

## 2.1 Solution

(a) Determine the equation of motion of the mass  $m$  in Fig. 1.



Figure 1

To determine the stiffness of the columns, we can use the unit dummy load method.



Figure 2

$$\begin{aligned}
 u &= \int_0^L \frac{(-Fx)(-x)}{EI} dx + \int_0^L \frac{M(-x)}{EI} dx \\
 &= \frac{FL^3}{3EI} - \frac{ML^2}{2EI} \\
 \theta &= \int_0^L \frac{(-Fx)(1)}{EI} dx + \int_0^L \frac{M(1)}{EI} dx \\
 &= -\frac{FL^2}{2EI} + \frac{ML}{EI}
 \end{aligned}$$

Since  $\theta = 0$ ,

$$M = \frac{FL}{2} \quad \text{and} \quad F = \frac{12EI}{L^3}u = ku$$



Figure 3

$$\sum F_x = m\ddot{u}$$

From the free-body diagram in Fig. 3,

$$-F_B - F_C = -\frac{12EI}{L^3}u - \frac{12EI}{L^3}u = m\ddot{u}$$

$$m\ddot{u} + \frac{24EI}{L^3}u = 0$$

Ans. (a)

(b) How would the equation of motion differ if the left-hand column had a stiffness  $2EI$ , with no other changes to the structure?

$$-F_B - F_C = -\frac{12(2EI)}{L^3}u - \frac{12EI}{L^3}u = m\ddot{u}$$

$$m\ddot{u} + \frac{36EI}{L^3}u = 0$$

Ans. (b)

# Fundamentals Of Structural Dynamics

**Keith D. Hjelmstad**



## **Fundamentals Of Structural Dynamics:**

**Fundamentals of Structural Dynamics** Roy R. Craig, Jr., Andrew J. Kurdila, 2006-07-11 From theory and fundamentals to the latest advances in computational and experimental modal analysis this is the definitive updated reference on structural dynamics This edition updates Professor Craig's classic introduction to structural dynamics which has been an invaluable resource for practicing engineers and a textbook for undergraduate and graduate courses in vibrations and or structural dynamics Along with comprehensive coverage of structural dynamics fundamentals finite element based computational methods and dynamic testing methods this Second Edition includes new and expanded coverage of computational methods as well as introductions to more advanced topics including experimental modal analysis and active structures With a systematic approach it presents solution techniques that apply to various engineering disciplines It discusses single degree of freedom SDOF systems multiple degrees of freedom MDOF systems and continuous systems in depth and includes numeric evaluation of modes and frequency of MDOF systems direct integration methods for dynamic response of SDOF systems and MDOF systems and component mode synthesis Numerous illustrative examples help engineers apply the techniques and methods to challenges they face in the real world MATLAB is extensively used throughout the book and many of the m files are made available on the book's Web site **Fundamentals of Structural Dynamics Second Edition** is an indispensable reference and refresher course for engineering professionals and a textbook for seniors or graduate students in mechanical engineering civil engineering engineering mechanics or aerospace engineering

**Fundamentals of Structural Dynamics** Keith D. Hjelmstad, 2022 This text closes the gap between traditional textbooks on structural dynamics and how structural dynamics is practiced in a world driven by commercial software where performance based design is increasingly important The book emphasizes numerical methods nonlinear response of structures and the analysis of continuous systems e.g wave propagation **Fundamentals of Structural Dynamics Theory and Computation** builds the theory of structural dynamics from simple single degree of freedom systems through complex nonlinear beams and frames in a consistent theoretical context supported by an extensive set of MATLAB codes that not only illustrate and support the principles but provide powerful tools for exploration The book is designed for students learning structural dynamics for the first time but also serves as a reference for professionals throughout their careers

*Fundamentals of Structural Dynamics* Zihui Zhou, Ying Wen, Chenzhi Cai, Qingyuan Zeng, 2021-06-08 **Dynamics of Structural Dynamics** explains foundational concepts and principles surrounding the theory of vibrations and gives equations of motion for complex systems The book presents classical vibration theory in a clear and systematic way detailing original work on vehicle bridge interactions and wind effects on bridges Chapters give an overview of structural vibrations including how to formulate equations of motion vibration analysis of a single degree of freedom system a multi degree of freedom system and a continuous system the approximate calculation of natural frequencies and modal shapes and step by step integration methods Each chapter includes extensive practical

examples and problems This volume presents the foundational knowledge engineers need to understand and work with structural vibrations also including the latest contributions of a globally leading research group on vehicle bridge interactions and wind effects on bridges Explains the foundational concepts needed to understand structural vibrations in high speed railways Gives the latest research from a leading group working on vehicle bridge interactions and wind effects on bridges Lays out routine procedures for generating dynamic property matrices in MATLAB Presents a novel principle and rule to help researchers model time varying systems Offers an efficient solution for readers looking to understand basic concepts and methods in vibration analysis

