UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 6 Examination in Engineering: November 2014

Module Number: EE6319 **Module Name: Control Theory**

[Two Hours]

[Answer **all questions**, each question carries **7.5 marks**]
Note: A table of Laplace Transformation is attached

Q1 a)

i) Describe the terms manual control system and automatic control system in control system design.

ii) Explain the difference between open loop control and closed loop control.

iii) Draw a block diagram to illustrate a general feedback control system and briefly explain the terms sensor, controller, actuator and disturbance of the system you have drawn.

iv) What is the purpose of having summing junction in the system you have drawn above (iii)?

v) What is the purpose of the input filter in a feedback control system? [4.0 Marks]

b) Figure Q1 (b) shows an electrical circuit involving an RC network.

i) Obtain an expression for i(t) in terms of $e_i(t)$, $e_o(t)$, R_1 and C_1.

ii) Obtain an expression for $e_o(t)$ in terms of C_2, R_2 and i(t).

iii) Hence, obtain the transfer function $E_o(S)/E_i(S)$. State any assumptions you have made.

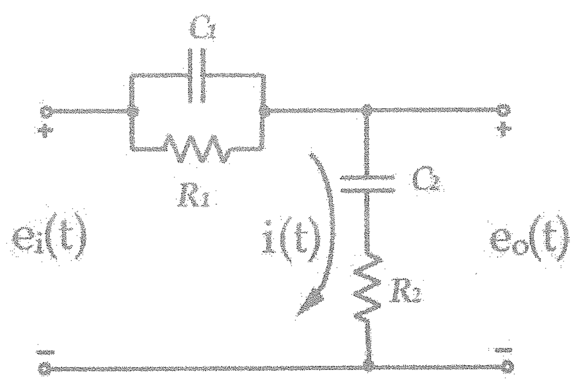
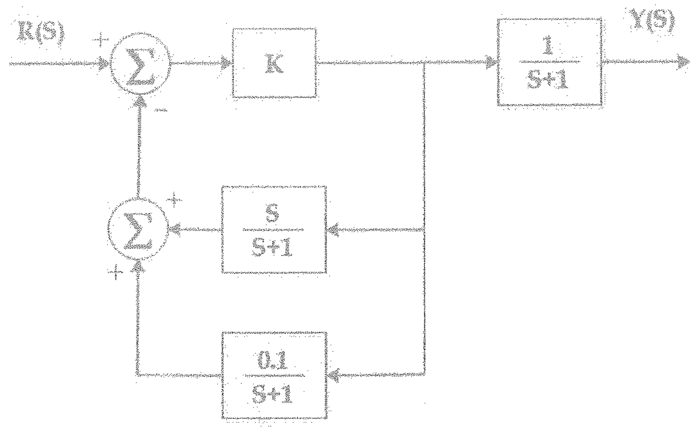


Figure Q1(b):RC Network

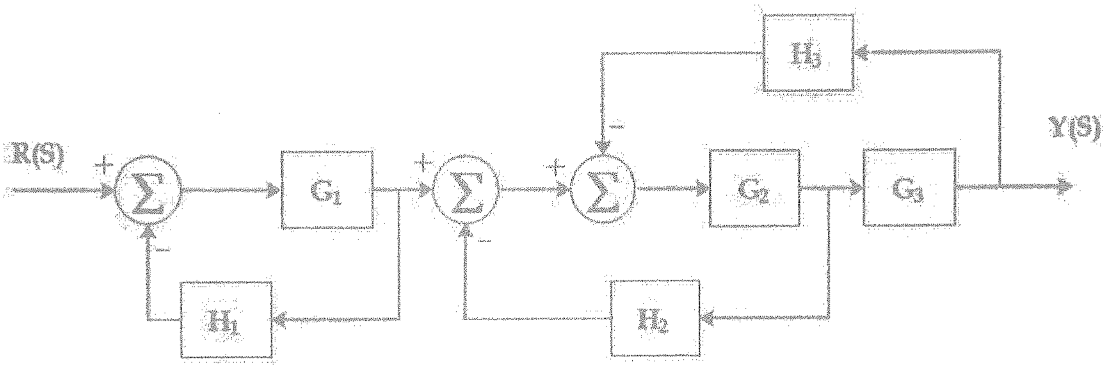
[3.5 Marks]

Q2 a) By using the block diagram reduction techniques, simplify the following block diagrams and obtain the transfer function Y(S)/R(S). Show necessary simplifying steps.

i)



ii)



[3.5 Marks]

b) i) Find the time function corresponding to the unit impulse response for the systems given below using partial-fraction expansion. Show poles and zeros in the s-plane for each of the systems.

1) $G(S) = \dfrac{2}{S(S+2)}$ 2) $G(S) = \dfrac{S^2+2S+2}{S^2+3S+2}$ 3) $G(S) = \dfrac{2(S+2)}{S^3+S^2+4S+4}$

ii) Calculate the steady state value of the unit impulse response for each of the systems obtained in Q2 b) and determine which systems are bounded.

