

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,

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

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

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.

i.e. $m_{\text{tup}} \dot{\theta}_{\text{tup}} + m_2 (0) = m_{\text{tup}} \dot{\theta}_0 + m_2 \dot{\theta}_2$ (E₁)

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

Also,

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

i.e. $e = \frac{\dot{\theta}_2 - \dot{\theta}_0}{\dot{\theta}_{\text{tup}}} \quad \text{or} \quad \dot{\theta}_0 = \dot{\theta}_2 - e \dot{\theta}_{\text{tup}}$ (E₂)

From Eqs. (E₁) and (E₂),

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

For given data,

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

\therefore Initial conditions are:

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



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1. Understanding the eBook Mechanical Vibrations Rao 4th Edition Solution Manual
 - The Rise of Digital Reading Mechanical Vibrations Rao 4th Edition Solution Manual
 - Advantages of eBooks Over Traditional Books
2. Identifying Mechanical Vibrations Rao 4th Edition Solution Manual
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Mechanical Vibrations Rao 4th Edition Solution Manual
 - User-Friendly Interface
4. Exploring eBook Recommendations from Mechanical Vibrations Rao 4th Edition Solution Manual
 - Personalized Recommendations
 - Mechanical Vibrations Rao 4th Edition Solution Manual User Reviews and Ratings

- Mechanical Vibrations Rao 4th Edition Solution Manual and Bestseller Lists
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 - Mechanical Vibrations Rao 4th Edition Solution Manual Budget-Friendly Options
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 - Mechanical Vibrations Rao 4th Edition Solution Manual Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Mechanical Vibrations Rao 4th Edition Solution Manual
 - Highlighting and Note-Taking Mechanical Vibrations Rao 4th Edition Solution Manual
 - Interactive Elements Mechanical Vibrations Rao 4th Edition Solution Manual
- 8. Staying Engaged with Mechanical Vibrations Rao 4th Edition Solution Manual
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Mechanical Vibrations Rao 4th Edition Solution Manual
- 9. Balancing eBooks and Physical Books Mechanical Vibrations Rao 4th Edition Solution Manual
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Mechanical Vibrations Rao 4th Edition Solution Manual
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Mechanical Vibrations Rao 4th Edition Solution Manual
 - Setting Reading Goals Mechanical Vibrations Rao 4th Edition Solution Manual
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Mechanical Vibrations Rao 4th Edition Solution Manual
 - Fact-Checking eBook Content of Mechanical Vibrations Rao 4th Edition Solution Manual
 - Distinguishing Credible Sources

13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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