EME 304– Mechanical Vibrations
Sheet 2
Free Damped Single Degree of Freedom

1. A shock absorber is to be designed to limit its overshoot to 15 percent of its initial displacement when released. Find the damping ratio ζ required. What will be the overshoot if ζ is made equal to (a) $\frac{3}{4}\zeta_0$ and (b) $\frac{5}{4}\zeta_0$.

2. The free-vibration responses of an electric motor of weight 500 N mounted on different types of foundations are shown in Figs. 2.107(a) and (b). Identify the following in each case: (i) the nature of damping provided by the foundation, (ii) the spring constant and damping coefficient of the foundation, and (iii) the undamped and damped natural frequencies of the electric motor.

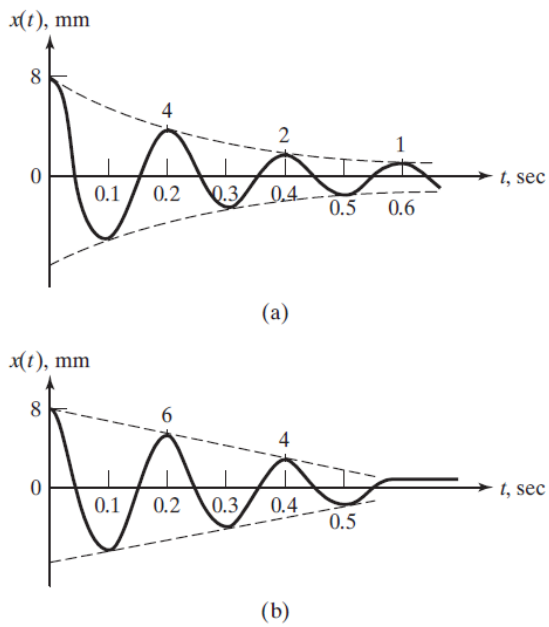

Fig.1.

3. A railroad car of mass 2,000 kg traveling at a velocity of $v = 10$ m/s is stopped at the end of the tracks by a spring-damper system, as shown in Fig. 2. If the stiffness of the spring is $k = 80$ N/mm and the damping constant is $c = 20$ N-s/mm, determine (a) the maximum displacement of the car after engaging the springs and damper and (b) the time taken to reach the maximum displacement.

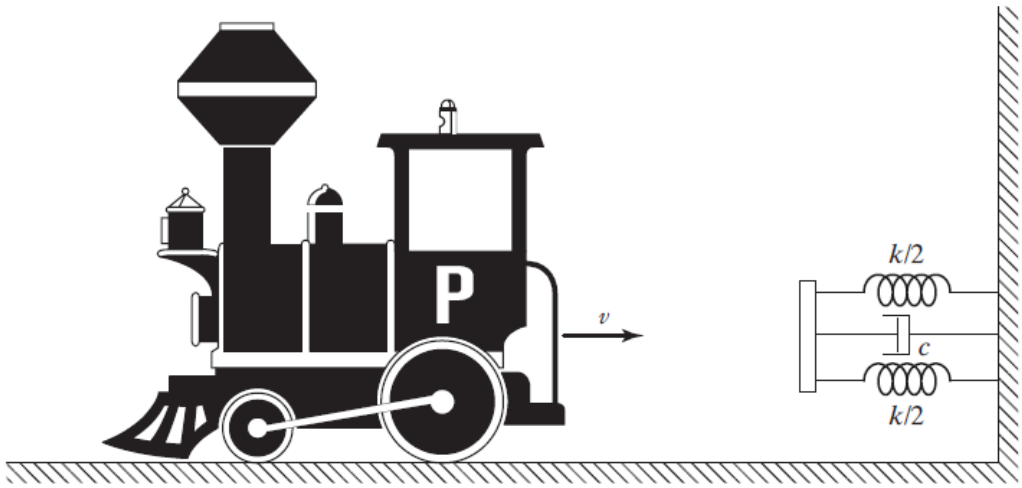

Fig. 2.

