The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX4543/MEX4243 Control systems engineering**
Academic Year	: 2019/20
Date	: 20th January 2021
Time	: 0930-1230hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (6)** pages.
3. Write the answers for the Section A and Section B in separate answer books.
4. **Answer Q1**, which is **compulsory** and **FOUR** other questions, selecting at least ONE from **SECTION A** and **TWO (2)** from **SECTION B.** Answer for each question should commence from a new page.
5. Relevant charts / codes are provided.
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear hand writing.
8. Do not use red colour pen.

SECTION A

Q1.

(a) (i) Provide 2 advantages and 2 disadvantages of open loop control systems.

(ii) Explain how you overcome the above-mentioned disadvantages using a closed loop control system with a simple example. [05]

(b) An antenna azimuth (Direction that antenna is pointing) position control system is shown in Figure Q1. The purpose of the system is to adjust the azimuth angle of the antenna.

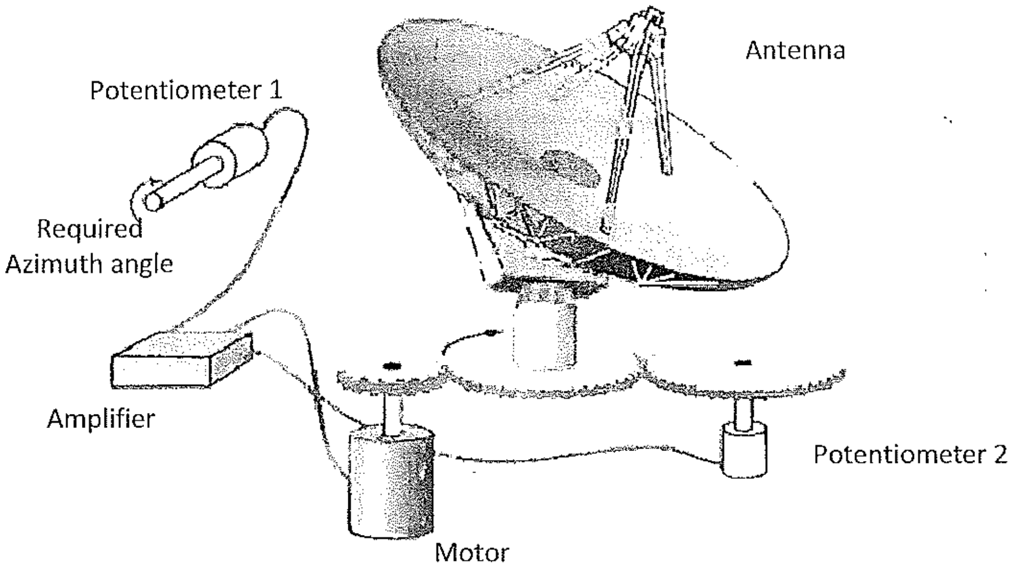


Figure Q1

(i) What is the system output? What type of transducer is used for measuring the output? [02]

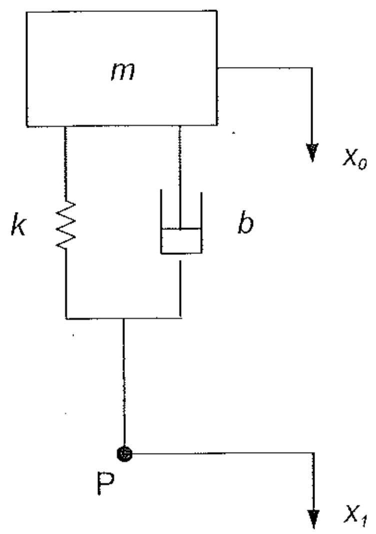
(ii) What is the system Actuator? What type of transducer is used here? [02]

(iii) Briefly explain the operation of this control system highlighting the function of each relevant component. [05]

(iv) Draw a complete block diagram of this control system. [06]

Q2.

(a) Figure Q2 shows a simplified version of a vehicle suspension system. Assume that the motion at X_I at point P is the input to the system and vertical motion X_0 of the vehicle body is the output. Consider the motion of the body is only in the vertical direction. Displacement, X_0 is measured from the equilibrium position in the absence of input X_I.



(i) Draw the free body diagram of the system. [04]

(ii) Obtain the differential equation which describes the system. [03]

(iii) Hence obtain the system transfer function $G(s) = X_0(s)/X_1(s)$ [03]

Figure Q2(a)

(b) The Step response of a negative feedback second order system is shown in figure Q2(b).

(i) Use this diagram to find the following parameters:

(a) Percent Overshoot of the system. [02]

(b) Damping ratio of the system. [02]

(c) Natural frequency [02]

(ii) Hence deduce the transfer function of the system. [02]

(iii) Comment on how the damping ratio affects the stability of the system. [02]

