00199

The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX4243 – Control Systems Engineering**
Academic Year	:	2012/13
Date	:	18th August 2013
Time	:	0930hrs-1230hrs
Duration	:	3 hours

General instructions

1. This question paper has 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.**

SECTION A

Q1 (a) Differentiate the following systems giving a simple example for each.

(i) Open loop control vs closed loop control

(ii) Feedback control vs feed forward control [06 marks]

(b) Figure Q1 depicts a control system which can be used to control the temperature of a chemical processing plant:

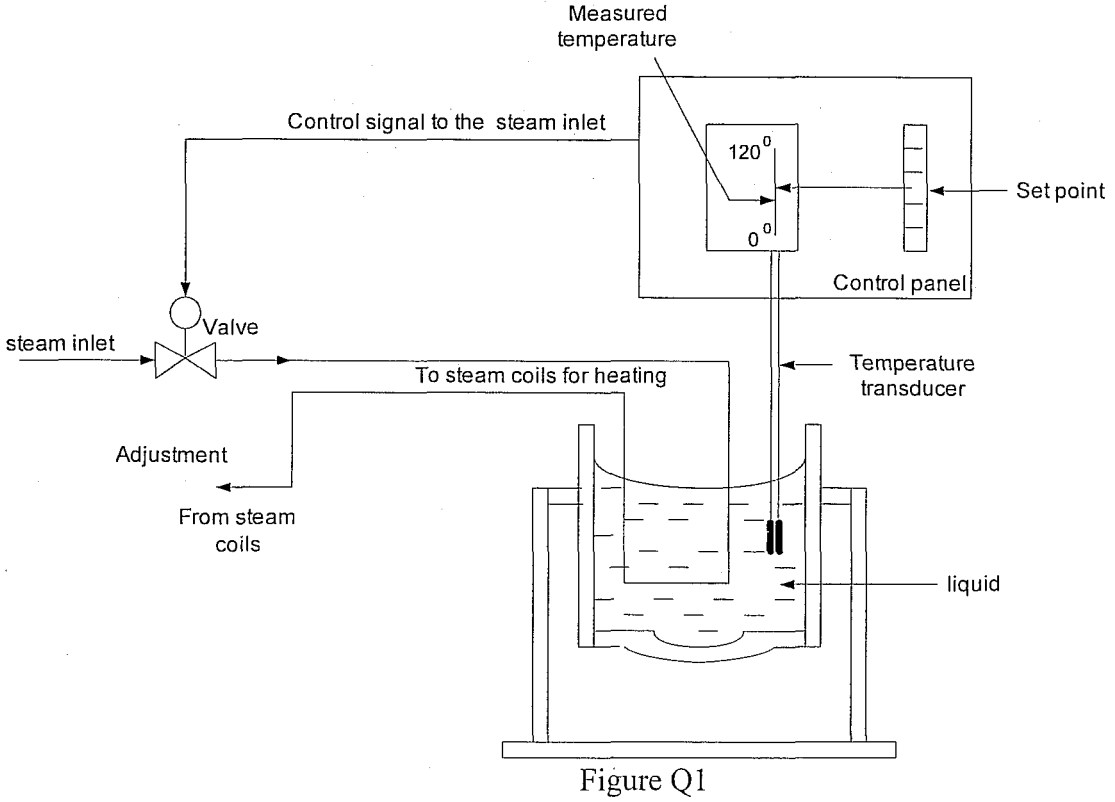


Figure Q1

(i) By studying the diagram in Figure Q1, explain the operation of this control system. [03 marks]

(ii) Draw a complete block diagram of this control system showing all necessary parameters and state the functions of each block. [05 marks]

(iii) Assuming that the transfer function of the processing plant is $G_p(s)$, gain of the temperature transducer is K_T, Gain of the controller is K_C and the gain of the control valve is K_V, find

a. Forward transfer function

b. Open loop transfer function

c. Closed loop transfer function

d. Error function of the above system. [06 marks]

Q2 Figure Q2 shows a block diagram representation of a feedback control system.

