



KENYATTA UNIVERSITY
UNIVERSITY EXAMINATIONS 2011/2012
SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR
OF SCIENCE IN ELECTRICAL ENGINEERING

EEE 310: CONTROL SYSTEMS I

DATE: Thursday, 19th April, 2012

TIME: 11.00 a.m. – 1.00 p.m.

INSTRUCTIONS:

- (i) This paper contains **FIVE (5)** questions.
- (ii) Answer question **ONE** and any other **TWO** questions.
- (iii) You will be provided with a graph paper.

Question One

1. (a) With an aid of a diagram explain the difference between the following:
- (i) Open loop control system [2marks]
 - (ii) Closed loop control system [2marks]
- (b) Explain the difference between a control input and a disturbance input. [2marks]
- (c) State five important features of a feedback controlled system [5 marks]
- (d) Find an expression for the unit step response of a first order system below and plot the response [6 marks]
- $$G(s) = \frac{2}{1 + 0.2s}$$
- (e) Find the differential equations relating $v_1(t)$ and $v_2(t)$ for the networks shown in Fig Q.1(e) below [4marks]

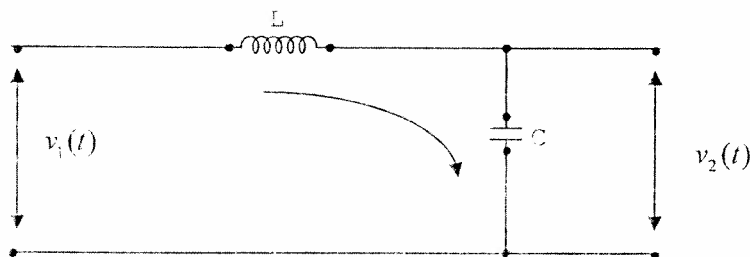


Fig Q.1(e)

(f) State one necessary and the two necessary and sufficient Routh – Hurwitz stability criterion [3 marks]

(g) Show that the step response of a second order system $G_o(s) = \frac{K\omega_n^2}{(s^2 + 2\xi\omega_n s + \omega_n^2)}$ when the damping ration (ξ) = 1 is given by [6marks]

$$x_o(t) = K [1 - e^{-\omega_n t} (1 + \omega_n t)]$$

Question Two

2. (a) Differentiate between the following
- (i) Actuating signal (error signal) [1marks]
 - (ii) Plant [1marks]
 - (iii) Feedback element [1marks]
- (b) Define a mathematical model of a system give a differential equation representing a fourth order system [3marks]
- (c) Heat flows from a heat source at a temperature $\theta_1(t)$ through a wall having a thermal resistance R_T to a heat sink at temperature $\theta_2(t)$ having ideal thermal capacitance C_T as shown in **Fig Q.2(c)** below. Find the differential equation relating $\theta_1(t)$ and $\theta_2(t)$. [4marks]

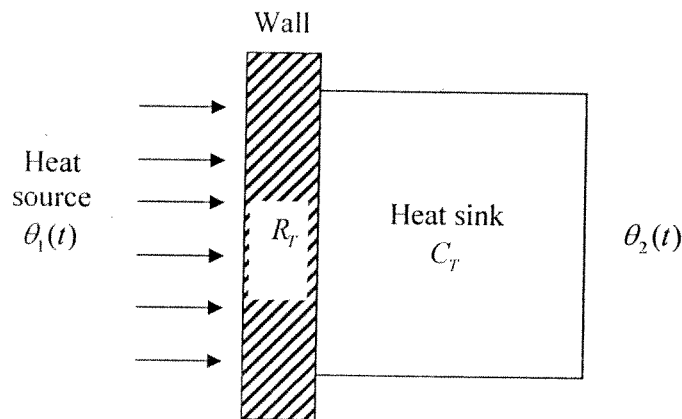


Fig Q.2(c)

- (d) **Fig Q.2(d)** below is an RC network. Find the differential equation relating $v_1(t)$ and $v_2(t)$ [10marks]

