Document No : UniKL MFI_SD_AC41
Revision No: 02
Effective Date: 01 December 2008

CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
JANUARY 2014 SESSION

SUBJECT CODE	:	**FAB 30803**
SUBJECT TITLE	:	**CONTROL SYSTEM**
LEVEL	:	**BACHELOR**
TIME / DURATION	:	**(3 HOURS)**
DATE	:	

INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **This question paper consists of SIX (6) questions. Answer FIVE (5) questions only.**
6. **Answer all questions in English.**
7. **The semi-log paper, Nichol's chart, graph paper and formula are appended.**

THERE ARE 6 PAGES OF QUESTIONS AND 1 PAGE OF APPENDIX, EXCLUDING THIS PAGE.

Question 1

(a) Give **two** (2) advantages of a closed loop system

(2 marks)

(b) Many luxury automobiles have thermostatically controlled air-conditioning systems for the comfort of the passengers. Draw the functional block diagram of an air-conditioning system where the driver sets the desired interior temperature on a dashboard panel.

(3 marks)

(c) The schematic diagram for the positional servo system is shown in **Figure 1**. Assume that the input and output of the system are the input shaft position and the output shaft position respectively. Assume the following for the system constants:

K = gain of the potentiometer error detector (7.64 v/rad)
K_p = amplifier gain (10 volts/volt)
R_a = armature winding resistance (0.2 ohms)
L_a = armature winding inductance (negligible)
i_a = armature winding current (A)
K_b = back emf constant (5.5×10^{-2} volt-sec/rad)
K_m = motor torque constant (6×10^{-5} N-m/ampere)
J_m = moment of inertia of the motor (1×10^{-5} kg-m$^{2)}$
b_m = viscous-friction coefficient of the motor (negligible)
J_L = moment of inertia of the load (4.4×10^{-5} kg-m^2)
b_L = viscous-friction coefficient of the load (negligible)
N_1/N_2 = Assuming the gear ratio is 1

i. Write the mathematical equations of each of the subsystems and draw the functional block diagram of the system.

(12 marks)

ii. Determine the overall transfer function $\frac{\theta_o(s)}{\theta_i(s)}$ of the system.

(3 marks)

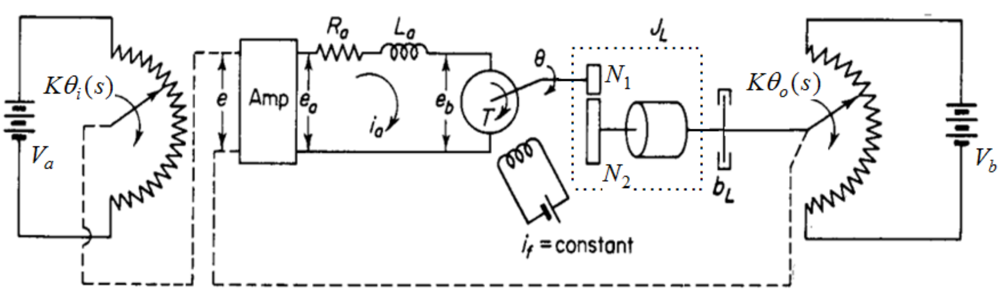

Figure 1: Schematic diagram of a positional servo motor

Question 2

(a) Find the transfer function, $\frac{C(s)}{R(s)}$ for a block diagram of a system in **Figure 2** by using the block diagram reduction method.

(10 marks)

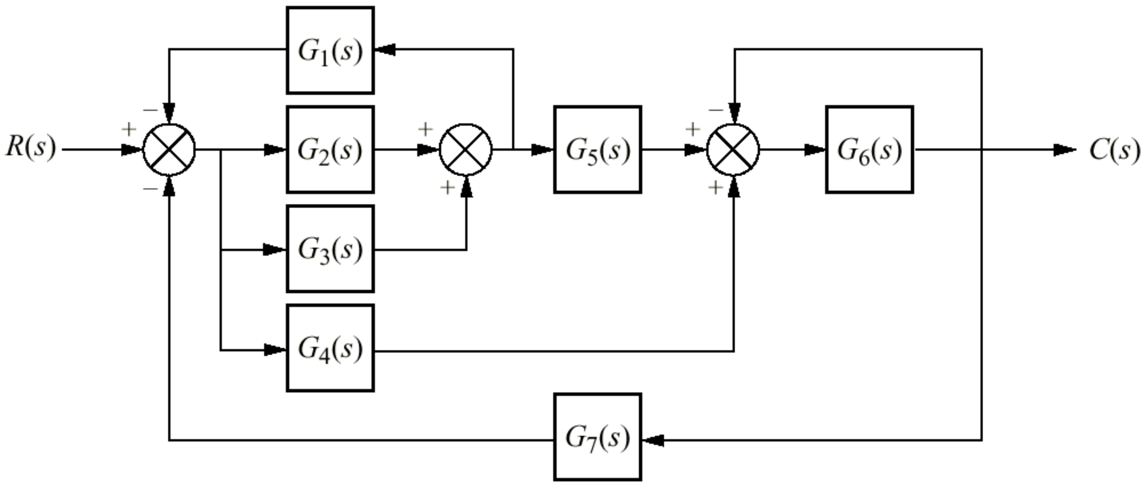

Figure 2: A block diagram of a system

(b) **Figure 3** shows a block diagram of a unity feedback system**.** Answer the following questions:

