THE OPEN UNIVERSITY OF SRI LANKA

FACULTY OF ENGINEERING TECHNOLOGY

DIPLOMA IN TECHNOLOGY – LEVEL 03

FINAL EXAMINATION – 2008/2009

MEX3273 – MODELLING OF MECHATRONIC SYSTEMS

046

DATE : ***29 MARCH 2009***

TIME : ***0930HRS -1230HRS***

DURATION : ***THREE HOURS***

PLEASE READ THE FOLLOWING INSTRUCTIONS BEFORE ANSWERING THE PAPER

INSTRUCTIONS:

1. *This paper consists of eight questions. Answer any* ***five questions only.***
2. *Each question carries equal marks.*
3. *Answers should be written on the answer books provided by the Examinations Division.*

Question 01

(1.1) Explain what is meant by a 'Model' and state the building blocks of a mathematical model in terms of its variables.

(1.2) Distinguish between a 'lumped parameter model' and a 'distributive parameter model'. Elaborate on your answer by taking suitable examples.

(1.3) *Modeling plays a significant role in the field of systems engineering. However, it has its limitations.* Elaborate on the above statement by taking suitable examples.

(1.4) By taking a suitable example, describe the procedure of model development for a particular system.

Question 02

(2.1) Elaborate on the significance of signals and systems in the context of Systems Engineering.

(2.2) Taking suitable examples, describe the following types of signals.
(i) Continuous vs. Discrete
(ii) Deterministic vs. Stochastic

(2.3) Discuss the following properties in relation to systems.

(i) Causality.
(ii) Linearity.
(iii) Time invariance.
(iv) Memoryless.

(2.4) Consider the system represented by the block diagram given in figure-01.

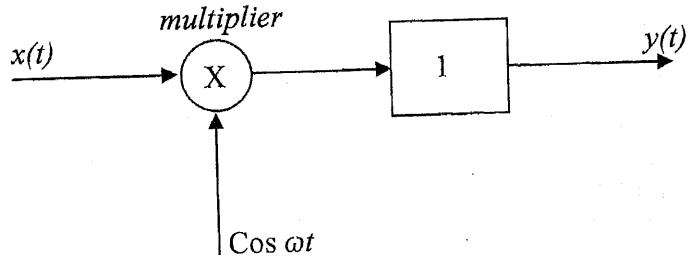


Figure - 01

Determine whether the system is.

(i) Causal.
(ii) Linear.
(iii) Time invariant.

Question 03

(3.1) Show that the equivalent mass of the cantilever spring (beam) shown in figure-02, is approximately 23% of the beam mass.

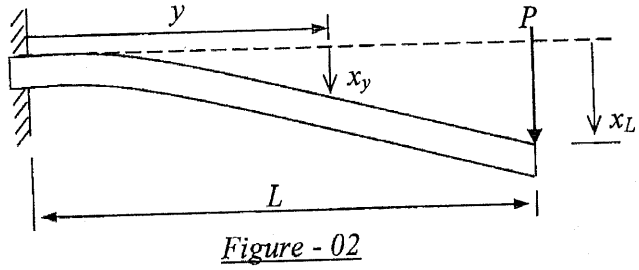


Figure - 02

Where:

L – Length of the beam
P – Load applied at the end of the beam
x_y *– Vertical deflection at a point 'y' distance from the fixed end*
x_L *– Vertical deflection at the end of the beam*

***Hint**: The static deflection of a cantilever beam is governed by,* $x_L = \frac{P}{6EI} y^2 (3L - y)$

(3.2) Figure-03 shows a homogenous cylinder of radius R and a mass m, rotating freely about an axle that is connected to supports by a spring and a damper. Assume that the cylinder rolls without slipping or bouncing on a surface of inclination β. Using first principles, find the equations of motion in terms of displacement x_1 , which is the displacement of cylinder's center parallel to the inclined surface, and is measured from the rest position. State all assumptions you make during your derivation.

