THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
DIPLOMA IN TECHNOLOGY – LEVEL 4
FINAL EXAMINATION – ACADEMIC YEAR 2007/2008
MEX4243 - CONTROL SYSTEMS ENGINEERING/
ECX4242 - CONTROL SYSTEMS

Date : April 27, 2008 **Time: 0930 - 1230 hrs**

Important:

1. This question paper consists of **eight** questions.
2. Write the answers for the **Section A** and **Section B** in separate answer books.
3. Answer **Q1, which is compulsory,** and FOUR other questions selecting at least ONE from SECTION A and TWO from SECTION B.
4. Present important but relevant facts and information briefly. Any missing information can be sensibly and reasonably assumed provided that you state them clearly. Wherever necessary, use neatly drawn sketches to explain answers.

SECTION A

Q1 Figure Q1 shows an Automatic depth control of a Submarine in the deep sea.

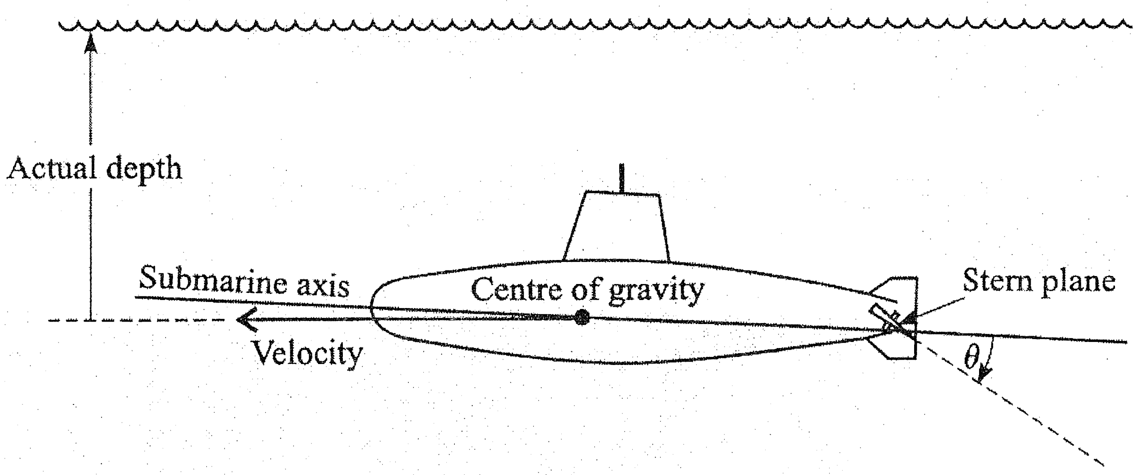


Figure Q1

Suppose the captain of the submarine wants the submarine to hover (float) at a desired depth, and sets the desired depth as a voltage from calibrated potentiometer.

(i) What is the system output? How it can be measured and the type of transducer to be used? Explain briefly.
(ii) What is the system Actuator?
(iii) Propose and explain the operation of this control system.
(iv) Draw a complete block diagram, identifying each block with its function.
(v) Assign G_i's for forward path blocks, H_i's for feedback path blocks ($i = 1, 2, 3, \ldots$) and find the transfer function of the system.

[20 marks]

Q2 The transfer function of a control system is given by

$$T(s) = \frac{4}{2s^2 + Ks + 8}$$

(i) Find the value of under-damped natural frequency.
(ii) Find the value of K such that the damping ratio is equal to 0.5.
(iii) Assume that a unit step function is applied to the input of the above control system. With your value of K, find the rise time, the maximum overshoot and the settling time (with the 2% criterion).
(iv) Mark each result of **Q2** (iii) on an 'amplitude' vs 'time' plot.
(v) How could you reduce the maximum overshoot of this system?