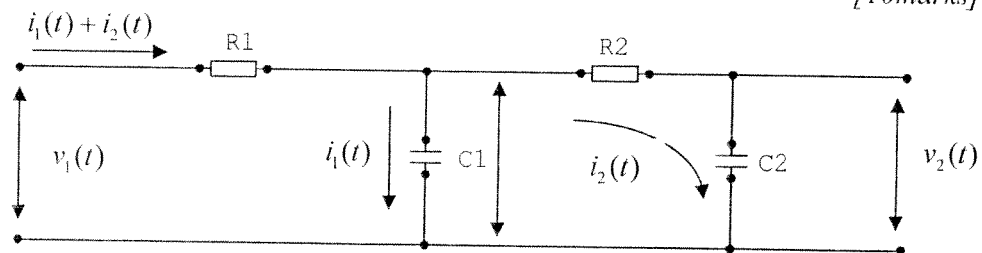


Fig Q.2(d)

Question Three

3. (a) Differentiate between the following

- Time response and time response analysis
- Rise time and settling time

[2 marks]

[2 marks]

(b) Given the differential equation of a second order system is

$$a \frac{d^2 x_o}{dt^2} + b \frac{dx_o}{dt} + cx_o = ex_i(t) \text{ Find in terms of } a, b, c \text{ and } e;$$

(i) The transfer function of the system

[2marks]

(ii) The undamped natural frequency

[2marks]

(iii) The damping ratio

[2marks]

(iv) The percentage overshoot given an impulse response

[2marks]

(c) Find the value of the critical damping coefficient C_c in terms of K and m for the spring – mass – damper system in Fig Q.3(c)

[8 marks]

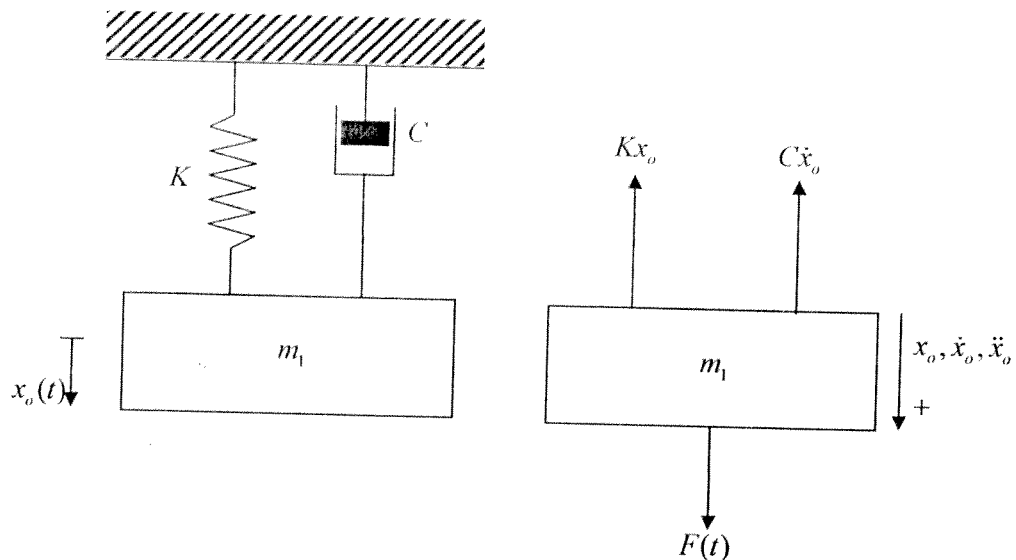


Fig Q.3(c)

Question Four

4. (a) Show that the closed loop transfer function is the forward-path transfer function divided by one plus the open loop transfer function given by

[4marks]

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

(b) Find the overall closed loop transfer function of the system shown in Fig Q.4(b) below using block diagram reduction technique

[6 marks]