[4.0 Marks]

Q3 a) Consider the standard second order system given below.

$$H(s) = \frac{\omega_n^{\ 2}}{S^2 + 2\varepsilon\omega_n S + \omega_n^{\ 2}}$$

Assume that H(s) has complex poles ($S = -\sigma \pm j\,\omega_d$) in the left half of the s-plane.

i) Define the terms ε and ω_n in H(S).

ii) Find the time function of the Step Response of H(S).

[2.5 Marks]

b) i) Briefly explain the terms rise time, settling time, overshoot and peak time associated with the Step Response obtained in a) (ii).

ii) Sketch a suitable time response to illustrate the terms in b) (i).

[2.0 Marks]

c) Consider the second order system given below.

$$G(S) = \frac{1.667K \times 10^{-6}}{S^2 + \frac{1}{30}S + 1.667K \times 10^{-6}}$$

What values of K will provide a rise time less than 80 Seconds?

[1.0 Mark]

d) i) State the final value theorem.

ii) When the input is unit step function to the following systems, use final value theorem to find the final value of the output signal.

1) $H(S) = \frac{3S + 2}{S^2 + 4S + 20}$ 2) $H(S) = \frac{2(S+2)(S+7)}{(S+1)(S+3)}$ 3) $H(S) = \frac{(S+5)(2S+15)}{(S+1)(s^2+8S+15)}$

[2.0 Marks]

Q4 a) i) Why stability is an important consideration in control system design?

ii) What is the necessary (but not sufficient) condition for the stability of a control system, in terms of its characteristic equation point of view?

iii) State Routh's necessary and sufficient condition to have a stable system.

[2.0 Marks]

b) Use Routh's stability criterion to determine the stability of the systems with the characteristic equations given below and state the number of poles in RHP.

i)

$$S^5 + 5S^4 + 10S^3 + 10S^2 + 5S + 2 = 0$$

ii)

$$S^5 + 2S^4 + 3S^3 + 7S^2 + 4S + 4 = 0$$

[2.0 Marks]

c) Determine the range of K that stabilizes the system shown in Figure Q4 (c). Note that K is a positive value.

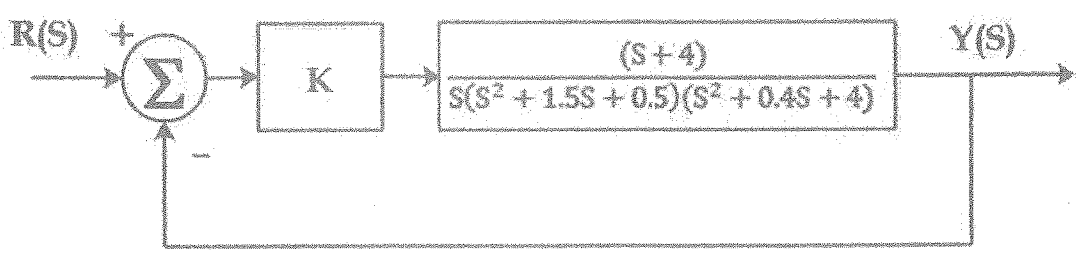


Figure Q4 (c)

[3.5 Marks]

Table of Laplace transforms

Number	$F(s)$	$f(t), t \geq 0$
1	1	$\delta(t)$
2	$\frac{1}{s}$	$1(t)$
3	$\frac{1}{s^2}$	t
4	$\frac{2!}{s^3}$	t^2
5	$\frac{3!}{s^4}$	t^3
6	$\frac{m!}{s^{m+1}}$	t^m
7	$\frac{1}{(s+a)}$	e^{-at}
8	$\frac{1}{(s+a)^2}$	te^{-at}
9	$\frac{1}{(s+a)^3}$	$\frac{1}{2!}t^2e^{-at}$
10	$\frac{1}{(s+a)^m}$	$\frac{1}{(m-1)!}t^{m-1}e^{-at}$
11	$\frac{a}{s(s+a)}$	$1-e^{-at}$
12	$\frac{a}{s^2(s+a)}$	$\frac{1}{a}(at-1+e^{-at})$
13	$\frac{b-a}{(s+a)(s+b)}$	$e^{-at}-e^{-bt}$
14	$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$
15	$\frac{a^2}{s(s+a)^2}$	$1-e^{-at}(1+at)$
16	$\frac{(b-a)s}{(s+a)(s+b)}$	$be^{-at}-ae^{-at}$
17	$\frac{a}{(s^2+a^2)}$	$\sin at$
18	$\frac{s}{(s^2+a^2)}$	$\cos at$
19	$\frac{s+a}{(s+a)^2+b^2}$	$e^{-at}\cos bt$
20	$\frac{b}{(s+a)^2+b^2}$	$e^{-at}\sin bt$
21	$\frac{a^2+b^2}{s\left[(s+a)^2+b^2\right]}$	$1-e^{-at}\left(\cos bt+\frac{a}{b}\sin bt\right)$