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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	**:DMX4572/MEX4272 Vibration and Fault Diagnosis**
Academic Year	: 2017/18
Date	: 29th January 2019
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 **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]*

a) Dynamic modeling, both analytical and experimental (e.g., experimental modal analysis), is quite important in the design and development of a product for good performance with regard to vibration. Indicate how a dynamic model may be utilized in design of a device giving due consideration to vibration.

b) A spring-mass system, having a mass of $10kg$ and a spring of stiffness of $4000\ N/m$, vibrates on a horizontal surface. The coefficient of friction is 0.12. When subjected to a harmonic force of frequency $2Hz$, the mass is found to vibrate with an amplitude of $40mm$. Find the amplitude of the harmonic force applied to the mass.

Question 02 *[20 marks]*

a) A precision milling machine, weighing $1000kg$, is supported on a rubber mount. The force-deflection relationship of the rubber mount is given by following equation, where the force (F) and the deflection (x) are measured in pounds and inches, respectively. Determine the equivalent linearized spring constant of the rubber mount at its static equilibrium position.

$$F = 2000x + 200x^3$$

b) Figure Q2 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 $20km/hr$, determine the displacement amplitude of the vehicle. The road surface varies sinusoidally with an amplitude of $Y = 0.05m$ and a wavelength of $6m$.

