

# 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:

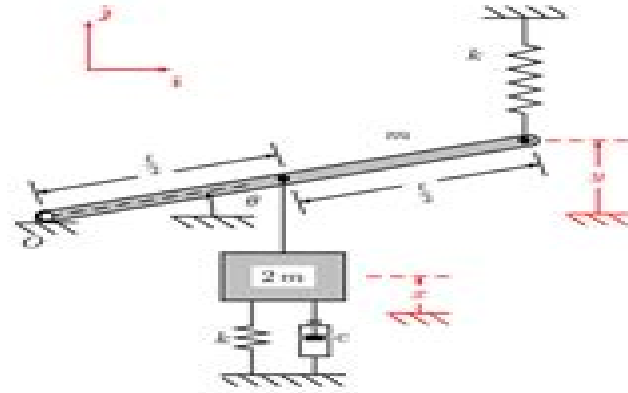
- find the equations of motion;
- Identify the damping ratio and natural frequency in terms of the parameters  $m$ ,  $c$ ,  $k$ , and  $\ell$ .
- For:

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

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  $\theta$  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.

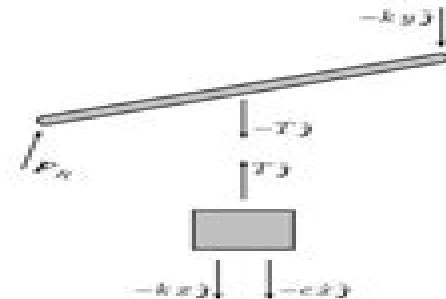
A free body diagram for this system is shown to the right. Note that the tension in the cable between the bar and the block is unknown and represented with  $T$  while the reaction force  $\mathbf{F}_R$  is included, although both its magnitude and direction are unspecified. In terms of the identified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

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

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



# Mechanical Vibration Solved Problems

**Kathleen Armour**



## **Mechanical Vibration Solved Problems:**

*Mechanical Vibration* Ivana Kovacic, Dragi Radomirovic, 2017-07-17 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

**Mechanical Vibrations** Shrikant Bhawe, 2010 Mechanical Vibrations is an unequalled combination of conventional vibration techniques along with analysis design computation and testing Emphasis is given on solving vibration related issues and failures in industry **Solved Problems in Mechanical Vibrations. Ediz. Integrale** S. Zuin, G. Bucca, F. Ripamonti, A. Collina, S. Bruni, 2021 Theory and problems of mechanical vibrations William W. Seto, 1970 Schaum's Outline of Theory and Problems of Mechanical Vibrations William W. Seto, 1964 **Introductory Course on Theory and Practice of Mechanical Vibrations** J. S. Rao, 1999 The Book Presents The Theory Of Free Forced And Transient Vibrations Of Single Degree Two Degree And Multi Degree Of Freedom Undamped And Damped Lumped Parameter Systems And Its Applications Free And Forced Vibrations Of Undamped Continuous Systems Are Also Covered Numerical Methods Like Holzer's And Myklestad's Are Also Presented In Matrix Form Finite Element Method For Vibration Problem Is Also Included Nonlinear Vibration And Random Vibration Analysis Of Mechanical Systems Are Also Presented The Emphasis Is On Modelling Of Engineering Systems Examples Chosen Even Though Quite Simple Always Refer To Practical Systems Experimental Techniques In Vibration Analysis Are Discussed At Length In A Separate Chapter And Several Classical Case Studies Are Presented Though The Book Is Primarily Intended For An Undergraduate Course In Mechanical Vibrations It Covers Some Advanced Topics Which Are Generally Taught At Postgraduate Level The Needs Of The Practising Engineers Have Been Kept In Mind Too A Manual Giving Solutions Of All The Unsolved Problems Is Also Prepared Which Would Be Extremely Useful To Teachers *Mechanical Vibration* Haym Benaroya, 2004-10-13 An effective text must be well balanced and thorough in its

approach to a topic as expansive as vibration and Mechanical Vibration is just such a textbook Written for both senior undergraduate and graduate course levels this updated and expanded second edition integrates uncertainty and control into the discussion of vibration outlining basic concepts before delving into the mathematical rigors of modeling and analysis Mechanical Vibration Analysis Uncertainties and Control Second Edition provides example problems end of chapter exercises and an up to date set of mini projects to enhance students computational abilities and includes abundant references for further study or more in depth information The author provides a MATLAB primer on an accompanying CD ROM which contains original programs that can be used to solve complex problems and test solutions The book is self contained covering both basic and more advanced topics such as stochastic processes and variational approaches It concludes with a completely new chapter on nonlinear vibration and stability Professors will find that the logical sequence of material is ideal for tailoring individualized syllabi and students will benefit from the abundance of problems and MATLAB programs provided in the text and on the accompanying CD ROM respectively A solutions manual is also available with qualifying course adoptions

