00041

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/MEX3273 Modelling of Mechatronics Systems**
Academic Year	: 2019/20
Date	: 9th October 2020
Time	: 1400-1700hrs

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 [*20 marks*]

An aircraft arresting gear is used on an aircraft carrier as shown in Figure Q1. The linear model of each energy absorber has a drag force $f_D = K_D \dot{x}_3$. It is desired to halt the airplane within $30m$ after engaging the arresting cable. The speed of the aircraft on landing is $60m/s$.

a) Describe the operation principle of aircraft arresting gear.

b) Select the required constant K_D.

c) Draw the block diagram to represent the system.

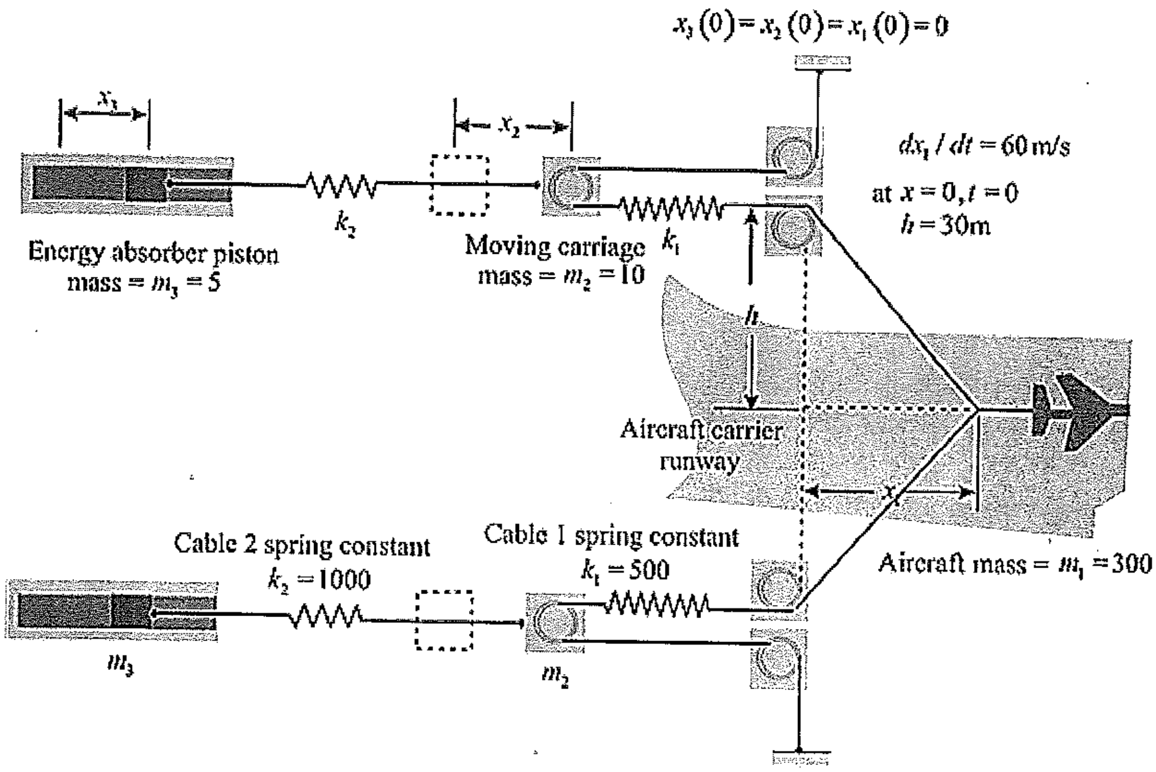

Figure Q1

Question 02 *[20 marks]*

a) Illustrate the speed control system of a motorcycle with a human driver, in the form of a block diagram. Describe each block in the system.

b) In a chemical process control system, it is valuable to control the chemical composition of the product. To do so, a measurement of the composition can be obtained by using an infrared stream analyzer, as shown in Figure Q2. The valve on the additive stream may be controlled. Complete the control feedback loop, and sketch a block diagram describing the operation of the control loop.

