Experimental Methods For Engineers Solution Manual

A method for organizing and conducting scientific experiments is described in this volume which enables experimenters to reduce the number of trials run, while retaining all the parameters that may influence the result. The choice of ideal experiments is based on mathematical concepts, but the author adopts a practical approach and uses theory only when necessary. Written for experimenters by an experimenter, it is an introduction to the philosophy of scientific investigation. Researchers with limited time and resources at their disposal will find this text a valuable guide for solving specific problems efficiently. The presentation makes extensive use of examples, and the approach and methods are graphical rather than numerical. All calculations can be performed on a personal computer; readers are assumed to have no previous knowledge of the subject. The presentation is such that the beginner may acquire a thorough understanding of the basic concepts. However, there is also sufficient material to challenge the advanced student. The book is, therefore, suitable for both first and advanced courses. The many examples can also be used in detail for self-study or as a reference.

Successful characterization of polymer systems is one of the most important objectives of today's experimental research of polymers. Considering the tremendous scientific, technological, and economic importance of polymeric materials, not only for today's applications but for the industry of the 21st century, it is impossible to overestimate the usefulness of experimental techniques in this field. Since the chemical, pharmaceutical, medical, and agricultural industries, as well as many others, depend on this progress to an enormous degree, it is critical to be as efficient, precise, and cost-effective in our empirical understanding of the performance of polymer systems as possible. This presupposes our proficiency with, and understanding of, the most widely used experimental methods and techniques. This book is designed to fulfill the requirements of scientists and engineers who wish to be able to carry out experimental research in polymers using modern methods. Each chapter describes the principle of the respective method, as well as the detailed procedures of experiments with examples of actual applications. Thus, readers will be able to apply the concepts as described in the book to their own experiments. Addresses the most important practical techniques for experimental research in the growing field of polymer science The first well-documented presentation of the experimental methods in one consolidated source Covers principles, practical techniques, and actual examples Can be used as a handbook or lab manual for both students and researchers Presents ideas and methods from an international perspective Techniques addressed in this volume include: Light Scattering Neutron Scattering and X-Ray Scattering Fluorescence Spectroscopy NMR on Polymers Rheology Gel Experiments

Composed of papers presented at the 10th conference on Multiphase flow this book presents the latest research on the subject. The research included in this volume focuses on using synergies between experimental and computational techniques to gain a better understanding of all classes of multiphase and complex flow.

This book covers a wide variety of topics related to the application of experimental methods, in addition to the pedagogy of chemical engineering laboratory unit operations. The purpose of this book is to create a platform for the exchange of different experimental techniques, approaches and lessons, in addition to new ideas and strategies in teaching laboratory unit operations to undergraduate chemical engineering students. It is recommended for instructors and students of chemical engineering and natural sciences who are interested in reading about different experimental setups and techniques, covering a wide range of scales, which can be widely applied to many areas of chemical engineering interest.

Modern Experimental Stress Analysis

Solutions Manual to Accompany Experimental Methods for Engineers

Heat Transfer

Experimental Methods for Social Policy Research

Experimental Methods for Phosphor Evaluation and Characterization

Environmental Economics, Experimental Methods

This is an indespensible guide to both researchers in academia and industry who wish to perform tribological experiments more effectively. With an extensive range of illustrations which communicate the basic concepts in experimental methods tribology more effectively than text alone. An extensive citation list is also provided at the end of each chapter facilitating a more thorough navigation through a particular subject. * Contains extensive illustrations * Highlights limitations of current techniques

Although books covering experimental design are often written for academic courses taken by statistics majors, most experiments performed in industry and academic research are designed and analyzed by non-statisticians. Therefore, a need exists for a desk reference that will be useful to practitioners who use experimental designs in their work. This book fills that gap. It is written as a guide that can be used as a reference book or as a sole or supplemental text for a university course.

This concise and easy to read text introduces first year students to the analysis and presentation of experimental data. Written for students taking introductory physics courses at tertiary level, Experimental Methods will be a vital resource for all students involved in experimental or laboratory work. It will be equally useful for other quantitative subjects such as chemistry, engineering and geology. Topics of fundamental importance such as keeping a laboratory notebook, analysing experimental data and report writing are often dealt with in separate texts. This book integrates these topics and provides many of the tools that students will need at first year level and beyond.

