00263

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	:	2016/17
Date	:	25th November 2017
Time	:	0930hr-1230hr
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **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 2 from **SECTION B.**
5. State important, but relevant facts and information briefly and clearly. Where ever necessary, use neatly drawn sketches to explain answers.

SECTION A

Q1.

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

(i) Positive Feedback VS Negative Feedback Control systems.

(ii) Feedback control systems VS Feed forward control systems. [2 marks]

(b) Figure Q1-(a) shows a wheeled human transportation vehicle **(WHTV).**

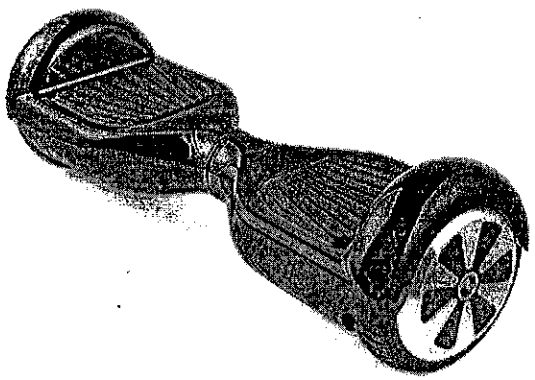


Figure Q1-(a)

In the past decade, lightweight and uncomplicated vehicles have been created for use as individual conveyance tools. Many passenger transportation vehicles such as two-wheeled cars, single-wheeled motorcycles and bicycles have been developed. **WHTV** is a simple electric moving platform and a modern model of individual conveyance tools. **WHTVs** have superior maneuverability (a strategic way to change its movement) and are appropriate for use in urban areas. The self-balancing **WHTV** is actively controlled to allow safe and easy transportation of a single person.

(i) Draw the block diagram of this feedback control system by clearly showing each and every blocks and variables. [5 marks]

(ii) Describe how the closed-loop feedback control system assists the rider of the WHTV in balancing and maneuvering the vehicle. [2 marks]

(c) Figure Q1- (b) shows a mechanical vibratory system. When a 2N force (step input) is applied to the system, the mass oscillates as shown in Figure Q1-(c).

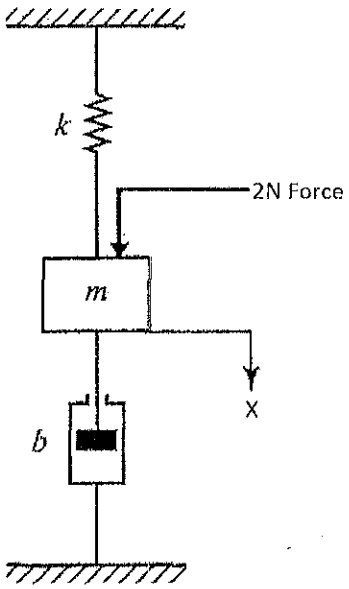


Figure Q1-(b)

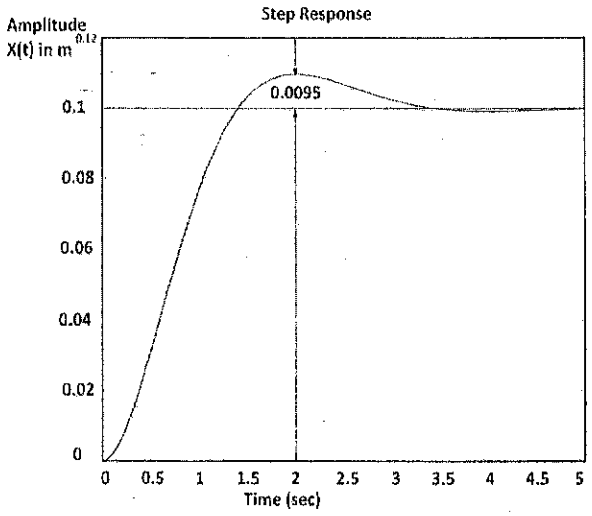


Figure Q1-(c)

(i).Draw the free body diagram of the mechanical vibratory system. [2 marks]

(ii).Obtain the transfer function for the system. [2 marks]

(iii).Determine 'm', 'b', and 'k' of the system from the response curve. The displacement 'x' is measured from the equilibrium position. [7 marks]

Q2.

(a) Define the following terms related to 2nd Order Control Systems.

(i) Peak Time (iii) Rise Time
(ii) Settling Time (iv) % Over Shoot [2 marks]

(b) How do the following responses of a 2nd Order systems behave when applying a step input?

(i) Over damped (ii) Under damped (iii) Critically Damped [3 marks]

(c) Consider the closed loop system shown in figure Q2.

