

## Continuum Mechanics For Engineers Solution Manual

This is an intermediate book for beginning postgraduate students and junior researchers, and offers up-to-date content on both continuum mechanics and elasticity. The material is self-contained and should provide readers sufficient working knowledge in both areas. Though the focus is primarily on vector and tensor calculus (the so-called coordinate-free approach), the more traditional index notation is used whenever it is deemed more sensible. With the increasing demand for continuum modeling in such diverse areas as mathematical biology and geology, it is imperative to have various approaches to continuum mechanics and elasticity. This book presents these subjects from an applied mathematics perspective. In particular, it extensively uses linear algebra and vector calculus to develop the fundamentals of both subjects in a way that requires minimal use of coordinates (so that beginning graduate students and junior researchers come to appreciate the power of the tensor notation).

Continuum Mechanics for Engineers, Third Edition provides engineering students with a complete, concise, and accessible introduction to advanced engineering mechanics. The impetus for this latest edition was the need to suitably combine the introduction of continuum mechanics, linear and nonlinear elasticity, and viscoelasticity for a graduate-level course sequence. An outgrowth of course notes and problems used to teach these subjects, the third edition of this bestselling text explores the basic concepts behind these topics and demonstrates their application in engineering practice. Presents Material Consistent with Modern Literature A new rearranged and expanded chapter on elasticity more completely covers Saint-Venant's solutions. Subsections on extension, torsion, pure bending and flexure present an excellent foundation for posing and solving basic elasticity problems. The authors' presentation enables continuum mechanics to be applied to biological materials. In light of their current importance. They have also altered the book's notation—a common struggle for many students—to better align it with modern continuum mechanics literature. This book addresses students' need to understand the sophisticated simulation programs that use nonlinear kinematics and various constitutive relationships. It includes an introduction to problem solution using MATLAB®, emphasizing this language's value in enabling users to stay focused on fundamentals. This book provides information that is useful in emerging engineering areas, such as micro-mechanics and biomechanics. With an abundance of worked examples and chapter problems, it carefully explains necessary mathematics as required and presents numerous illustrations, giving students and practicing professionals an excellent self-study guide to enhance their skills. Through a mastery of this volume's contents and additional rigorous finite element training, they will develop the mechanics foundation necessary to skillfully use modern, advanced design tools.

Fundamentals of Continuum Mechanics provides a clear and rigorous presentation of continuum mechanics for engineers, physicists, applied mathematicians, and materials scientists. This book emphasizes the role of thermodynamics in constitutive modeling, with detailed application to nonlinear elastic solids, viscous fluids, and modern smart materials. While emphasizing advanced material modeling, special attention is also devoted to developing novel theories for incompressible and thermally expanding materials. A wealth of carefully chosen examples and exercises illuminate the subject matter and facilitate self-study. Uses direct notation for a clear and straightforward presentation of the mathematics, leading to a better understanding of the underlying physics Covers high-interest research areas such as small- and large-deformation continuum electrodynamics, with application to smart materials used in intelligent systems and structures Offers a unique approach to modeling incompressibility and thermal expansion, based on the authors' own research

This volume presents a collection of contributions on advanced approaches of continuum mechanics, which were written to celebrate the 60th birthday of Prof. Holm Altenbach. The contributions are on topics related to the theoretical foundations for the analysis of rods, shells and three-dimensional solids, formulation of constitutive models for advanced materials, as well as development of new approaches to the modeling of damage and fractures.

FLAC and Numerical Modeling in Geomechanics  
An Applied Mathematics Introduction  
Generalized Continuum Mechanics and Engineering Applications  
Multi-Scale Continuum Mechanics Modelling of Fibre-Reinforced Polymer Composites  
With Applications to Continuum Mechanics

