

Chapter 3

Harmonically Excited Vibration

3.1 (a) $\delta = \frac{W}{k} = \frac{40}{4000} = 0.01 \text{ m}$
 (b) $\delta_{st} = \frac{F_0}{k} = \frac{40}{4000} = 0.01 \text{ m}$
 (c) $\omega_n = \sqrt{\frac{k}{m}} = \left(\frac{4000 \times 9.81}{40} \right)^{1/2} = 31.3049 \text{ rad/sec}$
 $\omega = 2 \pi \times 15 = 31.4159 \text{ rad/sec}$

$$X = \delta_{st} \left| \frac{1}{1 - \left(\frac{\omega}{\omega_n} \right)^2} \right| = 0.01 \left| \frac{1}{1 - \left(\frac{31.4159}{31.3049} \right)^2} \right| = 0.0195 \text{ m}$$

3.2 $T_1 = \frac{2\pi}{\omega_n - \omega} = \frac{2\pi}{31.4159 - 31.3049} = 5 \text{ sec}$

3.3 $k = 4000 \text{ N/m}$, $m = 10 \text{ kg}$, $F(t) = 400 \cos 10t \text{ N}$
 $F_0 = 400 \text{ N}$, $\omega = 10 \text{ rad/s}$
 $\omega_n = \sqrt{\frac{k}{m}} = 20 \text{ rad/s}$, $\frac{\omega^2}{\omega_n^2} = \frac{10}{40} = 0.25 < 1$
 Response is given by Eq. (3.9):

$$x(t) = \left(x_0 - \frac{F_0}{k - m\omega^2} \right) \cos \omega_n t + \left(\frac{\dot{x}_0}{\omega_n} \right) \sin \omega_n t + \frac{F_0}{k - m\omega^2} \cos \omega t \quad (E-1)$$

(a) $x_0 = 0.1$, $\dot{x}_0 = 0$:

Eq. (E-1) becomes

$$x(t) = \left\{ 0.1 - \frac{400}{4000 - 10(100)} \right\} \cos 20t + \frac{400}{4000 - 10(100)} \cos 10t$$

$$= -0.033333 \cos 20t + 0.133333 \cos 10t \quad (E-2)$$

(b) $x_0 = 0$, $\dot{x}_0 = 10$:

Eq. (E-1) becomes

$$x(t) = \left\{ 0 - \frac{400}{4000 - 10(100)} \right\} \cos 20t + \frac{10}{20} \sin 20t$$

$$+ \left\{ \frac{400}{4000 - 10(100)} \right\} \cos 10t$$

$$= -0.133333 \cos 20t + 0.5 \sin 20t + 0.133333 \cos 10t \quad (E-3)$$

Rao Mechanical Vibrations Chapter 3 Solutions

Rao

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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 **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 Holzers And Myklestads 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 **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

ENGINEERING MECHANICS C. LAKSHAMANA RAO, J. LAKSHINARASHIMAN, RAJU SETHURAMAN, SRINIVASAN M. SIVAKUMAR, 2003-01-01 This compact and easy to read text provides a clear analysis of the principles of equilibrium of rigid

bodies in statics and dynamics when they are subjected to external mechanical loads The book also introduces the readers to the effects of force or displacements so as to give an overall picture of the behaviour of an engineering system Divided into two parts statics and dynamics the book has a structured format with a gradual development of the subject from simple concepts to advanced topics so that the beginning undergraduate is able to comprehend the subject with ease Example problems are chosen from engineering practice and all the steps involved in the solution of a problem are explained in detail The book also covers advanced topics such as the use of virtual work principle for finite element analysis introduction of Castigliano's theorem for elementary indeterminate analysis use of Lagrange's equations for obtaining equilibrium relations for multibody system principles of gyroscopic motion and their applications and the response of structures due to ground motion and its use in earthquake engineering The book has plenty of exercise problems which are arranged in a graded level of difficulty worked out examples and numerous diagrams that illustrate the principles discussed These features along with the clear exposition of principles make the text suitable for the first year undergraduate students in engineering Modern Computational Methods Herbert Koenig, 2019-05-20 This book is an introduction to computational mechanics proceeding from basic computational tools to advanced computational procedures and applications Emphasis is placed on the numerical techniques and how they form the bases for algorithms Numerous worked examples in structural mechanics heat transfer fluid flow and biomechanics are given with the numerical codes to illustrate how the methods are applied A concluding section addresses advanced applications in such areas as finite volume methods and biomechanics 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

