Inverse Heat Transfer

This book introduces the fundamental concepts of inverse heat transfer solutions and their applications for solving problems in convective, conductive, radiative, and multi-physics problems. Inverse Heat Transfer: Fundamentals and Applications, Second Edition includes techniques within the Bayesian framework of statistics for the solution of inverse problems. By modernizing the classic work of the late Professor M. Necati Özisik and adding new examples and problems, this new edition provides a powerful tool for instructors, researchers, and graduate students studying thermal-fluid systems and heat transfer. FEATURES Introduces the fundamental concepts of inverse heat transfer Presents in systematic fashion the basic steps of powerful inverse solution techniques Develops inverse techniques of parameter estimation, function estimation, and state estimation Applies these inverse techniques to the solution of practical inverse heat transfer problems Shows inverse techniques for conduction, convection, radiation, and multi-physics phenomena M. Necati Özisik (1923–2008) retired in 1998 as Professor Emeritus of North Carolina State University's Mechanical and Aerospace Engineering Department. Helcio R. B. Orlande is a Professor of Mechanical Engineering at the Federal University of Rio de Janeiro (UFRJ), where he was the Department Head from 2006 to 2007.

Here is the only commercially published work to deal with the engineering problem of determining surface heat flux and temperature history based on interior temperature measurements. Provides the analytical techniques needed to arrive at otherwise difficult solutions, summarizing the findings of the last ten years. Topics include the steady state solution, Duhamel's Theorem, ill-posed problems, single future time step, and more.

Computational engineering/science uses a blend of applications, mathematical models and computations. Mathematical models require accurate approximations of their parameters, which are often viewed as solutions to inverse problems. Thus, the study of inverse problems is an integral part of computational engineering/science. This book presents several aspects of inverse problems along with needed prerequisite topics in numerical analysis and matrix algebra. If the reader has previously studied these prerequisites, then one can rapidly move to the inverse problems in chapters 4-8 on image restoration, thermal radiation, thermal characterization and heat transfer. "This text does provide a comprehensive introduction to inverse problems and fills a void in the literature". Robert E White, Professor of Mathematics, North Carolina State University

The Art of Measuring in the Thermal Sciences provides an original state-of-the-art guide to scholars who are conducting thermal experiments in both academia and industry. Applications include energy generation, transport, manufacturing, mining, processes, HVAC&R, etc. This book presents original insights into advanced measurement techniques and systems, explores the fundamentals, and focuses on the analysis and design of thermal systems. Discusses the advanced measurement techniques now used in thermal systems Links measurement techniques to concepts in thermal science and engineering Draws upon the original work of current researchers and experts in thermal-fluid measurement Includes coverage of new technologies, such as micro-level heat transfer measurements Covers the main types of instrumentation and software used in thermal-fluid measurements This book offers engineers, researchers, and graduate students an overview of the best practices for conducting sound measurements in the thermal sciences.

Inverse problems arise in many areas of mathematical physics, and applications are rapidly expanding to such areas as geophysics, chemistry, medicine, and engineering. The main theme of this book is uniqueness, stability, and existence of solutions of inverse problems for partial differential equations. Focusing primarily on the inverse problem of potential theory and closely related questions such as coefficient identification problems, this book will give readers an understanding of the results of a substantial part of the theory of inverse problems and of some of the new ideas and methods used.The author provides complete proofs of most general uniqueness theorems for the inverse problem of gravimetry, a detailed study of regularity properties (including examples of non-regular domains with regular potentials), counterexamples to uniqueness and uniqueness theorems, and a treatment of the theory of non-stationary problems. In addition, the book deals with the orthogonality method, formulates several important unsolved problems, and suggests certain technical means appropriate for further study; some numerical methods are also outlined. Requiring a background in the basics of differential equations and function theory, this book is directed at mathematicians specializing in partial differential equations and potential theory, as well as physicists, geophysicists, and engineers.

This Second Edition for the standard graduate level course in conduction heat transfer has been updated and oriented more to engineering applications partnered with real-world examples. New features include: numerous grid generation--for finding solutions by the finite element method--and recently developed inverse heat conduction. Every chapter and reference has been updated and new exercise problems replace the old.