**Approach your problems from the right end It isn't that they can't see the solution. It is and begin with the answers. Then one day, that they can't see the problem, perhaps you will find the final question. G. K. Chesterton. The Scandal of Father 'The Hermit Clad in Crane Feathers' in R. Brown 'The point of a Pin'. van Gulik's The Chinese Maze Murders. Growing specialization and diversification have brought a host of monographs and textbooks on increasingly specialized topics. However, the "tree" of knowledge of mathematics and related fields does not grow only by putting forth new branches. It also happens, quite often in fact, that branches which were thought to be completely disparate are suddenly seen to be related. Further, the kind and level of sophistication of mathematics applied in various sciences has changed drastically in recent years: measure theory is used (non trivially) in regional and theoretical economics; algebraic geometry interacts with physics; the Minkowski lemma, coding theory and the structure of water meet one another in packing and covering theory; quantum fields, crystal defects and mathematical programming profit from homotopy theory; Lie algebras are relevant to filtering; and prediction and electrical engineering can use Stein spaces. And in addition to this there are such new emerging subdisciplines as "experimental mathematics", "CFD", "completely integrable systems", "chaos, synergetics and large-scale order", which are almost impossible to fit into the existing classification schemes. They draw upon widely different sections of mathematics.**

**DIVComprehensive treatment offers 115 solved problems and exercises to promote understanding of vector and tensor theory, basic kinematics, balance laws, field equations, jump conditions, and constitutive equations. /div**

**Designing engineering components that make optimal use of materials requires consideration of the nonlinear characteristics associated with both manufacturing and working environments. The modeling of these characteristics can only be done through numerical formulation and simulation, and this requires an understanding of both the theoretical background and associated computer solution techniques. By presenting both nonlinear continuum analysis and associated finite element techniques under one roof, Bonet and Wood provide, in this edition of this successful text, a complete, clear, and unified treatment of these important subjects. New chapters dealing with hyperelastic plastic behavior are included, and the authors have thoroughly updated the FLAGSHYP program, freely accessible at www.flagshyp.com. Worked examples and exercises complete each chapter, making the text an essential resource for postgraduates studying nonlinear continuum mechanics. It is also ideal for those in industry requiring an appreciation of the way in which their computer simulation programs work.**

**There is a large gap between engineering courses in tensor algebra on one hand, and the treatment of linear transformations within classical linear algebra on the other. This book addresses primarily engineering students with some initial knowledge of matrix algebra. Thereby, mathematical formalism is applied as far as it is absolutely necessary. Numerous exercises provided in the book are accompanied by solutions enabling autonomous study. The last chapters deal with modern developments in the theory of isotropic and anisotropic tensor functions and their applications to continuum mechanics and might therefore be of high interest for PhD-students and scientists working in this area.**

**Advanced Methods of Continuum Mechanics for Materials and Structures**

**Continuum and Computational Mechanics for Geomechanical Engineers**

**From Fundamental Concepts to Governing Equations**

**Continuum Mechanics for Engineers, Third Edition**

**Continuum Mechanics and Thermodynamics**

This new edition provides a complete, concise, and accessible introduction to advanced engineering mechanics. It explores the basic concepts behind continuum mechanics, linear and nonlinear elasticity, and viscoelasticity, and demonstrates their application in engineering practice.

The book covers new developments in structural topology optimization. Basic features and limitations of Michell's solutions, its extension to a broader class of support conditions, generalizations of trust topology optimization, and Michell continua are reviewed. For elastic bodies, the layout problems in linear elasticity are discussed and the method of relaxation by homogenization is outlined. The classical problem of free material design is shown to be reducible to a locking material problem, even in the multiload case. For structures subjected to dynamic loads, it is explained how they can be designed so that the structural eigenfrequencies of vibration are as far away as possible from a prescribed external excitation frequency (or a band of excitation frequencies) in order to avoid resonance phenomena with high vibration and noise levels. For diffusive and convective transport processes and multiphysics problems, applications of the density method are discussed. In order to take uncertainty in material parameters, geometry, and operating conditions into account, techniques of reliability-based design optimization are introduced and reviewed for their applicability to topology optimization.

The purposes of the text are: To introduce the engineer to the very important discipline in applied mathematics-tensor methods as well as to show the fundamental unity of the different fields in continuum mechanics-with the unifying material formed by the matrix-tensor theory and to present to the engineer modern engineering problems.

Undergraduate text offers an analysis of deformation and stress, covers laws of conservation of mass, momentum, and energy, and surveys the formulation of mechanical constitutive equations. 1992 edition.

