THE OPEN UNIVERSITY OF SRI LANKA

FACULTY OF ENGINEERING TECHNOLOGY

DIPLOMA IN TECHNOLOGY – LEVEL 03

FINAL EXAMINATION – 2007

MEX3273 – MODELLING OF MECHATRONICS SYSTEMS

DATE	:	***26 APRIL 2008***
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) Using a suitable example, explain the terms '*System*', '*Model*', '*Input variables*' and '*Output variables*' in the context of System Modelling.

(1.2) Briefly explain the following variables in relation to mathematical models. Support your answers by giving relevant examples.

(a) Decision variables.

(b) Exogenous variables.

(c) Random variables.

(1.3) Distinguish between 'Validation' and 'Verification' and discuss its importance in the developing process of a system model.

(1.4) '*Modelling of Mechatronics Systems has become a challenging issue for system analysis's and engineers*'. Elaborate on the above statement.

Question 02

(2.1) "*Wind conditions play a major role during the taking off and landing of aircrafts.*" What would you consider in this case to be the 'signal', 'system' and identify its independent variable/s? Also, draw the behavior of the system.

(2.2) Establish a mathematical relationship between a unit impulse signal and a unit step signal.

(2.3) Explain the term 'Causality' with regard to signals and show that the causality for a continuous-time linear system is equivalent to the statement "*For any time t_0 and any input $x(t)$ with $x(t)=0$ for $t \le t_0$, the output $y(t)$ is zero for $t \le t_0$*".

Question 03

Consider the double pendulum system given in figure 01 below.

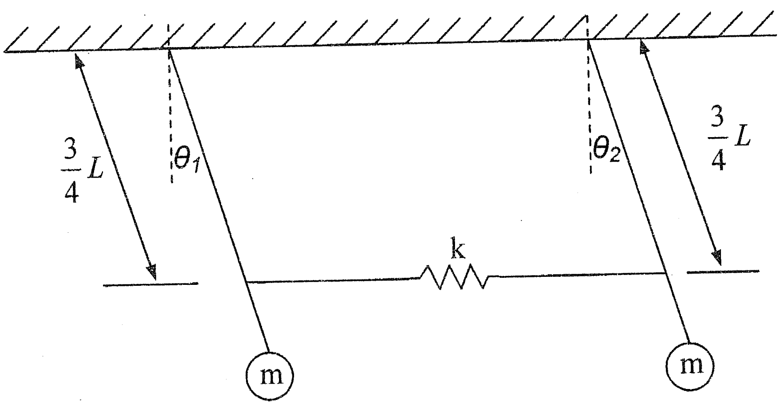

Figure 01

(3.1) Obtain the governing equation/s for the above system, assuming that the spring remains horizontal at all times and the length of the rod is "L".

(3.2) Simplify the equation/s obtained in (3.1) by considering small rotational angles.

(3.3) State all the assumptions you made during the above derivation.

Question 04

Consider the d-c servo-motor system given in figure 02 below.