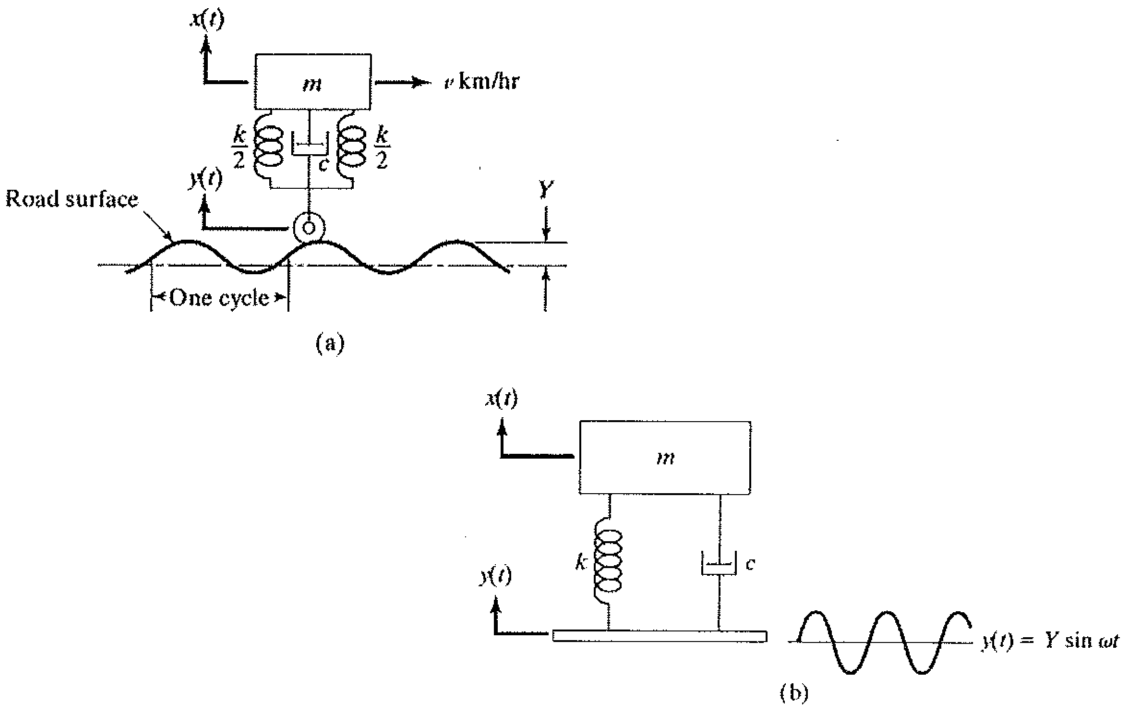

Figure Q2

Question 03 *[20 marks]*

The schematic diagram of a large cannon is shown in Figure Q3. When the gun is fired, high pressure gases accelerate the projectile inside the barrel to a very high velocity. The reaction force pushes the gun barrel in the direction opposite that of the projectile. Since it is desirable to bring the gun barrel to rest in the shortest time without oscillation, it is made to translate backward against a critically damped spring-damper system called the recoil mechanism. In a particular case, the gun barrel and the recoil mechanism have a mass of $500kg$ with a recoil spring of stiffness $10{,}000N/m$. The gun recoils $0.4m$ upon firing.

a) Find the critical damping coefficient of the damper.

b) Find the initial recoil velocity of the gun.

c) Find the time taken by the gun to return to a position 0.1 m from its initial position.

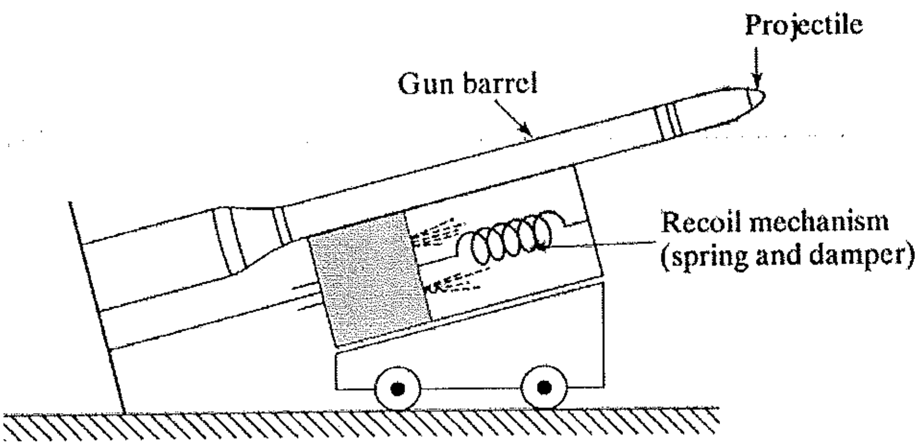

Figure Q3

Question 04 *[20 marks]*

The experimental setup to demonstrate energy conversion and natural oscillation is shown in Figure Q4. It has been demonstrated of some important concepts in mechanical vibration. The mass m of the ball is known. The interior of the see-through tube may be assumed frictionless. By hanging known weights from the string and noting the corresponding deflections of the top end of the spring, it is possible to determine the stiffness k of the spring. After this is done, the relaxed position of the spring is noted. Then the ball is carefully placed on the top platform of the spring. The string is pulled by hand, so that the spring deflects through a distance x from the relaxed position, and then carefully released. The ball ejects vertically as a result and rises to a maximum height of h (without hitting the height indicator) as measured from the relaxed configuration of the spring.

a) Derive an expression for h in terms of x, k, and m. Give all the details of the derivation and the assumptions made.

b) Explain the reasons why, in practice your expression as derived in Q4(a), will not exactly hold.

c) The ball drops on the platform and pushes the spring as a result. Is there a process of natural oscillation in the resulting response? Explain.

