00063

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	**:DMX4572/MEX4272 Vibration and Fault Diagnosis**
Academic Year	: 2019/20
Date	: 17th October 2020
Time	: 0930-1230hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (6)** 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]*

The inverted pendulum may be used as a simple model in the stability studies of inherently unstable systems such as rockets. Consider an inverted pendulum of point mass m and length l, which is restrained at its pivot (assumed to be smooth) by a torsional spring of stiffness k. This arrangement is sketched in Figure Q1.

a) Derive an equation of motion for this system.

b) Obtain an expression for the natural frequency of small oscillations θ about the vertical configuration. Under what conditions would such oscillations not be possible (i.e., the system would become unstable)?

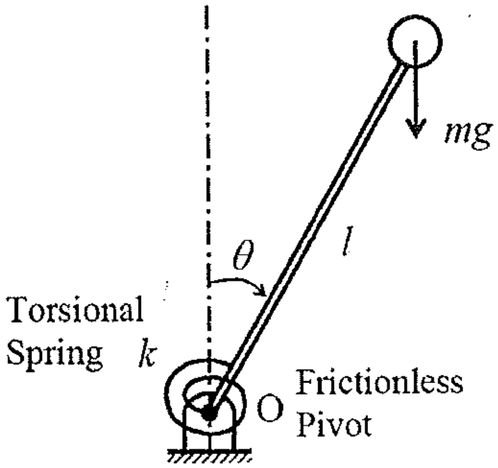

Figure Q1

Question 02 *[20 marks]*

a) Consider the simplified model of a single-degree-of-freedom robot arm (single link) shown in Figure Q2. The link is driven by a dc motor, through a light shaft of torsional stiffness k_s. Discuss how mechanical vibrations in a robot arm could adversely affect its performance.

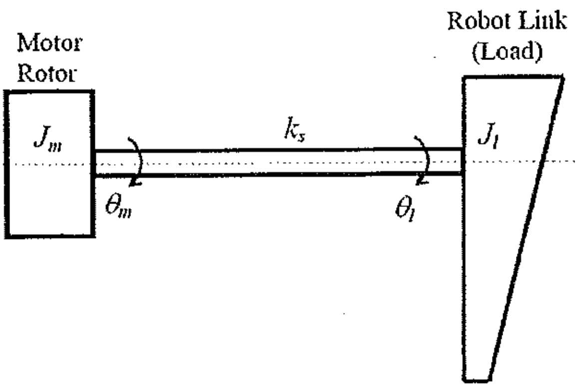

Figure Q2

b) Find the total response of a viscously damped single DoF system subjected to a harmonic base excitation for the following data:

$$m = 10\text{kg}, \quad c = \frac{20\text{Ns}}{\text{m}}, \quad k = \frac{4000\text{N}}{\text{m}}, \quad y(t) = 0.05 \sin 5t \text{ m}, \quad x_0 = 0.02\text{m},$$

$$\dot{x_0} = 10\text{m/s}$$

[20 marks]

Question 03

Figure Q3 shows a simple model of a motor vehicle that can vibrate in the vertical direction while traveling over a rough road. The vehicle has a mass of $1200kg$. The suspension system has a spring constant of $400kN/m$ and a damping ratio of $\zeta = 0.5$. If the vehicle speed is 20 km/h, determine the displacement amplitude of the vehicle. The road surface varies sinusoidal with an amplitude of $Y = 0.05$ and a wavelength of $6m$.