i. Determine the values of K and P of the closed–loop system so that the maximum overshoot is 25% and peak time is 2 seconds. Assume J = 1.

(8 marks)

ii. Determine the settling time (T_s),

(2 marks)

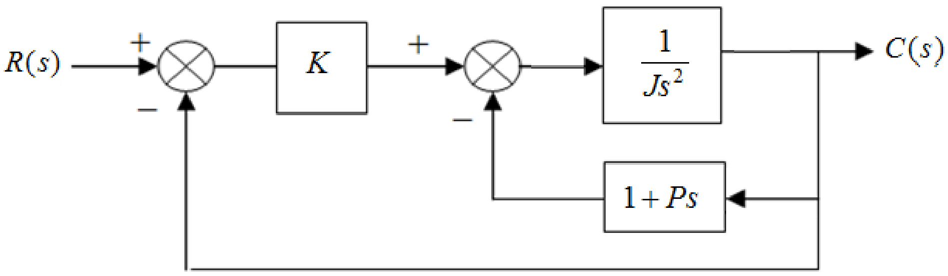

Figure 3: The block diagram of a system

Question 3

(a) **Figure 4** shows a signal flow graph of a system. Obtain the overall transfer function, $\frac{C(s)}{R(s)}$ of the system.

(10 marks)

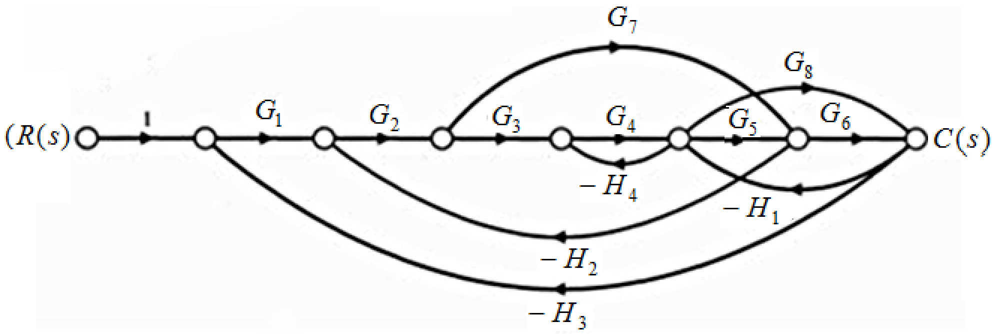

Figure 4: A signal flow graph

(b) Referring to the negative feedback system shown in **Figure 5**, find the number of closed-loop poles located in the right half-plane, left half-plane, and on the jω-axis by using Routh-Hurwitz criterion and comment on the system stability.

(10 marks)

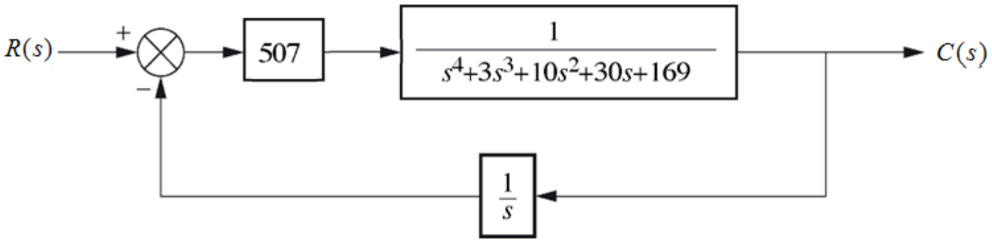

Figure 5: The negative feedback system

Question 4

(a) The block diagram of a position control of a crane with load on the end of cable is shown in **Figure 6**.

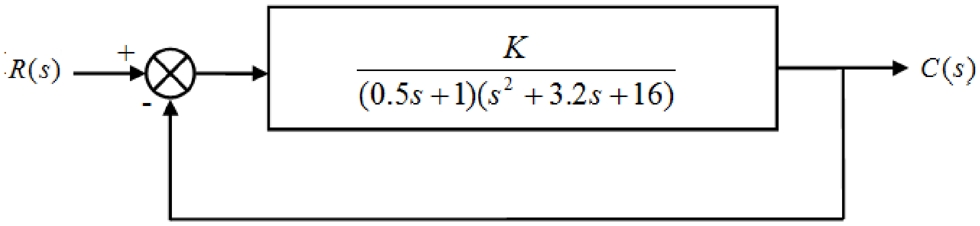

Figure 6: Crane position control system

i. Plot the asymptotic Bode diagram for the system if given that K = 1000.