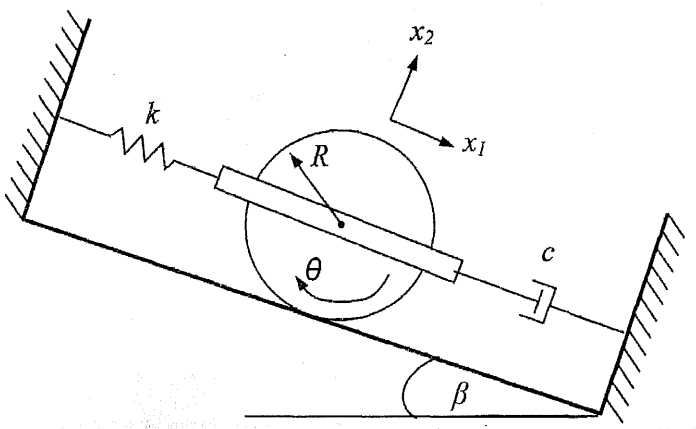


Figure - 03

Question 04

(4.1) Using the force-voltage analogy, show that springs connected parallel is analogous to electrical capacitors connected in a similar fashion.

(4.2) Obtain the Transfer Function for the bridged T network given in figure-04.

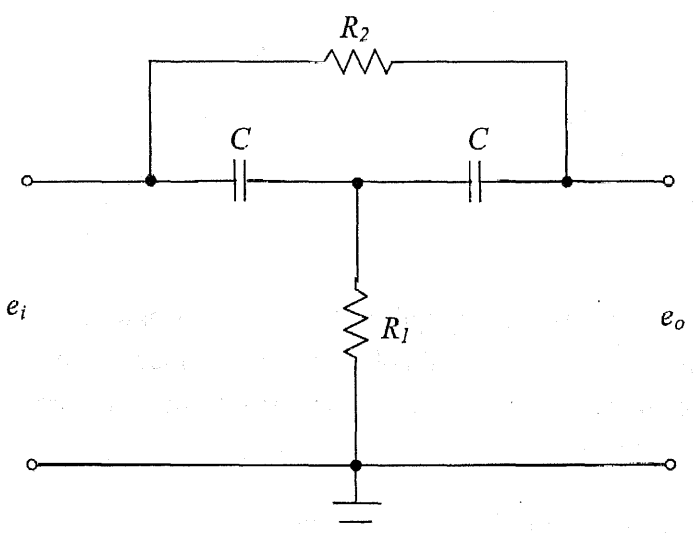


Figure - 04

Question 05

(5.1) Define the term 'Mechanical Impedance', and obtain the impedances for basic mechanical elements.

(5.2) Determine the Transfer Function $G(s) = \frac{X_2(s)}{F(s)}$ (Using the impedance method or otherwise) for the translational mechanical system given in Figure-05.

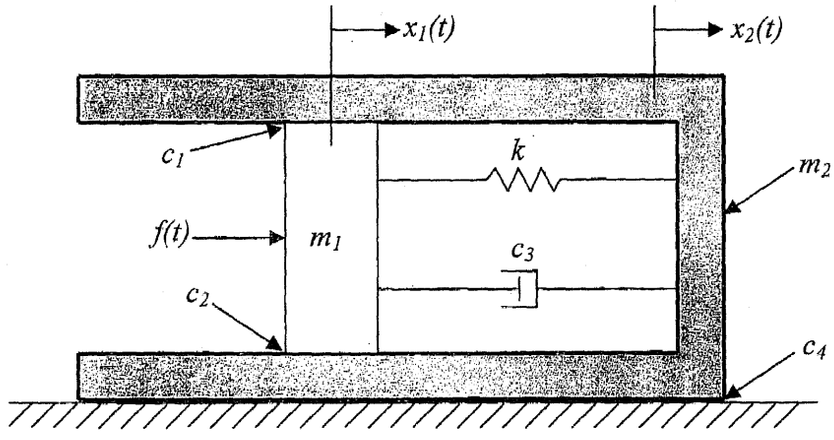


Figure - 05

For the above system:

$m_1 = m_2 = 1$ kg

$c_1 = c_2 = c_3 = c_4 = 1$ N-s.m

$k = 1$ N/m

Question 06

(6.1) Explain the following terms with respect to state-space modelling

(i) State of a system.