Concise Theory and Problems

Approximate Solution Methods in Engineering Mechanics

General Continuum Mechanics

Tensor Algebra and Tensor Analysis for Engineers

**A concise introductory course text on continuum mechanics Fundamentals of Continuum Mechanics focuses on the fundamentals of the subject and provides the background for formulation of numerical methods for large deformations and a wide range of material behaviours. It aims to provide the foundations for further study, not just of these subjects, but also the formulations for much more complex material behaviour and their implementation computationally. This book is divided into 5 parts, covering mathematical preliminaries, stress, motion and deformation, balance of mass, momentum and energy, and ideal constitutive relations and is a suitable textbook for introductory graduate courses for students in mechanical and civil engineering, as well as those studying material science, geology and geophysics and biomechanics. A concise introductory course text on continuum mechanics Covers the fundamentals of continuum mechanics Uses modern tensor notation Contains problems and accompanied by a companion website hosting solutions Suitable as a textbook for introductory graduate courses for students in mechanical and civil engineering**

**A concise account of classic theories of fluids and solids, for graduate and advanced undergraduate courses in continuum mechanics.**

**Extensive solved exercises and solutions to complement the authors' theoretical text Nonlinear Continuum Mechanics for Finite Element Analysis.**

**Treats subjects directly related to nonlinear materials modeling for graduate students and researchers in physics, materials science, chemistry and engineering.**

**Solutions Manual -- Continuum Mechanics for Engineers, Third Edition**

**Handbook of Continuum Mechanics**

**Engineering Solutions for CO2 Conversion**

**A First Course in Continuum Mechanics**

**Topology Optimization in Structural and Continuum Mechanics**

**Continuum mechanics studies the response of materials to different loading conditions. The concept of tensors is introduced through the idea of linear transformation in a self-contained chapter, and the interrelation of direct notation, indicial notation and matrix operations is clearly presented. A wide range of idealized materials are considered through simple static and dynamic problems, and the book contains an abundance of illustrative examples and problems, many with solutions. Through the addition of more advanced material (solution of classical elasticity problems, constitutive equations for viscoelastic fluids, and finite deformation theory), this popular introduction to modern continuum mechanics has been fully revised to serve a dual purpose: for introductory courses in undergraduate engineering curricula, and for beginning graduate courses.**

**This book offers a broad overview of the potential of continuum mechanics to describe a wide range of macroscopic phenomena in real-world problems. Building on the fundamentals presented in the authors' previous book, Continuum Mechanics using Mathematica®, this new work explores interesting models of continuum mechanics, with an emphasis on exploring the flexibility of their applications in a wide variety of fields.**

**This publication is aimed at students, teachers, and researchers of Continuum Mechanics and focused extensively on stating and developing Initial Boundary Value equations used to solve physical problems. With respect to notation, the tensorial, indicial and Voigt notations have been used indiscriminately. The book is divided into twelve chapters with the following topics: Tensors, Continuum Kinematics, Stress, The Objectivity of Tensors, The Fundamental Equations of Continuum Mechanics, An Introduction to Constitutive Equations, Linear Elasticity, Hyperelasticity, Plasticity (small and large deformations), Thermoelasticity (small and large deformations), Damage Mechanics (small and large deformations), and An Introduction to Fluids. Moreover, the text is supplemented with over 280 figures, over 100 solved problems, and 130 references.**

**Multi-scale modelling of composites is a very relevant topic in composites science. This is illustrated by the numerous sessions in the recent European and International Conferences on Composite Materials, but also by the fast developments in multi-scale modelling software tools, developed by large industrial players such as Siemens (Virtual Material Characterization toolkit and MultiMechanics virtual testing software), MSC/e-Xtream (Digimat software), Simulia (micromechanics plug-in in Abaqus), HyperSizer (Multi-scale design of composites), Altair (Altair Multiscale Designer) This book is intended to be an ideal reference on the latest advances in multi-scale modelling of fibre-reinforced polymer composites, that is accessible for both (young) researchers and end users of modelling software. We target three main groups: This book aims at a complete introduction and overview of the state-of-the-art in multi-scale modelling of composites in three axes: \* ranging from prediction of homogenized elastic properties to nonlinear material behaviour \* ranging from geometrical models for random packing of unidirectional fibres over meso-scale geometries for textile composites to orientation tensors for short fibre composites \* ranging from damage modelling of unidirectionally reinforced composites over textile composites to short fibre-reinforced composites The book covers the three most important scales in multi-scale modelling of composites: (i) micro-scale, (ii) meso-scale and (iii) macro-scale. The nano-scale and related atomistic and molecular modelling approaches are deliberately excluded, since the book wants to focus on continuum mechanics and there are already a lot of dedicated books about polymer nanocomposites. A strong focus is put on physics-based damage modelling, in the sense that the chapters devote attention to modelling the different damage mechanisms (matrix cracking, fibre/matrix debonding, delamination, fibre fracture,...) in such a way that the underlying physics of the initiation and growth of these damage modes is respected. The book also gives room to not only discuss the finite element based approaches for multi-scale modelling, but also much faster methods that are popular in industrial software, such as Mean Field Homogenization methods (based on Mori-Tanaka and Eshelby solutions) and variational methods (shear lag theory and more advanced theories). Since the book targets a wide audience, the focus is put on the most common numerical approaches that are used in multi-scale modelling. Very specialized numerical methods like peridynamics modelling, Material Point Method, eXtended Finite Element Method (XFEM), isogeometric analysis, SPH (Smoothed Particle Hydrodynamics),... are excluded. Outline of the book The book is divided in three large parts, well balanced with each a similar number of chapters:**

