The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX5233 – Dynamics of Mechanical Systems**
Academic Year	:	2015/16
Date	:	22nd November 2016
Time	:	0930hrs – 1230hrs
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. **Question 01 is compulsory.**
4. Answer any 5 questions with the compulsory (Question 01, answer either Part A or Part B) question.

Question No.01: (Attempt only PART A or PART B)

I. PART A

a. Explain the term "Vibrations" in a Mechanical Engineering Designing perspective.

b. What is "Vibration Isolation", distinguish "Active Isolation" and "Passive Isolation" using necessary sketches and equations.

c. State the two types of the vibration measurement equipment and explain the working principle of one instrument using necessary sketches.

d. State D 'Alembert Principle and define Degree of Freedom (DOF) and Free Body Diagram (FBD).

e. Name the four systems in the Figure-1 and

   i. write the governing equation of the motion (no need to prove)

   ii. sketch the response curve of each system.

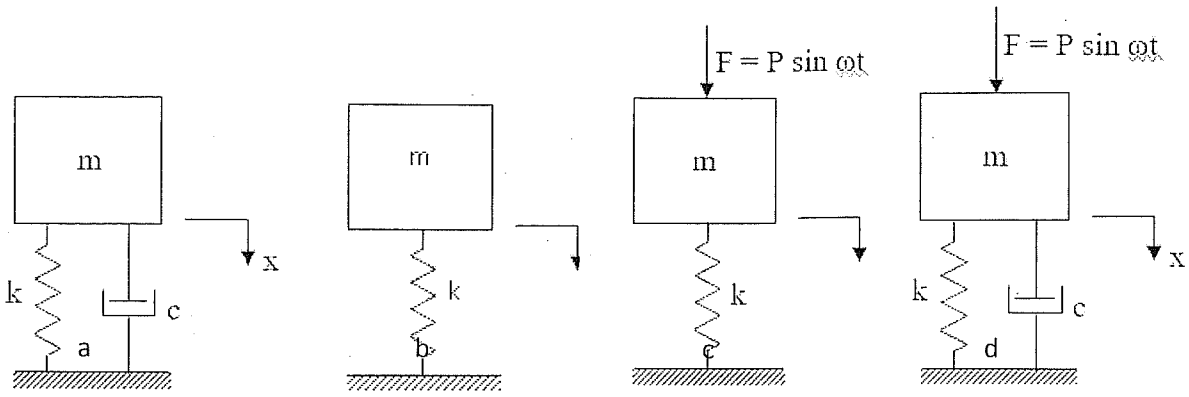


Figure - 1

II. PART B

a. Distinguish between "Open Loop Control Systems" and "Close Loop Control Systems"

b. Define five transient response specifications and sketch it on a typical transient response curve.

c. What are PID controllers and explain the main control objectives of PID controllers.

d. The open loop transfer function of a unity feedback control system is given by $G(s) = \frac{25}{s(s+5)}$, Calculate the damping ratio and the maximum overshoot.

If the damping ratio is to be made 0.75 using a "tachometer feedback", determine the tachometer constant and the maximum overshoot.

Question No.02:

A uniform bar of length **l** and mass **m** is attached to an additional mass **m** as shown in the Figure- 2. Then it is mounted on two springs which stiffness is **k** in two extreme ends.

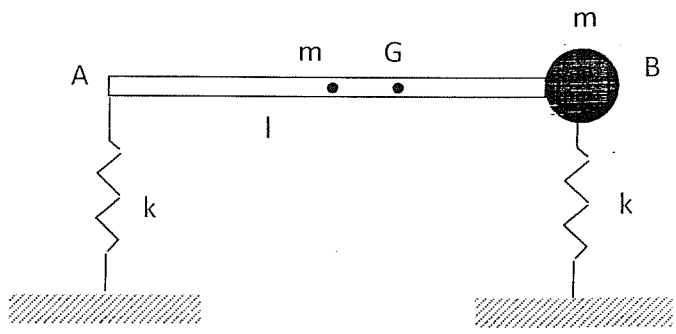


Figure - 2

a. Draw the Free Body Diagram (FBD) of the system.

b. Derive the frequency equation for the system using D' Alembert principles.

c. Hence calculate the natural frequencies of the system.

d. Draw the mode shapes for the given system.

Question No.03:

I. A shaft having 100 mm diameter and length 1 m has one of its ends fixed and the other end carries a disc of mass 500 kg and its radius of gyration 450 mm. The modulus of rigidity of the material of the shaft is 80 GN/m^2. Determine the frequency of torsional vibrations.

II. Figure - 3 shows a five rotor system which has the following parameters.
$I_1 = 1, I_2 = 2, I_3 = 3, I_4 = 4, I_5 = 2$ kg m^2
$K_1 = K_2 = K_3 = K_4 = 1$ Nm/rad

Using Holzer method show that the natural frequency of torsional vibration of the system is 1 rad/s.