4. A boy riding a bicycle can be modeled as a spring-mass-damper system with an equivalent weight, stiffness, and damping constant of 800 N, 50,000 N/m, and 1,000 N-s/m, respectively. The differential setting of the concrete blocks on the road caused the level surface to decrease suddenly, as indicated in Fig. 3. If the speed of the bicycle is 5 m/s (18 km/hr), determine the displacement of the boy in the vertical direction. Assume that the bicycle is free of vertical vibration before encountering the step change in the vertical displacement.

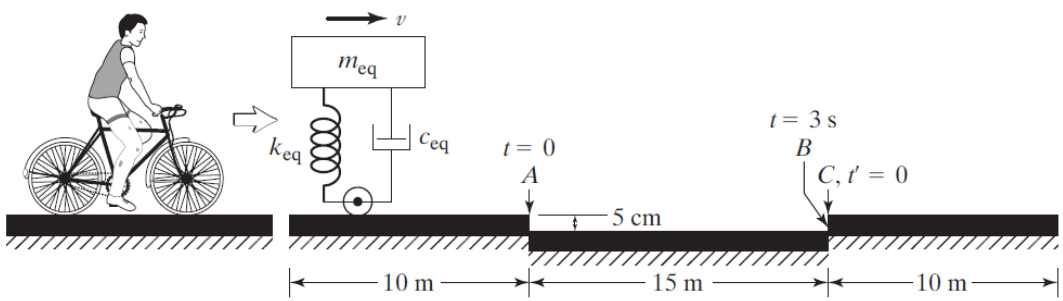

Fig. 3.

5. A body vibrating with viscous damping makes five complete oscillations per second, and in 50 cycles its amplitude diminishes to 10 percent. Determine the logarithmic decrement and the damping ratio. In what proportion will the period of vibration be decreased if damping is removed?

6. The maximum permissible recoil distance of a gun is specified as 0.5 m. If the initial recoil velocity is to be between 8 m/s and 10 m/s, find the mass of the gun and the spring stiffness of the recoil mechanism. Assume that a critically damped dashpot is used in the recoil mechanism and the mass of the gun has to be at least 500 kg.

7. Derive the equation of motion and find the natural frequency of vibration of each of the systems shown in Figs. 4,5,6 and 7.

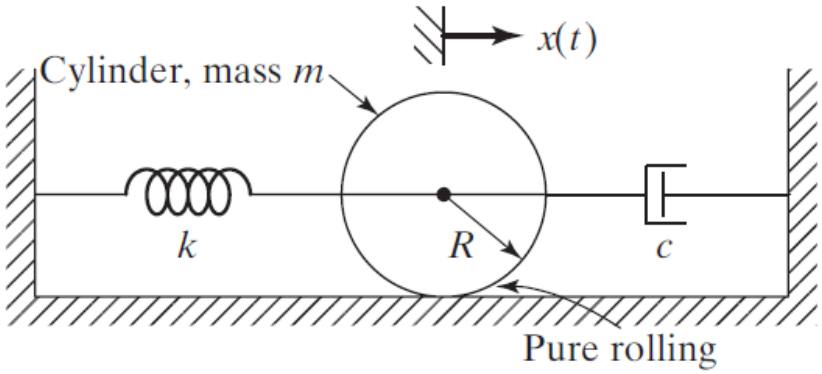

Fig. 4.

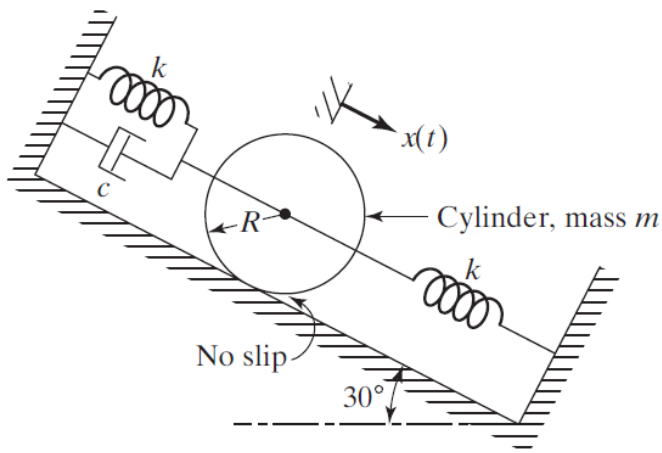

Fig. 5.