[20 marks]

Q3

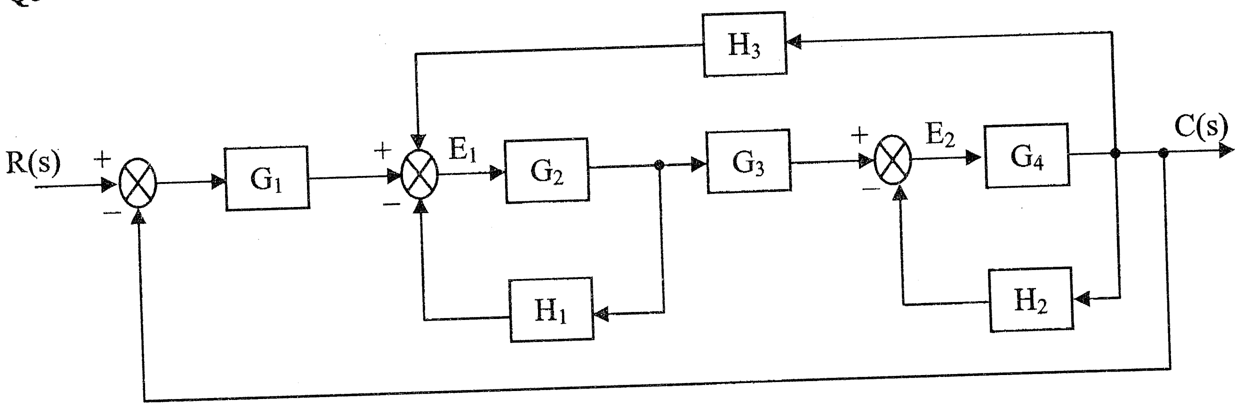


Figure Q3

(i) Draw the signal flow graph for the block diagram given in figure Q3.
(ii) State the Mason's Gain formula and explain each parameter.
(iii) Use Mason's Gain Formula to obtain the transfer function C(s)/R(s) of the system. **(You must clearly show all steps.)**

[20 marks]

Q4

(i) A unity feedback system has the following open loop transfer function.

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

(a) What is the *type* of this system?

(b) For the system, find the following constants:

i. acceleration error   ii. velocity error   iii. position error

(c) For the system, find the steady state errors for the following inputs:

i. a unit parabolic   ii. a unit ramp   iii. a unit step

(ii) Figure Q4 shows a feedback control system.

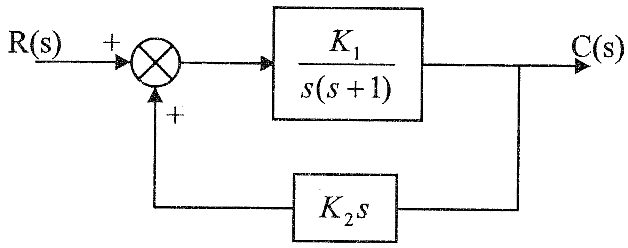


Figure Q4

(a) What is meant by *sensitivity* of a system?

(b) Determine the sensitivity of the system to variations in each of the parameters K_1 and K_2 separately.

[20 marks]

SECTION B

Q5

(i) The stability can be classified as **absolute stability** and **relative stability**. Explain absolute stability and relative stability of a control system.

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

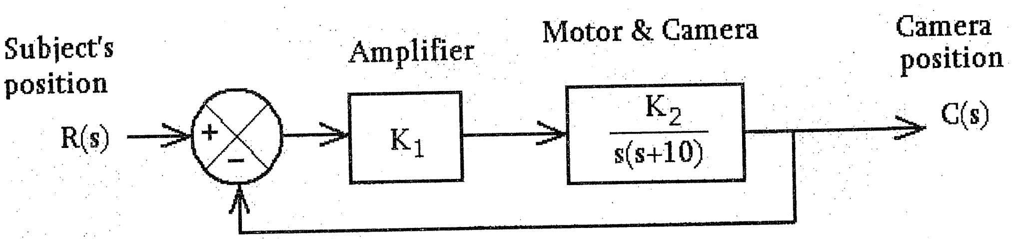
$$G(s)H(s)=\frac{K}{s(s+4)(s^2+2s+2)}$$

(a) Using ***Routh criterion*** determine the range of 'K' for which the system will be stable.

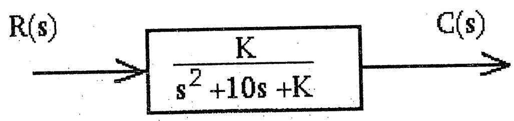
(b) If a zero at $s=-4$ is added to the forward transfer function, how is the stability affected?