This market leader offers the broadest range of experimental measurement techniques available for mechanical and general engineering applications. Offering clear descriptions of the general behavior of different measurement techniques, such as pressure, flow, and temperature, the text emphasizes the use of uncertainty analysis and statistical data analysis in estimating the accuracy of

measurements.
Experimental Methods in Polymer Science
Experimental Methods for Science and Engineering Students
The Jacob Aboudi Volume
Methods and Experimental Techniques in Computer Engineering
Select Proceedings of ICITFES 2020
Solutions Manual to Accompany

This book brings a fresh new approach to practical problem solving in engineering, covering the critical concepts and ideas that engineers must understand to solve engineering problems. Problem Solving for New Engineers: What Every Engineering Manager Wants You to Kno provides strategy and tools needed for new engineers and scientists to become apprentice experimenters armed only with a problem to sol and knowledge of their subject matter. When engineers graduate, they enter the work force with only one part of what's needed to effective solve problems -- Problem solving requires not just subject matter expertise but an additional knowledge of strategy. With the combination o both knowledge of subject matter and knowledge of strategy, engineering problems can be attacked efficiently. This book develops strategy minimizing, eliminating, and finally controlling unwanted variation such that all intentional variation is truly representative of the variables of interest.

In this book, the authors discuss some of the main challenges and new opportunities in science and engineering research, which involve combining computational and experimental approaches as a promising strategy for arriving at new insights into composition–structure–property relations, even at the nanoscale. From a practical standpoint, the authors show that significant improvemen in the material/biomolecular foresight by design, including a fundamental understanding of their physical and chemical properties, are vital and will undoubtedly help us to reach a new technological level in the future.

Developments in Numerical and Experimental Methods Applied to Tribology contains the proceedings of the 10th Leeds-Lyon Symposium o Tribology held at the Institut National des Sciences Appliquées in Lyon, France, on September 6-9, 1983. The papers explore development numerical and experimental methods used in tribology and cover topics ranging from ferrography and rheology to bearings and bearing dynamics, hydrodynamics, contact phenomena, and plasticity. The papers are organized into 13 sessions. The first two papers examine th of ferrography in the analysis of non-ferrous particles as well as some of the methods of obtaining approximate numerical solutions to boundary-value problems that arise in elastohydrodynamic lubrication. The next session is concerned with rheology and contains papers th describe numerical solutions for power law fluids as applied to slider bearings; grease lubricated finite length bearings; and the use of the b bearing as rheological test device. The papers that follow discuss bearings and their dynamics, oil films on lubricated surfaces, hydrodynam lubrication, and finite element analysis of transient elastohydrodynamic lubrication. The final session considers plastic deformation, two boc abrasion processes, and micropitting and asperity deformation. This monograph will appeal to tribologists.

A unified and coherent treatment of analytical, computational and experimental techniques of nonlinear dynamics with numerous illustrative applications. Features a discourse on geometric concepts such as Poincaré maps. Discusses chaos, stability and bifurcation analysis for systems of differential and algebraic equations. Includes scores of examples to facilitate understanding.

Design of Experiments for Engineers and Scientists
Proceedings of ICCES2019
Theoretical, Computational, and Experimental Solutions to Thermo-Fluid Systems
Reproducibility and Replicability in Science
Methods for Experimental Design

This book presents select proceedings of the International Conference on Innovations in Thermo-Fluid Engineering and Sciences (ICITFES 2020). It covers topics in theoretical and experimental fluid dynamics, numerical methods in heat transfer and fluid mechanics, different modes of heat transfer, multiphase flow, fluid machinery, fluid power, refrigeration and air conditioning, and cryogenics. The book will be helpful to the researchers, scientists, and professionals working in the field of fluid mechanics and machinery, and thermal engineering.

The experimental method is one commonly applied to issues of environmental economics; this book brings together 63 leading researchers in the area and their latest work exploring the behavioural underpinnings of experimental environmental economics. The essays in this volume will be illuminating for both researchers and practitioners, specifically in relation to questions of environmental policy and how a proposed change in incentives or benefits might affect behaviour and consequently, the likely success of a policy. This book argues that the experimental evidence complements theoretic insights, field date and simulating models to improve our understanding of the underlying assumptions and incentives that drive behavioural responses to policy. Covering topical areas of interest such as tradable permit markets, common property and public goods, regulation and compliance and valuation and preferences, the critical advantage of this volume is that each section concludes with discussion points written by economists who do not use experimental methods.