Applied Mechanics Reviews, 1972 **Vibration of Strongly Nonlinear Discontinuous Systems** V.I. Babitsky, V.L. Krupenin, 2012-11-02 Among the wide diversity of nonlinear mechanical systems it is possible to distinguish a representative class of the systems which may be characterised by the presence of threshold nonlinear positional forces Under particular configurations such systems demonstrate a sudden change in the behaviour of elastic and dissipative forces Mathematical study of such systems involves an analysis of equations of motion containing large factored nonlinear terms which are associated with the above threshold nonlinearity Due to this we distinguish such discontinuous systems from the much wider class of essentially nonlinear systems and define them as strongly nonlinear systems The vibration occurring in strongly nonlinear systems may be characterised by a sudden and abrupt change of the velocity at particular time instants Such a vibration is said to be non smooth The systems most studied from this class are those with relaxation Van Der Pol Andronov Vitt Khaikhin Teodorchik etc 5 65 70 71 98 171 181 where the non smooth vibration usually appears due to the presence of large nonconservative nonlinear forces Equations of motion describing the vibration with relaxation may be written in such a manner that the highest derivative is accompanied by a small parameter The methods of integration of these equations have

been developed by Vasilieva and Butuzov 182 Volosov and Morgunov 190 Dorodnitsin 38 Zheleztssov 201 Mischenko and Rozov 115 Pontriagin 137 Tichonov 174 175 etc In a system with threshold nonlinearity the non smooth vibration occurs due to the action of large conservative forces This is distinct from a system with relaxation

Nonlinear Oscillations Ivana Kovacic, 2020-08-14 This book presents exact closed form solutions for the response of a variety of nonlinear oscillators free damped forced The solutions presented are expressed in terms of special functions To help the reader understand these non standard functions detailed explanations and rich illustrations of their meanings and contents are provided In addition it is shown that these exact solutions in certain cases comprise the well known approximate solutions for some nonlinear oscillations

Vehicle Vibrations Reza N. Jazar, Hormoz Marzbani, 2024-01-10 Vehicle Vibrations Linear and Nonlinear Analysis Optimization and Design is a self contained textbook that offers complete coverage of vehicle vibration topics from basic to advanced levels Written and designed to be used for automotive and mechanical engineering courses related to vehicles the text provides students automotive engineers and research scientists with a solid understanding of the principles and application of vehicle vibrations from an applied viewpoint Coverage includes everything you need to know to analyze and optimize a vehicle s vibration including vehicle vibration components vehicle vibration analysis flat ride vibration tire road separations and smart suspensions

System Dynamics Ernest Doebelin, 1998-02-10 Addressing topics from system elements and simple first and second order systems to complex lumped and distributed parameter models of practical machines and processes this work details the utility of systems dynamics for the analysis and design of mechanical fluid thermal and mixed engineering systems It emphasizes digital simulation and integrates frequency response methods throughout College or university bookshops may order five or more copies at a special student price available on request

Dynamics of Plates Rao, 1998-10-01 Details the design and application of plates and shells in machines that are subject to great stress and highly fluctuating forces Anticipate accurately the dynamic behavior of shaft gas and compressor blades while maintaining optimal safe operation of turbomachines

Advanced Mechanical Vibration: Modeling, Analysis, and Simulation Bingen Yang, 2025-02-28 Modeling analysis and simulation everything vibration engineering students need to succeed including late breaking advances in this ever changing field Advanced Mechanical Vibration covers modeling and analysis of vibrating systems with damping and gyroscopic effects dynamics of combined distributed lumped systems and approximate methods for solutions of complex vibration problems which are often overlooked in other such textbooks Case studies and pre coded MATLAB toolboxes for vibration analysis and simulation help readers understand and retain the most important concepts This is an ideal text for an upper undergraduate or graduate course in vibration engineering Includes both analytical and numerical methods for vibration analysis Addresses the latest developments in this fast changing field Prepares the student and professional for advanced R D Includes chapter ending questions with faculty only answer key multiple case studies and MATLAB toolkit for simulations SI units are used with a table converting to US

Miles' Equation

in Random Vibrations Jaap Wijker, 2018-01-25 This book discusses the theory applicability and numerous examples of Miles equation in detail Random vibration is one of the main design drivers in the context of the design development and verification of spacecraft structures instruments equipment etc and Miles equation provides a valuable tool for solving random vibration problems It allows mechanical engineers to make rapid preliminary random response predictions when the complex structure is exposed to mechanical and acoustical loads The book includes appendices to support the theory and applications in the main chapters