**Continuum Mechanics and Linear Elasticity**

**Elements of Continuum Mechanics**

**Solutions Manual for Continuum Mechanics for Engineers**

**Nonlinear Continuum Mechanics for Finite Element Analysis**

**Solutions manual**

**Solutions Manual -- Continuum Mechanics for Engineers, Third EditionContinuum Mechanics for Engineers, Third EditionCRC Press**

**Outstanding approach to continuum mechanics. Its high mathematical level of teaching together with abstracts, summaries, boxes of essential formulae and numerous exercises with solutions, makes this handbook one of most complete books in the area. Students, lecturers, and practitioners will find this handbook a rich source for their studies or daily work.**

**General Continuum Mechanics provides an integrated and unified study of continuum mechanics.**

**Introduction to Continuum Mechanics is a recently updated and revised text which is perfect for either introductory courses in an undergraduate engineering curriculum or for a beginning graduate course. Continuum Mechanics studies the response of materials to different loading conditions. The concept of tensors is introduced through the idea of linear transformation in a self-contained chapter, and the interrelation of direct notation, indicial notation, and matrix operations is clearly presented. A wide range of idealized materials are considered through simple static and dynamic problems, and the book contains an abundance of illustrative examples of problems, many with solutions.Serves as either a introductory undergraduate course or a beginning graduate course textbook.Includes many problems with illustrations and answers.**

**An Introduction to Continuum Mechanics**

**Continuum Mechanics Via Problems and Exercises: Theory and problems**

**Variational Principles of Continuum Mechanics with Engineering Applications**

**Advanced Topics and Research Trends**

**Introduction to Continuum Mechanics**

The new concept of metamaterial is increasingly attracting the interest of physicists and mechanical engineers. Such materials are obtained by suitably assembling multiple individual elements but usually arranged in (quasi-)periodic substructures in order to show exotic global mechanical properties. Indeed, the particular shape, geometry, size, orientation and arrangement of their constituting elements can affect, the propagation of waves of light or sound in a manner not observed in natural materials, creating material properties which may give rise to unexpected engineering applications. Particularly promising in the design and description of metamaterials are those micro-structures which present high contrasts in their mechanical properties: these micro-structures, once homogenized, may produce generalized continuum media, for example, second gradient or micromorphic. Many scientific challenges related to the application of generalized continuum theories to the characterization and conception of high-performance metamaterials can be identified. In this book we identify and discuss four main potential fields of applications of generalized continuum theories, namely, mechanical behavior of fibrous composite reinforcements, wave propagation in metamaterials, mechanical behavior of concrete and mechanically driven remodeling of bone in presence of bio-resorbable materials. For each field, we underline how the use of a generalized continuum theory can be of help for describing how the presence of microstructure can affect the global mechanical behavior of the considered metamaterials. Covers four main fields of the application of continuum theories Learn how to apply generalised continuum theory to describe the effects of microstructure on the mechanical behavior of materials Decipher the material properties which aid your engineering applications

A bestselling textbook in its first three editions, Continuum Mechanics for Engineers, Fourth Edition provides engineering students with a complete, concise, and accessible introduction to advanced engineering mechanics. It provides information that is useful in emerging engineering areas, such as micro-mechanics and biomechanics. Through a mastery of this volume's contents and additional rigorous finite element training, readers will develop the mechanics foundation necessary to skillfully use modern, advanced design tools. Features: Provides a basic, understandable approach to the concepts, mathematics, and engineering applications of continuum mechanics Updated throughout, and adds a new chapter on plasticity Features an expanded coverage of fluids Includes numerous all new end-of-chapter problems With an abundance of worked examples and chapter problems, it carefully explains necessary mathematics and presents numerous illustrations, giving students and practicing professionals an excellent self-study guide to enhance their skills.