A benchmark publication, the first edition of the Phosphor Handbook, published in 1998, set the standard for references in the field. The second edition, updated and published in 2007, began exploring new and emerging fields. However, in the last 14 years, since the second edition was published, many notable advances and broader phosphor applications have occurred. Completely revised, updated, and expanded into three separate volumes, this third edition of the Handbook covers the most recent developments in phosphor research, characterization, and applications. This volume on ' Experimental Methods for Phosphor Evaluation and Characterization ' addresses the theoretical and experimental methods for phosphor evaluation and characterization. The chapters in the book cover: First principle and DFT analysis of optical, structural, and chemical properties of phosphors Phosphor design and tuning through structure and solid solution Design for IR, NIR, and narrowband emission and thermally stable phosphors and nanophosphors Detailed illustration for measurement of the absolute photoluminescence quantum yield of phosphors Phosphor analysis through

photoionization, high pressure, and synchrotron radiation studies

Over the past few decades there has been a prolific increase in research and development in area of heat transfer, heat exchangers and their associated technologies. This book is a collection of current research in the above mentioned areas and discusses experimental, theoretical and calculation approaches and industrial utilizations with modern ideas and methods to study heat transfer for single and multiphase systems. The topics considered include various basic concepts of heat transfer, the fundamental modes of heat transfer (namely conduction, convection and radiation), thermophysical properties, condensation, boiling, freezing, innovative experiments, measurement analysis, theoretical models and simulations, with many real-world problems and important modern applications. The book is divided in four sections : "Heat Transfer in Micro Systems", "Boiling, Freezing and Condensation Heat Transfer", "Heat Transfer and its Assessment", "Heat Transfer Calculations", and each section discusses a wide variety of techniques, methods and applications in accordance with the subjects. The combination of theoretical and experimental investigations with many important practical applications of current interest will make this book of interest to researchers, scientists, engineers and graduate students, who make use of experimental and theoretical investigations, assessment and enhancement techniques in this multidisciplinary field as well as to researchers in mathematical modelling, computer simulations and information sciences, who make use of experimental and theoretical investigations as a means of critical assessment of models and results derived from advanced numerical simulations and improvement of the developed models and numerical methods.

Modern Methods in Polymer Research and Technology

Experimental Methods

An Introduction to the Analysis and Presentation of Data

Computational and Experimental Simulations in Engineering

Pergamon International Library of Science, Technology, Engineering and Social Studies

Proceedings of ICCEMME 2021

This book includes selected peer-reviewed papers presented at third International Conference on Computational and Experimental Methods in Mechanical Engineering held in June 2021 at G.L. Bajaj Institute of Technology and Management, Greater Noida, U.P, India. The book covers broad range of topics in latest research including hydropower, heat transfer, fluid mechanics, advanced manufacturing, recycling and waste disposal, solar energy, thermal power plants, refrigeration and air conditioning, robotics, automation and mechatronics, and advanced designs. The authors are experienced and experts in their field, and all papers are reviewed by expert reviewers in respective field. The book is useful for industry peoples, faculties, and research scholars.

This collection of cutting-edge papers, written by leading authors in honor of Professor Jacob Aboudi, covers a wide spectrum of topics in the field, presents both theoretical and experimental approaches, and suggests directions for possible future research.

This book gathers the latest advances, innovations, and applications in the field of computational engineering, as presented by leading international researchers and engineers at the 24th International Conference on Computational & Experimental Engineering and Sciences (ICCES), held in Tokyo, Japan on March 25-28, 2019. ICCES covers all aspects of applied sciences and engineering: theoretical, analytical, computational, and experimental studies and solutions of problems in the physical, chemical, biological, mechanical, electrical, and mathematical sciences. As such, the book discusses highly diverse topics, including composites; bioengineering & biomechanics; geotechnical engineering; offshore & arctic engineering; multi-scale & multi-physics fluid engineering; structural integrity & longevity; materials design & simulation; and computer modeling methods in engineering. The contributions, which were selected by means of a rigorous international peer-review process, highlight numerous exciting ideas that will spur novel research directions and foster multidisciplinary collaborations.

