00131

The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	: Bachelor of Technology (Engineering)
Name of the Examination	: Final Examination
Course Code and Title	: **MEX3273 - MODELLING OF MECHATRONICS SYSTEMS**
Academic Year	: 2015/2016
Date	: 04th December 2016
Time	: 9.30am – 12.30pm
Duration	: 3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer any 5 questions only.
4. Laplace transformation table is attached at the end of this question paper.

(Q1)

a) Distinguish between a dynamic system and a static system. Elaborate by giving suitable examples.

b) What precaution may be taken in developing and operating mechanical system, in order to reduce system nonlinearities?

c) Describe the logical steps of the model development process with suitable examples.

d) Elaborate the properties of a linear system, by taking a suitable example.

(Q2)

a) List three practical dynamic systems each of which has at least one sensor, one actuator, and a feedback controller.

b) Briefly explain the ***conversion laws*** and ***property laws*** of engineering systems.

c) Discuss the importance of the use of analogies in modeling of dynamic systems.

d) Why are analogies important in modeling of dynamic systems? Explain.

(Q3)

Use Newton's second law to derive the governing motion of the system is shown in Figure 1 and answer the following;

a) How many degrees of freedom does this system constitute?

b) Draw the FBD for the forces involved in the system.

c) State assumptions you make.

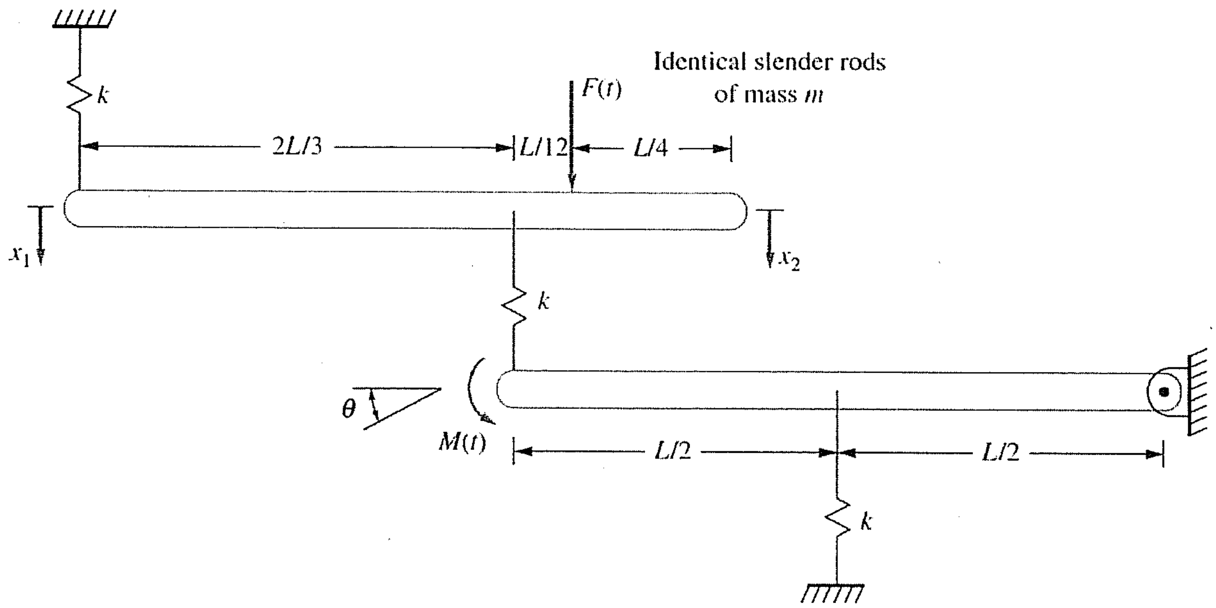

Figure 1

(Q4)

a) Figure 2 represents the block diagram of an engine-speed control system. The speed is measured by a set of flyweights. Draw a signal flow graph for this system.

b) Use the signal flow graph obtained in (Q4-a) to represent the actual speed in state space.

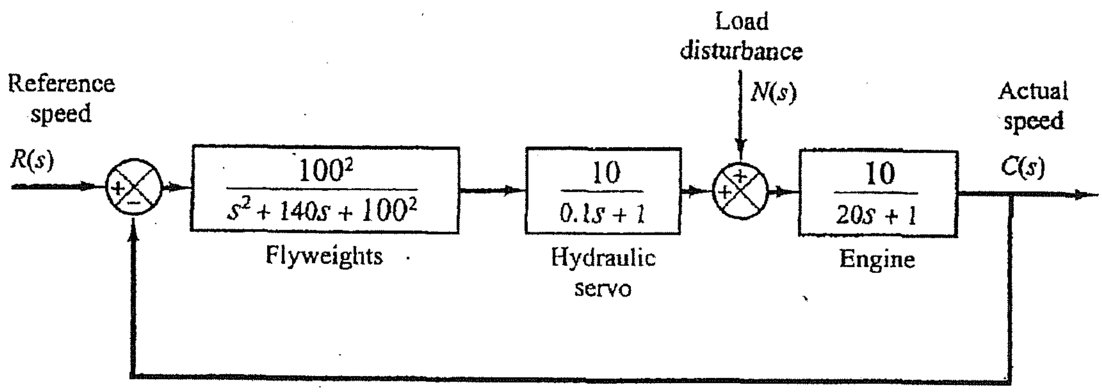

Figure 2

(Q5)

a) "The applicability of the concept of transfer function is limited to linear, time-invariant, differential equation systems". Comment on this statement.