(ii) State variables.

(iii) State vector.

(iv) State-space.

(6.2) Figure-06 given below represents a simplified model for a single wheel of a automobile suspension system. The main objective of this model is to study the dynamic response of the suspension system in order to reduce the vibrations $y_1(t)$ due to disturbance forces $f(t)$.

Develop a state-space model for the above system.

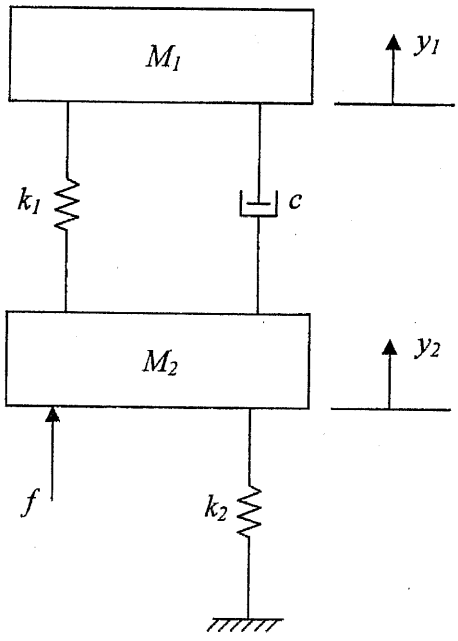


Figure - 06

Question 07

(7.1) What is a block diagram in the context of system modeling? Briefly discuss the pros and cons of block diagrams with respect to other system representation systems.

(7.2) Find the Transfer Function of the block diagram represented in Figure-07 by using block diagram manipulation techniques.