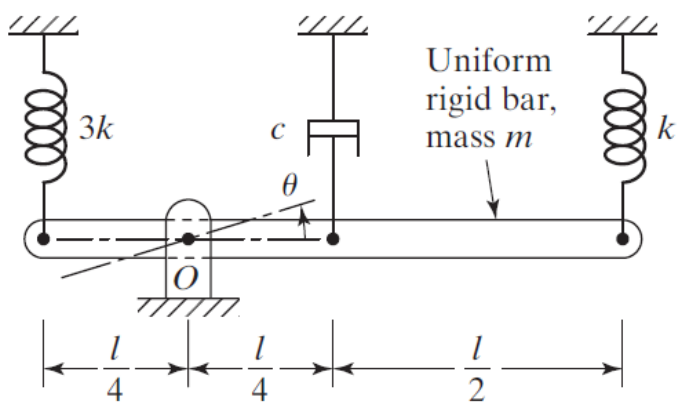

Fig. 6.

8. Determine The system shown in Fig. 7 has a natural frequency of 5 Hz for the following data: When the system is disturbed by giving it an initial displacement, the amplitude of free vibration is reduced by 80 percent in 10 cycles. Determine the values of k and c. m = 10 kg, J_0 = 5 kg-m^2, r_1 = 10 cm, r_2= 25 cm.

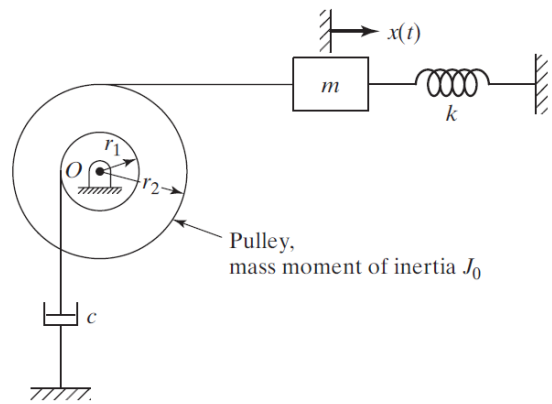

Fig. 7.

9. A metal block, placed on a rough surface, is attached to a spring and is given an initial displacement of 10 cm from its equilibrium position. It is found that the natural time period of motion is 1.0 s and that the amplitude reduces by 0.5 cm in each cycle. Find (a) the kinetic coefficient of friction between the metal block and the surface and (b) the number of cycles of motion executed by the block before it stops.

10. The mass of a spring-mass system vibrates on a dry surface inclined at 30º to the horizontal as shown in Fig. 8.
    a. Derive the equation of motion.
    b. Find the response of the system for the following data:
    m = 20 kg, k = 1,000 N/m, m = 0.1, x_0 = 0.1 m, $\dot{x}_0$ = 5 m/s.

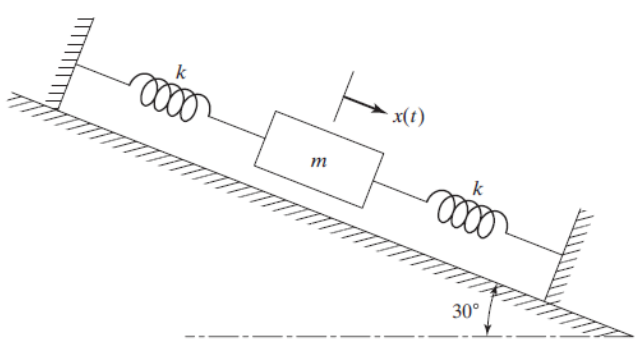

Fig. 8.

11. A The mass of a spring-mass system is initially displaced by 10 cm from its unstressed position by applying a force of 25 N, which is equal to five times the weight of the mass. If the mass is released from this position, how long will the mass vibrate and at what distance will it stop from the unstressed position? Assume a coefficient of friction of 0.2.