00114

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	: 2014/2015
Date	: 18th September 2015
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) "Real systems are nonlinear". Under what conditions does a linear model qualify to be studied as a real systems? Explain.

b) Briefly explain the classifications of models in dynamic systems.

c) Explain the logical steps of the analytical modelling process for a general physical system.

d) List advantages and disadvantages of experimental modelling over analytical modelling.

(Q2)

a) Why are analogies important in modelling of dynamic systems? Explain.

b) What are A-type and T-type elements? Classify mechanical inertia, mechanical spring, fluid inertia, and fluid capacitor into these two types. Explain a possible conflict that could arise due to this classification.

c) "Accurate design of the system should consider the entire system as a whole rather than designing the electrical, electronic, and mechanical aspects separately and sequentially". Explain.

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

(Q3)

a) Obtain governing equations for the basic rotational mechanical elements.

b) Figure 1 shows a motor driving a load through a gear-train which consists of two gears coupled together. The moment of inertia and viscous friction of motor and gear 1 are denoted by $I_{\theta 1}$ and $D_{\theta 1}$ and those of gear 2 and load are denoted by $I_{\theta 2}$ and $D_{\theta 2}$.

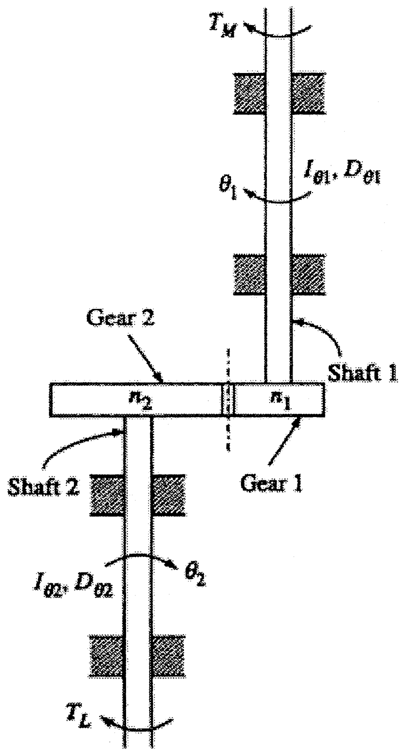

Figure 1

i. How many degrees of freedom does the above system have?

ii. Using first principles derive the governing equation of the system shown above.

(Q4)

a) State the relationship between the analogies ***Force-Current*** and ***Force-Voltage*** of electrical and mechanical systems.

b) Represent the analogous mechanical system for the electrical system depicted in Figure 4 using the force-current analogy.

(Q5)

a) "The transfer function approach is extensively used in the analysis and design of dynamic systems". Comment on this statement.

b) Obtain the transfer function $\frac{E_0}{E_i}$ of the op-amp circuit shown in figure 2.

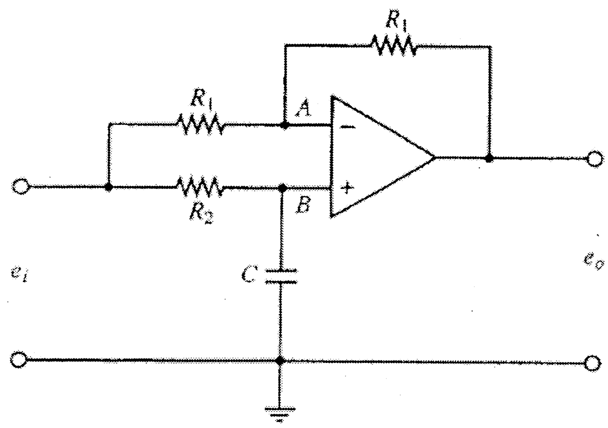

Figure 2

(Q6)

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

b) For the network given on figure 3, find the governing equations using the impedance method.