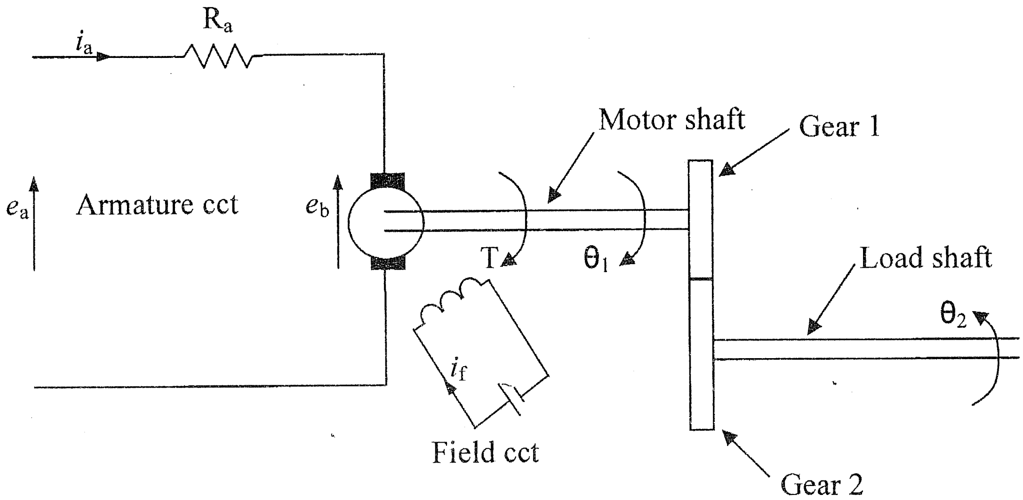

Figure 02

The above system consists of two electrical circuits, namely, the armature circuit and the field circuit. For the armature circuit, the armature resistance is considered to be R_a , and the armature inductance to be negligible.

The motor shaft, having a moment of inertia J_1 is connected to a load shaft of moment of inertia J_2 via a gear train. The numbers of teeth for the gear wheels are, n_1 and n_2 for gears 1 and 2 respectively.

Also,

- e_a – applied armature voltage
- e_b – back e.m.f. developed by the motor
- θ_1 – angular displacement of the motor shaft
- θ_2 – angular displacement of the load shaft
- T – torque developed by the motor
- i_a – armature current
- i_f – field current

Obtain the transfer function between the output θ_2 and the input e_a for the above d-c servo-motor system. State any assumptions you make during the derivation.

Question 05

(5.1) What are the limitations of Transfer Function approach in system representation?

(5.2) A system is defined by the differential equation, $\ddot{x} + 2\dot{x} + 5x = 3$. Find the solution using Laplace transform for $x(t)$ if, $x(t) = 0$ and $\dot{x}(t) = 0$.

(5.3) Consider the mechanical system shown in figure 03 below. The masses move along the ground with out slipping.

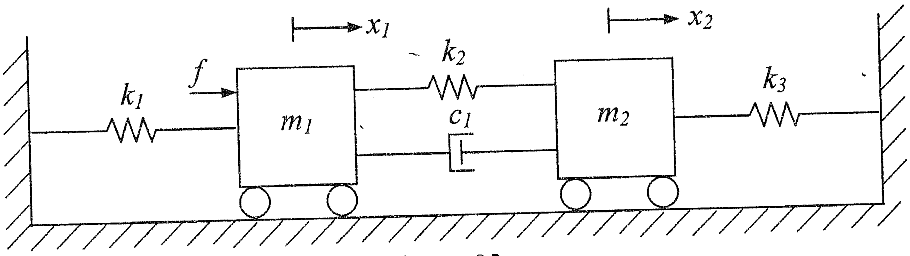

Figure 03

(a) Draw the Free body diagram of the forces acting on masses, m_1 and m_2.

(b) Obtain the governing equation/s for the above system, using first principles. (i.e., applying conservation laws and property laws)

(c) Find the transfer functions,

(i) X_1/F

(ii) X_2/F

Question 06

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

(6.2) Obtain the governing equations for the rotational mechanical system given in figure 04 below.

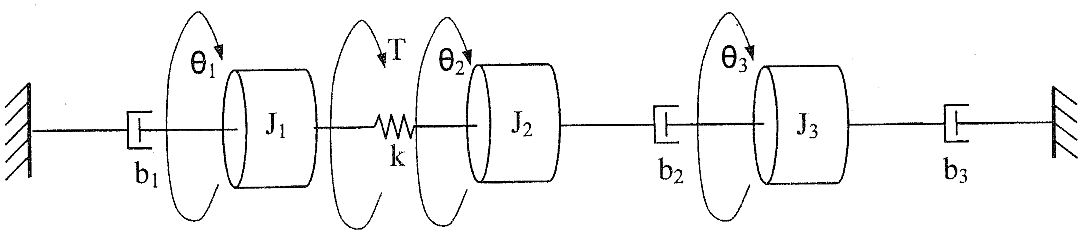

Figure 04

Question 07

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

(7.2) Represent the translation mechanical system given in figure 05, in state space form. You may take *f(t)* and x_3 to be the input and output respectively.

