00162

The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	**:**	**MEX4243- Control systems engineering**
Academic Year	:	2014/15
Date	:	21st September 2015
Time	:	1330hr-1630hr
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper has **eight** questions.
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 from SECTION B.
5. 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(a) Briefly explain the following giving a simple example for each.

(i) Feed forward control system
(ii) Positive feedback control system
(iii) Nonlinear control system [06 marks]

(b) Consider the inverted pendulum shown in Figure Q1. The objective is to keep the pendulum in the upright position. That is to keep $\theta = 0$ in the presence of disturbances.

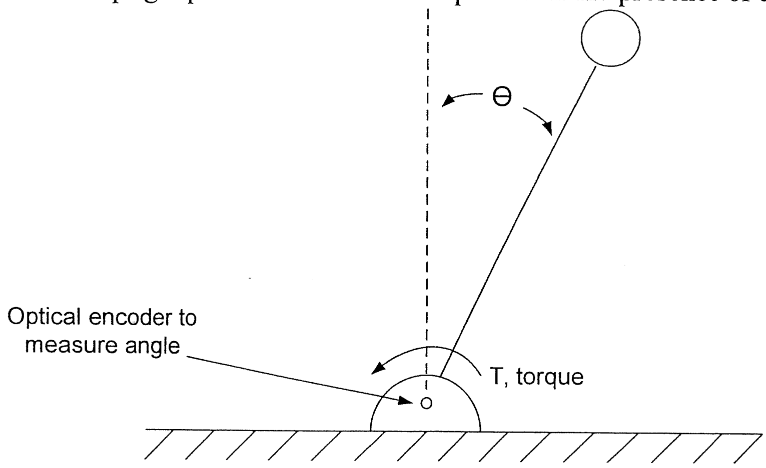

Figure Q1

(i) By studying the diagram in Figure Q1, explain how the system operates to achieve the objective.

(ii) Suggest a method to provide the necessary torque in this system.

(iii) Draw a complete block diagram of this control system showing all necessary parameters and state the functions of each block.

(iv) Assume that the pendulum is mounted on a moving cart which has a linear motion, how the operation differs from the system in Figure Q1?

[14 marks]

Q2

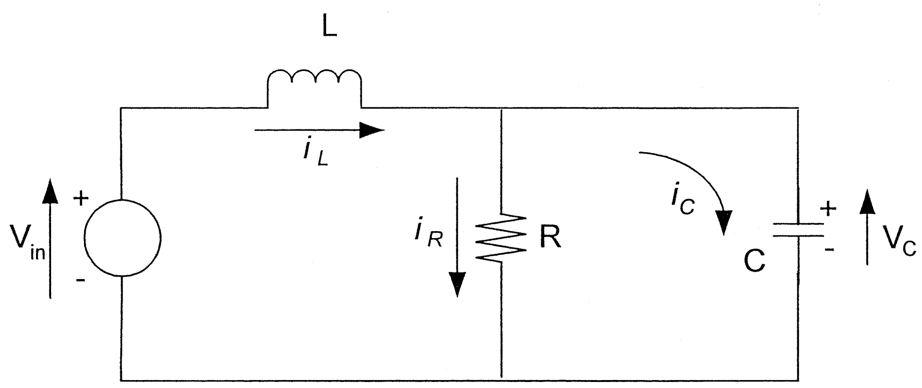

Figure Q2

(a) Explain the advantage of using state space approach over the transfer function approach for analysis and design of control systems. [04 marks]

(b) By writing the necessary differential equations, find the transfer function $G(s) = V_C(s)/V_{in}(s)$ of the circuit given in Figure Q2. [08 marks]

(c) Hence develop the state equation and the output equation by considering i_c as the output variable. [08 marks]