Experimental Methods in Orthopaedic Biomechanics is the first book in the field that focuses on the practicalities of performing a large variety of in-vitro laboratory experiments. Explanations are thorough, informative, and feature standard lab equipment to enable biomedical engineers to advance from a 'trial and error' approach to an efficient system recommended by experienced leaders. This is an ideal tool for biomedical engineers or biomechanics professors in their teaching, as well as for those studying and carrying out lab assignments and projects in the field. The experienced authors have established a standard that researchers can test against in order to explain the strengths and weaknesses of testing approaches. Provides step-by-step guidance to help with in-vitro experiments in orthopaedic biomechanics Presents a DIY manual that is fully equipped with illustrations, practical tips, quiz questions, and much more Includes input from field experts who combine their real-world experience to provide invaluable insights for all those in the field

Phosphor Handbook

Computational and Experimental Methods in Mechanical Engineering
Experimental Data on Aqueous Phase Equilibria and Solution Properties at Elevated Temperatures and Pressures
Experimental Methods and Instrumentation for Chemical Engineers
Buckling Experiments, Basic Concepts, Columns, Beams and Plates
Experimental Methods in Orthopaedic Biomechanics

One of the pathways by which the scientific community confirms the validity of a new scientific discovery is by repeating the research that produced it. When a scientific effort fails to independently confirm the computations or results of a previous study, some fear that it may be a symptom of a lack of rigor in science, while others argue that such an observed inconsistency can be an important precursor to new discovery. Concerns about reproducibility and replicability have been expressed in both scientific and popular media. As these concerns came to light, Congress requested that the National Academies of Sciences, Engineering, and Medicine conduct a study to assess the extent of issues related to reproducibility and replicability and to offer recommendations for improving rigor and transparency in scientific research. Reproducibility and Replicability in Science defines reproducibility and replicability and examines the factors that may lead to non-reproducibility and non-replicability in research. Unlike the typical expectation of reproducibility between two computations, expectations about replicability are more nuanced, and in some cases a lack of replicability can aid the process of scientific discovery. This report provides recommendations to researchers, academic institutions, journals, and funders on steps they can take to improve reproducibility and replicability in science.

Professor Fenner's definitive text is now back in print, with added corrections. It serves as an introduction to finite element methods for engineering undergraduates and other students at an equivalent level. Postgraduate and practising engineers will also find it useful if they are comparatively new to finite element methods. The main emphasis is on the simplest methods suitable for solving two-dimensional continuum mechanics problems, particularly those encountered in the fields of stress analysis, fluid mechanics and heat transfer. Complete FORTRAN programs are presented, described and discussed in detail, and several practical case studies serve to illustrate the methods developed in the book. Finite element methods are compared and contrasted with finite difference methods, and throughout the level of computer programming, continuum mechanics, numerical analysis, matrix algebra and other mathematics employed corresponds to that normally covered in undergraduate engineering courses. Contents:Introduction and Structural AnalysisContinuum Mechanics ProblemsFinite Element Analysis of Harmonic ProblemsFinite Element MeshesSome Harmonic ProblemsFinite Element Analysis of Biharmonic ProblemsSome Biharmonic ProblemsFurther Applications Readership: Undergraduates and postgraduates in civil engineering & mechanical engineering and practising engineers.

Experimental Techniques in Materials and Mechanics provides a detailed yet easy-to-follow treatment of various techniques useful for characterizing the structure and mechanical properties of materials. With an emphasis on techniques most commonly used in laboratories, the book enables students to understand practical aspects of the methods and derive the maximum possible information from the experimental results obtained. The text focuses on crystal structure determination, optical and scanning electron microscopy, phase diagrams and heat treatment, and different types of mechanical testing methods. Each chapter follows a similar format: Discusses the importance of each technique Presents the necessary theoretical and background details Clarifies concepts with numerous worked-out examples Provides a detailed description of the experiment to be conducted and how the data could be tabulated and interpreted Includes a large number of illustrations, figures, and micrographs Contains a wealth of exercises and references for further reading Bridging the gap between lecture and lab, this text gives students hands-on experience using mechanical engineering and materials science/engineering techniques for determining the structure and properties of materials. After completing the book, students will be able to confidently perform experiments in the lab and extract valuable data from the experimental results.

