

Applications of Finite Element Analysis for Undergraduates

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Abstract

The Engineering Science and Mechanics department and the Mechanical Engineering department at Penn State share responsibility for teaching an undergraduate course on finite element analysis applications. We present one approach for teaching this course. Instructors can approach a course like this in a variety of ways. Faculty, students, and industry generally disagree as to what the learning objectives of this course should be. Furthermore, it is very difficult to get consensus from any one of these three groups. Should the focus be on using commercial software? On writing software? On the finite element method itself? On understanding finite element results? Our course objectives are to produce students capable of undertaking linear finite element modeling, who understand the basics of how commercial software packages work and the results they give, and what errors could be present. We describe the course content, which includes a mix between the finite element method and applications using a commercial software package. Special attention is given to each of the four projects that are assigned during a semester, with emphasis on learning objectives, project specifics, and student results. The students use the PRO/MECHANICA software package for these projects. While these projects change somewhat from semester to semester they generally cover: (1) plane stress elements, (2) axisymmetric elements, (3) frame elements, and (4) solid elements. In the most recent semester, students were provided a solid model of a bicycle crank arm for one project and were asked to perform a stress analysis of the crank arm. Students presented their results to students in an advanced mechanics of materials course who were designing a crank arm for their class project. In this way students were introduced to how finite element modeling fits into the design process.

Background

The course, "Applied Finite Element Analysis" is a technical elective for undergraduates at Penn State University. It is cross-listed as an Engineering Mechanics course and a Mechanical Engineering course. While different instructors treat the course differently, the first author requires only that students have taken an elementary mechanics of materials course. The first two thirds of the semester are devoted to traditional engineering education; in-class lectures, textbook reading, homework assignments, and in-class examinations. The focus of the class is on the finite element method itself, which is broken down into seven steps:

1. Discretize the continuous system into finite elements
2. Describe the element connectivity at the nodal points
3. Determine the element response in terms of nodal variables
4. Assemble the global system of equations

Finite Element Analysis For Undergraduates

**Vincent Carl Prantil, Christopher
Papadopoulos, Paul D. Gessler**



Finite Element Analysis For Undergraduates:

Finite Element Analysis for Undergraduates J. E. Akin, 1986

Finite Element Analysis Ramakrishnan

Vaidyanathan, 2016-05-13 Engineering graduates and undergraduates having this subject in their curriculum will find in this book every thing they want to know about this subject Programmes will find it easy to program for analysis of complicated systems with the basics provided in this book Subtle differences in terms and definitions are brought out clearly in separate chapters

Introduction to Finite Element Analysis S. Unnikrishnan Nair, S. Somanath, 2023-10-09 This textbook covers the basic concepts and applications of finite element analysis It is specifically aimed at introducing this advanced topic to undergraduate level engineering students and practicing engineers in a lucid manner It also introduces a structural and heat transfer analysis software FEASTSMT which has wide applications in civil mechanical nuclear and automobile engineering domains This software has been developed by generations of scientists and engineers of Vikram Sarabhai Space Centre and Indian Space Research Organisation Supported with many illustrative examples the textbook covers the classical methods of estimating solutions of mathematical models The book is written in an easy to understand manner This textbook also contains numeral exercise problems to aid self learning of the students The solutions to these problems are demonstrated using finite element software Furthermore the textbook contains several tutorials and associated online resources on usage of the FEASTSMT software Given the contents this textbook is highly useful for the undergraduate students of various disciplines of engineering It is also a good reference book for the practicing engineers

Introduction to Finite Element Analysis and Design Nam-Ho Kim, Bhavani V. Sankar, Ashok V. Kumar, 2018-05-24 Introduces the basic concepts of FEM in an easy to use format so that students and professionals can use the method efficiently and interpret results properly Finite element method FEM is a powerful tool for solving engineering problems both in solid structural mechanics and fluid mechanics This book presents all of the theoretical aspects of FEM that students of engineering will need It eliminates overlong math equations in favour of basic concepts and reviews of the mathematics and mechanics of materials in order to illustrate the concepts of FEM It introduces these concepts by including examples using six different commercial programs online The all new second edition of Introduction to Finite Element Analysis and Design provides many more exercise problems than the first edition It includes a significant amount of material in modelling issues by using several practical examples from engineering applications The book features new coverage of buckling of beams and frames and extends heat transfer analyses from 1D in the previous edition to 2D It also covers 3D solid element and its application as well as 2D Additionally readers will find an increase in coverage of finite element analysis of dynamic problems There is also a companion website with examples that are concurrent with the most recent version of the commercial programs Offers elaborate explanations of basic finite element procedures Delivers clear explanations of the capabilities and limitations of finite element analysis Includes application examples and tutorials for commercial finite element software such as MATLAB ANSYS ABAQUS and NASTRAN Provides

