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Peperiksaan Semester Pertama  
Sidang Akademik 2005/2006  
*First Semester Examination  
2005/2006 Academic Session*

November 2005  
*November 2005*

**ESA 251/3 – Teori Sistem Kawalan**  
*Theory of Control System*

Masa : 3 jam  
*Duration : 3 hours*

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Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.

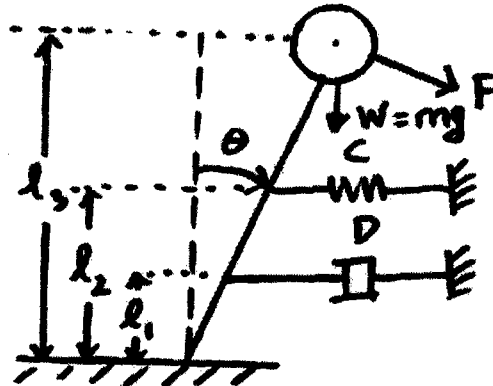
*Please check that this examination paper consists of EIGHT pages of printed material before you begin the examination.*

**Arahan:** Jawab **EMPAT (4)** soalan.

**Instructions :** Answer **FOUR (4)** questions.

1. Pertimbangkan sistem bandul pegas terendam seperti dalam Gambarajah 1 di bawah.

Consider the damped spring pendulum system below in Figure 1.



**Gambarajah 1 : Sistem bandul pegas terendam dalam kedudukan terpesong**  
**Figure 1 : Damped spring pendulum system in deflected position**

Anggapkan bahawa daya pegas dan daya terendam yang bertindak ke atas bandul adalah sifar bila bandul berada dalam keadaan mendatar atau  $\theta = 0$ . Anggapkan juga bahawa geseran yang terlibat boleh diabaikan dan sudut ayunan  $\theta$  adalah kecil.

Assume that the spring and damper force acting on the pendulum is zero when the pendulum is vertical or  $\theta = 0$ . Assume also that the friction involved is negligible and the angle of oscillation  $\theta$  is small.

- (a) Dapatkan model matematik bagi sistem itu dalam bentuk
- (i) Persamaan perbezaan
  - (ii) State Space Representation
  - (iii) Fungsi pindah

Obtain the mathematical model of the system in form of

- (i) The differential equation
- (ii) State Space Representation
- (iii) Transfer function

(50 markah/marks)

- (b) Tetapkan parameter dinamik sistem frekuensi tabii ( $\omega_0$ ), nisbah redaman ( $\rho$ ) dan frekuensi terendam ( $\omega_d$ ).

*Determine dynamic parameter of the system natural frequency ( $\omega_0$ ), damping ratio ( $\rho$ ) and damped frequency ( $\omega_d$ ).*

**(25 markah/marks)**

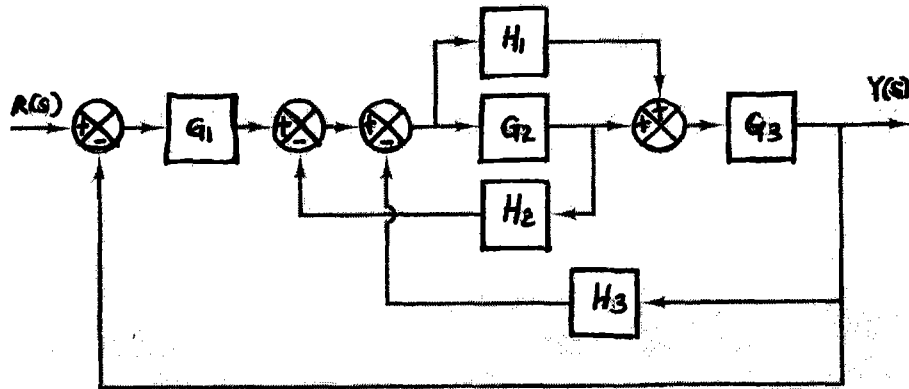
- (c) Sila ramalkan sambutan awal dan akhir sistem dengan menggunakan teori awal dan akhir.