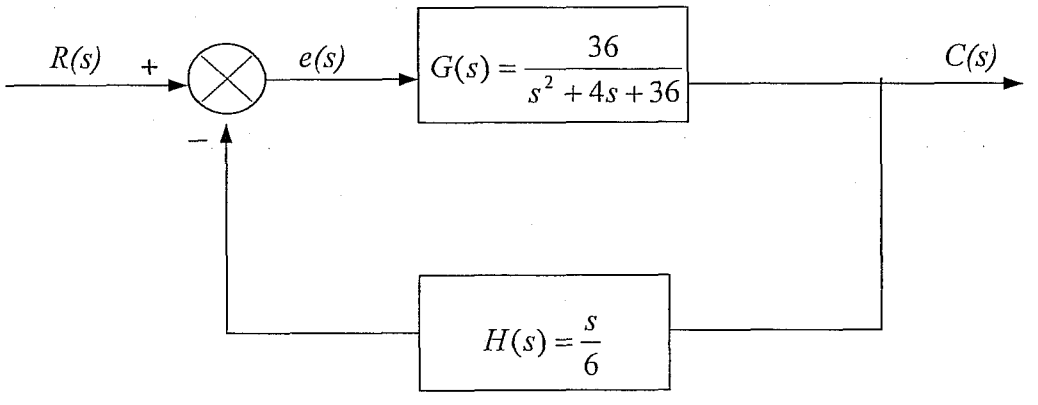


Figure Q2

(a) Find the closed loop transfer function. [02 marks]

(b) Write the characteristic equation of the system and find its roots. Locate these roots in the s-plane. [04 marks]

(c) Hence identify the nature of the unit step response. [02 marks]

(d) For a unit step input calculate,
(i) the natural frequency
(ii) the damping ratio
(iii) the maximum overshoot and
(iv)thesettling time (with the 2% criterion) of the system.
[08 marks]

(e) Obtain an expression for the output in time domain when a unit step input is given to the system. [04 marks]

Q3

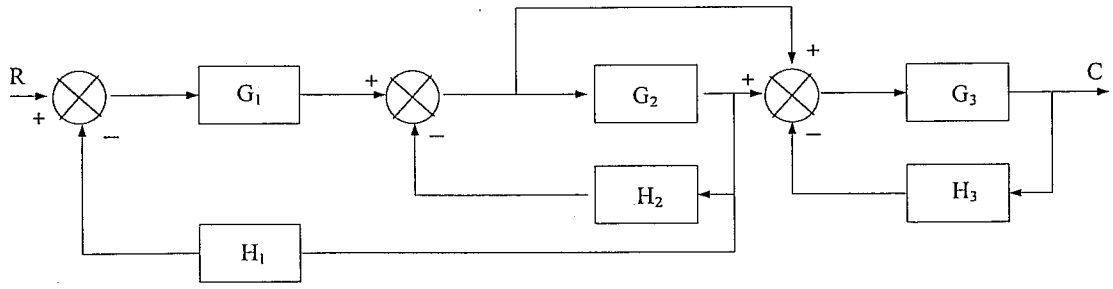


Figure Q3

(a) Reduce the block diagram shown in Figure Q3 to a single transfer function. [10 marks]

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

Q4

(a) Discuss the importance of the following when designing a control system:

(i) steady state error
(ii) static error constants
(iii) sensitivity [06 marks]

(b) Given the unity feedback system in figure Q4,

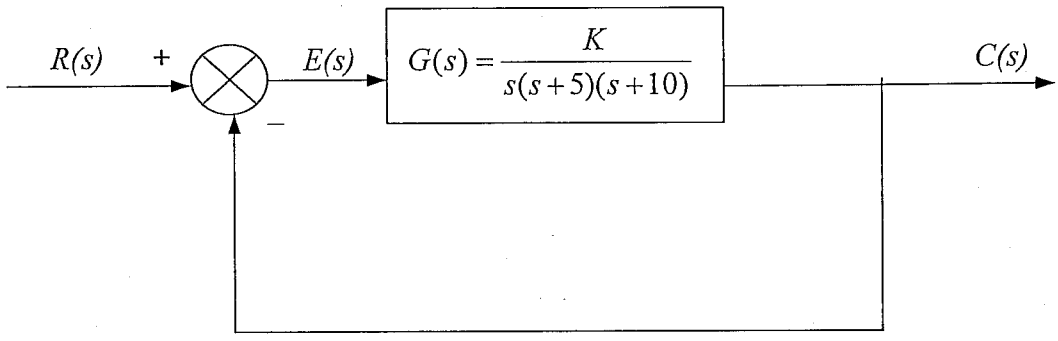


Figure Q4

(i) What is the *type* of this system? [02 marks]

(ii) Obtain an expression for the steady state error of the above system in terms of $R(s)$ and $G(s)$. [04 marks]

(iii) What value of K will yield a steady-state error of 0.01 for an input of $\left(\frac{1}{10}\right)t$? [04 marks]