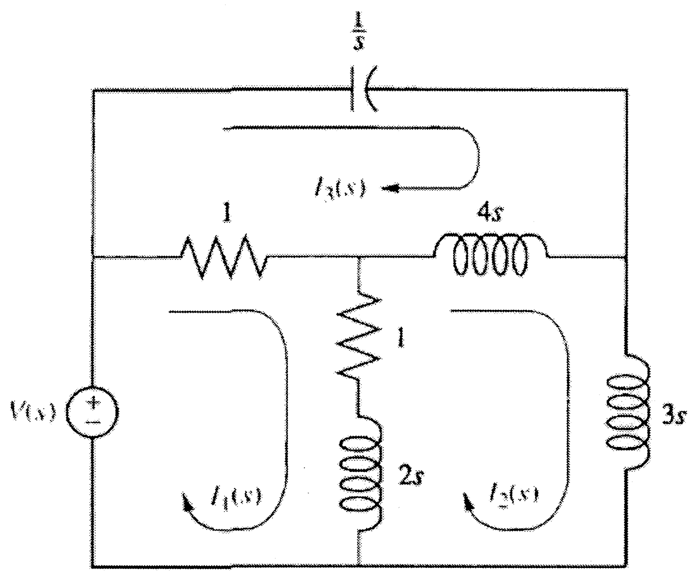

Figure 3

001

(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) Represent the electrical network given in Figure 4, in state-space form.

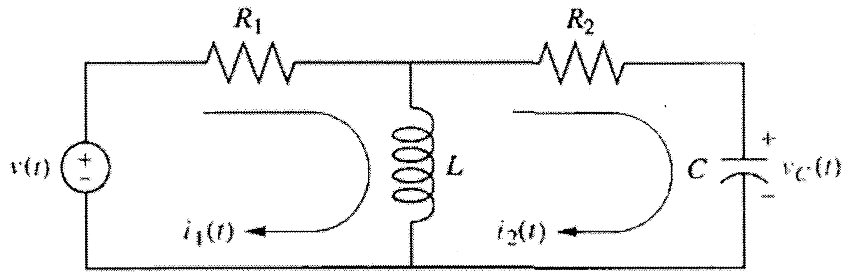

Figure 4

(Q8)

a) For the block diagram shown in figure 5, determine the transfer function $\frac{C(s)}{R(s)}$ by block diagram simplification.

b) Develop a signal flow graph for the block diagram in figure 5 and verify answer in part (a) by using the mason's rule.

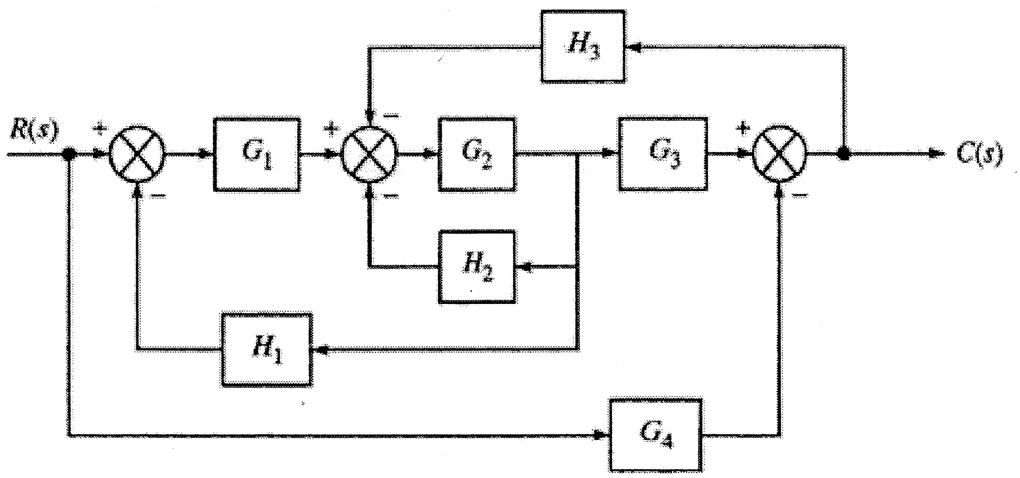

Figure 5

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

00114

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