Q3

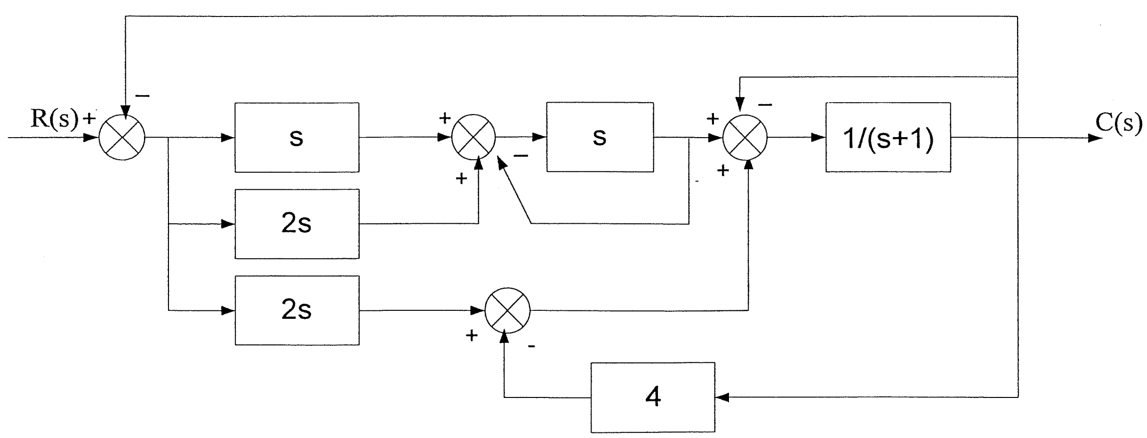

Figure Q3

(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(s)/R(s) of the system. **(You must clearly show all steps.)** [10 marks]

Q4

(a) Briefly describe the following terms related to the behavior of a control system.

(i) Transient analysis

(ii) Steady state analysis [04 marks]

(b) Consider the closed loop system shown in Figure Q4.

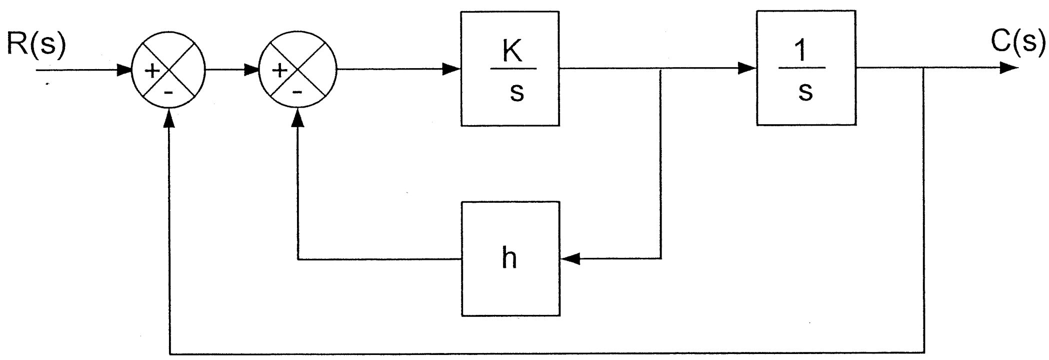

Figure Q4

(i) Obtain the open loop transfer function, G(s) and the closed loop transfer function, T(s) of the control system shown in figure Q4.

[04 marks]

(ii) Identify the system type of the above system. [02 marks]

(iii) Derive an expression for the steady state error in terms of G(s) and calculate the steady state error due to a ramp input. [05 marks]

(iv) Determine the values of K and h so that the maximum overshoot in unit step response is 25% and the peak time is 2 sec. [05 marks]

SECTION B

Q5

The output of a control system is related to its input by

$$[2s^3 + 2s^2 + (3 + K)s + K]C(s) = K(s + 1)R(s)$$

where **K** represents the positive gain of an amplifier.

(a) With K=6 and a step input, will the output response be stable? [10 marks]

(b) Using the Routh criterion, calculate the range of values of K for the system to be stable. [10 marks]

Q6

A feedback control system has a open-loop transfer function

$$G(s)H(s) = \frac{K}{s(s + 4)(s^2 + 4s + 20)}$$

(a) Find the root locus as ***K*** is varied from 0 to ∞. [15 marks]

(b) Hence find the range of ***K***to keep the system stable. [05 marks]

Q7

(a) Define the following terms.

i) Gain margin
ii) Phase margin
iii) Gain crossover point
iv) Phase crossover point

[08 marks]

(b) A servomechanism has an open-loop transfer function of

$$G(s) = \frac{10}{s(1 + 0.75s)(1 + 0.2s)}$$

Draw the Bode plot and determine the phase and gain margins. A network having the transfer function $(1 + 0.2s)/(1 + 0.02s)$ is now introduced in tandem. Determine the new gain and phase margins. Comment upon the improvement in system caused by the network.

[12 marks]

Q8

(a) Describe and compare the characteristics of

i) Proportional Controller.
ii) Proportional plus Integral Controller.
iii) Proportional plus Integral plus Derivative Controller.

[06 marks]

(b) The closed loop transfer function of a control system is given by

$$G(s) = \frac{16}{s^2 + 1.6s + 16}$$

Determine the derivative feedback constant K_d, if it is desired to have the damping ratio to be 0.8.

[06 marks]

(c) Derive the state space equation for following transfer functions.

i) $\dddot{y} + 7\ddot{y} + 6\dot{y} + 5y = 4u(t)$

ii)
$$\frac{Y(s)}{U(s)} = \frac{5}{(s-1)(s+2)(s+3)}$$

[08 marks]

-END-