This book comprises selected papers from the International Conference on Numerical Heat Transfer and Fluid Flow (NHTFF 2018), and presents the latest developments in computational methods in heat and mass transfer. It also discusses numerical methods such as finite element, finite difference, and finite volume applied to fluid flow problems. Providing a good balance between computational methods and analytical results applied to a wide variety of problems in heat transfer, transport and fluid mechanics, the book is a valuable resource for students and researchers working in the field of heat transfer and fluid dynamics.

An authoritative guide to theory and applications of heat transfer in humans Theory and Applications of Heat Transfer in Humans 2V Set offers a reference to the field of heating and cooling of tissue, and associated damage. The author—a noted expert in the field—presents, in this book, the fundamental physics and physiology related to the field, along with some of the recent applications, all in one place, in such a way as to enable and enrich both beginner and advanced readers. The book provides a basic framework that can be used to obtain 'decent' estimates of tissue temperatures for various applications involving tissue heating and/or cooling, and also presents ways to further develop more complex methods, if needed, to obtain more accurate results. The book is arranged in three sections: The first section, named 'Physics', presents fundamental mathematical frameworks that can be used as is or combined together forming more complex tools to determine tissue temperatures; the second section, named 'Physiology', presents ideas and data that provide the basis for the physiological assumptions needed to develop successful mathematical tools; and finally, the third section, named 'Applications', presents examples of how the marriage of the first two sections are used to solve problems of today and tomorrow. This important text is the vital resource that: Offers a reference book in the field of heating and cooling of tissue, and associated damage. Provides a comprehensive theoretical and experimental basis with biomedical applications Shows how to develop and implement both, simple and complex mathematical models to predict tissue temperatures Includes simple examples and results so readers can use those results directly or adapt them for their applications Designed for students, engineers, and other professionals, a comprehensive text to the field of heating and cooling of tissue that includes proven theories with applications. The author reveals how to develop simple and complex mathematical models, to predict tissue heating and/or cooling, and associated damage.

With its uncommon presentation of instructional material regarding mathematical modeling, measurements, and solution of inverse problems, Thermal Measurements and Inverse Techniques is a one-stop reference for those dealing with various aspects of heat transfer. Progress in mathematical modeling of complex industrial and environmental systems has e

Thesis (M.A.) from the year 2009 in the subject Engineering - Power Engineering, , language: English, abstract: Inverse heat conduction problems occur in many theoretical and practical applications where it is difficult or practically impossible to measure the heat flux generated and the temperature of the layer conducting the heat flux to the body. Thus it becomes imperative to devise some means to cater for such a problem and estimate the heat flux inversely. Adaptive state estimator is one such technique which works by incorporating the semi-Markovian concept into a Bayesian estimation technique thereby developing an inverse input and state estimator consisting of a bank of parallel adaptively weighted Kalman filters. The problem presented in this study deals with a three dimensional system of a cube with one end conducting heat flux and all the other sides are insulated while the temperatures are measured on the accessible faces of the cube. The measurements taken on these accessible faces are fed into the estimation algorithm and the input heat flux and the temperature distribution at each point in the system is calculated. A variety of input heat flux scenarios have been examined to underwrite the robustness of the estimation algorithm and hence insure its usability in practical applications. These include sinusoidal input flux, a combination of rectangular, linearly changing and sinusoidal input flux and finally a step changing input flux. The estimator's performance limitations have been examined in these input set-ups and error associated with each set-up is compared to conclude the realistic application of the estimation algorithm in such scenarios. Different sensor arrangements, that is different sensor numbers and their locations are also examined to impress upon the importance of number of measurements and their location i.e. close or farther from the input area. Since practically it is both economically and physically tedious to install more number of measurement sensors, hence optimized number and location is very important to determine for making the study more application oriented. Before the inverse estimation, a comprehensive mesh sensitivity analysis is given for the system's governing equation finite difference calculations to get an optimized mesh size for the forward and inverse analysis to be correct and within the tolerable error limits and computationally undemanding at the same time.

