

# 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:

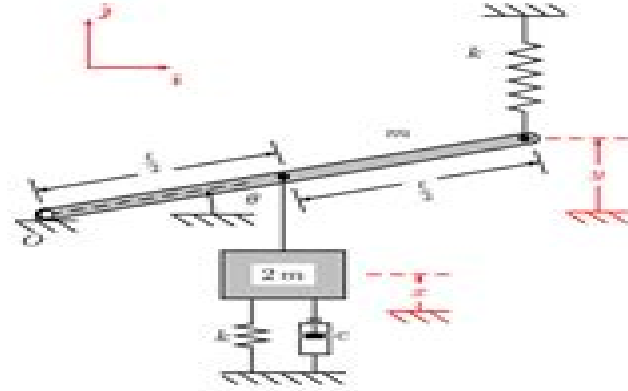
- find the equations of motion;
- Identify the damping ratio and natural frequency in terms of the parameters  $m$ ,  $c$ ,  $k$ , and  $\ell$ .
- For:

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

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

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

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



### Solution:

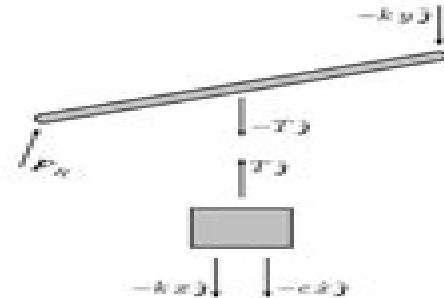
- In addition to the coordinate  $\theta$  identified in the original figure, we also define  $x$  and  $y$  as the displacement of the block and end of the bar respectively. The directions  $\hat{i}$  and  $\hat{j}$  are defined as shown in the figure.

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  $\alpha_\theta$  and the linear acceleration of the block  $\mathbf{a}_c$  are

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

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

# **Mechanical Vibration Solved Problems**

**Haym Benaroya, Mark Nagurka, Seon  
Mi Han**



## **Mechanical Vibration Solved Problems:**

**Mechanical Vibration** Ivana Kovacic,Dragi Radomirovic,2017-10-02 Mechanical oscillators in Lagrange s formalism a thorough problem solved approach This book takes a logically organized clear and thorough problem solved approach at instructing the reader in the application of Lagrange s formalism to derive mathematical models for mechanical oscillatory systems while laying a foundation for vibration engineering analyses and design Each chapter contains brief introductory theory portions followed by a large number of fully solved examples These problems inherent in the design and analysis of mechanical systems and engineering structures are characterised by a complexity and originality that is rarely found in textbooks Numerous pedagogical features explanations and unique techniques that stem from the authors extensive teaching and research experience are included in the text in order to aid the reader with comprehension and retention The book is rich visually including numerous original figures with high standard sketches and illustrations of mechanisms Key features Distinctive content including a large number of different and original oscillatory examples ranging from simple to very complex ones Contains many important and useful hints for treating mechanical oscillatory systems Each chapter is enriched with an Outline and Objectives Chapter Review and Helpful Hints Mechanical Vibration Fundamentals with Solved Examples is essential reading for senior and graduate students studying vibration university professors and researchers in industry

**Schaum's Outline of Theory and Problems of Mechanical Vibrations** William W. Seto,1964      **Mechanical Vibrations** Shrikant Bhawe,2010 Mechanical Vibrations is an unequaled combination of conventional vibration techniques along with analysis design computation and testing Emphasis is given on solving vibration related issues and failures in industry      *Mechanical Vibrations* Michel Geradin,Daniel J. Rixen,2014-11-24 Mechanical Vibrations Theory and Application to StructuralDynamics Third Edition is a comprehensively updated newedition of the popular textbook It presents the theory ofvibrations in the context of structural analysis and coversapplications in mechanical and aerospace engineering Key features include A systematic approach to dynamic reduction and substructuring based on duality between mechanical and admittance concepts An introduction to experimental modal analysis andidentification methods An improved more physical presentation of wave propagationphenomena A comprehensive presentation of current practice for solvinglarge eigenproblems focusing on the efficient linear solution oflarge sparse and possibly singular systems A deeply revised description of time integration schemes providing framework for the rigorous accuracy stability analysis ofnow widely used algorithms such as HHT and Generalized Solved exercises and end of chapter homework problems A companion website hosting supplementary material      Solved Problems in Mechanical Vibrations. Ediz. Integrale S. Zuin,G. Bucca,F. Ripamonti,A. Collina,S. Bruni,2021      *Schaum's Outline of Mechanical Vibrations* S Graham Kelly,1996-04-22 Logically organized this book guides readers through all aspects of vibration analysis Each chapter explains how to harness the problem solving capabilities of today s popular engineering software including Mathcad Maple Matlab and Mathematica

Topics covered include vibration measurement finite element analysis and eigenvalue determination Included are more than 300 solved problems completely explained Theory and problems of mechanical vibrations William W. Seto,1970