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 *Solving Vibration Analysis Problems Using MATLAB* Rao V. Dukkipati, 2007 Solving Engineering Vibration Analysis Problems using MATLAB book is designed as an introductory undergraduate or graduate course for engineering students of all disciplines Vibration analysis is a multidisciplinary subject and presents a system dynamics methodology based on mathematical fundamentals and stresses physical system modeling The classical methods of vibration analysis engineering are covered matrix analysis Laplace transforms and transfer functions The numerous worked examples and unsolved exercise problems are intended to provide the reader with an awareness of the general applicability of vibration analysis problems using MATLAB An extensive bibliography to guide the student to further sources of information on vibration analysis using MATLAB is provided at the end of the book All end of chapter problems are fully solved in the Solution Manual available only to Instructors Mechanical Vibrations Michel Geradin, Daniel J. Rixen, 2015-02-16 Mechanical Vibrations Theory and Application to Structural Dynamics Third Edition is a comprehensively updated new edition of the popular textbook It presents the theory of vibrations in the context of structural analysis and covers applications 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 and identification methods An improved more physical presentation of wave propagation phenomena A comprehensive presentation of current practice for solving large eigenproblems focusing on the efficient linear solution of

large sparse and possibly singular systems A deeply revised description of time integration schemes providing framework for the rigorous accuracy stability analysis of now widely used algorithms such as HHT and Generalized Solved exercises and end of chapter homework problems A companion website hosting supplementary material

**Theory and Problems of Mechanical Vibrations**, 1964\* **An Introduction to Mechanical Vibrations** Robert F. Steidel, 1971 Hilbert Transform Applications in Mechanical Vibration Michael Feldman, 2011-03-08 Hilbert Transform Applications in Mechanical Vibration addresses recent advances in theory and applications of the Hilbert transform to vibration engineering enabling laboratory dynamic tests to be performed more rapidly and accurately The author integrates important pioneering developments in signal processing and mathematical models with typical properties of mechanical dynamic constructions such as resonance nonlinear stiffness and damping A comprehensive account of the main applications is provided covering dynamic testing and the extraction of the modal parameters of nonlinear vibration systems including the initial elastic and damping force characteristics This unique merger of technical properties and digital signal processing allows the instant solution of a variety of engineering problems and the in depth exploration of the physics of vibration by analysis identification and simulation This book will appeal to both professionals and students working in mechanical aerospace and civil engineering as well as naval architecture biomechanics robotics and mechatronics Hilbert Transform Applications in Mechanical Vibration employs modern applications of the Hilbert transform time domain methods including The Hilbert Vibration Decomposition method for adaptive separation of a multi component non stationary vibration signal into simple quasi harmonic components this method is characterized by high frequency resolution which provides a comprehensive account of the case of amplitude and frequency modulated vibration analysis The FREEVIB and FORCEVIB main applications covering dynamic testing and extraction of the modal parameters of nonlinear vibration systems including the initial elastic and damping force characteristics under free and forced vibration regimes Identification methods contribute to efficient and accurate testing of vibration systems avoiding effort consuming measurement and analysis Precise identification of nonlinear and asymmetric systems considering high frequency harmonics on the base of the congruent envelope and congruent frequency Accompanied by a website at [www.wiley.com/go/feldman](http://www.wiley.com/go/feldman) housing MATLAB SIMULINK codes

**Mechanical Vibrations of Elastic Systems** Roy, Dr. N.S.V. Kameswara Rao, 2006 This Book Presents The Topic Of Vibrations Comprehensively In Terms Of Principles Of Dynamics Forces Responses Analysis Solutions Examples Measurement Interpretation Control And Probabilistic Approaches Idealised Discrete Systems As Well As Continuous Systems Are Discussed In Detail A Wide Array Of Numerical Methods Used In Vibration Analysis Are Presented In View Of Their Enormous Popularity Adaptability Using Personal Computers A Large Number Of Examples Have Been Worked Out To Help An Easy Understanding Of Even The Difficult Topics In Vibration Analysis And Control

**Applied Structural and Mechanical Vibrations** Paolo L. Gatti, 2014-02-24 The second edition of Applied Structural and Mechanical Vibrations

