

5.44

mass of tup: 2000 kg,  
mass of frame: 20000 kg,  
mass of anvil: 30000 kg,  
mass of foundation block: 65000 kg,  
stiffness of elastic pad: 1 GPa,  
stiffness of isolation: 500 MPa,  
striking velocity of tup: 4.5 m/s.

Solution:

(a) Natural frequencies of the system:

From problem 5.1,

$$\omega_{1,2}^2 = \frac{k_1 + k_2}{2 m_1} + \frac{k_2}{2 m_2} \pm \sqrt{\frac{1}{4} \left( \frac{k_1 + k_2}{m_1} + \frac{k_2}{m_2} \right)^2 - \frac{k_1 k_2}{m_1 m_2}}$$

$$\omega_{1,2}^2 = \frac{1.5 \times 10^9}{130000} + \frac{10^9}{100000} \pm \sqrt{\frac{1}{4} \left( \frac{1.5 \times 10^9}{65000} + \frac{10^9}{50000} \right)^2 - \frac{500 \times 10^{15}}{3.25 \times 10^9}}$$

$$\text{or } \omega_1 = 62.6894 \text{ rad/sec.}$$

$$\omega_2 = 197.8559 \text{ rad/sec.}$$

(b) Initial conditions of the system:

Let  $\dot{\theta}_2$  = initial velocity of anvil and frame just after the impact of tup.

From conservation of momentum principle, momentum of tup plus momentum of  $m_2$  just before impact = momentum of tup plus momentum of  $m_2$  just after impact.

$$\text{i.e. } m_{\text{tup}} \dot{\theta}_{\text{tup}} + m_2 (0) = m_{\text{tup}} \dot{\theta}_0 + m_2 \dot{\theta}_2 \quad (E_1)$$

where  $\dot{\theta}_0$  = velocity of rebound of tup after impact

Also,

$$\text{Coefficient of restitution (e)} = \left( \frac{\text{relative velocity after impact}}{\text{relative velocity before impact}} \right)$$

$$\text{i.e. } e = \frac{\dot{\theta}_2 - \dot{\theta}_0}{\dot{\theta}_{\text{tup}}} \quad \text{or } \dot{\theta}_0 = \dot{\theta}_2 - e \dot{\theta}_{\text{tup}} \quad (E_2)$$

From Eqs. (E<sub>1</sub>) and (E<sub>2</sub>),

$$\dot{\theta}_2 = \frac{m_{\text{tup}} \dot{\theta}_{\text{tup}} (1 + e)}{m_{\text{tup}} + m_2}$$

For given data,

$$\dot{\theta}_2 = \frac{2000 (-4.5) (1 + 0.5)}{2000 + 50000} = -0.2596 \text{ m/s}$$

$\therefore$  Initial conditions are:

$$x_1 (0) = 0, \quad \dot{x}_1 (0) = 0, \quad x_2 (0) = 0, \quad \dot{x}_2 (0) = -0.2596 \text{ m/s.}$$



# Mechanical Vibrations Rao Solution Manual 4th

**Robert R. Redfield**



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