b) Consider the Notch circuit is shown in Figure 3. Obtain the governing equations for the system and find the transfer function for $\frac{V_{out\,(s)}}{V_{in\,(s)}}$.

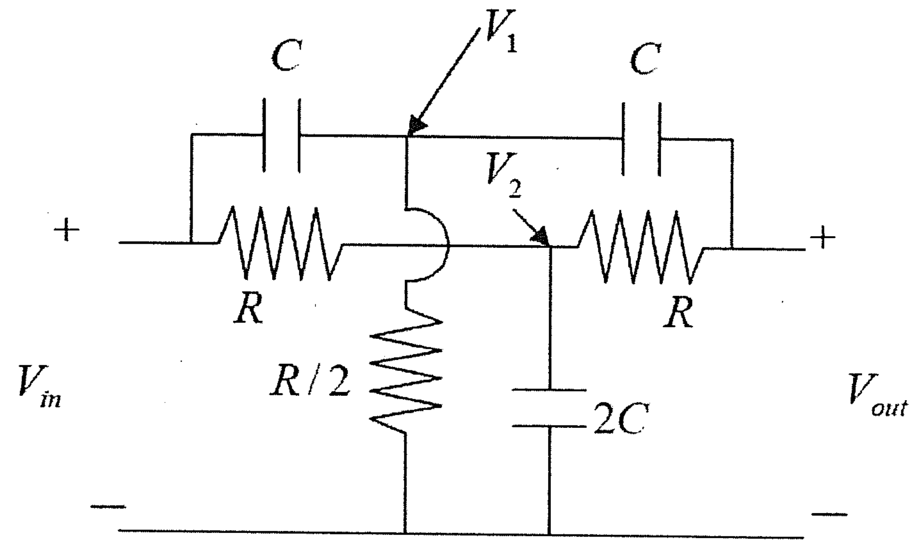

Figure 3

(Q6)

a) Obtain expressions for the impedance of basic mechanical and electrical elements.

b) Consider three-cart system illustrated in Figure 4. Assume all the surfaces are smooth. Using impedance method to derive governing equations of the motion of the system.

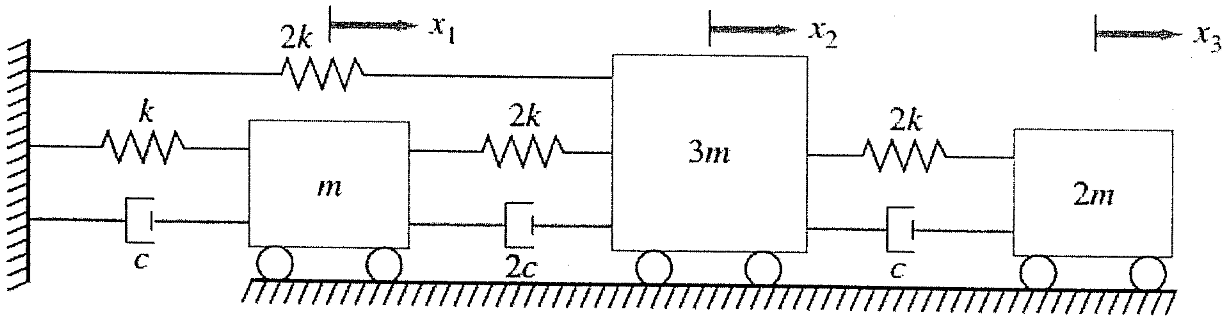

Figure 4

(Q7)

a) Define the following terms with regard to state-space representation of dynamic systems.

   i. State of a system

   ii. State variables

   iii. State vector

   iv. State-space

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

c) Find the state space representation for the electrical network shown in Figure 5 if the output vector is $y = [v_{R_2} \quad i_{R_2}]^T$, where T means transpose.