numerous examples and exercise problems Comes with a complete solution manual and results of several engineering design projects Introduction to Finite Element Analysis and Design 2nd Edition is an excellent text for junior and senior level undergraduate students and beginning graduate students in mechanical civil aerospace biomedical engineering industrial engineering and engineering mechanics **Practical Stress Analysis with Finite Elements (3rd Edition)** Bryan J Mac Donald, 2020-04-27 Updated with new material the third edition of this highly popular book is a no nonsense guide to finite element analysis aimed at beginners The emphasis in this book is doing FEA not becoming bogged down in endless mathematics The book is written so that it is not tied to any particular FE software so it doesn't matter which software you use A First Course in the Finite Element Method Daryl L. Logan, 2007 A First Course in the Finite Element Analysis provides a simple basic approach to the finite element method that can be understood by both undergraduate and graduate students It does not have the usual prerequisites such as structural analysis required by most available texts in this area The book is written primarily as a basic learning tool for the undergraduate student in civil and mechanical engineering whose main interest is in stress analysis and heat transfer The text is geared toward those who want to apply the finite element method as a tool to solve practical physical problems This revised fourth edition includes the addition of a large number of new problems including SI problems an appendix for mechanical and thermal properties and more civil applications

Engineering Finite Element Analysis Ramana M. Pidaparti, 2017-05-02 Finite element analysis is a basic foundational topic that all engineering majors need to understand in order for them to be productive engineering analysts for a variety of industries This book provides an introductory treatment of finite element analysis with an overview of the various fundamental concepts and applications It introduces the basic concepts of the finite element method and examples of analysis using systematic methodologies based on ANSYS software Finite element concepts involving one dimensional problems are discussed in detail so the reader can thoroughly comprehend the concepts and progressively build upon those problems to aid in analyzing two dimensional and three dimensional problems Moreover the analysis processes are listed step by step for easy implementation and an overview of two dimensional and three dimensional concepts and problems is also provided In addition multiphysics problems involving coupled analysis examples are presented to further illustrate the broad applicability of the finite element method for a variety of engineering disciplines The book is primarily targeted toward undergraduate students majoring in civil biomedical mechanical electrical and aerospace engineering and any other fields involving aspects of engineering analysis Finite Element Analysis S. S. Bhavikatti, 2005 With The Authors Experience Of Teaching The Courses On Finite Element Analysis To Undergraduate And Postgraduate Students For Several Years The Author Felt Need For Writing This Book The Concept Of Finite Element Analysis Finding Properties Of Various Elements And Assembling Stiffness Equation Is Developed Systematically By Splitting The Subject Into Various Chapters The Method Is Made Clear By Solving Many Problems By Hand Calculations The Application Of Finite Element Method To Plates Shells And

Nonlinear Analysis Is Presented After Listing Some Of The Commercially Available Finite Element Analysis Packages The Structure Of A Finite Element Program And The Desired Features Of Commercial Packages Are Discussed *A First Course in Finite Element Analysis* Xin-She Yang,2007-08 The book endeavors to strike a balance between mathematical and numerical coverage of a wide range of topics in finite element analysis It strives to provide an introduction especially for undergraduates and graduates to finite element analysis and its applications Topics include advanced calculus differential equations vector analysis calculus of variations finite difference methods finite element methods and time stepping schemes The book also emphasizes the application of important numerical methods with dozens of worked examples The applied topics include elasticity heat transfer and pattern formation A few self explanatory Matlab programs provide a good start for readers to try some of the methods and to apply the methods and techniques to their own modelling problems with some modifications The book will perfectly serve as a textbook in finite element analysis computational mathematics mathematical modelling and engineering computations **Finite Element Analysis with Error Estimators** J. E. Akin,2005-06-22 This key text is written for senior undergraduate and graduate engineering students It delivers a complete introduction to finite element methods and to automatic adaptation error estimation that will enable students to understand and use FEA as a true engineering tool It has been specifically developed to be accessible to non mathematics students and provides the only complete text for FEA with error estimators for non mathematicians Error estimation is taught on nearly half of all FEM courses for engineers at senior undergraduate and postgraduate level no other existing textbook for this market covers this topic The only introductory FEA text with error estimation for students of engineering scientific computing and applied mathematics Includes source code for creating and proving FEA error estimators **Finite Element Analysis** J.T. Boyle,1991 *Practical Guide to Finite Elements* Steven Lepi,2020-11-25 Assuming only basic knowledge of mathematics and engineering mechanics this lucid reference introduces the fundamentals of finite element theory using easy to understand terms and simple problems systematically grounding the practitioner in the basic principles then suggesting applications to more general cases Furnishes a wealth of practical insights drawn from the extensive experience of a specialist in the field Generously illustrated with over 200 detailed drawings to clarify discussions and containing key literature citations for more in depth study of particular topics this clearly written resource is an exceptional guide for mechanical civil aeronautic automotive electrical and electronics and design engineers engineering managers and upper level undergraduate graduate and continuing education students in these disciplines [Introduction to Finite Element Analysis and Design](#) Nam-Ho Kim,Bhavani V. Sankar,Ashok V. Kumar,2025-06-02 A clear and accessible overview of the Finite Element Method The finite element method FEM which involves solutions to partial differential equations and integro differential equations is a powerful tool for solving structural mechanics and fluid mechanics problems FEM results in versatile computer programs with flexible applications usable with minimal training to solve practical problems in a variety of