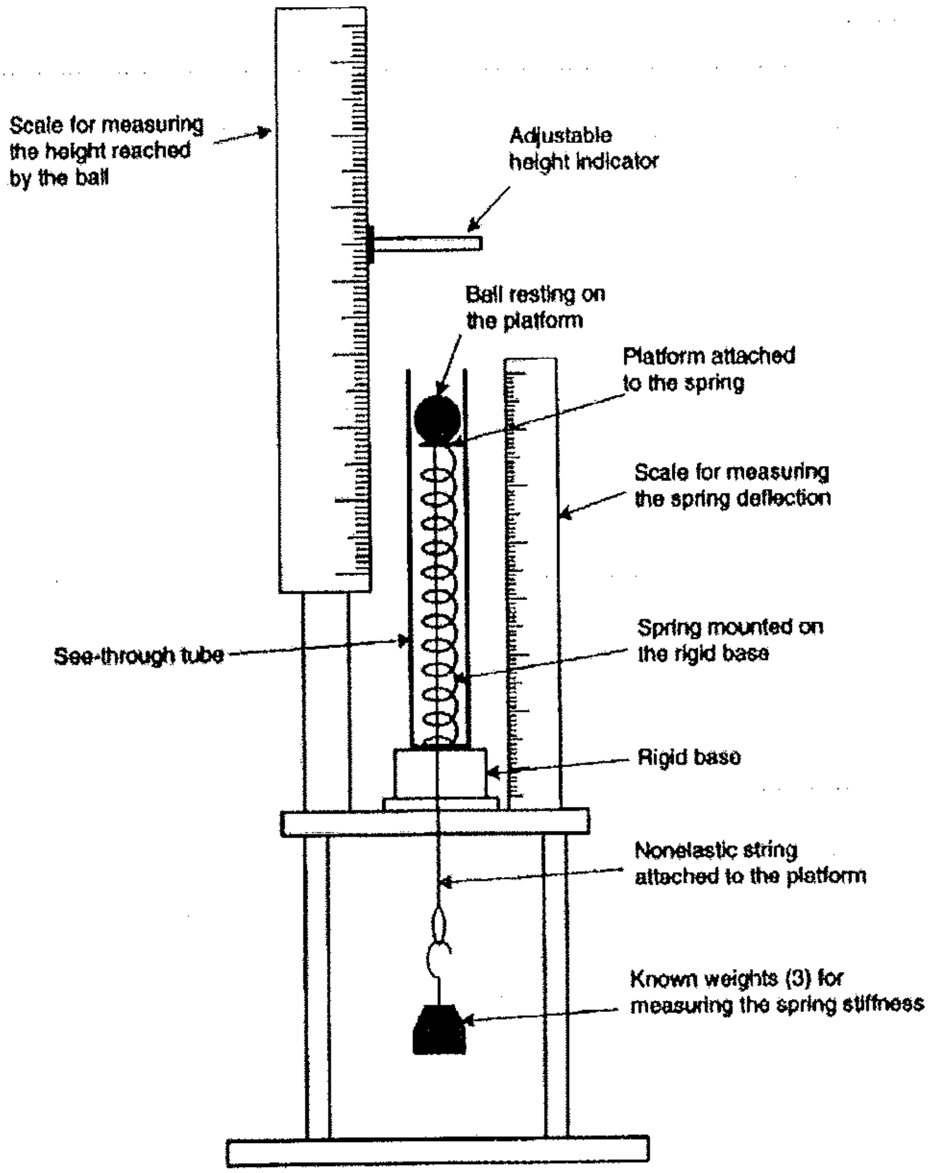
Scale for measuring
the height reached
by the ball
Adjustable
height indicator
Ball resting on
the platform
Platform attached
to the spring
Scale for measuring
the spring deflection
See-through tube
Spring mounted on
the rigid base
Rigid base
Nonelastic string
attached to the platform
Known weights (3) for
measuring the spring stiffness

Figure Q4

Question 05 *[20 marks]*

The schematic diagram of a marine engine connected to a propeller through gears is shown in Figure Q5. The mass moments of inertia of the flywheel, engine, $Gear\ 1$, $Gear\ 2$, and the propeller ($in\ kgm^2$) are 9000, 1000, 250, 150, and 2000, respectively. Find the natural frequencies and mode shapes of the system in torsional vibration.

