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

CONFIDENTIAL

SET B

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
JANUARY 2010 SESSION

SUBJECT CODE	:	FAB 30603
SUBJECT TITLE	:	CONTROL SYSTEM 1
LEVEL	:	BACHELOR
TIME / DURATION	:	9.00am – 12.00pm (3 HOURS)
DATE	:	30 APRIL 2010

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 FIVE (6) questions. Answer FOUR (4) questions only.
6. Answer all questions in English.
7. The semilog paper and Nichol's chart are appended.

THERE ARE 8 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

Question 1

(a) Explain one example of an open loop system.

(2 marks)

(b) Give three (3) comparisons between open loop and close loop control

(3 marks)

(c) A robotic hand is used to hold and grasp object as in **Figure 1**. If the grasping force is too small, the robot hand will release the object and if it is too large, the hand may crush the object. Thus, the robotic depends on slip sensing device to give measure the amount of slip using photo sensor. The robot will pick up and raise the object with the present of grasping force. The robot hand is controlled using microcontroller which then adjusts the servo motor to control the hand movement. Draw the functional block diagram.

(5 marks)

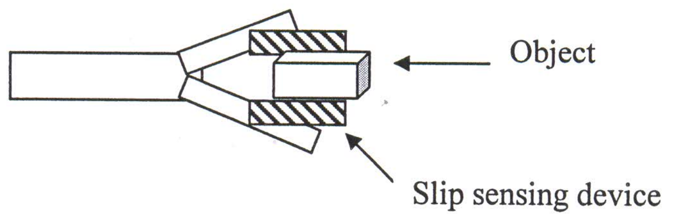

Figure 1: Robot hand grasping control system

(d) **Figure 2** shows a schematic diagram of a control system.

i. Write the mathematical equations of each of the subsystems.

(6 marks)

ii. Draw the functional block diagram of overall system

(4 marks)

iii. Determine the overall transfer function of the system.

$$G(s) = \frac{\theta(s)}{V(s)}$$

(5 marks)

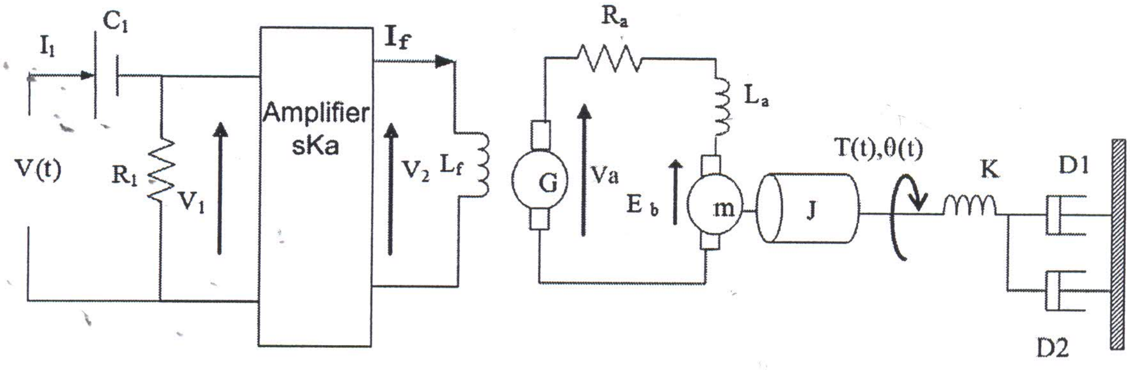

Figure 2: The schematic diagram of a control system.

K_g = Generator constant

K_m = Motor torque constant

K_b = Back emf constant

K = Spring coefficient

D_1 and D_2 = Viscous friction

J = Inertia

Question 2

(a) Referring to the block diagram in **Figure 3**, obtain the overall transfer function $\frac{C(s)}{R(s)}$ by using the Block Diagram Reduction Method or Mason's Rule.

(15 marks)

