THE OPEN UNIVERSITY OF SRI LANKA

FACULTY OF ENGINEERING TECHNOLOGY
DIPLOMA IN TECHNOLOGY – LEVEL 03
FINAL EXAMINATION – 2011

MEX3273 – MODELING OF MECHATRONICS SYSTEMS

DATE : *23MARCH 2012*
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) What is a model in the context of systems engineering? Explain with an aid of a suitable example.

(1.2) Distinguish the following types of models.

(i) Static vs. dynamic.

(ii) Lumped parameter vs. distributive parameter.

(iii) Deterministic vs. stochastic.

(1.3) *Even though modeling offers great advantages when analyzing and designing of systems, it may not necessarily be applicable in all situations.* Elaborate by giving suitable examples.

(1.4) Verification ensures that the system model is right, whereas, validation is about modeling the right system. Elaborate in the context of model development.

Question 02

(2.1) Briefly explain the **conservation laws** and **property laws** of engineering systems.

(2.2) Distinguish **effort storage** elements from **flow storage** elements in relation to generalized system elements and show that the effort and flow storage elements for a mechanical system is a **spring** and **mass** respectively.

(2.3) Explain the types of analogies used in modeling electro-mechanical systems. You may site a suitable example to elaborate.

Question 03

(3.1) Obtain the governing equations for the basic mechanical elements.

(3.2) Figure 1 below shows a mobile cart of mass **M** connected to a fixed wall by a damper of viscous friction coefficient **b** and rolls without slipping due to an action force of ***F(t)*** on the cart. A uniform slender rod of length **l** and mass **m** is hinged on top of the cart at point O. Obtain the governing equations which describe the movement of the cart. State all assumptions you make.

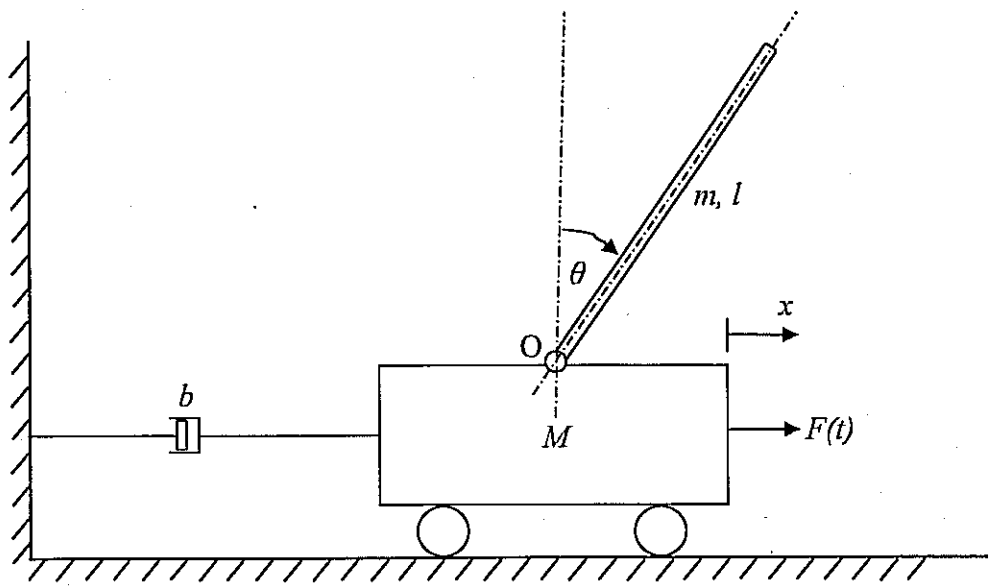


Figure 1

Question 04

(4.1) Derive the mathematical expressions (governing equations) for the following elements of a fluid system.

(i) Resistive element.

(ii) Capacitive element.

(iii) Inertial element.

(4.2) Figure 2 shows a two tank fluid-level system. Fluid is pumped into tank1 at a flow-rate of Q_1 and tank 2 discharges fluid at a flow-rate of Q_3 out of the system. Obtain the governing equations which describe the level changes in tank1 and tank2. State all assumptions you make.