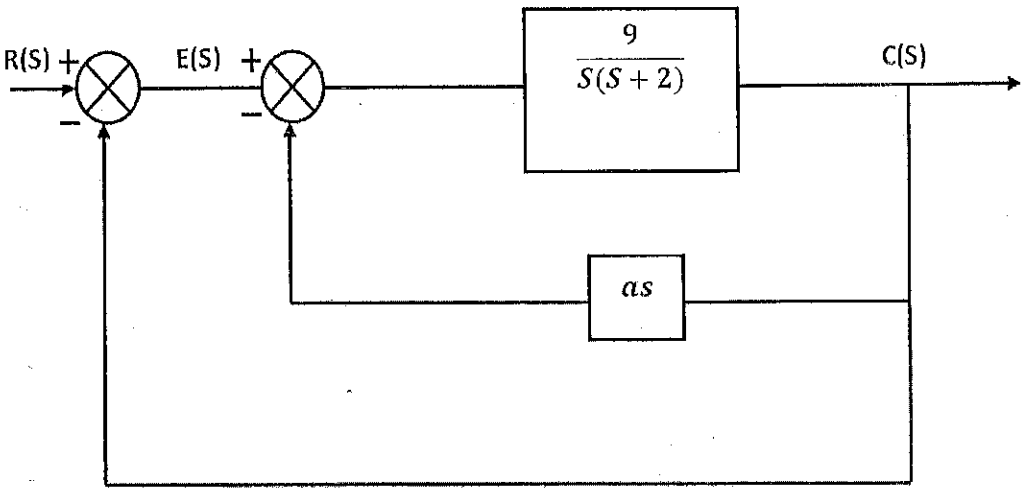


Figure Q2

i. In the absence of derivative feedback (a=0), determine the damping factor and the natural frequency. [4 marks]
ii. Determine the steady state error resulting from a unit ramp input. [2 marks]
iii. Determine the derivative feedback constant a, which will increase the damping factor of the system to 0.7. [5 marks]
iv. What is the steady state error to unit ramp input with this setting of the derivative feedback constant? [4 marks]

Q3.

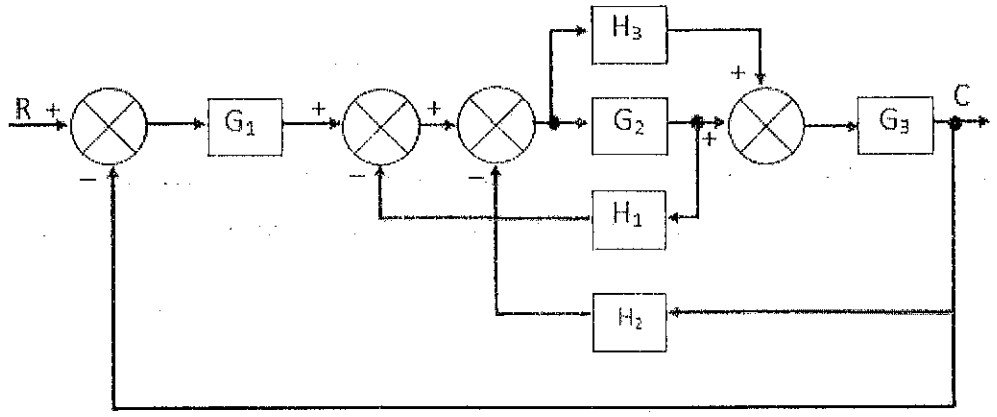


Figure Q3

(a) Reduce the block diagram shown in Figure Q3 to a single transfer function. [6 marks]

(b) Draw the signal flow graph for the block diagram. [6 marks]

(c) Use Mason's Gain Formula to obtain the transfer function C(s)/R(s) of the system. **(Clearly show all steps).** [8 marks]

Q4.

(a) Define the following terms with respect to a control system.

(i) Steady state error

(ii) Static error constant

(iii) Sensitivity [3 marks]

(b) Figure Q4 shows a feedback control system.

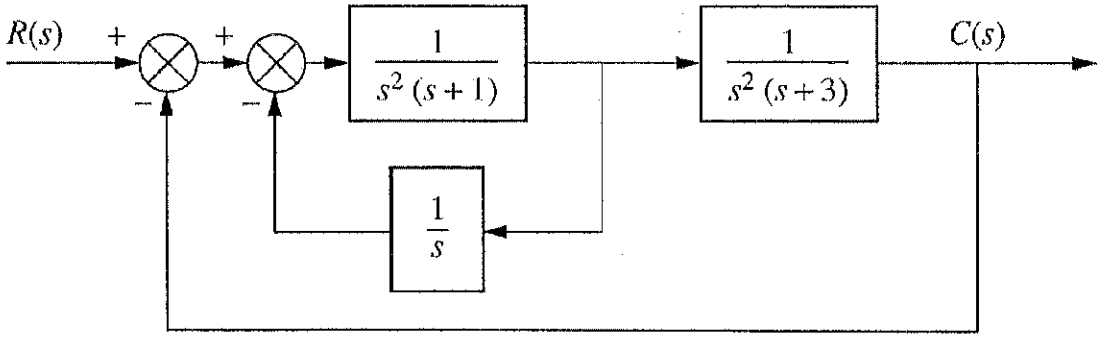


Figure Q4

i Find the closed-loop transfer function C(s)/R(s). [4 marks]

