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	:	2015/16
Date	:	03rd December 2016
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 TWO from SECTION B.
5. Present important, but relevant facts and information briefly. Any missing information can be sensible and reasonably assumed provided that you state them clearly. Wherever necessary, use neatly drawn sketches to explain answers.

SECTION A

Q1.

(a) Figure Q1(a) shows the operation of a cruise control system of a vehicle.

Cruise control allows the driver to set the vehicle speed and when this control is activated the speed of the vehicle is maintained automatically without touching the accelerator pedal. It continually monitors the vehicle speed while controlling the throttle valve to keep the speed at the set value.

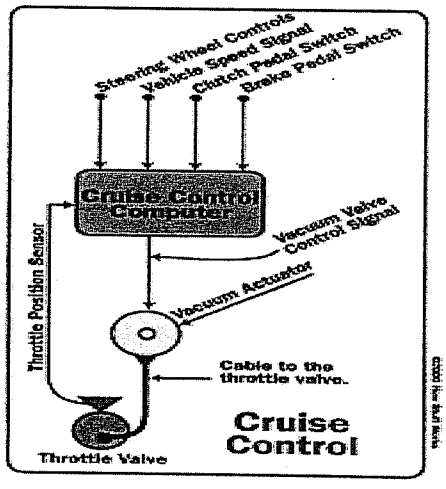


Figure Q1(a)

(reference: http://auto.howstuffworks.com/cruise-control3.htm)

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

(ii) Usually cruise control is applied when a vehicle is running on a long flat highway. Explain how this system will work when the vehicle climbs up a hill. [3 marks]

(b)

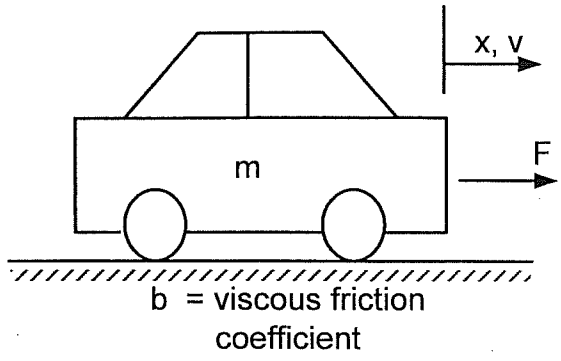


Figure Q1(b)(i) – When the car travels on a flat road

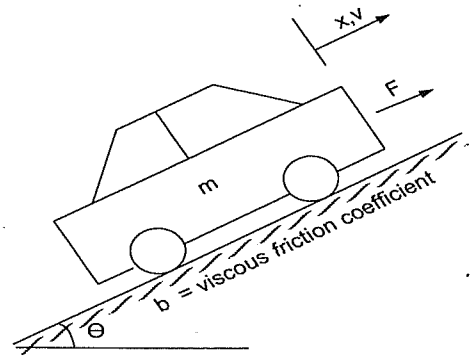


Figure Q1b(ii)- When the car climbs up a hill with an angle θ.

Consider a cruise control system given in Figure Q1(b)(i) above, in which the force generated by the engine of the car is F(t), the mass of the car is m, the velocity is v(t) and the displacement of the car is x(t). Viscous friction coefficient of the road is given as b. Figure Q1b(ii) shows the situation when the car climbs up a hill.

(i) Draw the free body diagrams of the car for both situations in Figure Q1(b)(i) and Q1(b)(ii). [6 marks]

(ii) Write the necessary differential equations for both situations. [4 marks]

(iii) Derive a time domain model for the system in terms of the displacement, x(t) considering both cases. [2 marks]

Q2. (a) Define the following terms related to 2nd order control systems

(i)	Percent Overshoot	(iii)	Rise time	
(iii)	Peak time	(iv)	Settling time	[8 marks]

(b) System performance specifications are often given in the time domain. Consider the following specifications:
Percent Overshoot $\leq$ 16%, Settling Time (2%) $\leq$ 2 s and Peak Time $\leq$ 0.8 s

Based on these specifications, answer the following questions.

(i) Sketch the lines defining each of these specifications in the s-plane. Shade the area of the graph that meets all three specifications. Be sure to indicate which line(s) correspond to which specification.

(ii) Determine a 2nd order transfer function that meets the first two specifications exactly (i.e. %OS = 16% and Settling Time = 2s).

(iii) Sketch the step response for the transfer function found in Q2(b)(ii) showing the peak time, settling time and percent overshoot on your sketch. [12 marks]

Q3.