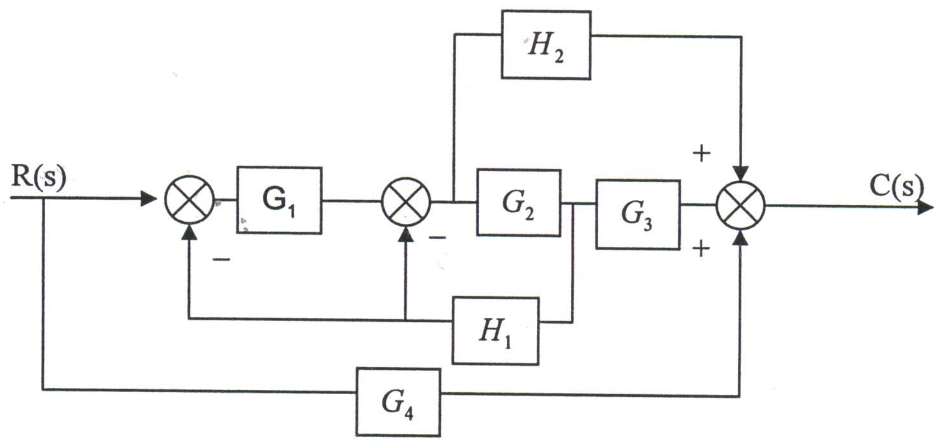

Figure 3: The block diagram of a control system.

(b) i. Explain the following control terminologies of rise time and settling time for a second order step response. (Hint: you may refer to the respective plotting shown in Figure 4)

(4 marks)

ii. Briefly describe the type of output response for A, B, and C in **Figure 4** when a step input is given to the system and explain how damping ratio (ζ) and pole location influence the output response.

(6 marks)

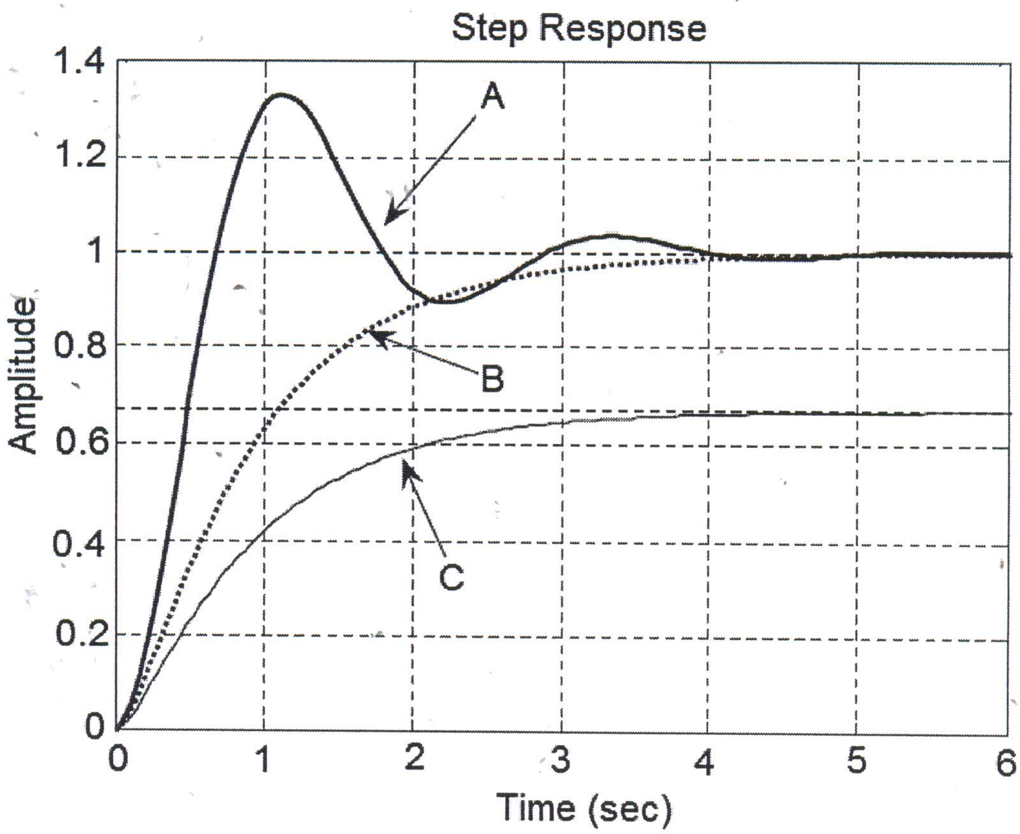

Figure 4: Output response when step input is given to a system

Question 3

(a) **Figure 5** shows the unit step response of an unknown first order open loop control system. From this response obtain :

i. Rise time (Tr), settling time (Ts) and time constant (τ)

(3 marks)

ii. Transfer function of the system

(2 marks)

