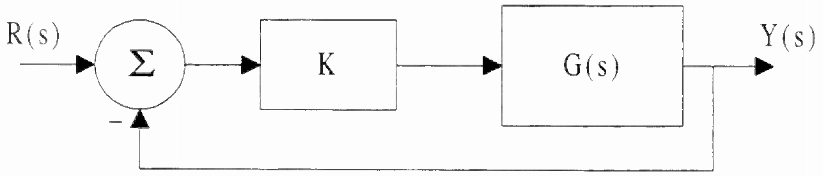
(b) Untuk masukan unit langkah, tentukan nilai K dan K_t supaya lelajak maksima ialah 10% dan masa naik ialah 0.1 saat.

For a unit step input, determine the values of K and K_t such that the maximum overshoot is 10% and the rise time is 0.1s.

(40%)

3. Suatu sistem kawalan suapbalik dengan pengawal perkadaran diwakilkan oleh rajah di bawah.

A feedback control system including a proportional controller is given in the following figure.



Rajah 3
Figure 3

Jika

If

$$G(s)=\frac{(s+1)(s+3)}{s^2(s+5)(s+10)};$$

...5/-

Tentukan

Determine:

(a) Persamaan ciri sistem gelung tertutup di atas.

The characteristic equation of the above system. (10%)

(b) Julat K di mana sistem tersebut stabil, menggunakan kaedah kriteria Routh-Hurwitz

The range of K where the system stable, using Routh-Hurwitz criterion.

(60%)

(c) Tentukan nilai-nilai frekuensi ayunan sistem pada keadaan sistem stabil kritikal.

The values of the oscillation frequencies when the system is critically stable.

(30%)

4. Gambarajah blok bagi suatu sistem kawalan dengan suapbalik takometer ditunjukkan dalam Rajah 4.

The block diagram for a control system with a tachometer feedback is shown in Figure 4.

(a) Binakan londar punca bagi sistem tersebut untuk $K \geq 0$ dan $K_t = 0$.

Construct the roots locus of the system for $K \geq 0$ *and* $K_t = 0$.

(50%)

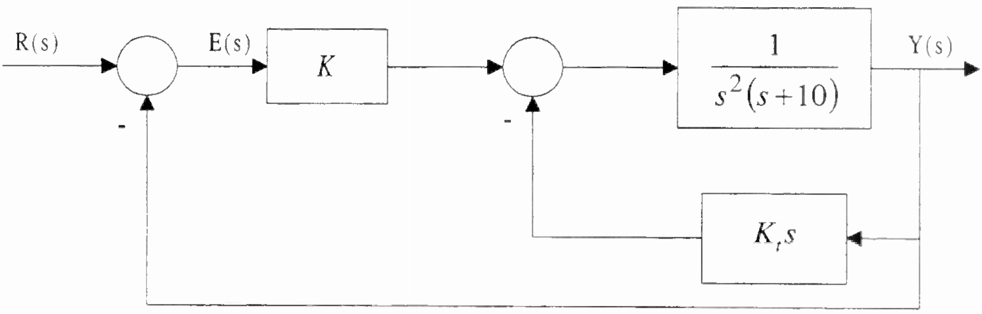
...6/-

(b) Setkan $K = 6$, binakan londar punca bagi sistem tersebut untuk $K_t \geq 0$. Bagi setiap kes, nyatakan sudut asimptot-asimptot, titik perpotongan asimptot-asimptot dan titik perpecahan di atas paksi nyata (jika berkenaan).

Set $K = 6$, Construct the roots locus of the system for $K_t \geq 0$. In each case, determine the angle of asymptotes, asymptotes intersection point and breakaway points on real axis (where applicable).

[Klue: $s^3 + 3s^2 + 6 = (s + 3.5)(s - 0.25 \pm j1.29)$;
Clue: $-2s^3 - 3s^2 + 6 = (s - 1.08)(s + 1.29 \pm j1.06)$]

(50%)



Rajah 4
Figure 4

5. Fungsi pindah suatu sistem kawalan suapbalik unit diberikan seperti berikut,
The forward transfer function of a unity feedback control system is given as:

$$G(s) = \frac{K(1 + 0.5s)}{s(s^2 + s + 1)}$$

...7/-

(a) Lakarkan gambarajah Bode sistem tersebut.

Sketch the Bode plot of the system. (60%)

(b) Anggarkan sut untung dan sut fasa sistem berdasarkan lakaran Bode dalam (a).

Estimate the gain margin and phase margin of the system based on the Bode plot in (a).

(10%)

(c) Anggarkan nilai untung K supaya

Estimate the value of K so that

(i) Sut untung sistem ditingkatkan kepada 20dB.

The gain margin will be increased to 20dB. (15%)

(ii) Sut fasa sistem ditingkatkan sebanyak 10°.