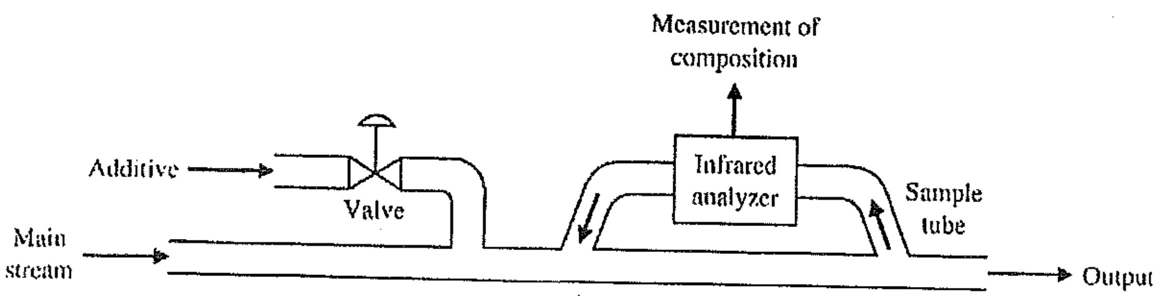

Figure Q2

Question 03 *[20 marks]*

a) Given the following differential equation, solve for $y(t)$ if all initial conditions are zero. Use the Laplace transform.

$$\frac{d^2t}{dt^2} + 12\frac{dy}{dt} + 32y = 32u(t)$$

b) Given the network of Figure Q3, find the transfer function, $I_2(s)/V(s)$.

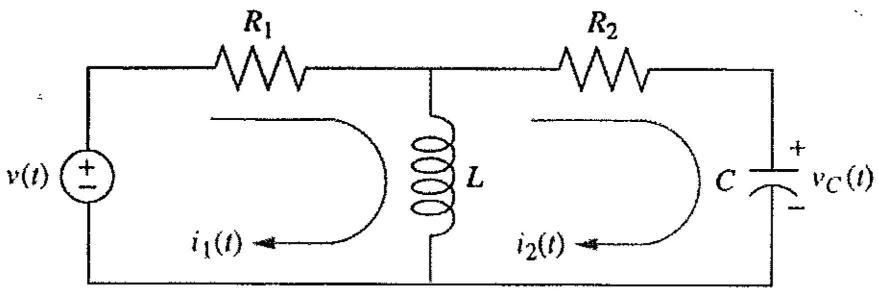

Figure Q3

Question 04 *[20 marks]*

Reduce the system shown in Figure Q4 to a single transfer function. (**you must clearly show all steps**).

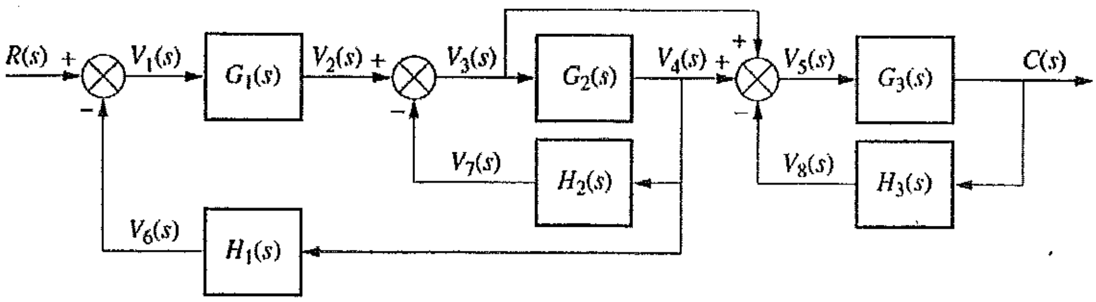

Figure Q4

Question 05

[20 marks]

a) Explain the term "signal" in the context of modeling. Elaborate on your answer by taking suitable example.

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

c) Name some of the multi domain systems that you are familiar with and explain why it is often considered difficult in obtaining system models for such systems.

d) "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.

Question 06

[20 marks]

a) Draw the block diagram of the linear, continuous time control system represented in state space.

b) Determine the state variable matrix equation for the circuit shown in Figure Q6. Let $x_1 = v_1, x_2 = v_2, and\ x_3 = i.$

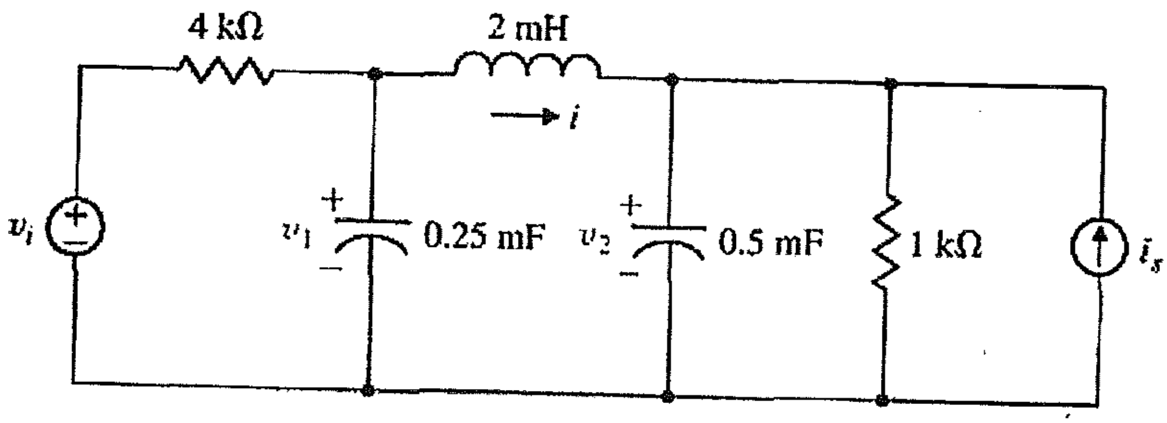

Figure Q6

Question 07 *[20 marks]*

a) A system is represented by a block diagram as shown in Figure Q7. Determine the state space representation.