*Please predict the initial and stationary step-response using initial final theorems.*

**(25 markah/marks)**

2. Dapatkan fungsi alih litar tertutup untuk blok diagram berikut:

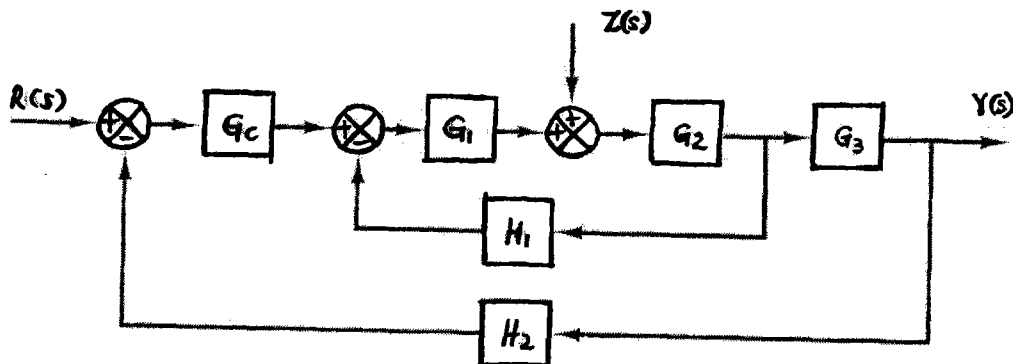
(a)



Gambarajah 2(a) : Block Diagram of Closed Loop 1  
 Figure 2 (a) : Block Diagram of Closed Loop 1

(40 markah/marks)

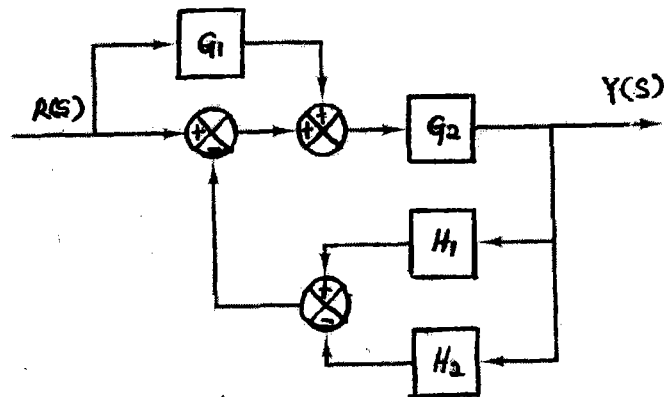
(b)



Gambarajah 2(b) : Block Diagram of Closed Loop System 2  
 Figure 2 (b) : Block Diagram of Closed Loop 2

(30 markah/marks)

(c)

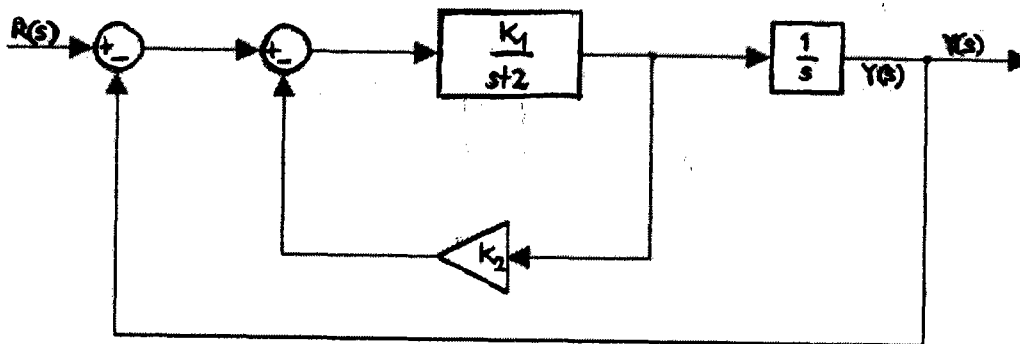


**Gambarajah 2(c) : Block Diagram of Closed Loop System 3**  
**Figure 2 (c) : Block Diagram of Close Loop System 3**

(30 markah/marks)

3. Merujuk kepada sistem yang ditunjukkan dalam Gambarajah 3 di bawah:

*Referring to the system shown in Figure 3 below:*



**Gambarajah 3 : Sistem Gelung Tertutup**  
**Figure 3 : A Closed-Loop System**

- (a) Tentukan nilai  $K_1$  dan  $K_2$  supaya sistem itu mempunyai nisbah redaman  $\rho = 0.7$  dan frekuensi tabii tak terendam  $\omega_o = 4 \text{ rad/sec}$ .