Computing and science reveal a synergic relationship. On the one hand, it is widely evident that computing plays an important role in the scientific endeavor. On the other hand, the role of scientific method in computing is getting increasingly important, especially in providing ways to experimentally evaluate the properties of complex computing systems. This book critically presents these issues from a unitary conceptual and methodological perspective by addressing specific case studies at the intersection between computing and science. The book originates from, and collects the experience of, a course for PhD students in Information Engineering held at the Politecnico di Milano. Following the structure of the course, the book features contributions from some researchers who are working at the intersection between computing and science.

Proceedings of the 10th Leeds–Lyon Symposium on Tribology Held at the Institut National des Sciences Appliquées, Lyon, France, 6th–9th September 1983
Advances in Mathematical Modeling and Experimental Methods for Materials and Structures
Computational & Experimental Methods in Multiphase & Complex Flow X
Engineering World
Problem Solving for New Engineers
Experimental Methods in Heat Transfer and Fluid Mechanics

The tools and techniques used in Design of Experiments (DoE) have been proven successful in meeting the challenge of continuous improvement in many manufacturing organisations over the last two decades. However research has shown that application of this powerful technique in many companies is limited due to a lack of statistical knowledge required for its effective implementation. Although many books have been written on this subject, they are mainly by statisticians, for statisticians and not appropriate for engineers. Design of Experiments for Engineers and Scientists overcomes the problem of statistics by taking a unique approach using graphical tools. The same outcomes and conclusions are reached as through using statistical methods and readers will find the concepts in this book both familiar and easy to understand. This new edition includes a chapter on the role of DoE within Six Sigma methodology and also shows through the use of simple case studies its importance in the service industry. It is essential reading for engineers and scientists from all disciplines tackling all kinds of manufacturing, product and process quality problems and will be an ideal resource for students of this topic. Written in non-statistical language, the book is an essential and accessible text for scientists and engineers who want to learn how to use DoE Explains why teaching DoE techniques in the improvement phase of Six Sigma is an important part of problem solving methodology New edition includes a full chapter on

DoE for services as well as case studies illustrating its wider application in the service industry
Solutions Manual to AccompanyExperimental Methods for Engineers /Solutions Manual to Accompany Experimental Methods for EngineersExperimental Methods for EngineersExperimental Methods for EngineersMcGraw-Hill Science, Engineering & MathematicsSolutions Manual to Accompany Experimental Methods for Engineers, Fourth EditionExperimental Methods for Engineers
Experimental Methods in Heat Transfer and Fluid Mechanics focuses on how to analyze and solve the classic heat transfer and fluid mechanics measurement problems in one book. This work serves the need of graduate students and researchers looking for advanced measurement techniques for thermal, flow, and heat transfer engineering applications. The text focuses on analyzing and solving classic heat transfer and fluid mechanics measurement problems, emphasizing fundamental principles, measurement techniques, data presentation, and uncertainty analysis. Overall, the text builds a strong and practical background for solving complex engineering heat transfer and fluid flow problems. Features Provides students with an understandable introduction to thermal-fluid measurement Covers heat transfer and fluid mechanics measurements from basic to advanced methods Explains and compares various thermal-fluid experimental and measurement techniques Uses a step-by-step approach to explaining key measurement principles Gives measurement procedures that readers can easily follow and apply in the lab
Hydrothermal Properties of Materials: Experimental Data on Aqueous Phase Equilibria and Solution Properties at Elevated Temperatures and Pressures is designed for any scientists and engineer who deals with hydrothermal investigations and technologies. The book is organized into eight chapters, each dealing with a key physical property of behavior of solutions, so that a reader can obtain information on: hydrothermal experimental methods; available experimental data and the main features of properties behavior in a wide range of temperatures and pressures; and possible ways of experimental data processing for obtaining the derivative properties.
Solutions Manual to Accompany Experimental Methods for Engineers, Fourth Edition
Emerging Research in Science and Engineering Based on Advanced Experimental and Computational Strategies
Experimental Methods for Engineers /
Hydrothermal Properties of Materials
Basic Experimental Strategies and Data Analysis for Science and Engineering
Experimental Techniques in Materials and Mechanics
All structures suffer from stresses and strains caused by factors such as wind loading and vibrations. Stress analysis and measurement is an integral part of the design and management of structures, and is used in a wide range of engineering areas. There are two main types of stress analyses – the first is conceptual where the structure does not yet exist and the analyst has more freedom to define geometry, materials, loads etc – generally such analysis is undertaken using numerical methods such as the finite element method. The second is where the structure (or a prototype) exists, and so some parameters are known. Others though, such as wind loading or environmental conditions will not be completely known and yet may profoundly affect the structure. These problems are generally handled by an ad hoc combination of experimental and analytical methods. This book therefore tackles one of the most common challenges facing engineers – how to solve a stress analysis problem when all of the required information is not available. Its central concern is to establish formal methods for including measurements as part of the complete analysis of such problems by presenting a new approach to the processing of experimental data and thus to experimentation itself. In addition, engineers using finite element methods will be able to extend the range of problems they can solve (and thereby the range of applications they can address) using the methods developed here. Modern Experimental Stress Analysis: Presents a comprehensive and modern reformulation of the approach to processing experimental data Offers a large collection of problems ranging from static to dynamic, linear to non-linear Covers stress analysis with the finite element method Includes a wealth of documented experimental examples Provides new ideas for researchers in computational mechanics
An overview of experimental methods providing practical advice to students seeking guidance with their experimental work.
Written by eminent researchers and renown authors of numerous publications in the buckling structures field. * Deals with experimental investigation in the industry. * Covers the conventional and more unconventional methods for testing for a wide variety of structures. * Various parameters which may influence the test results are systemically highlighted including, imperfections, boundary conditions, loading conditions as well as the effects of holes and cut-outs.
Experimental Methods and Instrumentation for Chemical Engineers, Second Edition, touches many aspects of engineering practice, research, and statistics. The principles of unit operations, transport phenomena, and plant design constitute the focus of chemical engineering in the latter years of the curricula. Experimental methods and instrumentation is the precursor to these subjects. This resource integrates these concepts with statistics and uncertainty analysis to define what is necessary to measure and to control, how precisely and how often. The completely updated second edition is divided into several themes related to data: metrology, notions of statistics, and design of experiments. The book then covers basic principles of sensing devices, with a brand new chapter covering force and mass, followed by pressure, temperature, flow rate, and physico-chemical properties. It continues with chapters that describe how to measure gas