Vibration with Control Daniel J. Inman, 2006-11-02 Engineers are becoming increasingly aware of the problems caused by vibration in engineering design particularly in the areas of structural health monitoring and smart structures Vibration is a constant problem as it can impair performance and lead to fatigue damage and the failure of a structure Control of vibration is a key factor in preventing such detrimental results This book presents a homogenous treatment of vibration by including those factors from control that are relevant to modern vibration analysis design and measurement Vibration and control are established on a firm mathematical basis and the disciplines of vibration control linear algebra matrix computations and applied functional analysis are connected Key Features Assimilates the discipline of contemporary structural vibration with active control Introduces the use of Matlab into the solution of vibration and vibration control problems Provides a unique blend of practical and theoretical developments Contains examples and problems along with a solutions manual and power point presentations Vibration with Control is an essential text for practitioners researchers and graduate students as it can be used as a reference text for its complex chapters and topics or in a tutorial setting for those improving their knowledge of vibration and learning about control for the first time Whether or not you are familiar with vibration and control this book is an excellent introduction to this emerging and increasingly important engineering discipline

Vibrations Balakumar Balachandran, Edward B. Magrab, 2018-11-01 This new edition explains how vibrations can be used in a broad spectrum of applications and how to meet the challenges faced by engineers and system designers The text integrates linear and nonlinear systems and covers the time domain and the frequency domain responses to harmonic and transient excitations and discrete and continuous system models It focuses on modeling analysis prediction and measurement to provide a complete understanding of the underlying physical vibratory phenomena and their relevance for engineering design Knowledge is put into practice through numerous examples with real world applications in a range of disciplines detailed design guidelines applicable to various vibratory systems and over forty online interactive graphics which provide a visual summary of system behaviors and enable students to carry out their own parametric studies Some thirteen new tables act as a quick reference for self study detailing key characteristics of physical systems and summarizing important results This is an essential text for undergraduate and graduate courses in vibration analysis and a valuable reference for practicing engineers

Dynamics of Rigid-Flexible Robots and Multibody Systems Paramanand Vivekanand Nandihal, Ashish Mohan, Subir Kumar Saha, 2021-11-28 This book discusses the dynamic analysis of rigid flexible

robots and multibody systems with serial as well as closed loop architecture The book presents a formulation of dynamic model of rigid flexible robots based on the unique approach of de coupling of natural orthogonal complements of velocity constraints Based on this formulation a computationally efficient and numerically stable forward dynamics algorithms for serial chain and closed loop robotic systems with rigid or flexible or rigid flexible links is presented The proposed algorithm is shown to be a numerically efficient for forward dynamics based on the investigation methodologies built on eigen value analytics Precision and functionality of the simulation algorithms is presented illustrated with application on different serial and closed loop systems both planar and spatial types Some of the major robotic arms used to illustrate the proposed dynamic formulation and simulation algorithms are PUMA robot Stanford robot arm and Canadarm It is envisaged that the book will be useful for researchers working on the development of rigid flexible robots for use in defense space atomic energy ocean exploration and the manufacturing of biomedical equipment *Eigenvalues of Inhomogeneous Structures*

Isaac Elishakoff,2004-10-28 The engineering community generally accepts that there exists only a small set of closed form solutions for simple cases of bars beams columns and plates Despite the advances in powerful computing and advanced numerical techniques closed form solutions remain important for engineering these include uses for preliminary design for evaluation **Hydraulics and Pneumatics in Environmental Engineering** S. David Graber,2024-12-24 Bring the tools of hydraulics and pneumatics to bear on key environmental challenges Hydraulics and pneumatics are essential tools in environmental engineering Any area of engineering which deals with harnessing managing and controlling fluid and flow will find hydraulics and pneumatics indispensable and environmental engineering is no exception These two subjects however are rarely integrated in standard teaching and research resources and there exists an urgent need for a work which brings them together Hydraulics and Pneumatics in Environmental Engineering meets this need with a thorough accessible overview of this vital subject Written for advanced environmental engineering students and assuming a sound undergraduate background in fluid mechanics this book otherwise provides everything needed to bring hydraulic and pneumatic tools and principles to bear on environmental engineering problems With civil and environmental engineering only becoming more essential as communities grow and the challenges of climate change mount the next generation of engineers will be amply served by this text Hydraulics and Pneumatics in Environmental Engineering readers will also find An emphasis on practical applications often under valued in civil engineering courses Detailed discussion of topics including Navier Stokes G Value incompressible flow and many more Diagrams and figures throughout to illustrate key points Hydraulics and Pneumatics in Environmental Engineering is ideal for graduate and advanced undergraduate students in civil and environmental engineering as well as for researchers and practicing engineers in need of a reference

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