*Determine the values of  $K_1$  and  $K_2$  such that the system has a damping ratio  $\rho = 0.7$  and undamped natural frequency  $\omega_o = 4 \text{ rad/sec}$ .*

**(50 markah/marks)**

- (b) Dapatkan masa naik  $t_r$ , masa puncak  $t_p$ , maksimum terlajak  $M_p$  dan masa penganapan  $t_s$  dalam unit sambutan langkah dan gambarkan/cantumkan masa-masa tersebut dalam lakaran unit sambutan langkah.

*Obtain the rise time  $t_r$ , peak time  $t_p$ , maximum overshoot  $M_p$ , setting time  $t_s$  in the unit step response and put the times into the sketch of step response.*

**(50 markah/marks)**

4. (a) Pertimbangkan persamaan ciri-ciri yang berikut:

$$S^4 + KS^3 + S^2 + S + 1 = 0$$

Tentukan julat K untuk kestabilan menggunakan Kriteria Routh.

*Consider the following characteristic equation:*

$$S^4 + KS^3 + S^2 + S + 1 = 0$$

*Determine the range of K for stability using Routh's Criterion.*

**(50 markah/marks)**

- (b) Pertimbangkan fungsi alih gelung terbuka

$$F_o(s) = \frac{K}{1 - TS} ; K = 1.0$$

- (i) Lakarkan plot polar  $F_o(s)$  di atas.
- (ii) Berdasarkan lakaran polar plot  $F_o(s)$  di atas, tentukan sama ada belung tertutup  $F_c(s)$  stabil atau tidak?.

*Consider the open-loop transfer function*

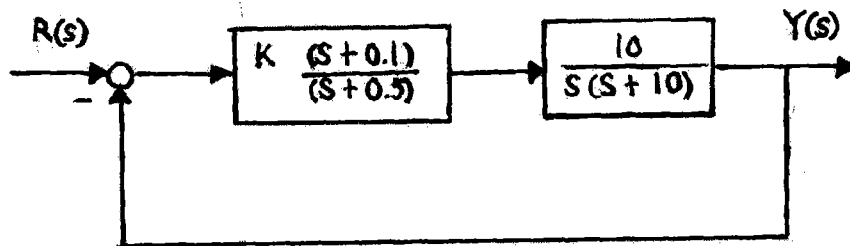
$$F_o(s) = \frac{K}{1 - TS} ; K = 1.0$$

- (i) *Draw polar plot for  $F_o(s)$  above.*
- (ii) *Based on polar plot  $F_o(s)$ , determine whether the closed loop  $F_c(s)$  stable or not using nyquist-stability criterion?.*

**(50 markah/marks)**

5. Pertimbangkan sistem seperti yang ditunjukkan dalam Gambarajah 4.

*Consider the system shown in Figure 4.*



**Gambarajah 4 : Rajah blok bagi penggerak hidraulik**

**Figure 4 : Block diagram of hydraulic servo actuator**

- (a) Lukiskan rajah bode bagi fungsi pindah gelung terbuka.

*Draw a bode diagram of open-loop transfer function.*

**(60 markah/marks)**

- (b) Tentukan nilai gandaan K supaya margin fasa ialah  $45^\circ$

*Determine the value of gain K such that the phase margin is  $45^\circ$*

**(20 markah/marks)**

- (c) Apakah margin gandaan bagi sistem untuk gandaan K di atas.

*What is the gain margin of the system with this gain K*

**(20 markah/marks)**