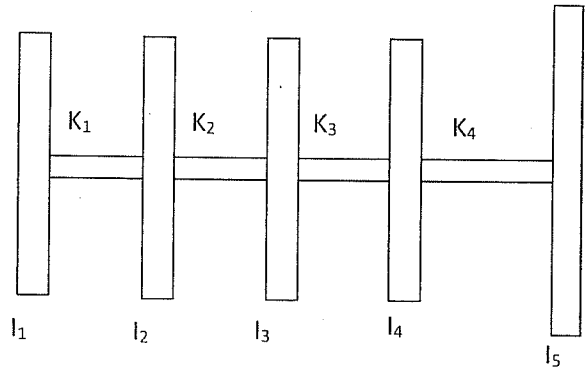


Figure - 3

Question No.04:

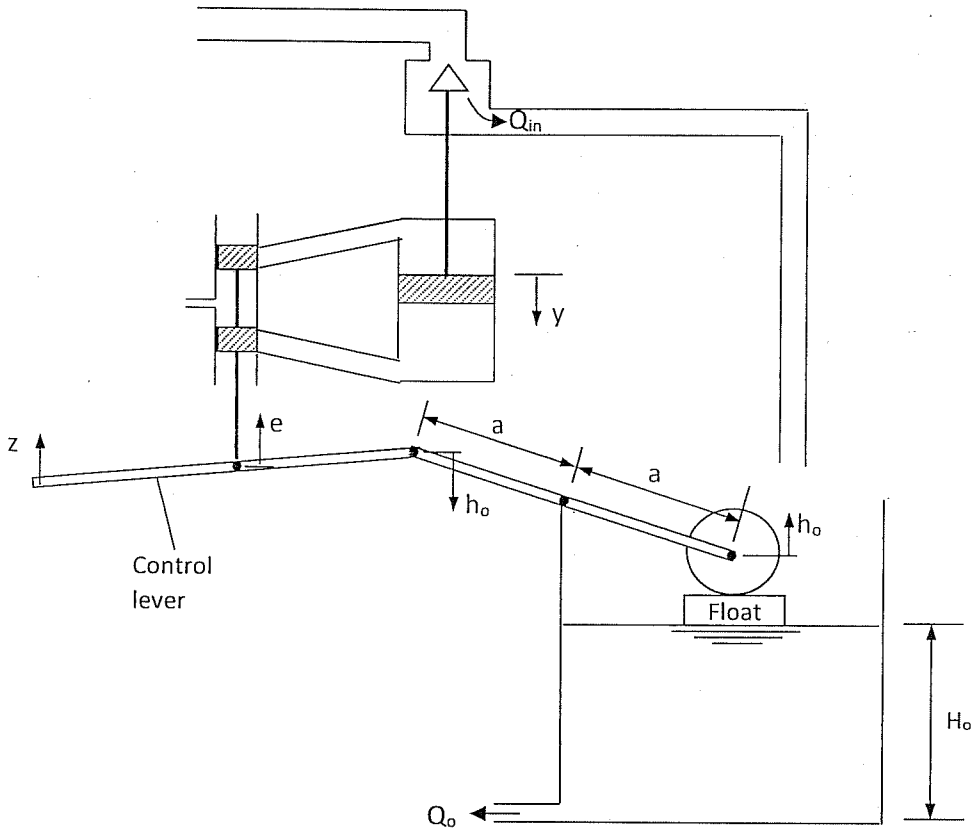


Figure - 4

Figure- 4 shows a liquid level controller. At steady state the liquid flowing into the system is Q_{in} and that is flowing out of the tank is Q_o. $Q_{in} = Q_o$ and the height H_o of the liquid level in the tank remains constant. Flow rate Q_o is proportional to the pressure head H_o. To raise the level of the liquid the control lever is moved up (That is position z is raised). This raises the valve position $e = \frac{(z - h_o)}{2}$, which increases y, thereby admitting (in addition to Q_{in}) more flow q_{in}. The flow into the cylinder of cross sectional area A_1 is equal to $K_1 e$ where K_1 is a constant. The flow q_{in} is directly proportional to the valve opening y and $q_{in} = K_2 y$ where K_2 is a constant. The change volume of liquid in the tank is the time integral $\frac{(q_{in} - q_o)}{D}$, which is equal to the cross sectional area of the tank A_2 times the change in level h_o. The additional flow out of the tank q_o is proportional to the head of liquid in the tank. Determine the overall block diagram for the system.

Question No.05:

Figure - 5 shows a simply supported beam of length L_1 with a concentrated load P_o ,acting at its middle point and its shear-force diagram.

If the load is suddenly withdrawn find its ensuring vibration.