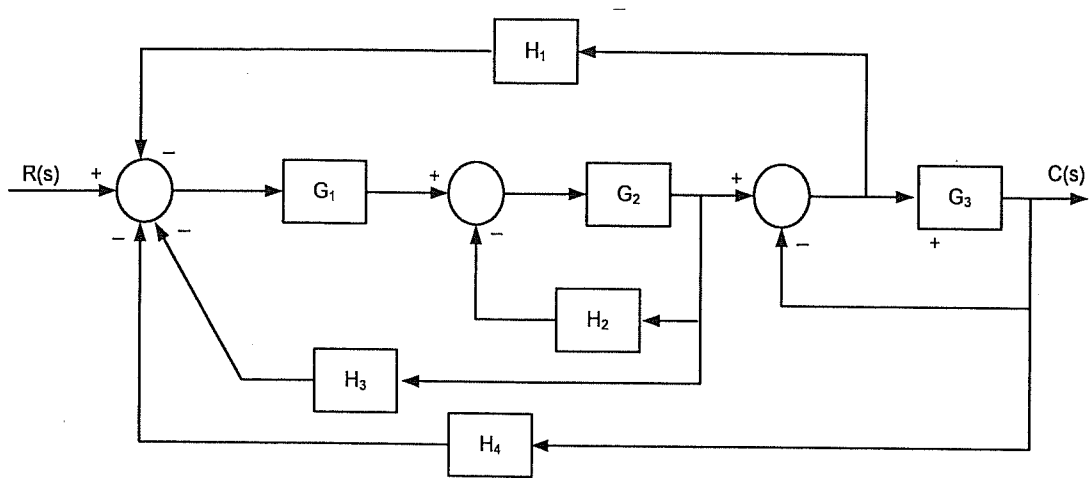


Figure Q3

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

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

Q4.

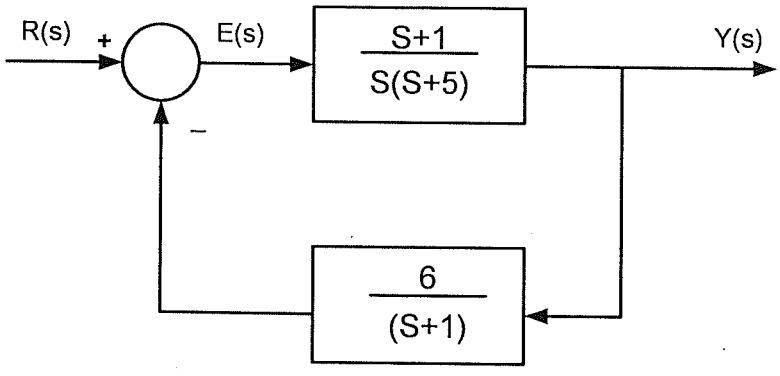


Figure Q4

(a) Find the transfer functions Y(s)/R(s) and E(s)/R(s) of the feedback control system shown in figure Q4. [4 marks]

(b) What is the type of this system? [2 marks]

(c) Compute the associated error constants of the system. [4 marks]

(d) Find the steady state output y(∞) and steady state error output e(∞) for a step input. [6 marks]

(e) Find the step response for the output y(t). [4 marks]

SECTION B

Q5. (a) The characteristic equation of a servo system is given by:

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

Determine the conditions which must be satisfied by the coefficients of the characteristic equation for the system to be stable. [10 marks]

(b) A unity negative feedback control system has an open-loop transfer function

$$G(s) = \frac{Ke^{-sT}}{s(1+s)(1+0.5s)}$$

Using Routh stability criterion, determine the range of valves of K . [10 marks]

Q6. (a) Define the following terms.

(i) Complementary Root Loci (CRL)
(ii) Root Contours (RC) [4 marks]

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

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

Find the root locus as ***K*** is varied from 0 to ∞. [11 marks]

(c) Hence find the range of ***K*** to keep the system stable. [5 marks]

Q7. (a) Determine the resonant frequency , resonance peak and bandwidth for the system whose transfer function is given by $\frac{C(s)}{R(s)}$.

$$\frac{C(s)}{R(s)} = \frac{5}{s^2+2s+5}$$ [8 marks]

(b) Sketch the asymptotic bode plot for a unity feedback system characterized by a loop transfer function

$$G(s) = \frac{K(1+0.5s)}{s\ (1+0.002s)}$$

Show that the system is continuously stable. Find the range of values for which the system is stable. [12 marks]

Q8. The open loop transfer function of a unit feedback system is given by

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

It is desired to have the velocity error constant K=12 and phase margin as 40^0 . Design a lead compensator to meet above specification.

[20,marks]

End