engineering and design contexts Introduction to Finite Element Analysis and Design offers a comprehensive yet readable overview of both theoretical and practical elements of FEM With a greater focus on design aspects than most comparable volumes it s an invaluable introduction to a key suite of software and design tools The third edition has been fully updated to reflect the latest research and applications Readers of the third edition of Introduction to Finite Element Analysis and Design will find 50% more exercise problems than the previous edition with an accompanying solutions manual for instructors A brand new chapter on plate and shell finite elements Tutorials for commercial finite element software including MATLAB ANSYS ABAQUS and NASTRAN Introduction to Finite Element Analysis and Design is ideal for advanced undergraduate students in finite element analysis or design related courses as well as for researchers and design engineers looking for self guided tools

Engineering Finite Element Analysis Ramana M. Pidaparti, 2022-06-01 Finite element analysis is a basic foundational topic that all engineering majors need to understand in order for them to be productive engineering analysts for a variety of industries This book provides an introductory treatment of finite element analysis with an overview of the various fundamental concepts and applications It introduces the basic concepts of the finite element method and examples of analysis using systematic methodologies based on ANSYS software Finite element concepts involving one dimensional problems are discussed in detail so the reader can thoroughly comprehend the concepts and progressively build upon those problems to aid in analyzing two dimensional and three dimensional problems Moreover the analysis processes are listed step by step for easy implementation and an overview of two dimensional and three dimensional concepts and problems is also provided In addition multiphysics problems involving coupled analysis examples are presented to further illustrate the broad applicability of the finite element method for a variety of engineering disciplines The book is primarily targeted toward undergraduate students majoring in civil biomedical mechanical electrical and aerospace engineering and any other fields involving aspects of engineering analysis

Finite Element Analysis of Thin-Walled Structures Dr John W. Bull, 1988-01-25 This book describes current developments in finite element analysis and the design of certain types of thin walled structures The first three chapters lay the foundations for the development and use of finite elements for thin walled structures look at finite elements packages and discuss data input and mesh arrangements The final four chapters use the finite element method to assist in the solution of thin walled structure problems Some of the problems solved include water and air inflated structures axisymmetric thin shells ship structures and offshore structures This book will be an interest to design engineers researchers and postgraduates

Fundamentals of Finite Element Analysis David V. Hutton, 2004 Hutton discusses basic theory of the finite element method while avoiding variational calculus instead focusing upon the engineering mechanics and mathematical background that may be expected of senior engineering students The text relies upon basic equilibrium principles introduction of the principle of minimum potential energy and the Galerkin finite element method which readily allows application of finite element analysis to nonstructural problems The text is software independent making

it flexible enough for use in a wide variety of programs and offers a good selection of homework problems and examples A Book Website is also included with book illustrations for class presentation complete problem solutions password protected the FEPC 2 D finite element program for student use instructions on FEPC and its use with the text and links to commercial FEA sites Book jacket