The content of this book covers several up-to-date approaches in the heat conduction theory such as inverse heat conduction problems, non-linear and non-classic heat conduction equations, coupled thermal and electromagnetic or mechanical effects and numerical methods for solving heat conduction equations as well. The book is comprised of 14 chapters divided into four sections. In the first section inverse heat conduction problems are discuss. The first two chapters of the second section are devoted to construction of analytical solutions of nonlinear heat conduction problems. In the last two chapters of this section wavelike solutions are attained.The third section is devoted to combined effects of heat conduction and electromagnetic interactions in plasmas or in pyroelectric material elastic deformations and hydrodynamics. Two chapters in the last section are dedicated to numerical methods for solving heat conduction problems.

Nowadays mathematical modeling and numerical simulations play an important role in life and natural science. Numerous researchers are working in developing different methods and techniques to help understand the behavior of very complex systems, from the brain activity with real importance in medicine to the turbulent flows with important applications in physics and engineering. This book presents an overview of some models, methods, and numerical computations that are useful for the applied research scientists and mathematicians, fluid tech engineers, and postgraduate students.

A HEAT TRANSFER TEXTBOOK
Finite Difference Methods in Heat Transfer
Parameter Estimation in Engineering and Science
Heat Conduction Using Greens Functions
An Introduction to Inverse Problems with Applications
Solving Direct and Inverse Heat Conduction Problems
Methods for Inverse Heat Conduction Problems
Systems Analysis of the Inverse Heat Conduction Problem

This book presents a solution for direct and inverse heat conduction problems, discussing the theoretical basis for the heat transfer process and presenting selected theoretical and numerical problems in the form of exercises with solutions. The book covers one-, two- and three dimensional problems which are solved by using exact and approximate analytical methods and numerical methods. An accompanying CD-Rom includes computational solutions of the examples and extensive FORTRAN code.

This is a thesis by publication for a PhD degree of engineering in the University of Adelaide. The current dissertation comprises five published/submitted journal articles. Three of these journal papers have already been published in the journal of "International Communications in Heat and Mass Transfer" and one has been accepted by the editorial board of "Chemical Engineering Communications". This study, based on research undertaken in the area of Inverse Heat Transfer Problems (IHTP), aims at analyzing the applicability of Intelligent Techniques (ITs) to solve sequential (real-time) heat flux estimation class of

IHTPs, especially those involving in the most complicated form of heat transfer, radiation. Currently, several optimization based methods have been developed and applied to solve heat flux estimation problems. These methods normally require detailed and accurate information regarding physical properties. Often, the measurement of such physical properties is extremely difficult, if not impossible. Moreover, all optimization-based methods require that the direct problem must be solved first. This constraint of the need for iterated direct problem solutions can produce significant computing errors and calculations may be excessively time-consuming. This thesis offers new inverse models to estimate heat flux based on a sequence of measured temperatures. The offered models developed by ITs, in accordance with the achievement of this research, only requires a series of temperature-input heat data for a few minutes of operation; the dimensions and thermophysical properties are not needed. As another significant advantage, the estimation stage by the trained ITs only includes a small number of simple calculations excluding any recursive computation; this means the method is very fast-paced in comparison with classical avenues of numerical heat transfer for similar problems. At the outset, the most general form of ITs in engineering applications, Artificial Neural Networks (ANNs), employed to formulate an inverse model in the studied furnace/dryer (see chapter 4). The promising results confirmed that ITs are sound candidates to create inverse models. In that study, some deficiencies in ANNs such as finding the relevant parameters by trial and errors motivated the authors to check GA-ANNs and ANFIS as the possible alternatives for ANNs. The comparison study between aforementioned methods (see chapter 5) provided good outlines to find the best method in different situation. As the ANNs optimized by Genetic Algorithms (GA) discovered as the best method in the chapter 5, different types of ANNs were compared to find the best one (see chapter 6) in terms of accuracy and computation time. The results demonstrated that Multilayer Perceptron (MLP) optimized by GA can perform the best among all studied ANNs. Since the literatures lack of a practical comparison between the proposed and optimization based methods, as the next phase of study, these two method were compared (see chapter 7) to reconfirm the superiority of inverse models developed by ITs. In the last stage (chapter 8), a two-input/ two-output problem defined to check the capability of the proposed method in the problems more closer to the real-world industrial applications. In short, a series of very accurate methods for inverse heat transfer problems is proposed and successfully tested using experimental data.