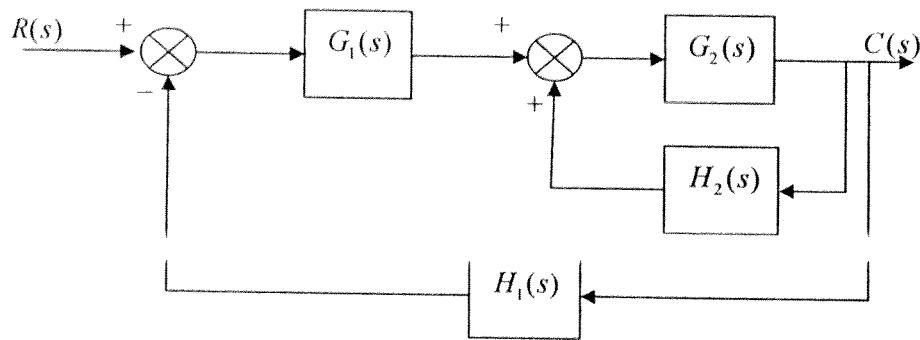


Fig Q.4(b)

- (c) Plot bode gain and bode phase plot of the transfer function below [10 marks]

$$G(s) = \frac{50(s+2)}{s(s^2 + 4s + 100)}$$

Question Five

5. (a) Check the stability of the system which has the following characteristic equation [3 marks]

$$s^4 + 2s^3 + s^2 + 4s + 2 = 0$$

- (b) Find the value of proportional controller gain K_1 to make the control system shown in Fig Q.5 (b) just unstable. [8 marks]

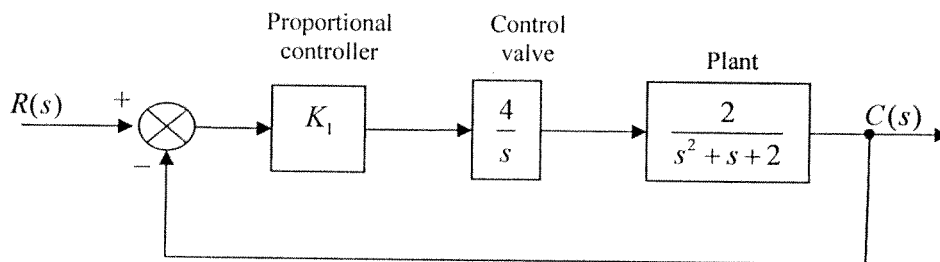


Fig Q.5 (b)

- (c) A control system has the following open loop transfer function:

$$G(s)H(s) = \frac{K}{s(s^2 + 4s + 13)}$$

- Sketch the root locus diagram by obtaining asymptotes and the angles of departure. [6 marks]
- What is the value of K for marginal stability [3 marks]

Table 1 Block diagram transform theorems

Transformation	Equation	Block diagram	Equivalent block diagram
1. Combining blocks in cascade	$Y = (G_1 G_2)X$		
2. Combining blocks in eliminating a forward loop			
3. Removing a block from a forward path	$Y = G_1 X \pm G_2 X$		
4. Eliminating a feedback loop	$Y = G_1(X \pm G_2 Y)$		
5. Removing a block from a feedback loop	$Y = G_1(X \pm G_2 Y)$		
6. Rearranging summing points	$Z = W \pm X \pm Y$		
7. Moving a summing point ahead of a block	$Z = G(X \pm Y)$		
8. Moving a summing point beyond a block	$Z = G(X \pm Y)$		
9. Moving a take-off point ahead of a block	$F = GX$		
10. Moving a take-off point beyond a block	$Y = GX$		

Time function $f(t)$		Laplace transform $\mathcal{L}[f(t)] = F(s)$
1	unit impulse $\delta(t)$	1
2	unit step 1	$1/s$
3	unit ramp t	$1/s^2$
4	t^n	$\frac{n!}{s^{n+1}}$
5	e^{-at}	$\frac{1}{(s + a)}$
6	$1 - e^{-at}$	$\frac{a}{s(s + a)}$
7	$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2}$
8	$\cos \omega t$	$\frac{s}{s^2 + \omega^2}$
9	$e^{-at} \sin \omega t$	$\frac{\omega}{(s + a)^2 + \omega^2}$
10	$e^{-at} (\cos \omega t - \frac{a}{\omega} \sin \omega t)$	$\frac{s}{(s + a)^2 + \omega^2}$

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