and liquid concentrations, how to characterize solids, and finally a new chapter on spectroscopic techniques such as UV/Vis, IR, XRD, XPS, NMR, and XAS. Throughout the book, the author integrates the concepts of uncertainty, along with a historical context and practical examples. A problem solutions manual is available from the author upon request. Includes the basics for 1st and 2nd year chemical engineers, providing a foundation for unit operations and transport phenomena Features many practical examples Offers exercises for students at the end of each chapter Includes up-to-date detailed drawings and photos of equipment

Finite Element Methods for Engineers

Experimental Methods for Engineers

Developments in Numerical and Experimental Methods Applied to Tribology

Theoretical Analysis, Experimental Investigations and Industrial Systems

What Every Engineering Manager Wants You to Know

Laboratory Unit Operations and Experimental Methods in Chemical Engineering

Experimental Methods for Social Policy Research explains how experimental methods can be used in social policy research to help solve contemporary human problems and to preserve and improve the world's physical and social climates. This book argues that scientists can make a major contribution to the solution of social problems by aiding the society in incorporating scientific methods into the social decision-making process. Two principal methods required for solving social problems are highlighted: methods for evaluating social models aimed at solving particular problems, and methods for disseminating those models that are beneficial to the state, the region, and the nation. This book is comprised of 14 chapters and begins with the argument that contemporary social policy decision making is inadequate for the late 20th and 21st centuries. It then defines the basic ingredients for an adequate social policy decision-making apparatus and explains how it can be accomplished. The next chapter outlines the basic parameters of social models and dissemination processes from a conceptual point of view. The remaining chapters describe general experimental procedures from the inception of the ideas to the implementation of social models found to be beneficial. The final chapter is reserved for a discussion of a proposed center for experimental social innovation that would provide research and training. This monograph will be a valuable resource for social scientists and researchers as well as social policymakers, public officials, and citizens who are committed to the improvement of living conditions for all members of society.

1967: July-December

Completing the Solution of Partially Specified Problems

Catalog of Copyright Entries. Third Series

Principles and Applications for Physicists and Chemists

College of Engineering

Applied Nonlinear Dynamics