THE OPENUNIVERSITY OF SRI LANKA

FACULTY OF ENGINEERING TECHNOLOGY
DIPLOMA IN TECHNOLOGY – LEVEL 03
FINAL EXAMINATION – 2010

MEX3273 – MODELING OF MECHATRONIC SYSTEMS

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Open University of Sri Lanka

DATE : ***22 MARCH 2011***
TIME : ***1400HRS -1700HRS***
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.*
4. *Commence to answer each question on a **fresh page***

Question 01

(1.1) Distinguish between a *dynamic system* and a *static system*. Give examples to illustrate your answer.

(1.2) Explain the procedure of model development for a particular system.

(1.3) Why are multi-domain systems such as mechatronic systems considered laborious in developing system models? Explain the approaches that can be employed when modeling such systems.

(1.4) List out the pros and cons of modeling in the context of systems engineering. Elaborate by taking suitable examples.

Question 02

(2.1) How would you describe a signal mathematically? Explain by taking a suitable example.

(2.2) Define the following functions in relation to basic signals.

(i) Unit step function

(ii) Unit impulse function

(iii) Unit ramp function

(iv) Signum function

(2.3) Distinguish between causal systems and memoryless systems. Taking a suitable example, show that all memoryless systems are causal, but not vice versa.

(2.4) A system is represented by the input-output relationship, $y = \mathrm{T}[x] = x^2$. Show that the system is non-linear.

Question 03

(3.1) List out the conservation laws of engineering systems. Show that the continuity equation is the result of the law of conservation of mass.

(3.2) Describe the meaning of *effort* and *flow* variables. Identify the effort and flow variables for mechanical, electrical, fluid and thermal systems.

(3.3) Explain the concept of generalized elements in engineering systems.

(3.4) Elaborate on the two system analogies used to describe elements in mechanical and electrical systems?

Question 04

Consider the mechanical system given in figure 01. The input and the output for the system are $f(t)$ and $x_1(t)$ respectively. Assume $x_2 > x_1$

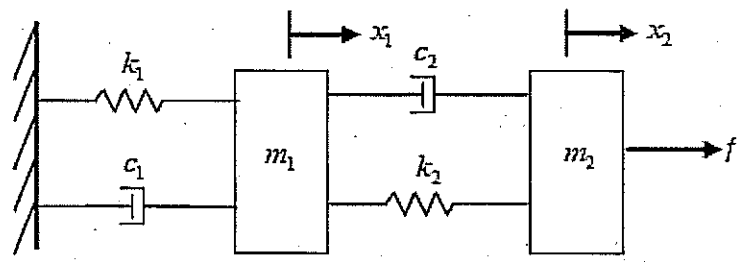


Figure 01

(4.1) How many degrees of freedom the above system have?

(4.2) Draw the free body diagram for the above system.

(4.3) Obtain the input-output equation. (You may use the D operator method in obtaining the input-output equation)

Question 05

(5.1) What are the assumptions made in transfer function representation of dynamic systems?

(5.2) The output to an impulse response for a dynamic system is $\sin t$. Determine the transfer function of the system and its governing differential equation.

(5.3) The input and output for the lead-lag compensation circuit given in figure 02 are, v_i and v_o respectively. Determine the transfer function of the circuit.

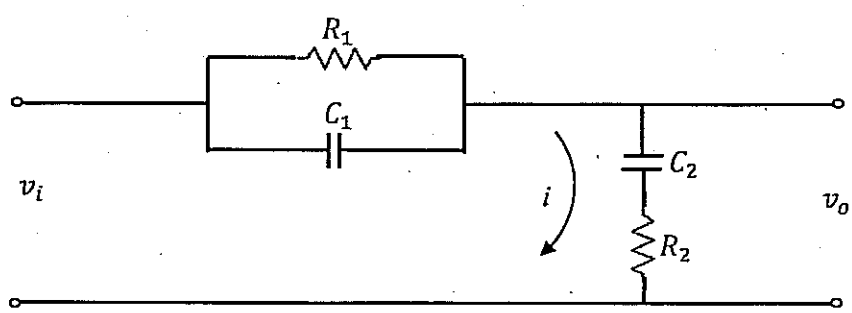


Figure 02

Question 06

(6.1) Explain the concept of Mechanical Impedance, and obtain expressions for the impedances of basic mechanical elements.