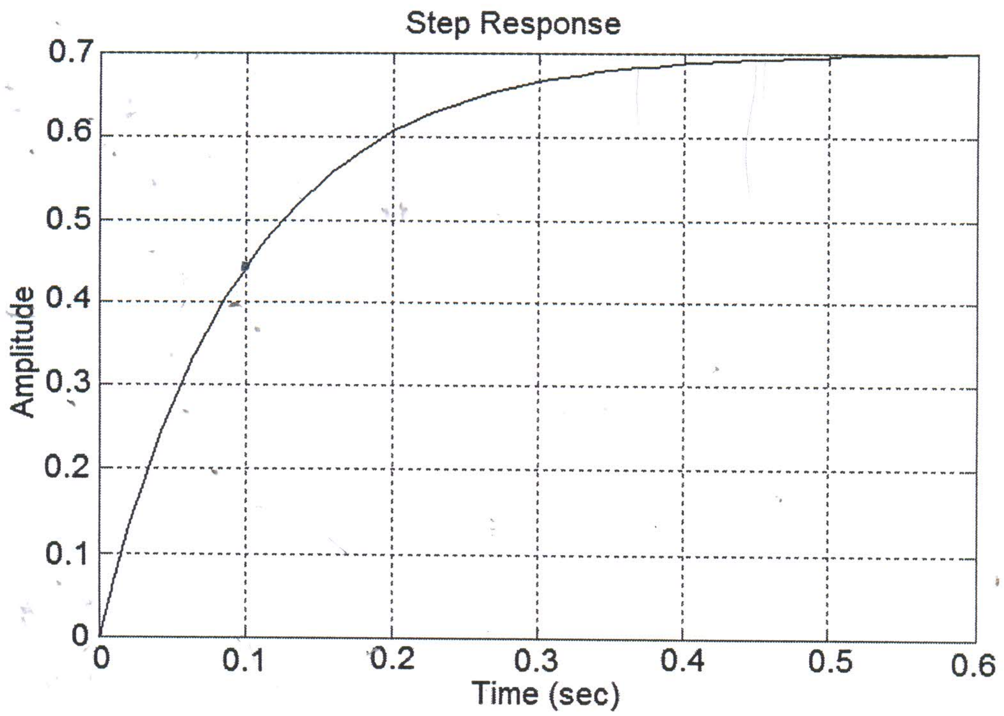

Figure 5: Unit step response of an unknown first order system

(b) **Figure 6 shows** a block diagram of a system. Determine:

i. The system type

(3 marks)

ii. Kp, Kv and Ka

(3 marks)

iii. The steady state error for inputs R(s) are 30u(t), 30tu(t) and $30t^2u(t)$

(3 marks)

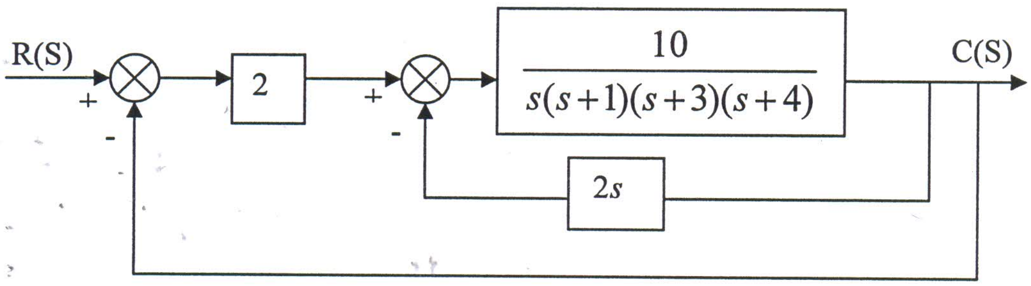

Figure 6: A block diagram of a system

(c) **Figure 7** shows a block diagram of a system.

i. Determine the number of poles in the right-half plane, the left-hand plane, on the origin and $j\omega$ axis.

(9 marks)

ii. Draw the conclusion on the stability of the system.

(2 marks)

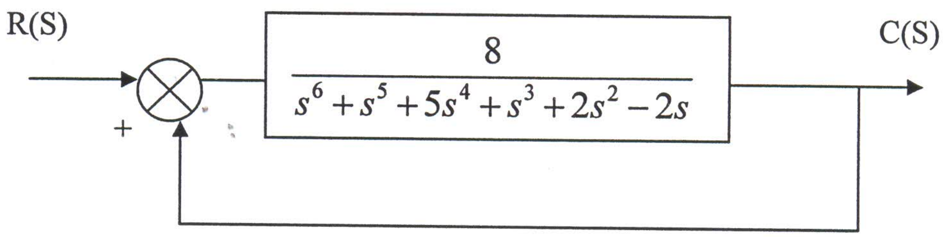

Figure 7: A block diagram of a system

Question 4

(a) Consider a unity feedback control system as shown in **Figure 8**.