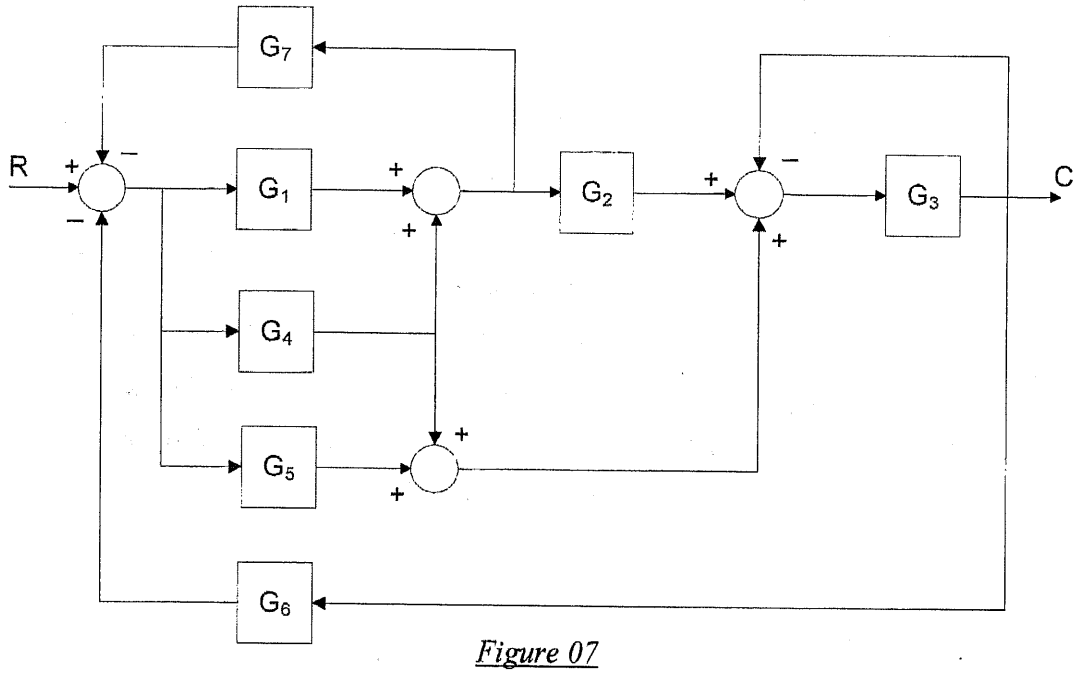


Figure 07

Question 08

(8.1) What are the properties of signal flow graphs? Explain.

(8.2) Using Mason's gain formula, find the transfer function C/R for the signal flow diagram given in Figure-08.

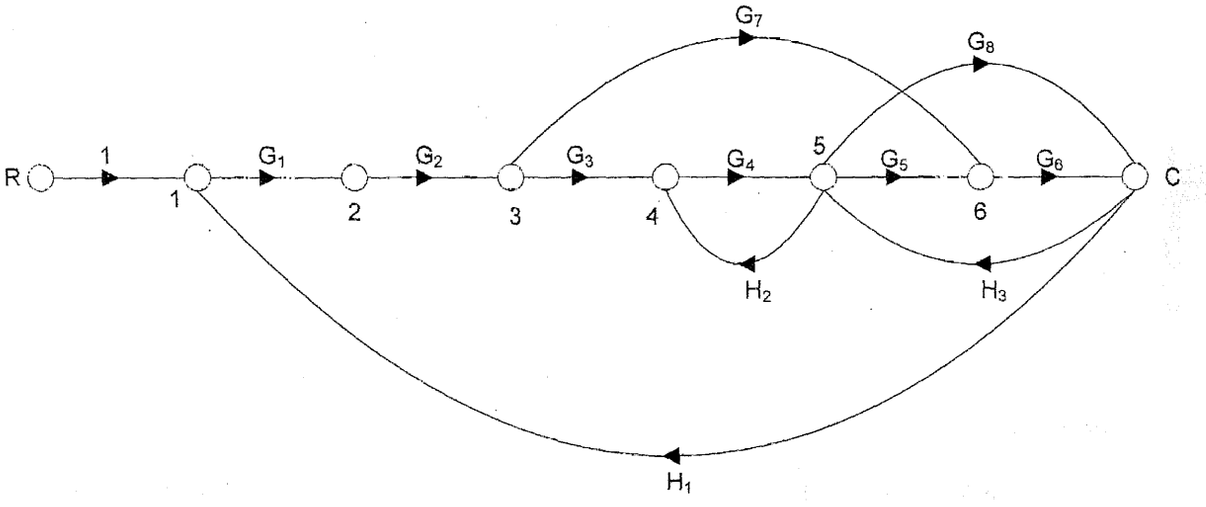


Figure - 08

Mason's Gain Formula:

$$G(s)=\frac{C(s)}{R(s)}=\frac{\sum_k T_k \Delta_k}{\Delta}$$ where,

k = number of forward paths

T_k = the k^{th} forward path gain

Δ = 1 – Σ loop gains + Σ non-touching loop gains taken two at a time – Σ non-touching loop gains taken three at a time + Σ non-touching loop gains taken four at a time - .....

Δ_k = Δ - Σ loop gain terms in Δ that touch the k^{th} forward path. That is, Δ_k is formed by eliminating from Δ those loop gains that touch the k^{th} forward path.

~ END ~

ALL RIGHTS RESERVED

LAPLACE TRANSFORM TABLE

f(t)	F(s)
Unit impulse $\delta(t)$	1
Unit step $u(t)$	$1/s$
t	$1/s^2$
t^n	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$