The only complete collection of prevalent approximation methods Unlike any other resource, Approximate Solution Methods in Engineering Mechanics, Second Edition offers in-depth coverage of the most common approximate numerical methods used in the solution of physical problems, including those used in popular computer modeling packages. Descriptions of each approximation method are presented with the latest relevant research and developments, providing thorough, working knowledge of the methods and their principles. Approximation methods covered include: \* Boundary element method (BEM) \* Weighted residuals method \* Finite difference method (FDM) \* Finite element method (FEM) \* Finite strip/layer/prism methods \* Meshless method Approximate Solution Methods in Engineering Mechanics, Second Edition is a valuable reference guide for mechanical, aerospace, and civil engineers, as well as students in these disciplines.

This textbook is intended to introduce engineering graduate students to the essentials of modern continuum mechanics. The objective of an introductory course is to establish certain classical continuum models within a broader framework. Engineering students need a firm understanding of classical models such as linear viscous fluids (Navier-Stokes theory) and infinitesimal elasticity. This understanding should include an appreciation for the status of the classical models as special cases of general nonlinear continuum models. The relationship of the classical models to nonlinear models is essential in light of the increasing reliance, by engineering designers and researchers, on prepackaged computer codes. These codes are based upon models which have a specific and limited range of validity. Given the danger associated with the use of these computer codes in circumstances where the model is not valid, engineers have a need for an in-depth understanding of continuum mechanics and the continuum models which can be formulated by use of continuum mechanics techniques. Classical continuum models and others involve a utilization of the balance equations of continuum mechanics, the second law of thermo dynamics, and the principles of material frame indifference and material symmetry. In addition, they involve linearizations of various types. In this text, an effort is made to explain carefully how the governing principles, linearizations, and other approximations combine to yield classical continuum models. A fundamental understanding of how these models evolve is most helpful when one attempts to study models which account for a wider array of physical phenomena.

Tensor Analysis for Engineers and Physicists - With Application to Continuum Mechanics, Turbulence, and Einstein's Special and General Theory of Relativity

Worked Examples in Nonlinear Continuum Mechanics for Finite Element Analysis

Continuum Mechanics for Engineers

Volume 1: Critical Points Theory

Continuum Mechanics Modeling of Material Behavior

This best-selling textbook presents the concepts of continuum mechanics, and the second edition includes additional explanations, examples and exercises.

The field of rock mechanics and rock engineering utilizes the basic laws of continuum mechanics and the techniques developed in computational mechanics. This book describes the basic concepts behind these fundamental laws and their utilization in practice irrespective of whether rock/rock mass contains discontinuities. This book consists of nine chapters and six appendices. The first four chapters are concerned with continuum mechanics aspects, which include the basic operations, definition of stress and strain tensors, and derivation of four fundamental conservation laws in the simplest yet precise manner. The next two chapters are the preparation for computational mechanics, which require constitutive laws of geomaterials relevant to each conservation law and the procedure to determine required parameters of the constitutive laws. Computational mechanics solves the resulting ordinary and partial differential equations. In Chapter 7, the methods of exact (closed-form) solutions are explained and they are applied to ordinary/partial differential equations with solvable boundary and initial conditions. In Chapter 8, the fundamentals of approximate solution methods are explained for one dimension first and then how to extend them to two-/dimensional problems. The readers are expected to learn and clearly understand how they are derived and applied to various problems in geomechanics. The final chapter involves the applications of the approximate methods to the actual problems in practice for geomechanical engineers, which cover the continuum to discontinuum, including the stress state of the earth as well as the ground motions induced by earthquakes. Six appendices are provided to have a clear understanding of continuum mechanics operations and procedures for how to deal with discontinuities/interfaces often encountered in rock mechanics and rock engineering.