Inverse problems have been the focus of a growing number of research efforts over the last 40 years-and rightly so. The ability to determine a "cause" from an observed "effect" is a powerful one. Researchers now have at their disposal a variety of techniques for solving inverse problems, techniques that go well beyond those useful for relatively simple parameter estimation problems. The question is, where can one find a single, comprehensive resource that details these methods? The answer is the Inverse Engineering Handbook. Leading experts in inverse problems have joined forces to produce the definitive reference that allows readers to understand, implement, and benefit from a variety of problem-solving techniques. Each chapter details a method developed or refined by its contributor, who provides clear explanations, examples, and in many cases, software algorithms. The presentation begins with methods for parameter estimation, which build a bridge to boundary function estimation problems. The techniques addressed include sequential function estimation, mollification, space marching techniques, and adjoint, Monte Carlo, and gradient-based methods. Discussions also cover important experimental aspects, including experiment design and the effects of uncertain parameters. While many of the examples presented focus on heat transfer, the techniques discussed are applicable to a wide range of inverse problems. Anyone interested in inverse problems, regardless of their specialty, will find the Inverse Engineering Handbook to be a unique and invaluable compendium of up-to-date techniques.

This monograph is based on the author's studies carried out to investigate one of the most promising trends in the theory of ill-posed problems, namely, iterative regularization and its application to inverse heat transfer problems. Effective methods for solving inverse problems have allowed researchers to simplify experiments considerably, and to increase the accuracy and confidence of results in experimental data processing. The authors discuss a broad range of problems concerned with both the theory of regularizing gradient algorithms and peculiarities of their application to the most often encountered inverse problems of reconstruction of external heat fluxes and the identification of mathematical models for heat transfer processes.

The book will also be of interest to those involved in energy systems, aerospace, chemical engineering and mechanical engineering generally.

This thesis describes the different methods used when trying to solve inverse heat transfer problems, particularly those involving recovering heat flux. There are currently several techniques to measure the temperature history in an object subjected to heat transfer using various temperature sensors, however these types of sensors are gradually being replaced by Temperature Sensitive Paints (TSP), a technique that is more accurate and provides a better spatial resolution. TSP is a polymer that is applied on a base object. Changes in temperature in the polymer result in variations of the luminescence intensity in the paint. These variations can be captured by a monochrome Coupled Charged Device (CCD) camera, with a grayscale. Knowing the temperature history at the surface of an object will allow for the recovery of the heat flux provided that the inverse problem can be solved. Liu, along with others, have studied, created, and tested solutions that would allow the heat flux to be recovered analytically considering a semi-infinite base (Liu 2010) as well as a finite base (Liu 2017). A numerical solution to recover the heat flux history using a finite base for TSP data was presented by Cai (Cai 2017). However, depending on the size of the image used to measure the temperature history of an object and the number of images, both solutions might require a significant amount of time, sometimes days, to recover the heat flux of the object. Using MATLAB the method created by Liu was optimized so that the time required to recover the heat flux history has been significantly reduced from about 2 days to 30-60 seconds.

Numerical Simulation
Inverse Source Problems
Numerical Heat Transfer and Fluid Flow
Theory and Applications of Heat Transfer in Humans
Ill-Posed Problems
Inverse Heat Conduction and Heat Exchangers
Heat Conduction
Solving Inverse Heat Transfer Problems When Using CFD Modeling

Finite Difference Methods in Heat Transfer, Second Edition focuses on finite difference methods and their application to the solution of heat transfer problems. Such methods are based on the discretization of governing equations, initial and boundary conditions, which then replace a continuous partial differential problem by a system of algebraic equations. Finite difference methods are a versatile tool for scientists and for engineers. This updated book serves university students taking graduate-level coursework in heat transfer, as well as being an important reference for researchers and engineering. Features Provides a self-contained approach in finite difference methods for students and professionals Covers the use of finite difference methods in convective, conductive, and radiative heat transfer Presents numerical solution techniques to elliptic, parabolic, and hyperbolic problems Includes hybrid analytical-numerical approaches

