THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
FINAL EXAMINATION – 2007

MEX4272 – VIBRATION AND FAULT DIAGNOSIS

DATE : 02 ND MAY 2008
TIME : 0930 HRS. – 1230 HRS.
DURATION : THREE (03) HOURS

ANSWER ANY FIVE (05) QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

QUESTION 01

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

Mechanical vibrations are known to have harmful effects as well as useful ones. Briefly describe three practical examples of good vibration and three examples of bad vibration.

(ii) 'Out of the indicators such as vibration, temperature, pressure and oil quality, that indicate the overall mechanical condition of a machine, vibration is the best and the earliest indicator of defects developing'

Comment on this statement.

QUESTION 02

Fig. Q2 shows a sphere of mass m and diameter $2r$, rolling on the inside surface of a fixed cylinder of radius R, without slipping. Determine the frequency of small rolling oscillations of the sphere, about the lowest point of the cylinder. Take moment of inertia of the sphere about an axis through the centre as J.

Show that this frequency is equal to $\frac{1}{2\pi}\sqrt{\frac{5g}{7(R-r)}}$ Hz, if $J = (2/5)\ mr^2$.

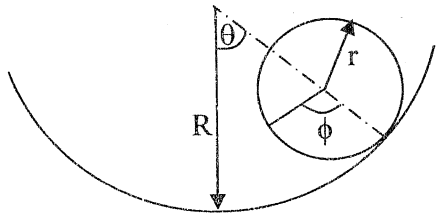

Fig. Q2

QUESTION 03

Two rods of negligible mass each carrying a single concentrated mass m are supported on two springs, each having a stiffness k, as shown in Fig. Q3. The system is free to oscillate in the vertical plane and the rods are horizontal in the equilibrium position. Determine the equations of motion and the frequency equation for small angular oscillations of the rods.

Also determine the natural frequencies of angular oscillations.

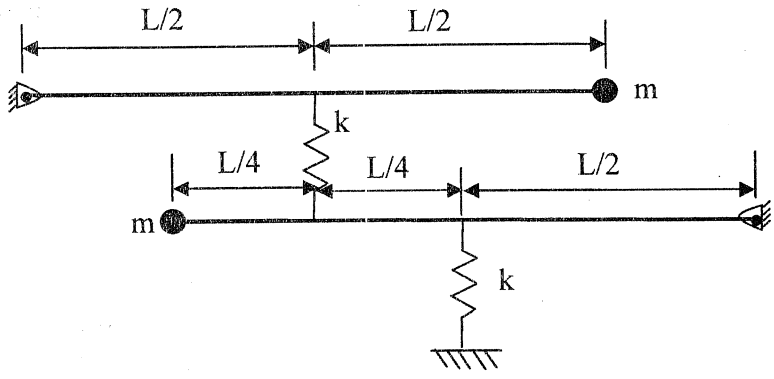

Fig. Q3

QUESTION 04

Fig. Q4 shows a simple oscillator consisting of a mass m, spring of stiffness k and a damper of damping constant b. Assuming an exponential solution of the form $x = Ce^{\lambda t}$, obtain the characteristic equation of the system.

If $m = 5$ kg, $k = 2 \times 10^3$ N/m, determine the free response of the oscillator for
(i) $b = 100$ Ns/m and (ii) $b = 400$ Ns/m.

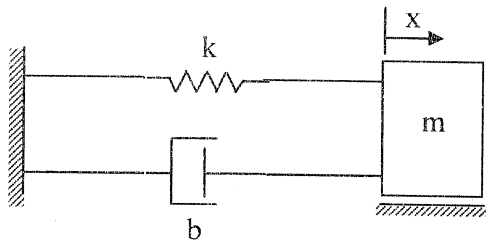

Fig. Q4

QUESTION 05

Fig. Q5 shows a spring-mass system having two degrees of freedom. Write the equations of motion for the system and determine its natural frequencies and two mode shapes.

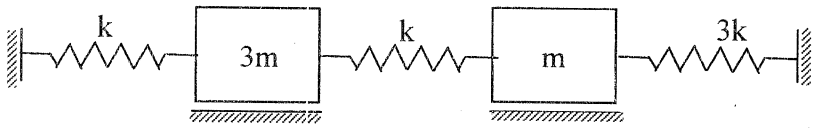

Fig. Q5

QUESTION 06

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

$$y = [2e^{-t} \sin t]\, u(t)$$

(i) Write the input-output differential equation of the system.

(ii) What is the transfer function?

(iii) Determine the damped natural frequency, undamped natural frequency and the damping ratio.

(iv) Obtain the response of the system to a unit impulse input.

(v) What is the steady state response for a unit step input?

QUESTION 07

A flexible shaft rotor system is shown in Fig. Q7. The rotors have moments of inertia I_1 and I_2 and the shaft sections have torsional stiffnesses K_1, K_2 and K_3 as indicated in the figure. Derive an expression for the natural frequencies of free torsional oscillations of the system.

If $K_1 = K_2 = K_3 = 1$ Nm/rad and $I_1 = 2I_2 = 2$ kgm^2, determine the frequencies and the mode shapes.

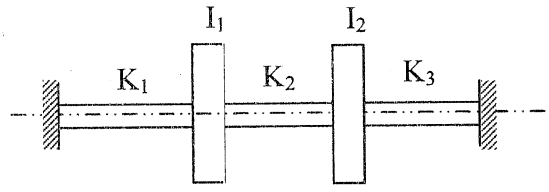

Fig. Q7

QUESTION 08

(i) Write short notes on the following terms.

(a) Measurement accuracy

(b) Instrument accuracy

(c) Precision

(ii) Explain the advantages and disadvantages of the three basic maintenance strategies adopted in maintaining machinery and equipment.

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	$\frac{n1}{s^{n+1}}$
$\frac{df(t)}{dt}$	$sF(s)-f(o)$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$