### **Structural Dynamics Fundamentals and Advanced Applications,**

**Volume I** Alvar M. Kabe, Brian H. Sako, 2020-06-28 The two volume work Structural Dynamics Fundamentals and Advanced Applications is a comprehensive work that encompasses the fundamentals of structural dynamics and vibration analysis as well as advanced applications used on extremely large and complex systems Volume I covers Newton's Laws single degree of freedom systems damping transfer and frequency response functions transient vibration analysis frequency and time domain multi degree of freedom systems forced vibration of single and multi degree of freedom systems numerical methods for solving for the responses of single and multi degree of freedom systems and symmetric and non symmetric eigenvalue problems In addition a thorough discussion of real and complex modes and the conditions that lead to each is included Stochastic methods for single and multi degree of freedom systems excited by random forces or base motion are also covered Dr Kabe's training and expertise are in structural dynamics and Dr Sako's are in applied mathematics Their collaboration has led to the development of first of a kind methodologies and solutions to complex structural dynamics problems Their experience and contributions encompass numerous past and currently operational launch and space systems The two volume work was written with both practicing engineers and students just learning structural dynamics in mind Derivations are rigorous and comprehensive thus making understanding the material easier Presents analysis methodologies adopted by the aerospace community to solve extremely complex structural dynamics problems

*Structural Dynamics Fundamentals and Advanced Applications, Volume II* Alvar M. Kabe, Brian H. Sako, 2020-07-02 The two volume Structural Dynamics Fundamentals and Advanced Applications is a comprehensive work that encompasses the fundamentals of structural dynamics and vibration analysis as well as advanced applications used on extremely large and complex systems In Volume II d'Alembert's Principle Hamilton's Principle and Lagrange's Equations are derived from fundamental principles Development of large structural dynamic models and fluid structure interaction are thoroughly covered Responses to turbulence gust buffet and static aeroelastic loading encountered during atmospheric flight are addressed from fundamental principles to the final equations including aeroelasticity Volume II also includes a detailed discussion of mode survey testing mode parameter identification and analytical model adjustment Analysis of time signals including digitization filtering and transform computation is also covered A comprehensive discussion of probability and statistics including statistics of time series small

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**Introduction to Structural Dynamics** Bruce K. Donaldson, 2006-10-23 This textbook first published in 2006 provides the student of aerospace civil and mechanical engineering with all the fundamentals of linear structural dynamics analysis It is designed for an advanced undergraduate or first year graduate course This textbook is a departure from the usual presentation in two important respects First descriptions of system dynamics are based on the simpler to use Lagrange equations Second no organizational distinctions are made between multi degree of freedom systems and single degree of freedom systems The textbook is organized on the basis of first writing structural equation systems of motion and then solving those equations mostly by means of a modal transformation The text contains more material than is commonly taught in one semester so advanced topics are designated by an asterisk The final two chapters can also be deferred for later studies The text contains numerous examples and end of chapter exercises *Structural Dynamics in Engineering Design* Nuno M. M. Maia, Dario Di Maio, Alex Carrella, 2024-03-18 World class authors describe and illustrate how structural dynamics is applied to the engineering design process Structural Dynamics in Engineering Design covers the fundamentals of structural dynamics and its application to the engineering design process providing all of the necessary information to implement an optimal design process Each of its seven chapters is written by an expert in the field and provides the reader with the structural dynamic theoretical background and its more practical aspects for the implementation of an advanced design capability The first three chapters are dedicated to the underlying theory of the three main processes the fundamentals of vibration theory the basis of experimental dynamics and the main numerical analysis tools including reference to the finite element method Having laid the foundation of the design philosophy the following three chapters present the reader with the three disciplines of identification nonlinear analysis and validation updating The final chapter presents some applications of the approach to real and complex engineering cases Key features Takes a multi disciplinary approach and contains critical information on theory testing and numerical analysis for structural dynamics Includes a chapter on industrial applications including aircraft design and ground vibration testing which illustrates the design process and explains how structural