Theory and Methods continues the first edition's dual focus on the mathematical theory and the practical aspects of engineering vibrations measurement and analysis. This book emphasises the physical concepts, brings together theory and practice and includes a number of worked out examples of varying difficulty and an extensive list of references. What's New in the Second Edition: Adds new material on response spectra. Includes revised chapters on modal analysis and on probability and statistics. Introduces new material on stochastic processes and random vibrations. The book explores the theory and methods of engineering vibrations. By also addressing the measurement and analysis of vibrations in real world applications, it provides and explains the fundamental concepts that form the common background of disciplines such as structural dynamics, mechanical, aerospace, automotive, earthquake and civil engineering. Applied Structural and Mechanical Vibrations: Theory and Methods presents the material in order of increasing complexity. It introduces the simplest physical systems capable of vibratory motion in the fundamental chapters and then moves on to a detailed study of the free and forced vibration response of more complex systems. It also explains some of the most important approximate methods and experimental techniques used to model and analyze these systems. With respect to the first edition, all the material has been revised and updated, making it a superb reference for advanced students and professionals working in the field.

**Fundamentals of Mechanical Vibrations** Liang-Wu Cai, 2016-04-25. This introductory book covers the most fundamental aspects of linear vibration analysis for mechanical engineering students and engineers. Consisting of five major topics, each has its own chapter and is aligned with five major objectives of the book. It starts from a concise, rigorous and yet accessible introduction to Lagrangian dynamics as a tool for obtaining the governing equations for a system, the starting point of vibration analysis. The second topic introduces mathematical tools for vibration analyses for single degree of freedom systems. In the process, every example includes a section 'Exploring the Solution with MATLAB'. This is intended to develop student's affinity to symbolic calculations and to encourage curiosity-driven explorations. The third topic introduces the lumped parameter modeling to convert simple engineering structures into models of equivalent masses and springs. The fourth topic introduces mathematical tools for general multiple degrees of freedom systems with many examples suitable for hand calculation and a few computer-aided examples that bridge the lumped parameter models and continuous systems. The last topic introduces the finite element method as a jumping point for students to understand the theory and the use of commercial software for vibration analysis of real world structures.

**MECHANICAL VIBRATIONS** R. VENKATACHALAM, 2014-11-01. Aiming at undergraduate and postgraduate students of mechanical engineering, the book has been written with a long teaching experience of the author. Lucid and beyond traditional writing style makes the text different from other books. In this text, every effort has been taken to make the subject easy and interesting. The concepts have been explained in such a manner that students do not require any prerequisite knowledge. The text, amalgamated with real world examples, helps students adhere to the book and learn the concepts on their own. Throughout the book, an engaging and thought-provoking approach has been

followed It discusses free and forced vibrations of undamped and damped single degree freedom systems self excited vibrations vibrations of two and multi degree freedom systems vibrations of continuous systems and Lagrangian formulation A chapter on Set up a Mechanical Vibration Laboratory helps students and teachers to learn how to develop a basic laboratory without involving a heavy cost Besides undergraduate and postgraduate students this text also serves as a launch pad for those who want to pursue research Key Features Simple practical demonstrations Helps the student in developing important skills such as reasoning interpretation and physical visualisation Helps to develop software Prepares for competitive examinations There are nearly 50 problems illustrated and around 200 problems given in exercises for practice

**TEXTBOOK OF MECHANICAL VIBRATIONS** DUKKIPATI, V. RAO, SRINIVAS, J., 2012-03-05 This comprehensive and accessible book now in its second edition covers both mathematical and physical aspects of the theory of mechanical vibrations This edition includes a new chapter on the analysis of nonlinear vibrations The text examines the models and tools used in studying mechanical vibrations and the techniques employed for the development of solutions from a practical perspective to explain linear and nonlinear vibrations To enable practical understanding of the subject numerous solved and unsolved problems involving a wide range of practical situations are incorporated in each chapter This text is designed for use by the undergraduate and postgraduate students of mechanical engineering Mechanical Vibrations in Spacecraft Design J. Jaap Wijker, 2013-04-17 All typical and special modal and response analysis methods applied within the frame of the design of spacecraft structures are described in this book It therefore addresses graduate students and engineers in the aerospace field *Mechanical Vibrations* György Szeidl, László Péter Kiss, 2020-06-16 This book presents a unified introduction to the theory of mechanical vibrations The general theory of the vibrating particle is the point of departure for the field of multidegree of freedom systems Emphasis is placed in the text on the issue of continuum vibrations The presented examples are aimed at helping the readers with understanding the theory This book is of interest among others to mechanical civil and aeronautical engineers concerned with the vibratory behavior of the structures It is useful also for students from undergraduate to postgraduate level The book is based on the teaching experience of the authors

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