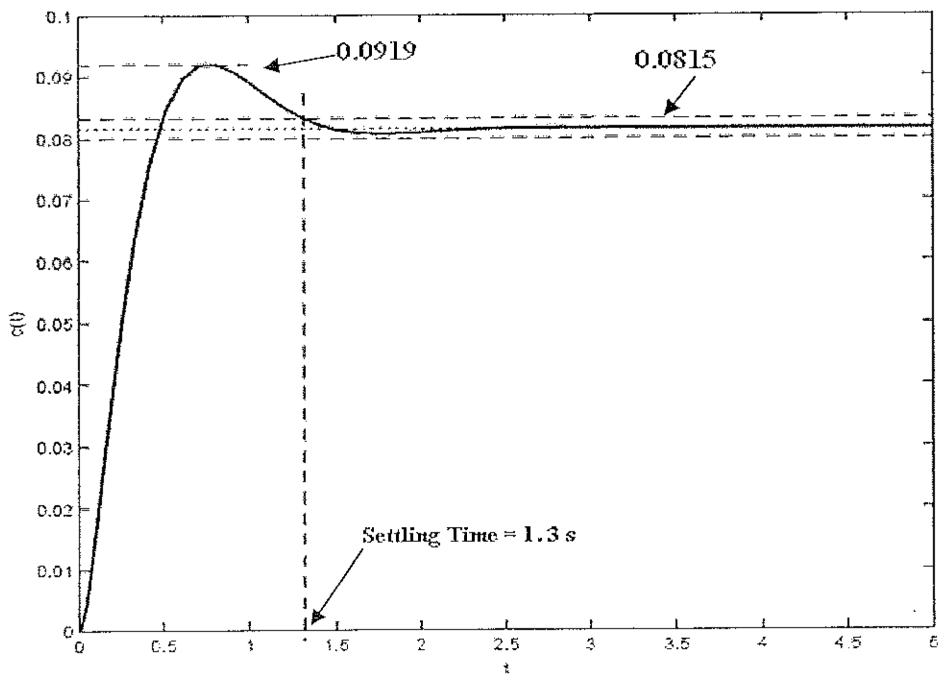


Figure Q2(b)

Q3

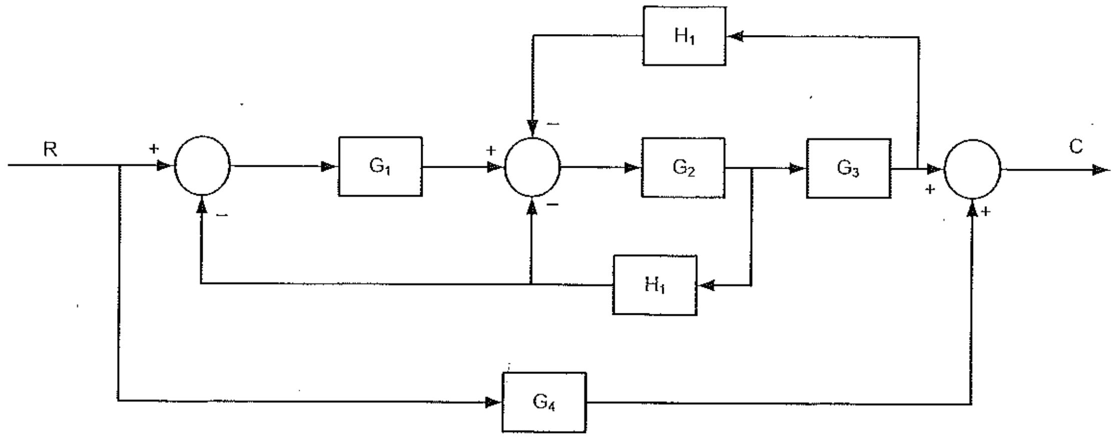


Figure Q3

(a) Draw the signal flow graph for the block diagram given in figure Q3. [10]

(b) Use Mason's Gain Formula to obtain the transfer function C(s)/R(s) of the system. (Clearly show all steps.) [10]

Q4.

(a) Explain the difference between <u>Order</u> and <u>Type</u> of control systems. [4]

(b) What is meant by Sensitivity of control systems? Explain briefly. [4]

(c) Figure Q4 shows the block diagram of a control system. K_1 and K_2 are constants.

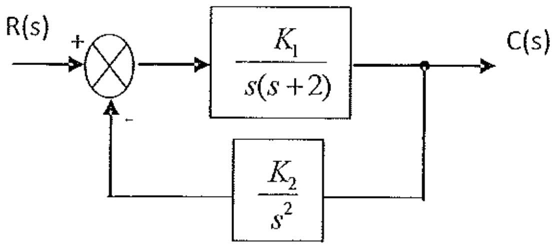


Figure Q4

i) Find the Order and Type of the above system. [4]

ii) Find the Sensitivity of the system separately with respect to K_1 and K_2. [8]

SECTION B

Q5

(a) A unity feedback system is characterized by the open- loop transfer function

$$G(s) = \frac{K(s+3)}{s(s+7)}$$

Using the Routh criterion, calculate the range of values of K for the system to be stable.

(b) A feedback control system has a open-loop transfer function

$$G(s)H(s) = \frac{K}{s(s+3)(s^2+2s+2)}$$

Find the root locus as K is varied from 0 to ∞.

(c) Hence find the range of ***K*** to keep the system stable.

Q6

(a) Define following terms.

i. Gain margin
ii. Phase margin
iii. Phase crossover point

(b) Sketch the Bode plot for a unity feedback system, characterized by the open loop transfer function

$$G(s) = \frac{K(1+0.2s)}{s(1+0.02s)}$$

Show that the system is conditionally stable. Find the range of values of K for which the system is stable.

Q7

(a) Sketch the Nyquist plot and determine stability of the open-loop transfer function of unity feedback control system.

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

(b) Sketch the Nichols Chart and determine the Main Margin and Phase Margin of unity feedback control system.

$$G(s) = \frac{20(s+2)}{s(s+10)}$$

Q8

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

$$G(s) = \frac{K}{s(s+3)(s+30)}$$

The system has to satisfy the following specifications:
Phase margin$\geq$35°
Gain Margin $\geq$20dB and
Steady state error for unit ramp input $\leq$25

Design a suitable Lead Compensator.

END