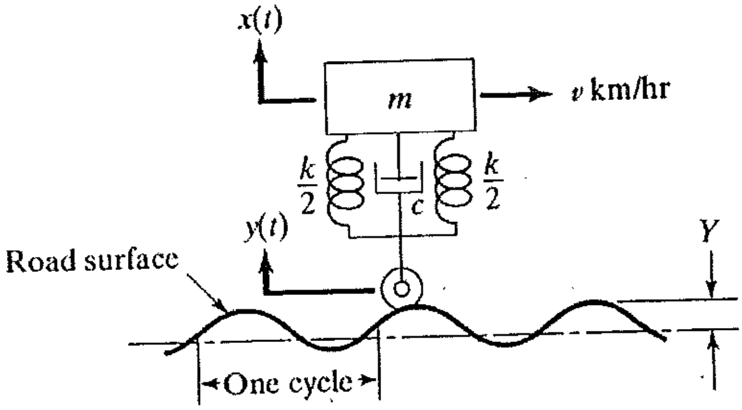

Figure Q3

[20 marks]

Question 04

a) Define these terms: *cycle, amplitude, phase angle, linear frequency, period,* and *natural frequency*.

b) How can we obtain the *frequency, phase,* and *amplitude of a harmonic motion* from the corresponding rotating vector?

c) What is the difference between a *discrete* and a *continuous* system? Is it possible to solve any vibration problem as a discrete one?

d) Describe three different ways of expressing a periodic function in terms of its harmonics.

Question 05 *[20 marks]*

a) Explain why mechanical vibration is an important area of study for engineers.

b) Mechanical vibrations are known to have harmful effects as well as useful ones. Briefly describe five practical examples of "good vibrations" and five practical examples of "bad vibrations".

c) Under some conditions it may be necessary to modify or redesign a machine with respect to its performance under vibrations.

   i. Describe the possible reasons for this.

   ii. Explain the modifications that could be carried out on a machine in order to suppress its vibrations.

Question 06 *[20 marks]*

A heavy machine, weighing $3000N$, is supported on a resilient foundation. The static deflection of the foundation due to the weight of the machine is found to be $7.5cm$. It is observed that the machine vibrates with an amplitude of $1cm$ when the base of the foundation is subjected to harmonic oscillation at the undamped natural frequency of the system with an amplitude of $0.25cm$.

a) Determine the damping constant of the foundation.

b) Find the dynamic force amplitude on the base.

c) Find the amplitude of the displacement of the machine relative to the base.

Question 07 *[20 marks]*

Find the natural frequencies and mode shapes of a spring-mass system, shown in Figure Q7, which is constrained to move in the vertical direction only. Take $n = 1$.

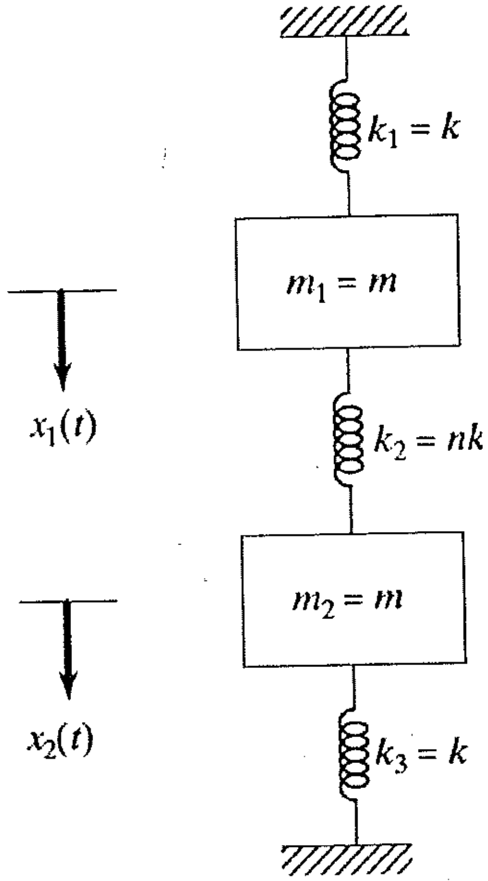

Figure Q7

Question 08 *[20 marks]*

A mechanical system that is at rest is subjected to a unit step input $u(t)$. Its response is given by following equation. Determine the following.

$$y(t) = 2 - e^{-t}(2\cos t + \sin t)$$

a) Transfer function of the system.

b) Input-Output differential equation of the system.

c) Damped natural frequency, undamped natural frequency, and the damping ratio.

d) Response of the system to a unit impulse input.

e) Steady state response for a unit step input.

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