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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX3573 Modeling of Mechatronics Systems**
Academic Year	: 2020/21
Date	: 08th January 2022
Time	: 14:00-17:00hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Eight (8)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
6. Answers should be in clear hand writing.
7. Do not use Red colour pen.

Question 01

a) Briefly explain the procedure in developing a model for a dynamic system. [*5 marks*]

b) Discuss the importance of the use of analogies in modeling of mixed systems such as mechatronics systems. [*5 marks*]

c) Obtain expressions for the impedance of basic mechanical and electrical elements. [*5 marks*]

Question 05

The transfer function of a human leg relates the output angular rotation about the hip joint to the input torque supplied by the leg muscle. A simplified model for the leg is shown in Figure Q5. The model assumes an applied muscular torque, $T_m(t)$, viscous damping, D, at the hip joint, and inertia, J, around the hip joint. Also, a component of the weight of the leg, Mg, where M is the mass of the leg and g is the acceleration due to gravity, creates a nonlinear torque. If we assume that the leg is of uniform density, the weight can be applied at $L/2$, where L is the length of the leg. Do the following:

a) Evaluate the nonlinear torque. *[10 marks]*

b) Find the transfer function, $\theta(s)/T_m(t)$, for small angles of rotation, where $\theta(s)$ is the angular rotation of the leg about the hip joint. *[10 marks]*

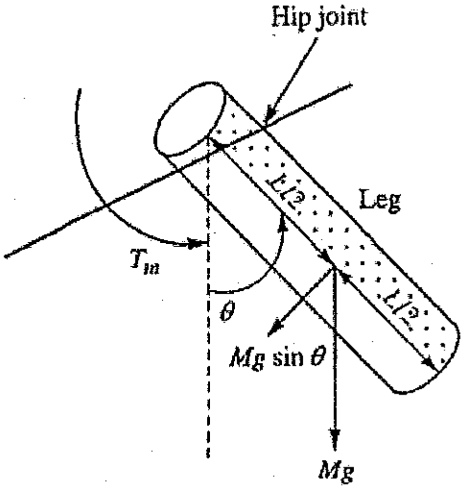

Figure Q5

Question 06

Obtain a state-space representation of the system shown in Figure Q6. *[20 marks]*

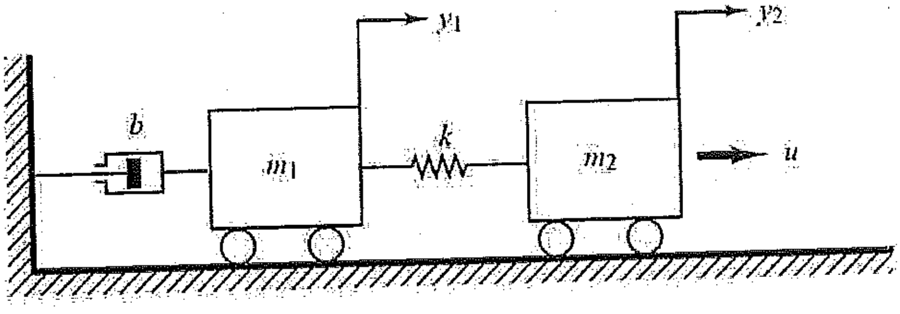

Figure Q6

Question 07

Obtain the transfer function $E_o(s)/E_i(s)$ of the electrical system shown in Figure Q7.

[20 marks]

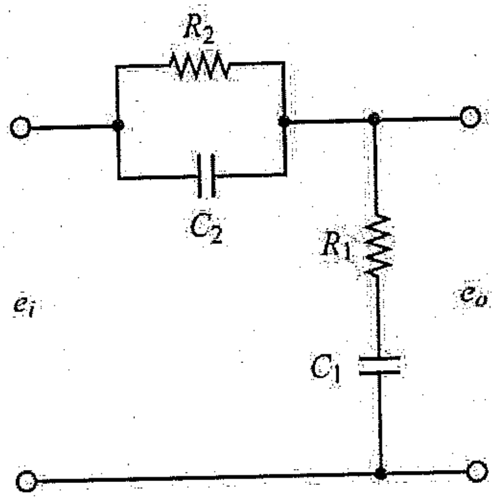

Figure Q7

Question 08

Simplify the block diagram shown in Figure Q8 and obtain the closed-loop transfer function $C(s)/R(s)$. *[20 marks]*

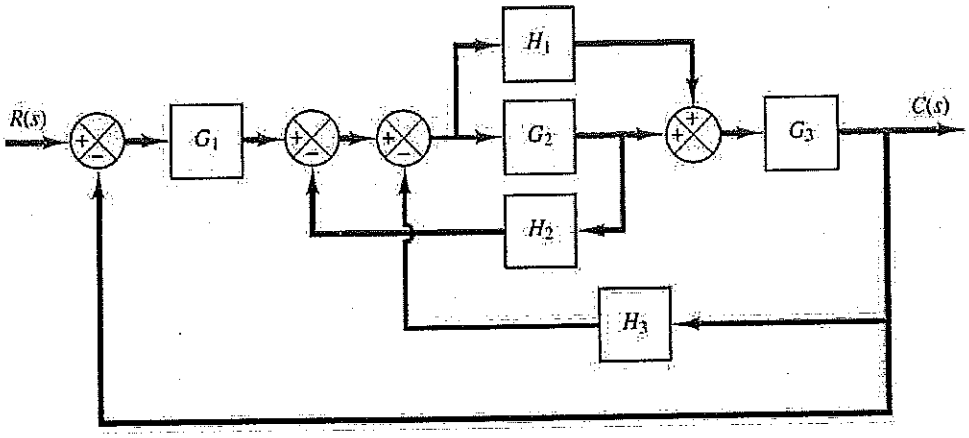

Figure Q8

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