ii What is the type of the system? [2 marks]

iii Find the steady-state error for an input of ***5u(t).*** [3 marks]

iv Find the steady-state error for an input of ***5tu(t).*** [3 marks]

v Discuss the validity of your answers to Parts **iii** and **iv.** [2 marks]

(c) Consider a feedback control system in which the open loop transfer function is $G(s) = \frac{k}{S(S+P)}$ and the feedback factor $H(s) = (1+\alpha s)$. Determine the sensitivity of its closed loop transfer function with respect to α, when $k = 12, P = 3$ and $\alpha = 0.14$. [3 marks]

SECTION B

Q5.

(a) Find the roots of the characteristic equations for the systems whose open loop transfer functions are given below. Locate the roots in s-plane and indicate the stability of each system.

i) $G(s)H(s) = \frac{(s+3)}{s(s+3)(s+8)}$ [3 marks]

ii) $G(s)H(s) = \frac{9}{s^2(s+2)}$ [3 marks]

(b) The characteristic equation of a servo system is given by:

$$a_0s^4 + a_1s^3 + a_2s^2 + a_3s + a_4 = 0$$

State the conditions which must be satisfied by the coefficients of the characteristic equation for the system to be stable. [4 marks]

(c) A system oscillates with frequency ω, if it has poles at $s = \pm j\omega$ and no poles in the right half s-plane. Determine values of K and α, so that the system shown in figure Q5 oscillates at a frequency 2 rad/sec.

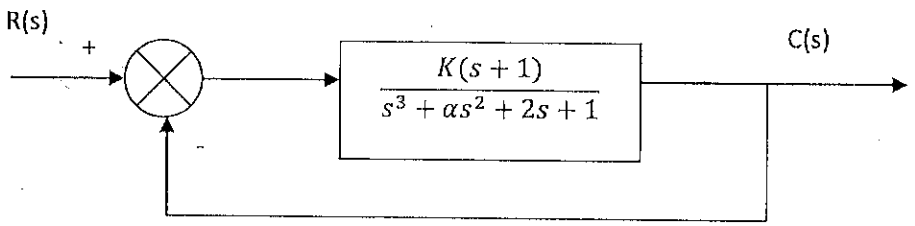


Figure Q5

[10 marks]

Q6.

A tape recorder has a speed control system, so that $H(s) = 1$ with negative feedback, and

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

a) Sketch a root locus for K is varied for 0 to ∞. [12 marks]

b) Hence find the range of K to keep the system stable. [4 marks]

c) Show that the dominant roots are $s = -0.35 \pm j0.80$ when K=6.5. [4 marks]

Q7.

(a) Write an expression for a ***Lead Compensation*** transfer function and define each terms. [4 marks]

(b) The open loop transfer function of a unity feedback system is given by,

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

It is desired to have the velocity error constant K_v as $12\,\text{sec}^{-1}$ and phase margin as 40^0. Design a lead compensator using ***Bode Plots*** to meet the above specifications.

[16 marks]

Q8.

(a) Define the following controllers and write Laplace transform for each controller.

i. P controller [1 marks]
ii. I controller [1 marks]
iii. D controller [1 marks]

(b) Write the possible combinations of P, I and D controller which could be used in control systems applications. [4 marks]

(c) Write the Laplace transform for PID controller. [3 marks]

(d) For the unity feedback system shown in Figure Q8, the damping ratio is required to be made 0.8, by using derivative control. Calculate the value T_d and compare the rise time, peak time and maximum overshoot for the system with and without a derivate controller.

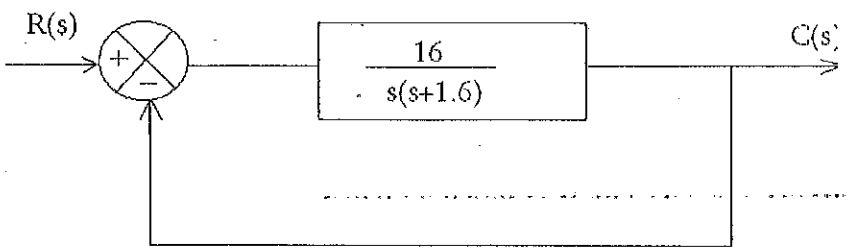


Figure Q8

[10 marks]

END