UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

Module Number: EE6302 **Module Name: Control System Design**

[Three Hours]

[Answer **all questions**, each question carries 12 marks]
Note: A table of Laplace Transformation is attached.

Q1 a) i) What is meant by control in control system design?

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

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

iv) 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.

[7.0 Marks]

b) i) A realistic model of an op-amp circuit is given by the following equations and is shown in Figure Q1. Using the given equation, find the transfer function of the simple amplification circuit shown in Figure Q1.

$$V_{out}(s) = \frac{10^7}{s+1}[V_+(s) - V_-(s)]$$

$$i_+ = i_- = 0$$

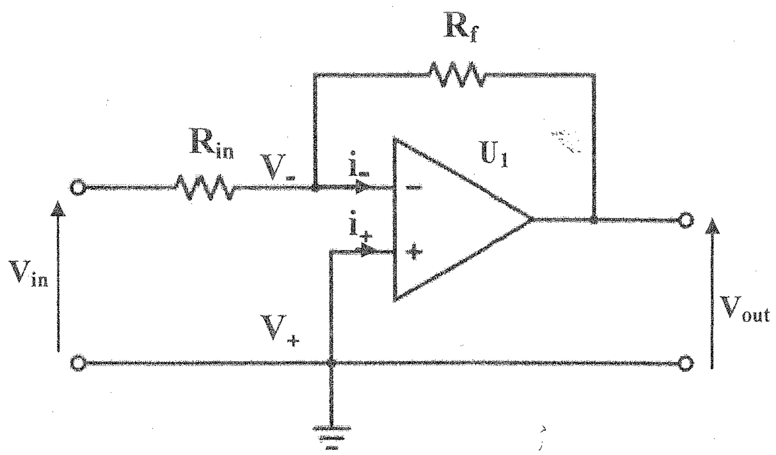


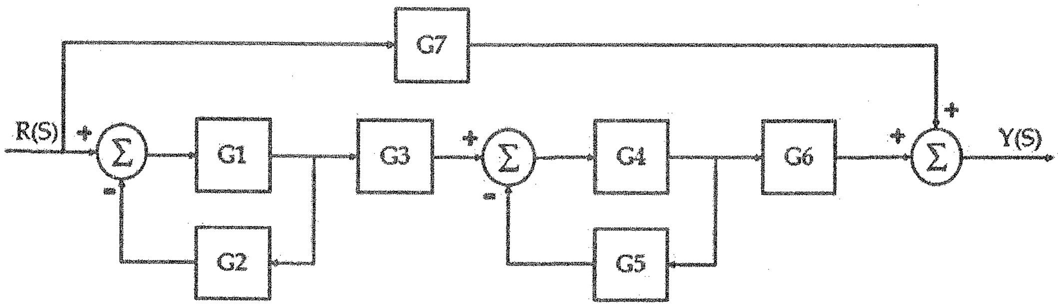
Figure Q1.

ii) By using the transfer function you derived in b)i), show that the system is stable.

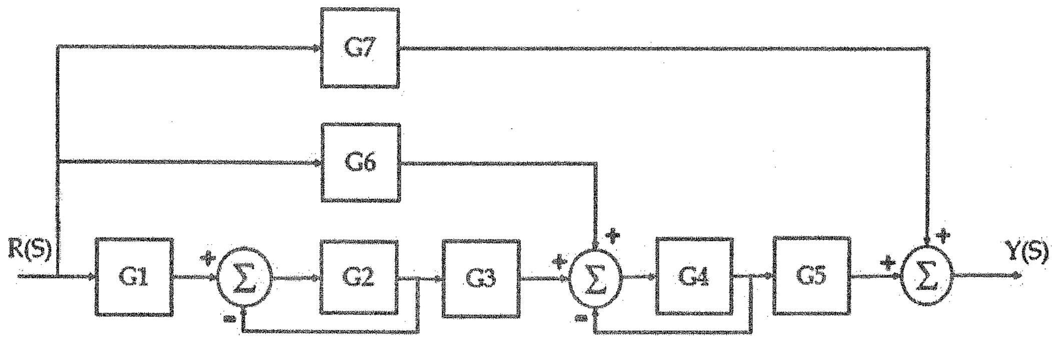
[5.0 Marks]

Q2 a) Find the transfer function of the following systems using block diagram reduction techniques.

i)



ii)



[9.0 Marks]

b) Consider the second order system with transfer function given below.

$$G(s) = \frac{3}{s^2 + 2s - 3}$$

Determine the following,

i) The DC gain.

ii) The final value of the system to a unit step input.