[20 marks]

Q6 Assume the block diagram representation of the tracking system of a camera is shown in figure Q6 (a) where the closed loop poles of the system change their location as the gain, K, is varied. Table 1, which was formed by applying the quadratic formula to the denominator of the transfer function in figure Q6 (b), shows the variation of pole location for different values of gain, K.



(a)



where $K=K_1K_2$

(b)

Figure Q6

K	Pole 1	Pole2
0	-10	0
5	-9.47	-0.53
10	-8.87	-1.13
15	-8.16	-1.84
20	-7.24	-2.76
25	-5	-5
30	-5+j2.4	-5-j2.4
35	-5+j3.16	-5-j3.16
40	-5+j3.87	-5-j3.87
45	-5+j4.47	-5-j4.47
55	-5+j5	-5-j5

Table 1

(i) Find the root sensitivity of the system in figure Q6 at $s = -9.47$ and $s = -5 + j5$. Also, calculate the change in the pole location for a 10% change in K.

(ii) Sketch the root locus for the above system and determine the range of "K" for stability.

[20 marks]

Q7 The forward path transfer function of a unity negative feedback control system is given by

$$G(s) = \frac{K}{s(s+2)(s+30)}$$

The system has to satisfy the following specifications:

Phase margin $\geq 35^{\circ}$,
Gain margin $\geq$ 20dB and
Steady state error for unit ramp input ≤ 25.

Design a suitable Lead compensator.

[20 marks]

Q8

(i) The Bode plot of a control system is shown in Figure Q8. Determine the Gain margin and Phase margin of the system. By using bode plot sketch the Nyquist diagram.

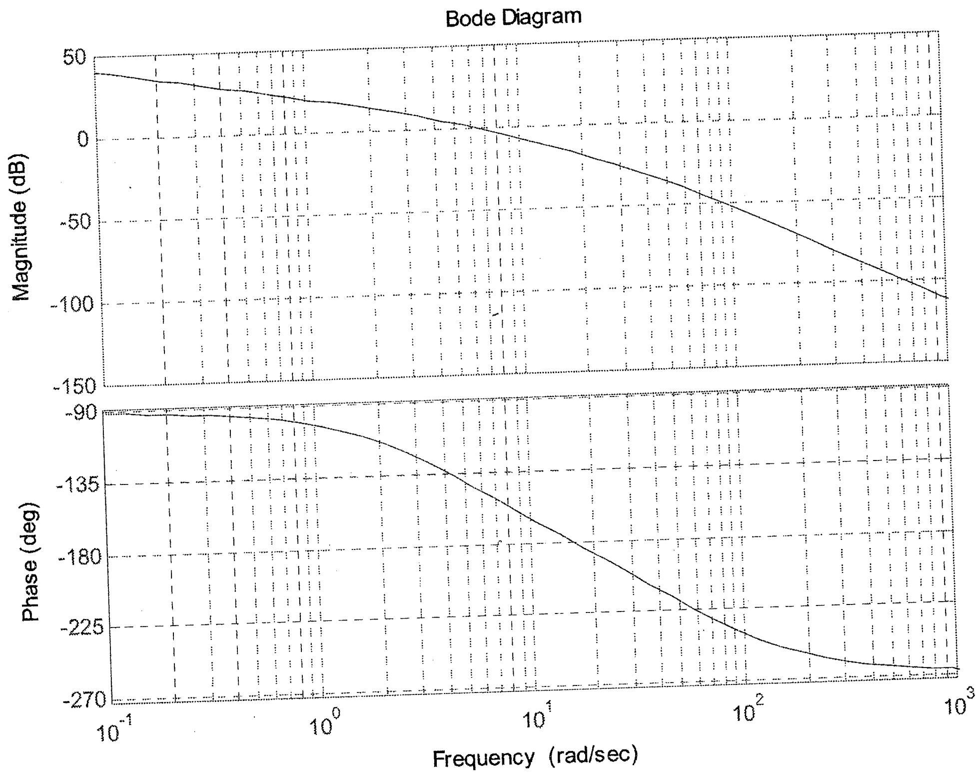


Figure Q8

(ii) Derive the state space equations for following transfer functions.

(a) $\dddot{y} + 7\ddot{y} + 14\dot{y} + 8y = 8u(t)$

(b) $\dfrac{Y(s)}{U(s)} = \dfrac{8}{(s+1)(s+2)(s+4)}$

[20 marks]