MASTER OF MECHANICALENGINEERING EXAMINATION, 2019

(1st Year, 2nd Semester)

MECHANICAL SYSTEMS AND VIBRATION CONTROL

Time: **Three hours** Full Marks: **100**

Different parts of a question must be answered together.
Provide sketches wherever applicable.
Answer any **Four (4)** questions

1.(*a*). Consider the two identical pendulum (Length – L and mass – m) connected by a linear spring of stiffness k, as shown in Figure 1. Assuming small rotations about the equilibrium position:

(*i*). Derive the equations of motion for the system and write them in matrix notation.

(*ii*). Find out the characteristic equation and evaluate the natural frequencies of the system.

(*iii*). Determine the modal vectors corresponding to the natural frequencies. [12]

1.(*b*). Explain what is understood by the following terms: Modal Orthogonality and Natural Coordinates. Determine the response of the system shown in Figure 1 following modal analysis. [03+03]

1.(*c*). The initial condition for the above system is given as follows: $\theta_1(0) = \theta_0$, $\theta_2(0) = 0$, $\dot{\theta}_1(0) = 0$, $\dot{\theta}_2(0) = 0$. Obtain the response of the system subjected to these initial conditions and schematically show the time-displacement plots for both the pendulums. [05+02]

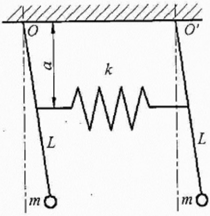

Figure 1

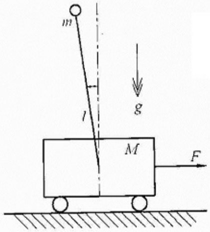

Figure 2

2.(*a*). A cart (Mass - M) with a pendulum (Length – l and mass – m) attached vertically to it, moves on a horizontal frictionless surface, under the action of a horizontal force (F) (as shown in Figure 2). Derive the governing equations of motion following energy method. Comment on how the equations are coupled. [14+01]

2.(*b*). Mention at least two distinct attributes where a nonlinear system differs from a linear system. Write a short note on: Sources of nonlinearity. What do you understand by hardening and softening type nonlinearity? [02+06+02]

3.(*a*). What is meant by complex stiffness? Mention two real life situations where springs show complex behaviour. [02+01]

3.(*b*). Define: Absolute and Relative Transmissibility. Classify vibration isolators on the basis of different types of damping models. For each of the types write down the complex stiffness expression and subsequently derive the expression for absolute transmissibility. Also draw schematic representations of variation of transmissibility with respect to frequency ratio for the above mentioned damping models and indicate the appropriate operating zones in each case. [03+01+03+09+06]

4.(*a*). Explain with a neat sketch what do you understand by damped dynamic vibration absorber. Derive an expression for the normalized response amplitude (steady state) of the primary mass, $|X/\delta_{st}|$. (Symbols have their usual meaning) [02+12]

4.(*b*). Write down the condition for which all curves of $|X/\delta_{st}|$ (for different values of ξ (Damping factor)) become ξ-insensitive at certain points in the normalized amplitude-frequency domain. Prove that the normalized response curves become ξ-insensitive at the following frequency ratios: (Symbols have their usual meaning) [01+05]

$$r_{1,2,3} = 0, \left[1 \pm \sqrt{\frac{\mu}{\mu+2}}\right]^{1/2}$$

4.(*c*). Determine the expression of normalized steady state response of primary mass, $|X/\delta_{st}|$, at the above-mentioned frequency ratios. [05]

5.(*a*). With a neat schematic diagram explain the different philosophies/approaches of vibration control. [08]

5.(*b*). Classify active vibration control systems according to basic control structure. Show schematic representations of the following active control mechanisms: Feedback Control, Feed forward control and Hybrid control. Derive an expression for closed loop transfer function for a feedback control system. [01+06+05]

5.(*c*). Write short notes on the following topics: (*Any one*) [05]

(*i*). Advantages and disadvantages of Active Control

(*ii*). Root locus method

6.(*a*). Free vibration equation of a SDoF system with a nonlinear restoring force is given by, $\ddot{x} + \omega^2 f(x) = 0$. Derive a general integral expression for the time period of vibration following an exact method when $f(x) = x^{2n-1}$. Consider that the system has a displacement x_0 and velocity 0 at the initial moment, $t = 0$. [08]

6.(*b*). The characteristic equation of a non-conservative SDoF system is given by, $\lambda^2 - p\lambda + q = 0$, where, p is the trace of coefficient matrix [*A*] and q is the determinant of coefficient matrix [*A*]. Point out the different regions of stability and instability in the *p-q* plane. [05]

6.(*c*). A system is described by the following nonlinear differential equation –

$$\ddot{x} + 0.1(x^2 - 1)\dot{x} + x = 0$$

(*i*). Transform the 2nd order differential equation into two equivalent 1st order differential equations.

(*ii*). Find the equilibrium position of the system

(*iii*). Determine the type of stability about the equilibrium point.

(*iv*). Determine the Eigenvalues of the system. [12]