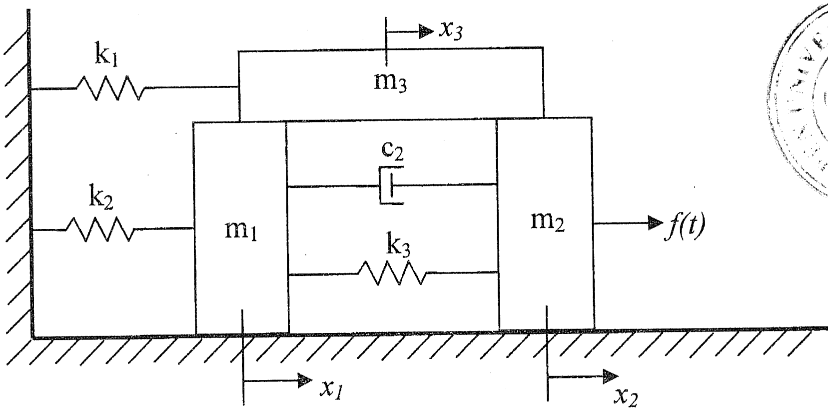

Figure 05

In figure 05,

- $m_1 = m_2 = m_3 = 1$ kg
- $c_2 = 1$ N-s/m
- $k_1 = k_2 = k_3 = 1$ N/m
- The friction between m_3 and m_1, m_3 and m_2 are c_1 and c_3 respectively.
- $c_1 = c_3 = 1$ N-s/m

Question 08

(8.1) Explain the advantages and disadvantages of block diagrams in system representation.

(8.2) Reduce the block diagram given in figure 06 to open loop form. You are required to show all important steps in solving question 8.2.

(8.3) Develop a signal flow graph for the block diagram in figure 06.

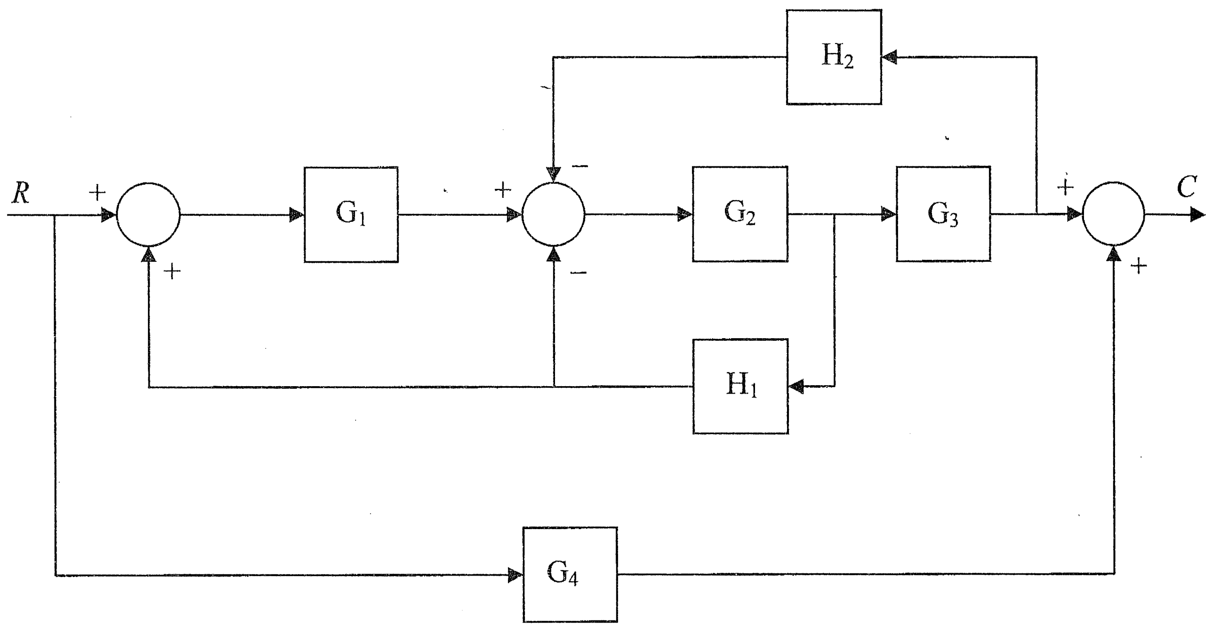

Figure 06

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LAPLACE TRANSFORM TABLE

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