(10 marks)

ii. From the bode plot, determine the gain margin (GM), phase margin (PM), gain cross over frequency (ω_{gco}), phase cross over frequency (ω_{pco}), and hence state and justify the stability of the system

(5 marks)

(b) An engineer has found the frequency response of an open loop system and tabulated it as shown in **Table 1**.

Table 1: The data of an open loop system.

ω (rad/s)	0.01	0.02	0.03	0.06	0.11	0.19	0.34	0.52
|G|dB	21	19.5	16.2	11.2	4	-3	-13	-19
$\angle G^{\circ}$	-32	-52	-76	-101	-125	-146	-160	-165

i. Sketch the Nichols plot on the Nichols chart.

(3 marks)

ii. Determine from the Nichol chart, the resonant peak and the bandwidth of the closed loop system.

(2 marks)

Question 5

(a) The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{100}{s^2(s+2)(s+5)}$$

i. Determine the system type

(1 mark)

ii. Find static error constants K_p, K_v and K_a for the unity feedback system.

(3 marks)

iii. Determine the steady state error when the input is $5u(t)$, $5tu(t)$ and $5t^2u(t)$.

(6 marks)

(b) An open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{60K}{s^3 + 6s^2 + 11s + 6}$$

i. Sketch the Nyquist diagram for $(0 < \omega < \infty)$ for $K = 1$

(7 marks)

ii. Determine the range of K for stability.

(2 marks)

iii. Determine the frequency of oscillation for marginal stable

(1 mark)

Question 6

The block diagram of a unity feedback closed loop system is shown in **Figure 7**.

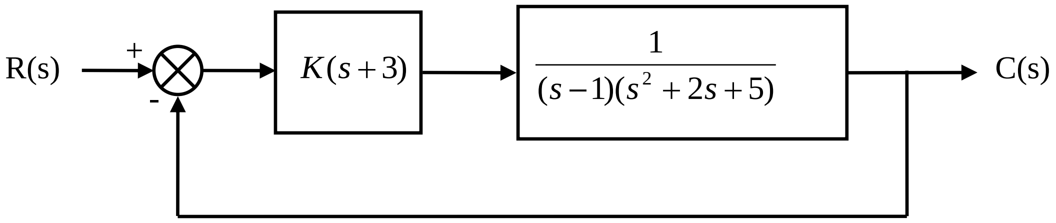

Figure 7: Unity feedback closed-loop system

i. Sketch the root locus of the closed loop system as *K* varies from zero to infinities, in the s-plane. Indicate the asymptotes, break points on the real axis, cross-over points at the imaginary axis, angle of departure or arrival, where appropriate.

(15 mark)

ii. Determine gain, *K* so that the closed-loop system operates at 22% overshoot.

(5 marks)

END OF QUESTION

Appendix 1

1. $G(s) = \frac{\omega_n^{\ 2}}{s^2 + 2\zeta\omega_n s + \omega_n^{\ 2}}$

2. $\%OS = e^{-\left(\zeta\pi/\sqrt{1-\zeta^2}\right)} \times 100$

3. $\zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$

4. $T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$

5. $T_s = \frac{4}{\zeta\omega_n}$ for 2% criteria

6. $T_r = \frac{\pi/2 + \phi}{\omega_n\sqrt{1-\zeta^2}}$

   where, $\phi = \tan^{-1}\frac{\zeta}{\sqrt{1-\zeta^2}}$

7. $e(\infty) = e_{step}(\infty) = \frac{1}{1 + \lim_{s\to 0} G(s)}$

8. $e(\infty) = e_{ramp}(\infty) = \frac{1}{\lim_{s\to 0} sG(s)}$

9. $e(\infty) = e_{parabola}(\infty) = \frac{1}{\lim_{s\to 0} s^2G(s)}$

10. $K_p = \lim_{s\to 0} G(s)$

11. $K_v = \lim_{s\to 0} sG(s)$

12. $K_a = \lim_{s\to 0} s^2G(s)$

Laplace Transform Table

Item no.	f(t)	F(s)
1.	$\delta(t)$	1
2.	$u(t)$	$\frac{1}{s}$
3.	$tu(t)$	$\frac{1}{s^2}$
4.	$t^n u(t)$	$\frac{n!}{s^{n+1}}$
5.	$e^{-at}u(t)$	$\frac{1}{s+a}$
6.	$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
7.	$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$