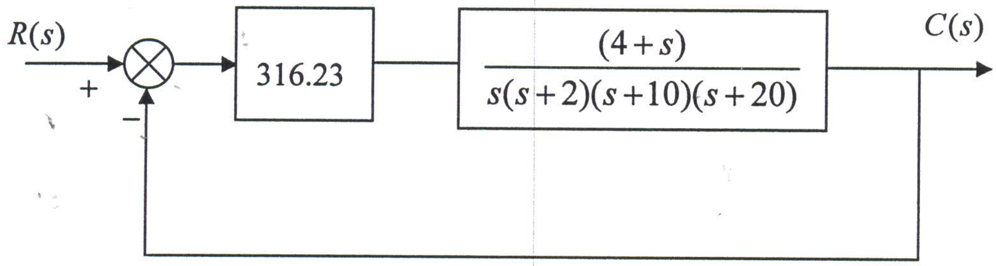

Figure 8: A unity feedback control system

i. Plot the asymptotic Bode plot for the system.

(8 marks)

iii. 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.

(6 marks)

(b) i. Plot the Nichol's chart for the system in **Figure 8** for *ω(rad/s) = 0.5,1.0, 1.5, 2.0, 2.5,3.0,3.5 and 4.0.*

(4 marks)

From the Nichol's plot, determine:

ii. Bandwidth (BW) of the closed loop system.

(3 marks)

iii. Resonance peak value, (M_r).

(2 marks)

iv. Resonance frequency, (ω_r).

(2 marks)

Question 5

(a) Consider a unity feedback control system shown in **Figure 9** where G(s) is the forward transfer function of the plant and K is the gain of the controller.

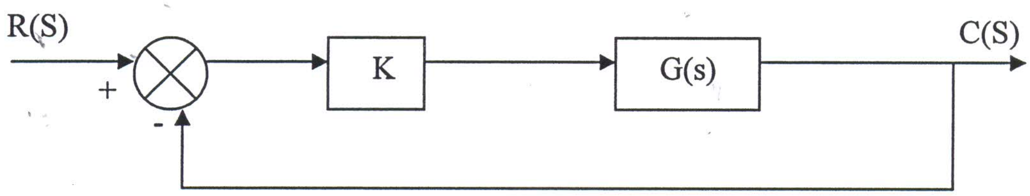

Figure 9: A unity feedback control system

where, $$G(s) = \frac{1}{s(s+3)(s+6)}$$

i. Determine the number of branches in the root locus plot.

(3 marks)

ii. Calculate the asymptotes and determine the breakaway points

(3 marks)

iii. Draw the root locus

(5 marks)

iv. Determine the range of K for the system to be stable

(5 marks)

(b) i. Using Nyquist criterion, sketch the Nyquist plot of the system below for $0<\omega<\infty$

(6 marks)

$$G(s) = \frac{5}{s(s+1)(s+2)}$$

ii. Determine the stability of the system

(3 marks)

Question 6

(a) Consider a unity feedback control system of a system where K is the gain of the controller.

$$G(s) = \frac{K}{s(s+2)(s+1)(s+4)(s+5)}$$

i. Determine the number of branches in the root locus plot.

(3 marks)

ii. Calculate the asymptotes and determine the breakaway points

(4 marks)

iii. Draw the root locus

(6 marks)

iv. Determine the jw axis crossing

(3 marks)

v. Determine the range of K for the system to be stable

(3 marks)

(b) Given a unity feedback control system :

$$G(s) = \frac{k}{s^n(s+a)}$$

Find the value of n, K and a in order to meet specification of 10% overshoot and Kv = 100.

(6 marks)

END OF QUESTION

Appendix 1

Time Response

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

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

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

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

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

$$T_s = \frac{3}{\zeta\omega_n} \text{ for 5\% criteria}$$

Root Locus

$$\angle KG(s)H(s) = -1 = 1\angle(2k+1)180^\circ$$

$$\sigma_a = \frac{\sum finite \quad poles - \sum finite \quad zeros}{\#\, finite \quad poles - \#\, finite \quad zeros}$$

$$\theta_a = \frac{(2k+1)\pi}{\#\, finite \quad poles - \#\, finite \quad zeros}$$

$$\theta = \sum finite \quad zero \quad angles - \sum finite \quad pole \quad angles$$

$$K = \frac{1}{|G(s)H(s)|} = \frac{1}{M} = \frac{\Pi\, finite \quad pole \quad lengths}{\Pi\, finite \quad zero \quad lengths}$$

Frequency Response

$$M_p = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$

$$\omega_p = \omega_n\sqrt{1-2\zeta^2}$$