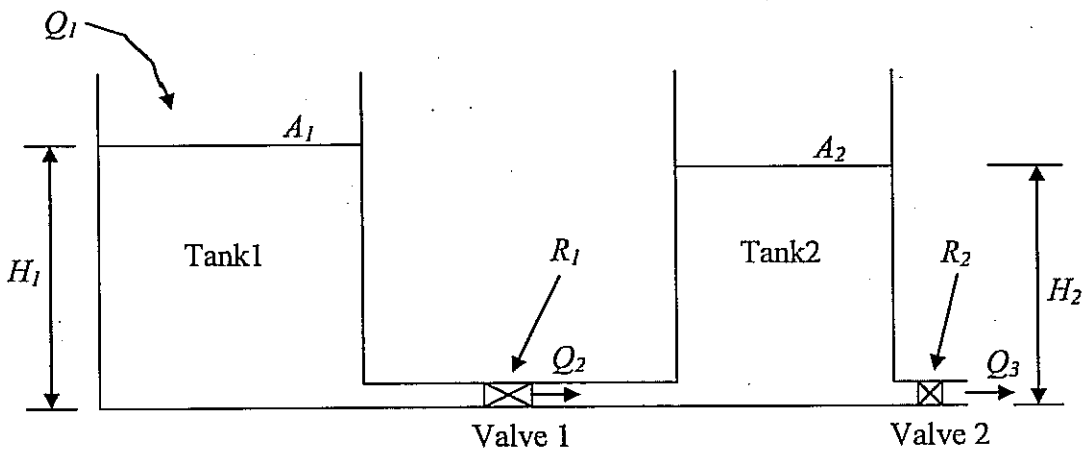


Figure 2

A – Cross sectional areas of tanks.

H – Height of fluid levels.

R – Valve resistance

Question 05

Answer the following questions with regard to a armature controlled dc motor.

(5.1) Using standard notations draw a circuit diagram for the motor.

(5.2) Develop the transfer function for the motor using first principles. State all assumptions you make during the derivation.

(5.3) Identify and obtain the mechanical and armature time constants.

(5.4) Represent the transfer function as a feed-back block diagram.

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 3 below. Assume, $k = 1\ N/m$, $c_1 = c_2 = c_3 = c_4 = 1\ N - s/m$, $m_1 = m_2 = 1\ kg$ and $x_3 > x_2 > x_1$.

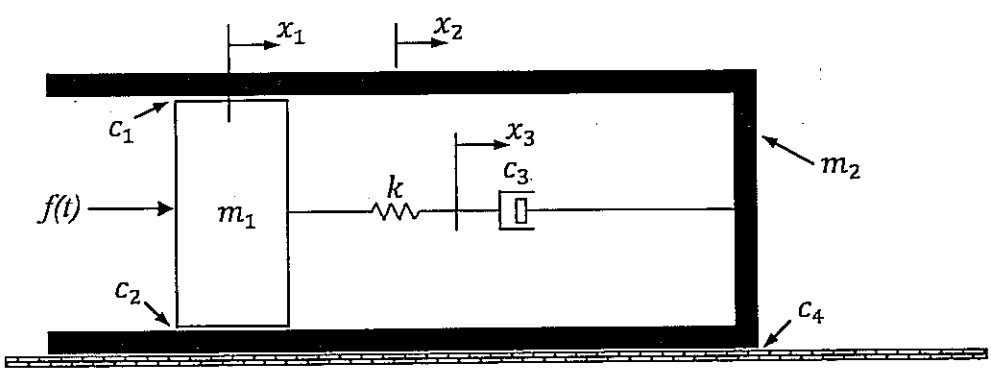


Figure 3

Question 07

(7.1) Explain the following with regard to state space modeling.

(i) State of a system.

(ii) State variables.

(iv) State vector.

(v) State-space.

