

1 Free Vibration of Single Degree-of-freedom Systems

1.1 Solved Problems

Problem 1:

For the mechanical system shown to the right, the uniform rigid bar has mass m and pinned at point O . For this system:

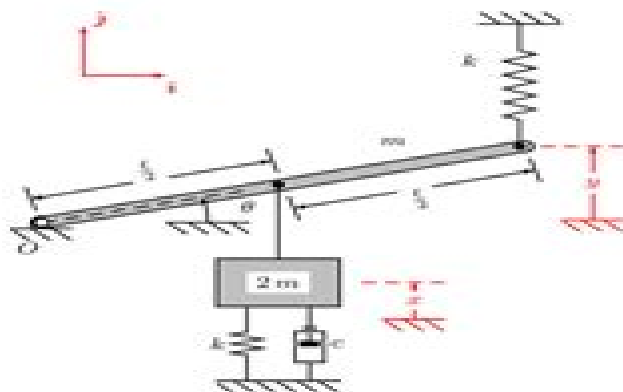
- find the equations of motion;
- Identify the damping ratio and natural frequency in terms of the parameters m , c , k , and ℓ .
- For:

$$m = 1.50\text{kg}, \quad \ell = 45\text{cm}, \\ c = 0.125\text{N}/(\text{m}/\text{s}), \quad k = 250\text{N}/\text{m},$$

find the angular displacement of the bar $\theta(t)$ for the following initial conditions:

$$\theta(0) = 0, \quad \dot{\theta}(0) = 10\text{rad}/\text{s}.$$

Assume that in the horizontal position the system is in static equilibrium and that all angles remain small.



Solution:

- In addition to the coordinate θ identified in the original figure, we also define x and y as the displacement of the block and end of the bar respectively. The directions $\hat{i}$ and $\hat{j}$ are defined as shown in the figure.

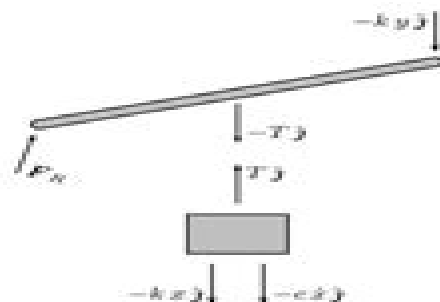
A free body diagram for this system is shown to the right. Note that the tension in the cable between the bar and the block is unknown and represented with T while the reaction force $\mathbf{F}_R$ is included, although both its magnitude and direction are unspecified. In terms of the identified coordinates, the angular acceleration of the bar α_θ and the linear acceleration of the block $\mathbf{a}_c$ are

$$\alpha_\theta = \ddot{\theta} \hat{k}, \quad \mathbf{a}_c = \ddot{x} \hat{j}.$$

We can also relate the identified coordinates as

$$x = \frac{\ell}{2} \theta, \quad y = \ell \theta.$$

The equations of motion for this system can be obtained with linear momentum balance applied to the block and angular momentum balance about O on the bar. These can be



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Table of Contents Mechanical Vibration Solved Problems

1. Understanding the eBook Mechanical Vibration Solved Problems
 - The Rise of Digital Reading Mechanical Vibration Solved Problems
 - Advantages of eBooks Over Traditional Books
2. Identifying Mechanical Vibration Solved Problems
 - 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 Vibration Solved Problems
 - User-Friendly Interface
4. Exploring eBook Recommendations from Mechanical Vibration Solved Problems
 - Personalized Recommendations
 - Mechanical Vibration Solved Problems User Reviews and Ratings
 - Mechanical Vibration Solved Problems and Bestseller Lists
5. Accessing Mechanical Vibration Solved Problems Free and Paid eBooks
 - Mechanical Vibration Solved Problems Public Domain eBooks
 - Mechanical Vibration Solved Problems eBook Subscription Services
 - Mechanical Vibration Solved Problems Budget-Friendly Options
6. Navigating Mechanical Vibration Solved Problems eBook Formats

- ePub, PDF, MOBI, and More
- Mechanical Vibration Solved Problems Compatibility with Devices
- Mechanical Vibration Solved Problems Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Mechanical Vibration Solved Problems
 - Highlighting and Note-Taking Mechanical Vibration Solved Problems
 - Interactive Elements Mechanical Vibration Solved Problems
- 8. Staying Engaged with Mechanical Vibration Solved Problems
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Mechanical Vibration Solved Problems
- 9. Balancing eBooks and Physical Books Mechanical Vibration Solved Problems
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Mechanical Vibration Solved Problems
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Mechanical Vibration Solved Problems
 - Setting Reading Goals Mechanical Vibration Solved Problems
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Mechanical Vibration Solved Problems
 - Fact-Checking eBook Content of Mechanical Vibration Solved Problems
 - 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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