The phase margin will be increased by 10°. (15%)

6. Fungsi pindah laluan hadapan suatu sistem kawalan suapbalik unit diberikan seperti berikut:

The forward transfer function of a unity feedback control system is given as:

$$G(s) = \frac{K(s+4)}{s(s+2)(s^2+2s+2)}$$

(a) Lakarkan gambarajah Nyquist untuk $G(j\omega)H(j\omega)$ bagi $\omega = 0$ hingga $\omega = \infty$.

Construct the Nyquist plot of $G(j\omega)H(j\omega)$ for $\omega = 0$ to $\omega = \infty$.

(70%)

...8/-

(b) Tandakan sut untung dan sut fasa di atas lakaran Nyquist dalam (a).

Label the gain margin and phase margin on the Nyquist plot in (a).

(10%)

(c) Berdasarkan lakaran Nyquist dalam (a), lakarkan secara kasar lakaran Nyquist sistem tersebut jika kutub pada asalan dibuang daripada laluan hadapan sistem.

(Nota: Anda tidak perlu buat sebarang pengiraan, cuma lakarkan bentuknya sahaja).

Based on the Nyquist plot in (a), roughly sketch the Nyquist plot of the system if the pole at the origin is excluded from the forward path of the system.

(Note: You do not have to calculate anything, only sketch the shape).

(20%)

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Laplace Transform Table

1	Unit-impulse function $\delta(t)$
$\dfrac{1}{s}$	Unit-step function $u_s(t)$
$\dfrac{1}{s^2}$	Unit-ramp function t
$\dfrac{n!}{s^{n+1}}$	t^n (n = positive integer)
$\dfrac{1}{s+\alpha}$	$e^{-\alpha t}$
$\dfrac{1}{(s+\alpha)^2}$	$te^{-\alpha t}$
$\dfrac{n!}{(s+\alpha)^{n+1}}$	$t^n e^{-\alpha t}$ (n = positive integer)
$\dfrac{1}{(s+\alpha)(s+\beta)}$	$\dfrac{1}{\beta-\alpha}(e^{-\alpha t}-e^{-\beta t})\ \ (\alpha \neq \beta)$
$\dfrac{s}{(s+\alpha)(s+\beta)}$	$\dfrac{1}{\beta-\alpha}(\beta e^{-\beta t}-\alpha e^{-\alpha t})\ \ (\alpha \neq \beta)$
$\dfrac{1}{s(s+\alpha)}$	$\dfrac{1}{\alpha}(1-e^{-\alpha t})$
$\dfrac{1}{s(s+\alpha)^2}$	$\dfrac{1}{\alpha^2}(1-e^{-\alpha t}-\alpha te^{-\alpha t})$
$\dfrac{1}{s^2(s+\alpha)}$	$\dfrac{1}{\alpha^2}(\alpha t-1+e^{-\alpha t})$
$\dfrac{1}{s^2(s+\alpha)^2}$	$\dfrac{1}{\alpha^2}\left[t-\dfrac{1}{\alpha}+\left(t+\dfrac{2}{\alpha}\right)e^{-\alpha t}\right]$

$\dfrac{s}{(s+\alpha)^2}$	$(1-\alpha t)e^{-\alpha t}$
$\dfrac{\omega_n^2}{s^2+\omega_n^2}$	$\sin \omega_n t$
$\dfrac{s}{s^2+\omega_n^2}$	$\cos \omega_n t$
$\dfrac{\omega_n^2}{s(s^2+\omega_n^2)}$	$1-\cos \omega_n t$
$\dfrac{\omega_n^2(s+\alpha)}{s^2+\omega_n^2}$	$\omega_n\sqrt{\alpha^2+\omega_n^2}\sin(\omega_n t+\theta)$ where $\theta=\tan^{-1}(\omega_n/\alpha)$
$\dfrac{\omega_n}{(s+\alpha)(s^2+\omega_n^2)}$	$\dfrac{\omega_n}{\alpha^2+\omega_n^2}e^{-\alpha t}+\dfrac{1}{\sqrt{\alpha^2+\omega_n^2}}\sin(\omega_n t-\theta)$ where $\theta=\tan^{-1}(\omega_n/\alpha)$
$\dfrac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin \omega_n\sqrt{1-\zeta^2}\,t \quad (\zeta<1)$
$\dfrac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$	$1-\dfrac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\cos^{-1}\zeta \quad (\zeta<1)$
$\dfrac{s\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{-\omega_n^2}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\theta)$ where $\theta=\cos^{-1}\zeta \quad (\zeta<1)$
$\dfrac{\omega_n^2(s+\alpha)}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\omega_n\sqrt{\dfrac{\alpha^2-2\alpha\zeta\omega_n+\omega_n^2}{1-\zeta^2}}\,e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\tan^{-1}\dfrac{\omega_n\sqrt{1-\zeta^2}}{\alpha-\zeta\omega_n} \quad (\zeta<1)$
$\dfrac{\omega_n^2}{s^2(s^2+2\zeta\omega_n s+\omega_n^2)}$	$t-\dfrac{2\zeta}{\omega_n}+\dfrac{1}{\omega_n^2\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\cos^{-1}(2\zeta^2-1) \quad (\zeta<1)$