(7.2) Obtain the state-space formulation for the mechanical system shown in figure 4. Assume that the masses are sliding on a frictionless surface.

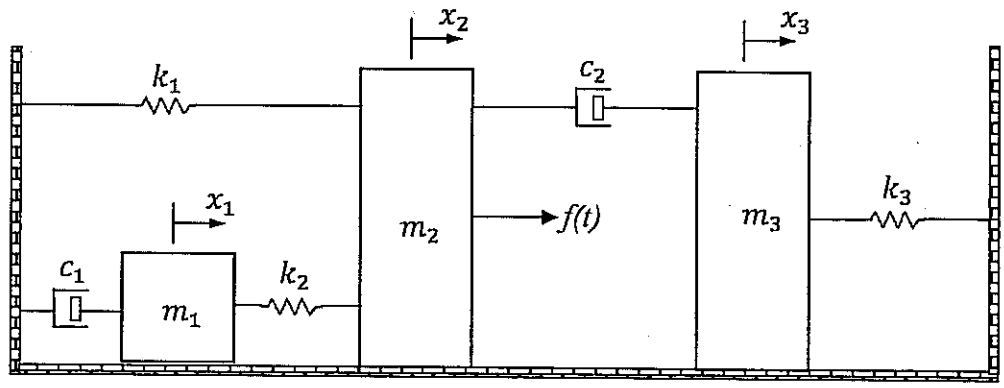


Figure 4

Question 08

(8.1) Distinguish block diagrams from signal flow graphs in the context of graphical representation of systems.

(8.2) Reduce the block diagram shown in figure 5 (*Please refer page 5*) to an open loop form. You are required to show all important steps during the reduction process.

(8.3) Convert the block diagram shown in figure 5 to a signal flow graph.

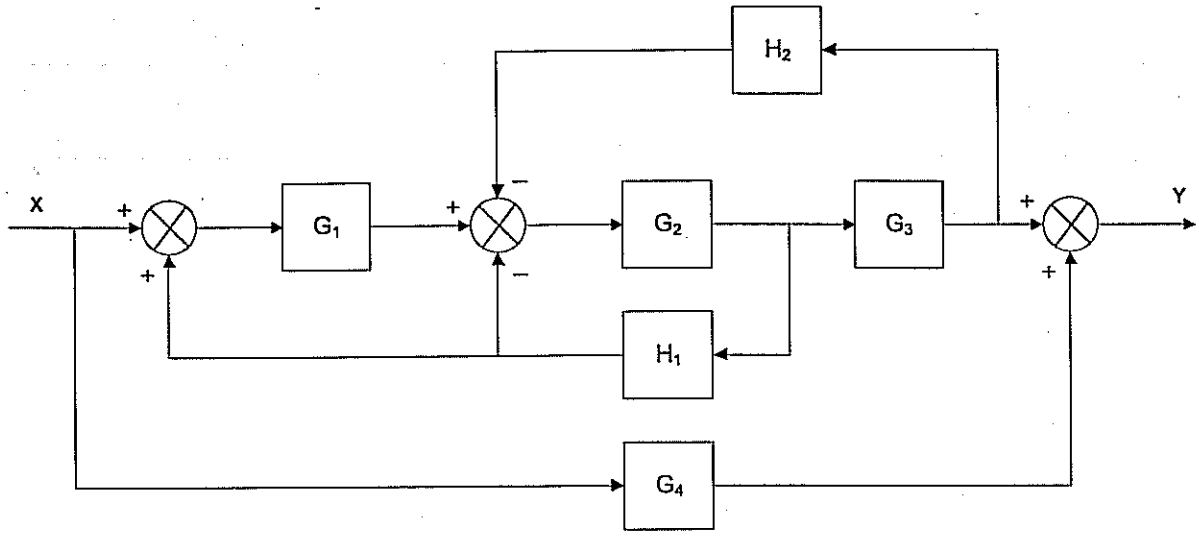


Figure 5

~ END ~

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