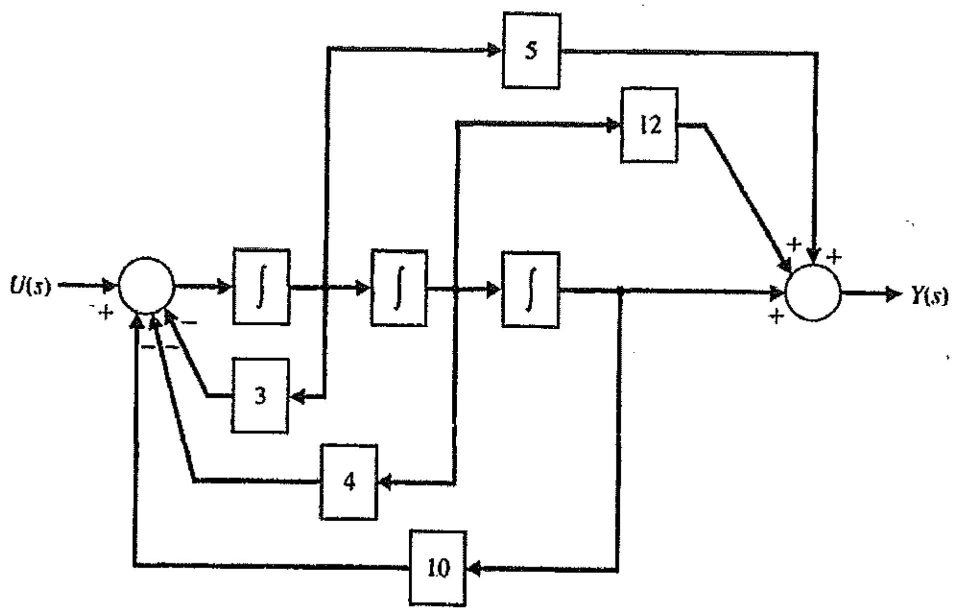

Figure Q7

b) A single-input, single-output system has the following matrix equations. Determine the transfer function $G(s) = Y(s)/U(s)$.

$$\dot{X} = \begin{bmatrix} 1 & 1 & -1 \\ 4 & 3 & 0 \\ -2 & 1 & 10 \end{bmatrix} X + \begin{bmatrix} 0 \\ 0 \\ 4 \end{bmatrix} u,$$

$$Y = [1 \quad 0 \quad 0]X$$

Question 08 *[20 marks]*

The model for the truck tire movement is shown in Figure Q8. Develop the analogous electrical circuit based on *force-voltage* and *force-current*.

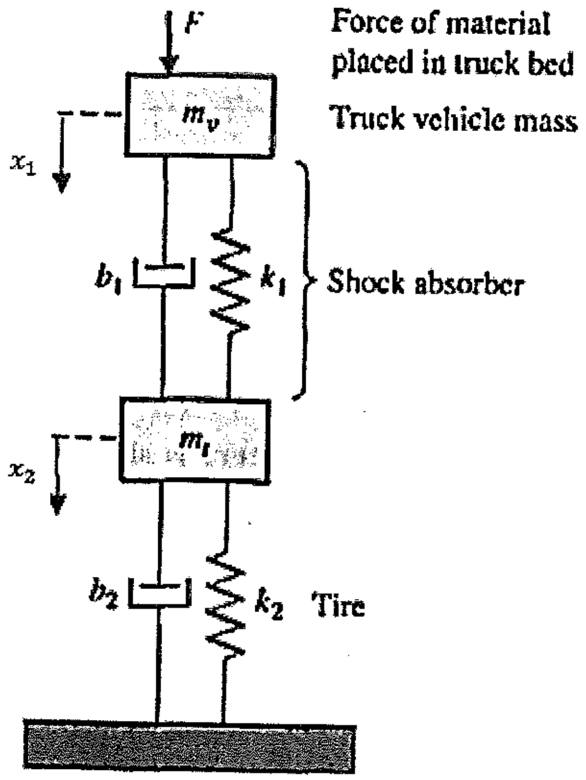

Figure Q8

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