I welcome the opportunity to have my book translated, because of the great emphasis on two-phase flow and heat transfer in the English-speaking world, as related to research, university education, and industrial practice. The 1988 Springer-Verlag edition of "Warmeiibergang beim Kondensieren und beim Sieden" has been enlarged to include additional material on falling film evaporation (Chapter 12) and pressure drop in two-phase flow (Chapter 13). Minor errors in the original text have also been corrected. I would like to express my sincere appreciation to Professor Green, Asso ciate Professor of German at Rensselaer, for his excellent translation and co operation. My thanks go also to Professor Bergles for his close attention to technical and linguistic details. He carefully read the typescript and made many comments and suggestions that helped to improve the manuscript. I hope that the English edition will meet with' a favorable reception and contribute to better understanding and to progress in the field of heat transfer in condensation and boiling. February 1992 K. Stephan Preface to the German-Language Edition This book is a continuation of the series "Heat and Mass Transfer" edited by U. Grigull, in which three volumes have already been published. Its aim is to acquaint students and practicing engineers with heat transfer during condensa tion and boiling, and is intended primarily for students and engineers in mechanical, chemical, electrical, and industrial processing engineering.

This research monograph presents a systematic treatment of the theory of the propagation of transient electromagnetic fields (such as optical pulses) through dielectric media which exhibit both dispersion a.nd absorption. The work divides naturally into two parts. Part I presents a summary of the fundamental theory of the radiation and propagation of rather general electromagnetic waves in causal, linear media which are homogeneous and isotropic but which otherwise have rather general dispersive and absorbing properties. In Part II, we specialize to the propagation of a plane, transient electromagnetic field in a homogeneous dielectric. Although we have made some contributions to the fundamental theory given in Part I, most of the results of our own research appear in Part II. The purpose of the theory presented in Part II is to predict and to explain in explicit detail the dynamics of the field after it has propagated far enough through the medium to be in the mature-dispersion regime. It is the subject of a classic theory, based on the research conducted by A. Sommerfeld and L.

Driven by the advancement of industrial mathematics and the need for impact case studies, Inverse Problems with Applications in Science and Engineering thoroughly examines the state-of-the-art of some representative classes of inverse and ill-posed problems for partial differential equations (PDEs). The natural practical applications of this examination arise in heat transfer, electrostatics, porous media, acoustics, fluid and solid mechanics – all of which are addressed in this text. Features: Covers all types of PDEs — namely, elliptic (Laplace's, Helmholtz, modified Helmholtz, biharmonic and Stokes), parabolic (heat, convection, reaction and diffusion) and hyperbolic (wave) Excellent reference for post-graduates and researchers in mathematics, engineering and any other scientific discipline that deals with inverse problems Contains both theory and numerical algorithms for solving all types of inverse and ill-posed problems

A direct solution of the heat conduction equation with prescribed initial and boundary conditions yields temperature distribution inside a specimen. The direct solution is mathematically considered as a well-posed one because the solution exists, is unique, and continuously depends on input data. The estimation of unknown parameters from the measured temperature data is known as the inverse problem of heat conduction. An error in temperature

measurement, thermal time lagging, thermocouple-cavity, or signal noise data makes stability a problem in the estimation of unknown parameters. The solution of the inverse problem can be obtained by employing the gradient or non-gradient based inverse algorithm. The aim of this book is to analyze the inverse problem and heat exchanger applications in the fields of aerospace, mechanical, applied mechanics, environment sciences, and engineering.
Heat Transfer Engineering: Fundamentals and Techniques reviews the core mechanisms of heat transfer and provides modern methods to solve practical problems encountered by working practitioners, with a particular focus on developing engagement and motivation. The book reviews fundamental concepts in conduction, forced convection, free convection, boiling, condensation, heat exchangers and mass transfer succinctly and without unnecessary exposition. Throughout, copious examples drawn from current industrial practice are examined with an emphasis on problem-solving for interest and insight rather than the procedural approaches often adopted in courses. The book contains numerous important solved and unsolved problems, utilizing modern tools and computational sources wherever relevant. A subsection on common issues and recent advances is presented in each chapter, encouraging the reader to explore a greater diversity of problems. Reveals physical solutions alongside their application in practical problems, with an aim of generating interest from reality rather than dry exposition Reviews pertinent, contemporary computational tools, including emerging topics such as machine learning Describes the complexity of modern heat transfer in an engaging and conversational style, greatly adding to the uniqueness and accessibility of the book
The Art of Measuring in the Thermal Sciences
Inverse Thermal Problems
Inverse Heat Transfer Problems
An Intelligent Approach to Inverse Heat Transfer Analysis of Irradiative Enclosures
Fundamentals and Applications
Estimation of Surface Temperature, Surface Heat Flux and Heat Transfer Coefficient in the Platform of Inverse Heat Conduction Problems
Extreme Methods for Solving Ill-posed Problems with Applications to Inverse Heat Transfer Problems
Thermal Measurements and Inverse Techniques