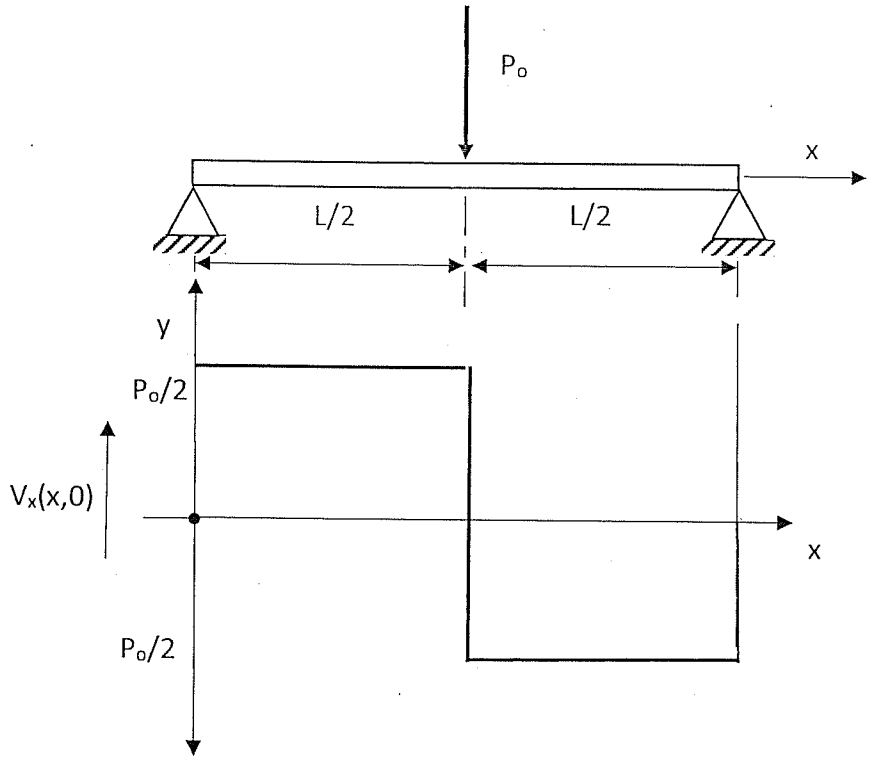


Figure - 5

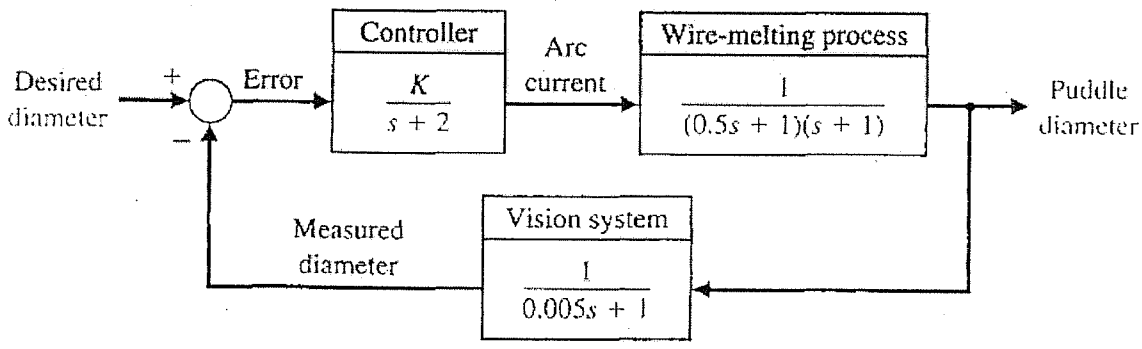
Question No.06:

Following block diagram shows in Figure – 6 is a control system of an industrial robot used for Arc welding applications. In many cases, robot encounters surface irregularities and complex geometries which requires a vision system to rectify the error. Many systems use vision aid to measure the geometry of the puddle of melted metal, as shown in Figure 6. The system shown in the block diagram uses a constant rate of feeding the wire to be melted.

a) Calculate the maximum value for K for the system that will result in a stable system (Hint: Use Routh–Hurwitz stability criteria)

b) For half of the maximum value (take round off value) of K found in part (a), determine the roots of the characteristic equation

c) Estimate the overshoot of the system of part (b) when it is subjected to a step input.



Robot Welding Control

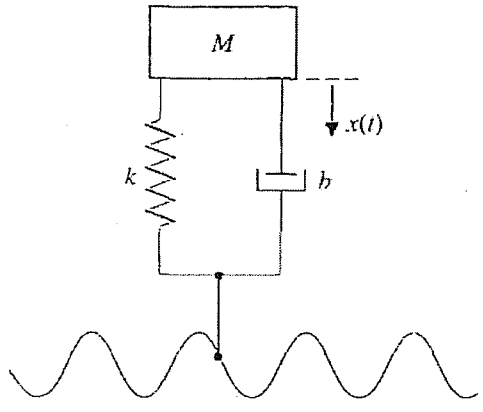
Figure - 6

Question No.07:

As an automobile moves along the road, the vertical displacements at the tires act as the motion excitation to the automobile suspension system. Figure -7 is a schematic diagram of a simplified automobile suspension system, for which we assume the input is sinusoidal.

Determine the transfer function X(s)/R(s), and

sketch the Bode diagram when M - 1 kg, b = 4 N s/m and k = 18 N/m.



Auto Suspension System Model

Figure - 7

Question No.08:

Define gain margin and phase margin of a unity feedback system with respect to a Nyquist plot.

The open loop transfer function of a unity feedback control system is given by

$$G(s) = \frac{K}{s(s+2)(s+6)}$$

where K is the gain of the controller.

Determine the value of K in order to have (i) a gain margin of 6 db (ii) a phase margin of 30^{o}.

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