[3.0 Marks]

Q3 a) Use the Routh's stability criterion to determine how many roots with positive real parts in the following equations have,

i) $s^4 + 8s^3 + 32s^2 + 80s + 100 = 0$

ii) $s^5 + 10s^4 + 30s^3 + 80s^2 + 344s + 480 = 0$

[4.0 Marks]

b) Find the range of K for which all the roots of the following polynomial are in the Left Half of the S-Plane.

$$s^5 + 5s^4 + 10s^3 + 10s^2 + 5s + K = 0$$

[4.0 Marks]

c) Consider the control system shown in Figure Q3. **K**, **a**, **A** and **T** are non-zero constants.

i) Determine the transfer function Y(s)/R(s).

ii) Determine the steady state error due to a unit step input.

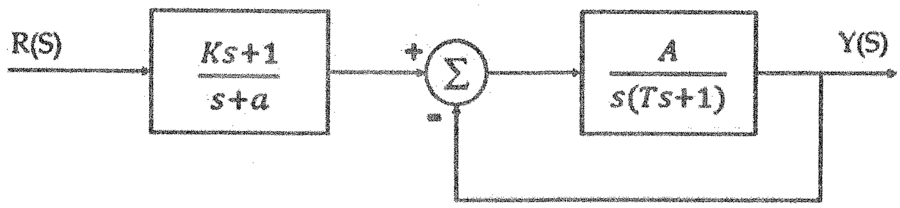


Figure Q3.

[4.0 Marks]

Q4 a) Give the definition for the Root Locus

[2.0 Marks]

b) Consider the system shown in Figure Q4. Assume that K has positive real values.

i) Showing all the necessary steps, sketch the Root Locus for the system.

ii) What is the range of K that the system becomes stable?

iii) Locate the complex poles in the root locus where the damping ratio is $1/\sqrt{2}$.

iv) Write the MATLAB .m file, including necessary comments to obtain the Root Locus you drawn in part i).

[10.0 Marks]

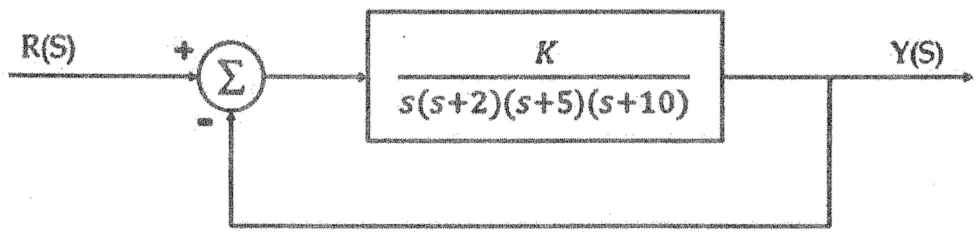


Figure Q4.

Q5 a) What is meant by system's Frequency Response?

[1.0 Mark]

b) Consider the system given in Figure Q5. Assume G(s) is a Linear Time Invariant (LTI) system. Let the time domain input to be r(t) = Asin(ωt). All the symbols have their usual meaning.

i) Using the Laplace Transformation, prove that,

$$Y(s) = G(s)\frac{A\omega}{s^2 + \omega^2}$$

ii) Prove that system's frequency response is given by,

$$y_{ss}(t) = A|G(j\omega)|\sin(\emptyset + \omega t)$$

[5.0 Marks]

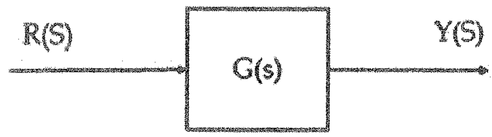


Figure Q5.

c) Describe the following terms.

   i) Gain crossover frequency

   ii) Phase crossover frequency

[2.0 Marks]

d) Consider the system with transfer function $G(s) = 1+Ts$ where T is a positive constant. Indicating all the relevant parameters, plot the bode plot of the system. All the symbols have their usual meanings.

[4.0 Marks]

The table of the Laplace Transformation

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	$\frac{(b-a)s}{(s+a)(s+b)}$	$be^{-bt}-ae^{-at}$
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	$\frac{a^2+b^2}{s[(s+a)^2+b^2]}$	$1-e^{-at}\left(\cos bt+\frac{a}{b}\sin bt\right)$