dynamics is applied at different stages The book is a must have for researchers and practitioners in mechanical and aerospace engineering in particular test engineers CAE analysts and structural dynamicists as well as graduate students in mechanical and aerospace engineering departments Fundamentals of Structural Engineering Jerome J. Connor, Susan Faraji, 2016-02-10 This updated textbook provides a balanced seamless treatment of both classic analytic methods and contemporary computer based techniques for conceptualizing and designing a structure New to the second edition are treatments of geometrically nonlinear analysis and limit analysis based on nonlinear inelastic analysis Illustrative examples of nonlinear behavior generated with advanced software are included The book fosters an intuitive understanding of structural behavior based on problem solving experience for students of civil engineering and architecture who have been exposed to the basic concepts of engineering mechanics and mechanics of materials Distinct from other undergraduate textbooks the authors of Fundamentals of Structural Engineering 2 e embrace the notion that engineers reason about behavior using simple models and intuition they acquire through problem solving The perspective adopted in this text therefore develops this type of intuition by presenting extensive realistic problems and case studies together with computer simulation allowing for rapid exploration of how a structure responds to changes in geometry and physical parameters The integrated approach employed in Fundamentals of Structural Engineering 2 e make it an ideal instructional resource for students and a comprehensive authoritative reference for practitioners of civil and structural engineering

**Dynamics of Structures** Levon Gregory Petrosian, 2024-11-29 This book presents dynamic calculation in the context of structural mechanics and civil engineering It explains the process of testing the strength of structures and determining the dynamic displacements velocities and accelerations whose values as measured by the influence of vibrations on people and certain types of precision equipment such as measuring instruments high precision machines and equipment for microelectronics production should not exceed the permissible limits The first part of the book 15 chapters is ideal as a textbook for advanced undergraduate graduate or post graduate students taking their first course in structural dynamics This text can be used for two semesters In addition the book will serve as a primary reference for practicing engineers and research workers as well as a self study guide for students researchers and professional engineers The second part of the book chapter 16 onwards is intended mainly for professionals and specialists in the field of dynamics of structures and related areas

Structural Dynamics All in One Textbook Jamie Flux, 2025-01-04 Unlock the World of Structural Dynamics with a Comprehensive Practice Oriented Approach Delve deep into the fundamentals of structural dynamics with this all in one textbook designed for both students and professionals seeking to enhance their understanding of the dynamic behavior of structures This meticulously crafted resource bridges the gap between theoretical concepts and practical application ensuring a robust grasp of the subject matter Key Features Comprehensive Coverage Explore 33 chapters encompassing essential topics from the basics of kinematics and Newton s laws to advanced subjects like blast and impact loading on structures Step by Step Solutions

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**Dynamics of Structure and Foundation - A Unified Approach** Indrajit Chowdhury, Shambhu P. Dasgupta, 2008-12-18 The second part of this well illustrated guide is dedicated to applications in various civil engineering problems related to dynamic soil structure interaction machine foundation and earthquake engineering The book presents innovative easy to apply and practical solutions to various problems and difficulties that a design engineer will encounter The book focuses on dynamic soil structure interaction DSSI the analysis and design of machine foundations and the analytical and design concepts for earthquake engineering

Structural Dynamics in Earthquake and Blast Resistant Design B. K. Raghu Prasad, 2020 Focusing on the fundamentals of structural dynamics required for earthquake blast resistant design Structural Dynamics in Earthquake and Blast Resistant Design initiates a new approach of blending a little theory with a little practical design in order to bridge this unfriendly gap thus making the book more structural engineer friendly This is attempted by introducing the equations of motion followed by free and forced vibrations of SDF and MDF systems D Alembert s principle Duhammel s integral relevant impulse pulse and sinusoidal inputs and most importantly support motion and triangular pulse input required in earthquake and blast resistant designs respectively Responses of multistorey buildings subjected to earthquake ground motion by a well known mode superposition technique are explained Examples of real size structures as they are being designed and constructed using the popular ETABS and STAAD are shown Problems encountered in such designs while following the relevant codes of practice like IS 1893 2016 due to architectural constraints are highlighted A very difficult constraint is in avoiding torsional modes in fundamental and first three modes the inability to get enough mass participation and several others In blast resistant design the constraint is to model the blast effects on basement storeys below ground

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**Dynamics of Structure and Foundation - A Unified Approach** Indrajit Chowdhury, Shambhu P. Dasgupta, 2008-12-17