(6.2) Using the impedance method find the governing equations for the translational mechanical system shown in figure 03 below. Assume $x_3 > x_2 > x_1$ and the masses are sliding on a frictionless surface.

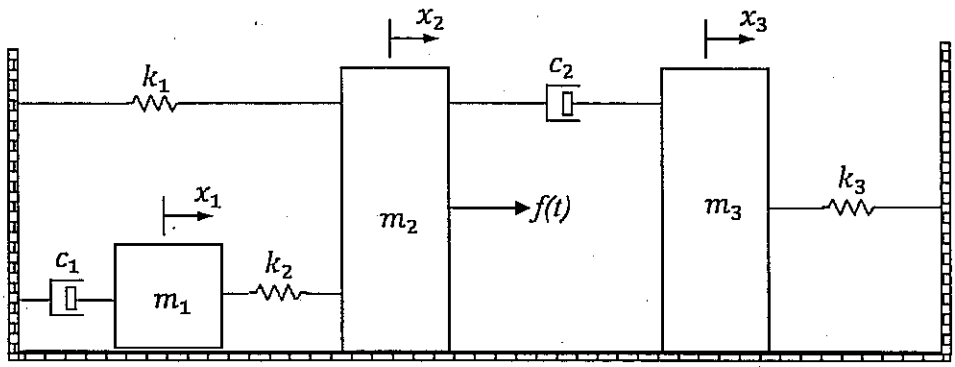


Figure 03

(6.3) If $k_1 = k_2 = k_3 = 1\ N/m$ and $c_1 = c_2 = 1\ N - s/m$ and $m_1 = m_2 = m_3 = 1\ kg$ find the transfer function $X_3(s)/F(s)$

Question 07

(7.1) Explain the methodology adopted in converting a transfer function to state-space form.

(7.2) Consider the mechanical system shown in figure 04. Find the transfer function Y(s)/F(s) if, k_1=6 N/m, k_2=4 N/m, c=0.4 N-s/m, and m=0.1 kg. The displacements *y* and *x* are measured from their respective equilibrium positions.

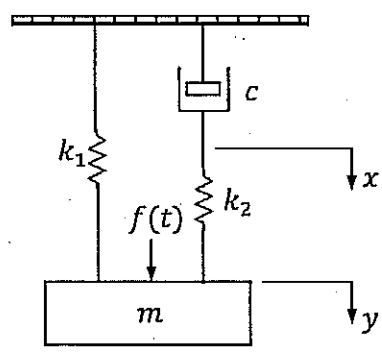


Figure 04

(7.3) Using the methodology explained in (7.1), find the state-space form of the above mechanical system.

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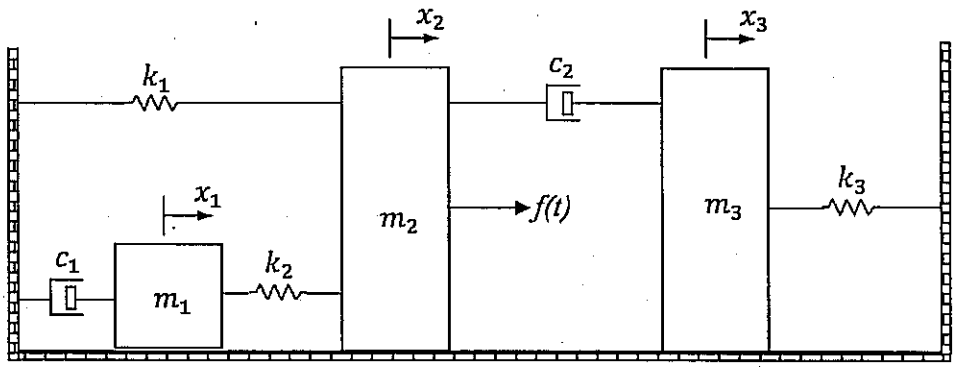