Using ANSYS for Finite Element Analysis, Volume I Wael A. Altabey, Mohammad Noori, Libin Wang, 2018-06-04 Over the past two decades the use of finite element method as a design tool has grown rapidly Easy to use commercial software such as ANSYS have become common tools in the hands of students as well as practicing engineers The objective of this book is to demonstrate the use of one of the most commonly used Finite Element Analysis software ANSYS for linear static dynamic and thermal analysis through a series of tutorials and examples Some of the topics covered in these tutorials include development of beam frames and Grid Equations 2 D elasticity problems dynamic analysis composites and heat transfer problems These simple yet fundamental tutorials are expected to assist the users with the better understanding of finite element modeling how to control modeling errors and the use of the FEM in designing complex load bearing components and structures These tutorials would supplement a course in basic finite element or can be used by practicing engineers who may not have the advanced training in finite element analysis

Lying by Approximation Vincent Carl Prantil, Christopher Papadopoulos, Paul D. Gessler, 2013 In teaching an introduction to the finite element method at the undergraduate level a prudent mix of theory and applications is often sought In many cases analysts use the finite element method to perform parametric studies on potential designs to size parts weed out less desirable design scenarios and predict system behavior under load In this book we discuss common pitfalls encountered by many finite element analysts in particular students encountering the method for the first time We present a variety of simple problems in axial bending torsion and shear loading that combine the students knowledge of theoretical mechanics numerical methods and approximations particular to the finite element method itself We also present case studies in which analyses are coupled with experiments to emphasize validation illustrate where interpretations of numerical results can be misleading and what can be done to allay such tendencies Challenges in presenting the necessary mix of theory and applications in a typical undergraduate course are discussed We also discuss a list of tips and rules of thumb for applying the method in practice Table of Contents Preface Acknowledgments Guilty Until Proven Innocent Let s Get Started Where We Begin to Go Wrong It s Only a Model Wisdom Is Doing It Summary Afterword Bibliography Authors Biographies

Finite Element Modeling and Simulation with ANSYS Workbench Xiaolin Chen, Yijun Liu, 2014-08-11 Learn Basic Theory and Software Usage from a Single Volume Finite Element Modeling and Simulation with ANSYS Workbench combines finite element theory with real world practice Providing an introduction to finite element modeling and analysis for those with no prior experience and written by authors with a combined experience of 30 years teaching the subject this text presents FEM formulations integrated with relevant hands on applications using ANSYS Workbench for finite element analysis FEA Incorporating the basic theories of

FEA and the use of ANSYS Workbench in the modeling and simulation of engineering problems the book also establishes the FEM method as a powerful numerical tool in engineering design and analysis Include FEA in Your Design and Analysis of Structures Using ANSYS Workbench The authors reveal the basic concepts in FEA using simple mechanics problems as examples and provide a clear understanding of FEA principles element behaviors and solution procedures They emphasize correct usage of FEA software and techniques in FEA modeling and simulation The material in the book discusses one dimensional bar and beam elements two dimensional plane stress and plane strain elements plate and shell elements and three dimensional solid elements in the analyses of structural stresses vibrations and dynamics thermal responses fluid flows optimizations and failures Contained in 12 chapters the text introduces ANSYS Workbench through detailed examples and hands on case studies and includes homework problems and projects using ANSYS Workbench software that are provided at the end of each chapter Covers solid mechanics and thermal fluid FEA Contains ANSYS Workbench geometry input files for examples and case studies Includes two chapters devoted to modeling and solution techniques design optimization fatigue and buckling failure analysis Provides modeling tips in case studies to provide readers an immediate opportunity to apply the skills they learn in a problem solving context Finite Element Modeling and Simulation with ANSYS Workbench benefits upper level undergraduate students in all engineering disciplines as well as researchers and practicing engineers who use the finite element method to analyze structures

Becoming a Finite Element Analyst Rebecca B. Dupaix, 2020-08-04 Becoming a Finite Element Analyst A Design Model Verify Approach helps students become solid finite element analysts through hands on lessons Rather than focusing on theory the book uses an inverted approach Students are first shown how to build finite element models of real engineering parts through increasingly complex examples and case studies They are then introduced to the accompanying theory The book is based on a design model verify approach that teaches three key skillsets stress analysis of solids beams shells and assemblies modal and buckling analysis and nonlinear and thermal analysis Students make critical decisions to convert a real part into an appropriately simplified model They choose the element types and boundary conditions to best represent their model and interpret simulation results to determine if the results are realistic and reasonable The revised first edition has been revised to enhance or replace tables figures questions and discussions about problem results Appendix B has been expanded to include more beam loading conditions as well as stress and deflection equations for some simple plates and shells Appendix E was added to include some basic natural frequency verification tables Becoming a Finite Element Analyst is suitable for senior level undergraduate or beginning graduate courses in applied finite element methods

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