A comprehensive guide that offers a review of the current technologies that tackle CO2 emissions The race to reduce CO2 emissions continues to be an urgent global challenge. "Engineering Solutions for CO2 Conversion" offers a thorough guide to the most current technologies designed to mitigate CO2 emissions ranging from CO2 capture to CO2 utilization approaches. With contributions from an international panel representing a wide range of expertise, this book contains a multidisciplinary toolkit that covers the myriad aspects of CO2 conversion strategies. Comprehensive in scope, it explores the chemical, physical, engineering and economical facets of CO2 conversion. "Engineering Solutions for CO2 Conversion" explores a broad range of topics including linking CFD and process simulations, membranes technologies for efficient CO2 capture-conversion, biogas sweetening technologies, plasma-assisted conversion of CO2, and much more. This important resource: \* Addresses a pressing concern of global environmental damage, caused by the greenhouse gases emissions from fossil fuels \* Contains a review of the most current developments on the various aspects of CO2 capture and utilization strategies \* Includes information on chemical, physical, engineering and economical facets of CO2 capture and utilization \* Offers in-depth insight into materials design, processing characterization, and computer modeling with respect to CO2 capture and conversion Written for catalytic chemists, electrochemists, process engineers, chemical engineers, chemists in industry, photochemists, environmental chemists, theoretical chemists, environmental officers, "Engineering Solutions for CO2 Conversion" provides the most current and expert information on the many aspects and challenges of CO2 conversion.

Continuum Mechanics Modeling of Material Behavior offers a uniquely comprehensive introduction to topics like RVE theory, fabric tensor models, micropolar elasticity, elasticity with voids, nonlocal higher gradient elasticity and damage mechanics. Contemporary continuum mechanics research has been moving into areas of complex material microstructural behavior. Graduate students who are expected to do this type of research need a fundamental background beyond classical continuum theories. The book begins with several chapters that carefully and rigorously present mathematical preliminaries; kinematics of motion and deformation; force and stress measures; and mass, momentum and energy balance principles. The book then moves beyond other books by dedicating the last chapter to constitutive equation development, exploring a wide collection of constitutive relations and developing the corresponding material model formulations. Such material behavior models include classical linear theories of elasticity, fluid mechanics, viscoelasticity and plasticity, as well as linear and nonlinear theories of solids and fluids, including finite elasticity, nonlinear/non-Newtonian viscous fluids, and nonlinear viscoelastic materials. Finally, several relatively new continuum theories based on incorporation of material microstructure are presented including: fabric tensor theories, micropolar elasticity, elasticity with voids, nonlocal higher gradient elasticity and damage mechanics. Offers a thorough, concise and organized presentation of continuum mechanics formulation Covers numerous applications in areas of contemporary continuum mechanics modeling, including micromechanical and multi-scale problems Integration and use of MATLAB software gives students more tools to solve, evaluate and plot problems under study Features extensive use of exercises, providing more material for student engagement and instructor presentation

**Matrix-Tensor Methods in Continuum Mechanics**

**General Concepts' Thermoelasticity**

**Introduction to Continuum Mechanics for Engineers**

**Continuum Mechanics**

**Notes on Continuum Mechanics**

This book presents an introduction into the entire science of Continuum Mechanics in three parts. The presentation is modern and comprehensive. Its introduction into tensors is very gentle. The book contains many examples and exercises, and is intended for scientists, practitioners and students of mechanics.

Many processes in materials science and engineering, such as the load deformation behaviour of certain structures, exhibit nonlinear characteristics. The computer simulation of such processes therefore requires a deep understanding of both the theoretical aspects of nonlinearity and the associated computational techniques. This book provides a complete set of exercises and solutions in the field of theoretical and computational nonlinear continuum mechanics and is the perfect companion to Nonlinear Continuum Mechanics for Finite Element Analysis, where the authors set out the theoretical foundations of the subject. It employs notation consistent with the theory book and serves as a great resource to students, researchers and those in industry interested in gaining confidence by practising through examples. Instructors of the subject will also find the book indispensable in aiding student learning.

Sixty-five papers cover a wide range of topics from engineering applications to theoretical developments in the areas of embankment and slope stability, underground cavity design and mining, dynamic analysis, soil and structure interaction, and coupled processes and fluid flow.

**Fundamentals of Continuum Mechanics**

**With Applications to Mechanical, Thermomechanical, and Smart Materials**