Designed to provide engineers with quick access to current and practical information on the dynamics of structure and foundation this unique work consisting of two separately available volumes serves as a complete reference especially for those involved with earthquake or dynamic analysis or the design of machine foundations in the oil gas and energy sector This first volume deals with theories and formulations covering the full range of topics involved and dynamics of structure and foundation It specifically focuses on a unified approach in dealing with dynamic soil structure interaction and geotechnical considerations for dynamic soil structure interaction The authors present new insights and theories such as the computation of Rayleigh damping for structures with a large number of degrees of freedom and the dynamic analysis of Hammer foundations considering non classical soil damping In a clear style this well illustrated column addresses detailed topics grouped in the following major themes Elasticity and numerical methods in engineering Lumped parameter vibration Soil structure systems under static load Structural and soil dynamics This reference and design guide is intended for academics and professionals in civil and structural engineering involved with earthquake or dynamic analysis or the design of machine foundations In combination with the Applications book volume 2 it could be used as course material for advanced university and professional education in structural dynamics soil dynamics analysis and design of machined foundations and earthquake engineering

Nonlinear Structural Dynamics Using FE Methods James F. Doyle, 2014 Nonlinear Structural Dynamics Using FE Methods emphasises fundamental mechanics principles and outlines a modern approach to understanding structural dynamics This will be useful to practising engineers but also students who will find advanced topics

presented in an accessible manner The book successfully presents the fundamentals of structural dynamics and infuses them with finite element FE methods First the author establishes and develops mechanics principles that are basic enough to form the foundations of FE methods Second the book presents specific computer procedures to implement FE methods so that general problems can be solved that is responses can be produced given the loads initial conditions and so on Finally the book introduces methods of analyses to leverage and expand the FE solutions *Proceedings 1985 Frontiers in Education Conference* Lawrence P. Grayson, Joseph M. Biedenbach, 1985

**Fundamentals of Structural Mechanics, Dynamics, and Stability** A.I. Rusakov, 2020-12-15 Fundamentals of Structural Mechanics Dynamics and Stability examines structural mechanics from a foundational point of view and allows students to use logical inference and creative reasoning to solve problems versus rote memorization It presents underlying theory and emphasizes the relevant mathematical concepts as related to structural mechanics in each chapter Problems examples and case studies are provided throughout as well as simulations to help further illustrate the content Features Presents the material from general theory and fundamentals through to practical applications Explains the finite element method for elastic bodies trusses frames non linear behavior of materials and more Includes numerous practical worked examples and case studies throughout each chapter Fundamentals of Structural Mechanics Dynamics and Stability serves as a useful text for students and instructors as well as practicing engineers

**Fundamentals of Structural Mechanics** Keith D. Hjelmstad, 2007-03-14 The last few decades have witnessed a dramatic increase in the application of numerical computation to problems in solid and structural mechanics The burgeoning of computational mechanics opened a pedagogical gap between traditional courses in elementary strength of materials and the finite element method that classical courses on advanced strength of materials and elasticity do not adequately fill In the past our ability to formulate theory exceeded our ability to compute In those days solid mechanics was for virtuosos With the advent of the finite element method our ability to compute has surpassed our ability to formulate theory As a result continuum mechanics is no longer the province of the specialist What an engineer needs to know about mechanics has been forever changed by our capacity to compute This book attempts to capitalize on the pedagogical opportunities implicit in this shift of perspective It now seems more appropriate to focus on fundamental principles and formulations than on classical solution techniques *Mechanical Engineering*, 1919 *Flow-induced Vibration of Power and Process Plant Components* M. K. Au-Yang, 2001 Information on the most common flow induced vibration problems in power and process plant components Based on the author's own experience that most errors in engineering analysis come from confusions in the units the author begins with a short chapter on units and dimensions He then provides step by step examples in dual US and SI units leading to the final objective of design analysis problem solving diagnosis and trouble shooting

**Adaptive Structures** Robert L. Clark, William R. Saunders, Gary P. Gibbs, 1998-03-31 Mechanical Engineering Materials Science An applications oriented approach for engineers and advanced students Adaptive Structures covers the

key concepts and practical issues involved in translating much of the theory of adaptive structures into successful real world hardware Easily applied to a variety of application physics the material emphasizes the integration of control strategies transduction device dynamics and spatial signal processing through novel sensing methods and actuator configurations physical or transformed coordinates The book contains essential models of adaptive structures and components to facilitate design approaches The accompanying disk features script files operating under MATLAB which can be used to generate most of the results presented throughout the book and are invaluable to readers developing their own structural models Topics include Fundamentals of structural dynamics linear systems and signals and signal processing and digital filters The integration of spatial and temporal signal processing techniques Transduction device dynamics and links between physical modal and wave domain models for structural dynamic analysis and control An overview of classical controls An application oriented review of adaptive feedforward control and multivariable feedback control system architectures

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