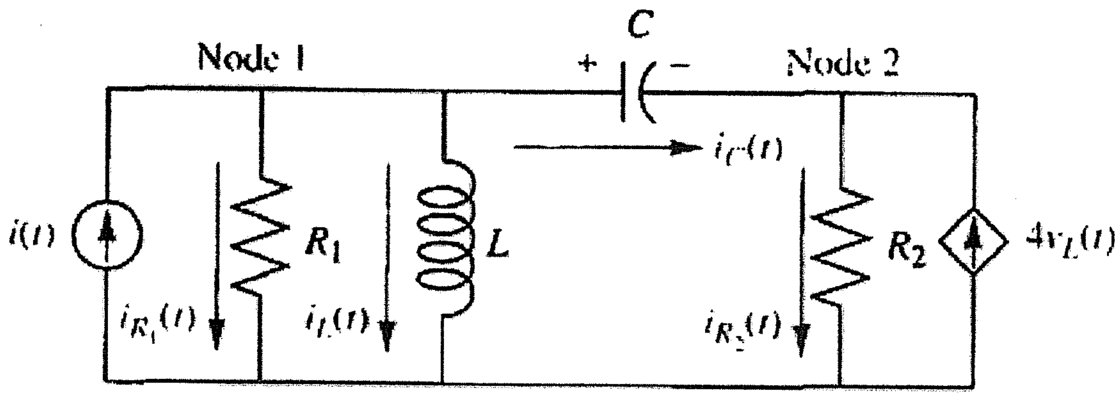

Figure 5

(Q8)

a) Name the two components of a signal flow graphs.

b) If a forward path touched all closed loops, what would be the value of Δ_k?

c) Using Mason's rule, find the transfer function $\frac{Y(s)}{R(s)}$, for the system represented in Figure 6.

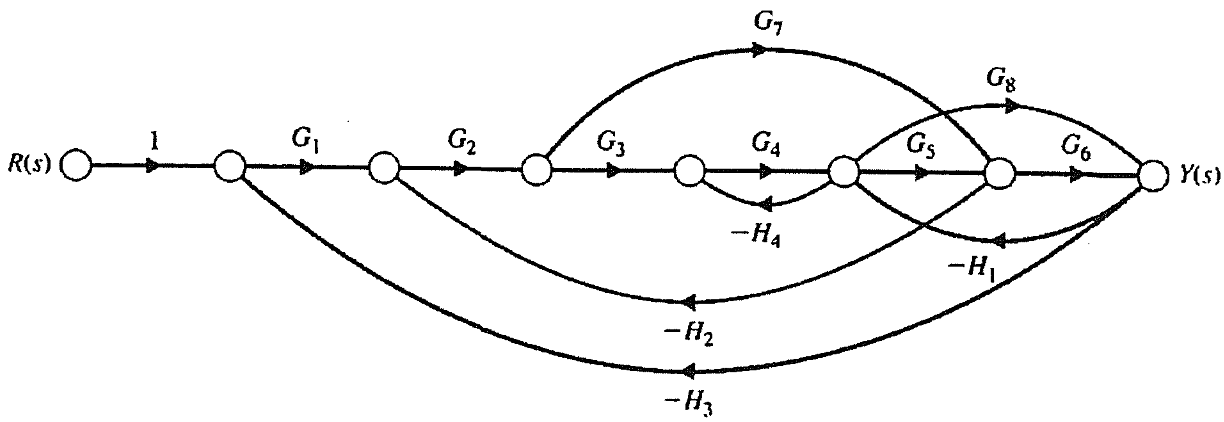

Figure 6

Mason's Gain formula:

$$G(s) = \frac{C(s)}{R(s)} = \frac{1}{\Delta}\sum_k T_k\Delta_k$$

Where,

T_k	Path gain or transmittance of k^{th} forward path
Δ	Determinant of graph 1 - (sum of all individual loop gains) + (sum of gain products of all possible combinations of two non-touching loops) - (sum of gain products of all possible combinations of three non-touching loops) + . . . $1 - \sum_a L_a + \sum_{b,c} L_b L_c - \sum_{d,e,f} L_d L_e L_f + \cdots\cdots$
$\sum_a L_a$	Sum of all individual loop gains
$\sum_{b,c} L_b L_c$	Sum of gain products of all possible combinations of two non-touching loops
$\sum_{d,e,f} L_d L_e L_f$	Sum of gain products of all possible combinations of three non-touching loops
Δ_k	Cofactor of the k^{th} forward path determinant of the graph with the loops touching the k^{th} forward path removed, that is, the cofactor Δ_k, is obtained from Δ by removing the loops that touch path P_k

Laplace transforms:

TIME FUNCTION $f(t)$	LAPLACE TRANSFORM $F(s)$
Unit Impulse $\delta(t)$	1
Unit step	$\frac{1}{s}$
t	$\frac{1}{s^2}$
t^n	$\frac{n!}{s^{n+1}}$
$\frac{df(t)}{dt}$	$sF(s)-f(0)$
$\frac{d^n f(t)}{dt^n}$	$s^n F(s)-s^{n-1}f(0)-s^{n-2}\frac{df(0)}{dt}\ldots-\frac{d^{n-1}f(0)}{dt^{n-1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at}\sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$

END