# THEORY OF MACHINE AND MECHANISM II

# TUTORIAL NO: 6(B)

## VIBRATION OF SINGLE DEGREE OF FREEDOM SYSTEMS

### (Damped Free Vibration)

1. Determine the free vibration response of the viscously damped with a mass of 10 kg and spring of stiffness 1000 N/m when $x_0 = 0.1$ m and $\dot{x}_0 = 10$ m/s.
   **(a)** c = 150 N.s/m
   **(b)** c = 200 N.s/m
   **(c)** c = 250 N.s/m

2. A piston of mass 4.53 kg travels a tube with a velocity of 15.24 m/s and engages a spring and damper as shown in **Figure P6(B).2** below. Determine the maximum displacement of the piston after it engages the mass-damper assembly.

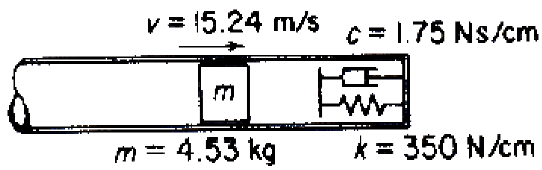


**Figure P6(B).2**

3. A 2 kg piston on a helical spring vibrates with a natural frequency of 125 cycles per minute. When oscillating within an oil-filled cylinder, the frequency of free oscillation is reduced to 120 cycles per minute. Determine the damping constant *c*.

4. An automobile suspension system is to be modeled as a single degree of freedom system as shown in **Figure P6(B).4**. The mass of the wheel and tire is lumped together, M = 20 kg. The tire stiffness, $K_t$ is 20 kN/m. The suspension spring stiffness $K_s$ is 180 kN/m. The viscous damping coefficient of the shock absorber is 200 N.s/m. Determine the following parameters:
   **(a)** Natural frequency,
   **(b)** The critical damping,
   **(c)** Damping ratio,
   **(d)** Damped natural frequency.

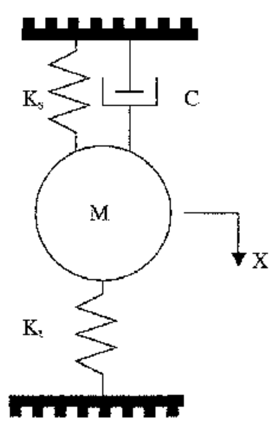


**Figure P6(B).4**

5. A mass of 10 kg is kept on two slabs of isolators placed one over the other. One of the isolators is of rubber having stiffness of 3 kN/m and damping coefficient of 100 Ns/m while the other isolator is of felt with stiffness of 12 kN/m and damping coefficient of 300 Ns/m. If the system

is set in motion in vertical direction, determine the damped and undamped natural frequency of the system.

**6.** A machine weighing 3600 kg is mounted on a supporting system consisting of four springs and four dampers. The vertical deflection of the supporting system under the weight of the machine is measured as 20 mm. The dampers are designed to reduce the amplitude of the vertical vibration to 1/8 of the initial amplitude after two complete cycles of free vibration. Calculate the undamped natural frequency, damping ratio and damped natural frequency of the system. Comment on the effect of damping on the natural frequency.

**7.** A vibrating system is defined by the following parameters: m = 3 kg, k = 100 N/m, C = 3 Ns/m. Determine:

**(a)** the damping ratio,
**(b)** the natural frequency of damped vibration $f_d$,
**(c)** logarithmic decrement,
**(d)** the ratio of two consecutive amplitudes and
**(e)** the number of cycles after which the original amplitude is reduced to 20 %.

**8.** A machine has a mass of 200 kg. It is placed on an isolator and the corresponding free vibration records as shown in **Figure P6(B).8**. Determine its spring constant and damping coefficient.

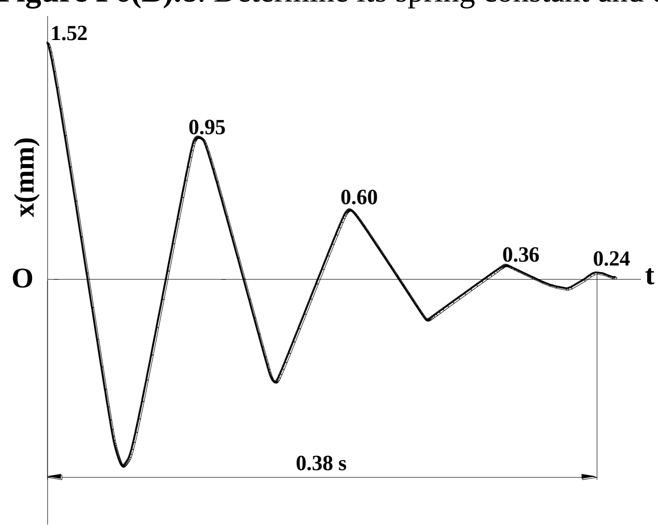


**Figure P6(B).8**

**9.** Write a computer program to take inputs of mass, stiffness, damping, initial velocity and initial displacement from the user and gives output for the natural frequency, damping type and response plot.

## ANSWERS

**1.** [1.6252 sin 6.614t + 0.1 cos 6.614t] $e^{-7.5t}$, [0.1 + 11t] $e^{-10t}$, 0.0667 (12 $e^{-5t}$ – 10.5 $e^{-20t}$)
**2.** 0.12476 m
**3.** 14.66 N.s/m
**4.** 100 rad/s, 4000 N s/m, 0.05, 99.875 rad/s
**5.** 15.49 rad/s, 15.03 rad/s
**6.** 22.147 rad/s, 0.165, 21.85 rad/s
**7.** 0.0866, 0.9154 Hz, 0.5462, 1.7266, 2.9467 cycles
**8.** k = 879.59 kN/m, c = 1942.97 Ns/m