(iv) What is the velocity error constant K_v for the value of K found in above part (iii)? [02 marks]

(v) Find the sensitivity of the steady state error to changes in parameter K for the input given in part (iii). [02 marks]

SECTION B

Q5

The TWIN ROTOR MIMO SYSTEM (TRMS) is shown in Figure Q5. It serves as a model of a helicopter and some of the important characteristics present in a helicopter are captured in the TRMS model with some significant simplifications. They are *TRMS is attached to a tower* and *helicopter position and velocity is controlled through the rotor velocity variation.* In a real helicopter, the angle of the rotor blades can be modified. Like in a real helicopter there is significant cross coupling between the two rotors. For instance, if we increase the speed of the main rotor, the helicopter will also turn in the horizontal plane.

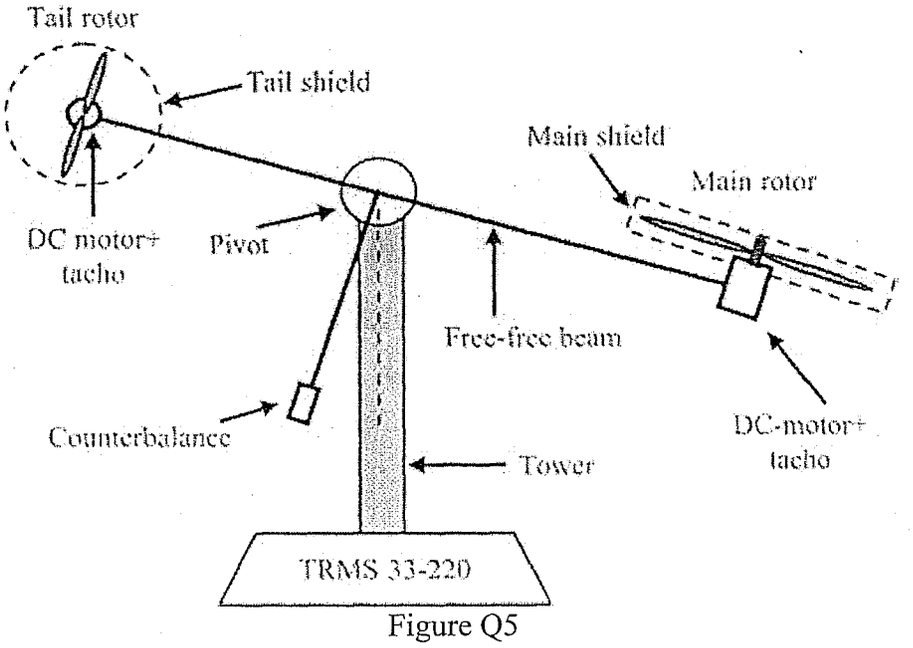


Figure Q5

(a) Identify the system inputs and outputs? What types of transducers are used for measuring the output signals? [5 marks]

(b) What are the system actuators? What types of transducers are used here? [5 marks]

(c) Draw a complete block diagram of this control system. [5 marks]

(d) Briefly explain what are the external disturbances for this control system? Indicate them on the block diagram you have drawn in part (c). [5 marks]

Q6

A unity negative feedback control system has the open loop transfer function

$$G(s)H(s) = \frac{K}{s^2(s+2)}$$ where K is a positive constant.

(a) Determine the characteristic equation of the system. [4 marks]

(b) Sketch the Root Locus as K increase from 0 to ∞, starting from the locations and directions of significant features of the diagram. [8 marks]

(c) The system is modified so that

$$G(s)H(s) = \frac{K}{s(s+2)(s+\alpha)}$$ where α is a positive constant.

Now determine the modified characteristic equation and describe the effect on the Root Locus as the value of α is increased from 0 to ∞. Detailed work is not necessary for this part. Just show how the Root Locus changes by using a simple sketch.[8 marks]

Q7

(a) State the advantages of bode plot. [2 marks]

(b) A unity negative feedback control system has a forward transfer function, $G(s) = \frac{Ks}{(s+1)(s^2+4s+2)}$. Draw asymptotic bode plot. [14 marks]

(c) Mark the phase margin and gain margin and hence comment on the stability of the system. [4 marks]

Q8

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

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

Design a lead compensator for this system to meet the following specifications:
Damping ratio ζ=0.7
Setting time $t_s = 1.4sec$
Velocity error constant $K_v = 2sec^{-1}$. [20 marks]

END