*Mechanical Vibration* Haym Benaroya,Mark Nagurka,Seon Mi Han,2022-07-15 Mechanical Vibration Analysis Uncertainty and Control presents comprehensive coverage of the fundamental principles of mechanical vibration including the theory of vibration as well as discussions and examples of the applications of these principles to practical engineering problems In dealing with the subject of vibration the engineer must also consider the effects of uncertainties in the analysis and methods for the control of vibration As such this book includes treatment of both subjects modeling of uncertainties and vibration control Many example problems with solutions are included and are been carefully chosen and are presented at strategic points enabling the reader to have a thorough understanding of the subject and to help cement core ideas the book includes compelling case studies and stories of real world applications of mechanical vibration **An Introduction to Mechanical Vibrations** Robert F. Steidel,1971 **Mechanical Vibration** Haym Benaroya,Mark Nagurka,Seon Mi Han,2022-07-15 The Fifth edition of this classic textbook includes a solutions manual Extensive supplemental instructor resources are forthcoming in the Fall of 2022 Mechanical Vibration Theory and Application presents comprehensive coverage of the fundamental principles of mechanical vibration including the theory of vibration as well as discussions and examples of the applications of these principles to practical engineering problems The book also addresses the effects of uncertainties in vibration analysis and design and develops passive and active methods for the control of vibration Many example problems with solutions are provided These examples as well as compelling case studies and stories of real world applications of mechanical vibration have been carefully chosen and presented to help the reader gain a thorough understanding of the subject There is a solutions manual for instructors who adopt this book Request a solutions manual here <https://www.rutgersuniversitypress.org/mechanical-vibration> **Mechanical Vibration Practice with Basic Theory** Viswanatha Ramamurti,2000 Use of 3D beam element to solve the industrial problems along with the source code and more than 100 practical worked out examples make the book versatile Written in a lucid language emphasising concepts the book will be a priceless possession for students teachers and professional engineers **BOOK JACKET** *Theory and Problems of Mechanical Vibrations* ,1964\* *Basic Mechanical Vibrations* A J Pretlove,2013-09-24 BASIC Mechanical Vibrations deals with vibrations and combines basic theory with the development of useful computer programs to make design calculations The programs in the book are written in BASIC This book is comprised of six chapters and begins with a brief introduction to computing with special emphasis on the fundamentals of the BASIC computer language The chapters that follow give concise elements of vibration theory followed by problem solving examples making use of BASIC programs The vibration analysis of engineering systems which may be modeled by a single degree of freedom is presented Simple systems with damping and no damping are considered along with systems having two and several degrees of freedom The final chapter is concerned with

bending vibrations The text includes some subroutines for performing simple matrix operations on two dimensional arrays that can be used in vibration calculations This monograph will be useful to engineers who need to make vibration design calculations and to students of mechanical engineering      *Mechanical Vibration* Haym Benaroya, Mark Nagurka, 2009-06-10

*Mechanical Vibration Analysis Uncertainties and Control* simply and comprehensively addresses the fundamental principles of vibration theory emphasizing its application in solving practical engineering problems The authors focus on strengthening engineers command of mathematics as a cornerstone for understanding vibration control and the ways in which uncertainties affect analysis It provides a detailed exploration and explanation of the essential equations involved in modeling vibrating systems and shows readers how to employ MATLAB as an advanced tool for analyzing specific problems Forgoing the extensive and in depth analysis of randomness and control found in more specialized texts this straightforward easy to follow volume presents the format content and depth of description that the authors themselves would have found useful when they first learned the subject The authors assume that the readers have a basic knowledge of dynamics mechanics of materials differential equations and some knowledge of matrix algebra Clarifying necessary mathematics they present formulations and explanations to convey significant details The material is organized to afford great flexibility regarding course level content and usefulness in self study for practicing engineers or as a text for graduate engineering students This work includes example problems and explanatory figures biographies of renowned contributors and access to a website providing supplementary resources These include an online MATLAB primer featuring original programs that can be used to solve complex problems and test solutions      **Mechanical Vibrations** Francis S. Tse, 1963      *Mechanical Vibration* William John Palm, 2007

Model analyze and solve vibration problems using modern computer tools Featuring clear explanations worked examples applications and modern computer tools William Palm s *Mechanical Vibration* provides a firm foundation in vibratory systems You ll learn how to apply knowledge of mathematics and science to model and analyze systems ranging from a single degree of freedom to complex systems with two and more degrees of freedom Separate MATLAB sections at the end of most chapters show how to use the most recent features of this standard engineering tool in the context of solving vibration problems The text introduces Simulink where solutions may be difficult to program in MATLAB such as modeling Coulomb friction effects and simulating systems that contain non linearities Ample problems throughout the text provide opportunities to practice identifying formulating and solving vibration problems

**KEY FEATURES** Strong pedagogical approach including chapter objectives and summaries Extensive worked examples illustrating applications Numerous realistic homework problems Up to date MATLAB coverage The first vibration textbook to cover Simulink Self contained introduction to MATLAB in Appendix A Special section dealing with active vibration control in sports equipment Special sections devoted to obtaining parameter values from experimental data      **Applied Mechanical Vibrations** David V. Hutton, 1981      **Schaum's Outline of Theory and Problems of Mechanical Vibrations** S. Graham Kelly, 1996-01-01

Theory and Problems of Mechanical Vibrations William W. Sete, 1984      **Mechanical Vibrations** Singiresu S. Rao, 1990

With an emphasis on computer techniques of analysis this book presents the theory computational aspects and applications of vibrations in as simple a manner as possible This text gives expanded explanations of the fundamentals of vibration including history of vibration degree of freedom systems vibration control vibration measurement and more For engineers and other professionals who want a clear introduction to vibration engineering

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  - Chapter 4: Mechanical Vibration Solved Problems in Specific Contexts
  - Chapter 5: Conclusion
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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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