The chapter presents solving steady-state inverse heat transfer problems using Computational Fluid Dynamics (CFD) software. Two examples illustrate the application of the proposed m the first inverse problem determining the absorbed heat flux to water walls in furnaces of steam boilers is presented in detail. Three different measurement devices (flux tubes) were desig identify steady-state boundary conditions in water wall tubes of combustion chambers. The first meter is made of a short eccentric tube in which four thermocouples on the fire side below and outer tube surfaces are installed. The fifth thermocouple is situated at the rear of the tube on the housing side of the water wall tube. The second meter has two longitudinal fins that a welded to the bare eccentric tube. In the third option of the instrument, the fins are attached to the water wall tubes but not to the flux tubes as in the second version of the flux tubes. The instrument is used to measure the heat flux to water walls made from bare tubes, while another two heat flux tubes are designated for measuring the heat flux to membrane walls. Unlike existing devices, the flux tube is not attached to neighboring water-wall tubes. The absorbed heat flux on the outer surface and the heat transfer coefficient at the inner surface of the flux determined from temperature measurements at internal points. The thermal conductivity of the flux-tube material is a function of temperature. The nonlinear inverse problem of heat cond (IHCP) is solved using the least-squares method. Three unknown parameters are determined using the Levenberg-Marquardt method. In each iteration, the temperature distribution in th section of the heat flux instrument is determined using the ANSYS/CFX software.

A study of the errors introduced when one-dimensional inverse heat conduction techniques are applied to problems involving two-dimensional heat transfer effects was performed. The g used for the study was a cylinder with similar dimensions as a typical container used for the transportation of radioactive materials. The finite element analysis code MSC P/Thermal was generate synthetic test data that was then used as input for an inverse heat conduction code. Four different problems were considered including one with uniform flux around the outer su the cylinder and three with non-uniform flux applied over 360°, 180°, and 90° sections of the outer surface of the cylinder. The Sandia One-Dimensional Direct and Inverse Thermal (SOD code was used to estimate the surface heat flux of all four cases. The error analysis was performed by comparing the results from SODDIT and the heat flux calculated based on the tem results obtained from P/Thermal. Results showed an increase in error of the surface heat flux estimates as the applied heat became more localized. For the uniform case, SODDIT provic flux estimates with a maximum error of 0.5% whereas for the non-uniform cases, the maximum errors were found to be about 3%, 7%, and 18% for the 360°, 180°, and 90° cases, respec

Introduction to and survey of parameter estimation; Probability; Introduction to statistics; Parameter estimation methods; Introduction to linear estimation; Matrix analysis for linear parame estimation; Minimization of sum of squares functions for models nonlinear in parameters; Design of optimal experiments.

Since its publication more than 15 years ago, Heat Conduction Using Green's Functions has become the consummate heat conduction treatise from the perspective of Green's functions- newly revised Second Edition is poised to take its place. Based on the authors' own research and classroom experience with the material, this book organizes the so

This book introduces the fundamental concepts of inverse heat transfer problems. It presents in detail the basic steps of four techniques of inverse heat transfer protocol, as a parameter approach and as a function estimation approach. These techniques are then applied to the solution of the problems of practical engineering interest involving conduction, convection, and radiation. The text also introduces a formulation based on generalized coordinates for the solution of inverse heat conduction problems in two-dimensional regions.

From Brain Imaging to Turbulent Flows
Inverse Problems with Applications in Science and Engineering