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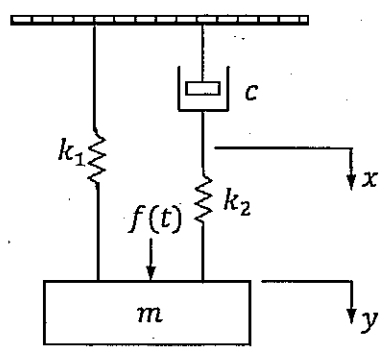


Figure 04

(7.3) Using the methodology explained in (7.1), find the state-space form of the above mechanical system.

Question 08

(8.1) Distinguish between block diagrams and signal flow graphs in the context of system representation.

(8.2) Figure 05 represents a two path signal flow graph for a particular system. Convert this signal flow graph into a block diagram.

(8.3) Using block diagram reduction techniques, reduce the block diagram obtained in (8.2) and find the overall transfer function of the system.

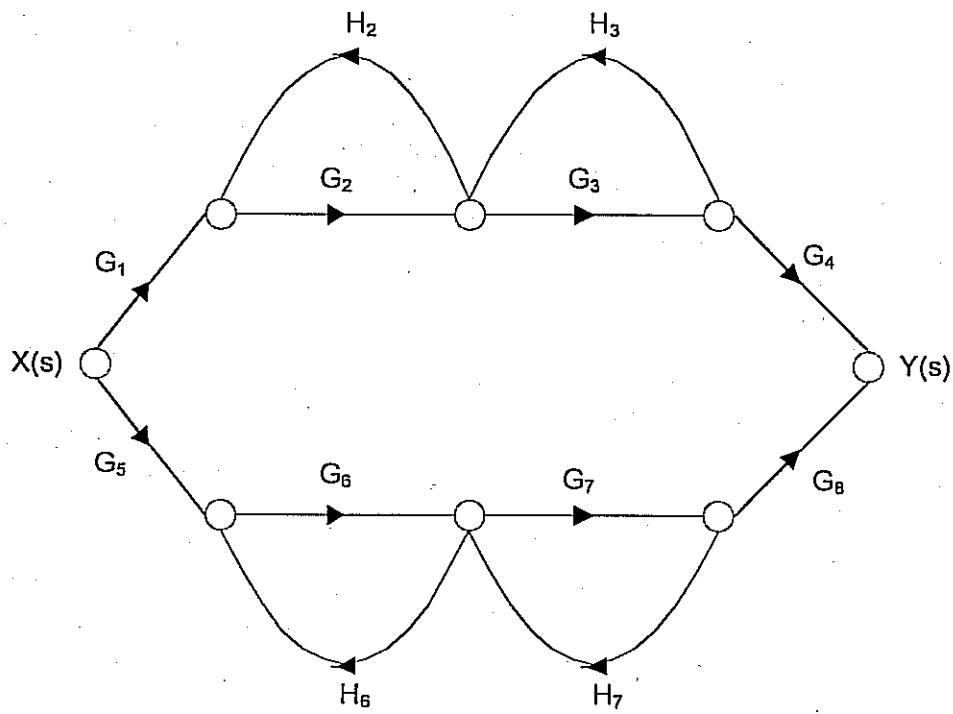


Figure 05

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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}	$\frac{1}{s+a^2}$
$t^n e^{-at}$	$\frac{n!}{s+a^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$f^{(k)}(t) = \frac{d^k(t)}{dt^k}$	$s^k F(s) - s^{k-1}f(0^-) - s^{k-2}f'(0^-) \ldots\ldots - f^{k-1}(0^-)$
$\int_{-\infty}^{t} f(t)dt$	$\frac{F(s)}{s} + \frac{1}{s}\int_{-\infty}^{0} f(t)dt$
$e^{-at}\sin \omega t$	$\frac{\omega}{(s+a^2)+\omega^2}$
$e^{-at}\cos \omega t$	$\frac{(s+a)}{(s+a^2)+\omega^2}$