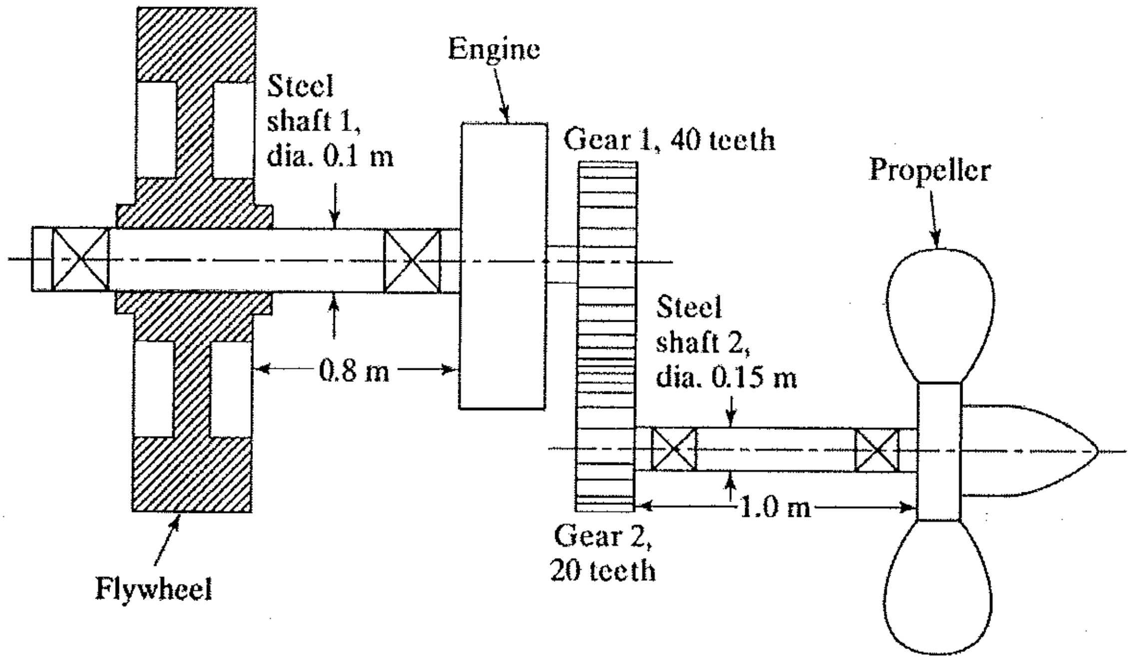

Figure Q5

Question 06 *[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.

$$y(t) = 2 - 2e^{-2t}cos4t - e^{-2t}sin4t$$

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.

Question 07 *[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 08 *[20 marks]*

An electric motor of mass M, mounted on an elastic foundation, is found to vibrate with a deflection of $0.15m$ at resonance as shown in Figure Q8. It is known that the unbalanced mass of the motor is 8% of the mass of the rotor due to manufacturing tolerances used, and the damping ratio of the foundation is $\zeta = 0.025$. Determine the following:

a) The eccentricity or radial location of the unbalanced mass (e).

b) The peak deflection of the motor when the frequency ratio varies from resonance.

c) The additional mass to be added uniformly to the motor if the deflection of the motor at resonance is to be reduced to $0.1m$.

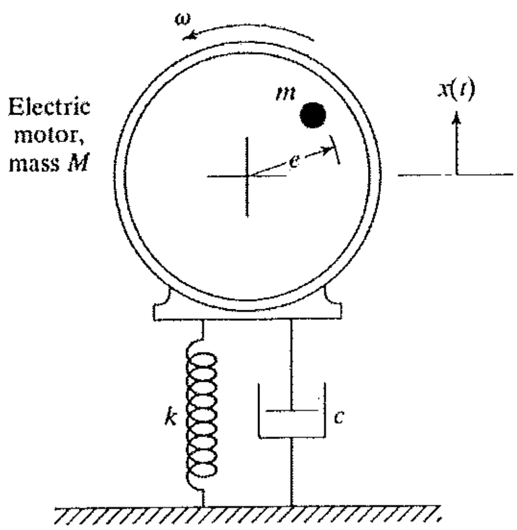

Figure Q8

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