

53

An introduction to partial differential equations

53.1 Introduction

A partial differential equation is an equation that contains one or more partial derivatives. Examples include:

$$(i) \quad a \frac{\partial u}{\partial x} + b \frac{\partial u}{\partial y} = c$$

$$(ii) \quad \frac{\partial^2 u}{\partial x^2} = \frac{1}{c^2} \frac{\partial u}{\partial t}$$

(known as the heat conduction equation)

$$(iii) \quad \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

(known as Laplace's equation)

Equation (i) is a **first order partial differential equation**, and equations (ii) and (iii) are **second order partial differential equations** since the highest power of the differential is 2.

Partial differential equations occur in many areas of engineering and technology; electrostatics, heat conduction, magnetism, wave motion, hydrodynamics and aerodynamics all use models that involve partial differential equations. Such equations are difficult to solve, but techniques have been developed for the simpler types. In fact, for all but for the simplest cases, there are a number of numerical methods of solutions of partial differential equations available.

To be able to solve simple partial differential equations knowledge of the following is required:

- (a) partial integration,
- (b) first and second order partial differentiation — as explained in Chapter 34, and
- (c) the solution of ordinary differential equations — as explained in Chapters 46–51.

It should be appreciated that whole books have been written on partial differential equations and their

solutions. This chapter does no more than introduce the topic.

53.2 Partial integration

Integration is the reverse process of differentiation.

Thus, if, for example, $\frac{\partial u}{\partial t} = 5 \cos x \sin t$ is integrated partially with respect to t , then the $5 \cos x$ term is considered as a constant,

$$\begin{aligned} \text{and } u &= \int 5 \cos x \sin t \, dt = (5 \cos x) \int \sin t \, dt \\ &= (5 \cos x)(-\cos t) + c \\ &= -5 \cos x \cos t + f(x) \end{aligned}$$

Similarly, if $\frac{\partial^2 u}{\partial x \partial y} = 6x^2 \cos 2y$ is integrated partially with respect to y ,

$$\begin{aligned} \text{then } \frac{\partial u}{\partial x} &= \int 6x^2 \cos 2y \, dy = (6x^2) \int \cos 2y \, dy \\ &= (6x^2) \left(\frac{1}{2} \sin 2y \right) + f(x) \\ &= 3x^2 \sin 2y + f(x) \end{aligned}$$

and integrating $\frac{\partial u}{\partial x}$ partially with respect to x gives:

$$\begin{aligned} u &= \int [3x^2 \sin 2y + f(x)] \, dx \\ &= x^3 \sin 2y + (x)f(x) + g(y) \end{aligned}$$

$f(x)$ and $g(y)$ are functions that may be determined if extra information, called **boundary conditions** or **initial conditions**, are known.

Introduction To Partial Differential Equations

Arne Broman



Introduction To Partial Differential Equations:

Introduction to Partial Differential Equations Peter J. Olver, 2013-11-08 This textbook is designed for a one year course covering the fundamentals of partial differential equations geared towards advanced undergraduates and beginning graduate students in mathematics science engineering and elsewhere The exposition carefully balances solution techniques mathematical rigor and significant applications all illustrated by numerous examples Extensive exercise sets appear at the end of almost every subsection and include straightforward computational problems to develop and reinforce new techniques and results details on theoretical developments and proofs challenging projects both computational and conceptual and supplementary material that motivates the student to delve further into the subject No previous experience with the subject of partial differential equations or Fourier theory is assumed the main prerequisites being undergraduate calculus both one and multi variable ordinary differential equations and basic linear algebra While the classical topics of separation of variables Fourier analysis boundary value problems Green's functions and special functions continue to form the core of an introductory course the inclusion of nonlinear equations shock wave dynamics symmetry and similarity the Maximum Principle financial models dispersion and solutions Huygens Principle quantum mechanical systems and more make this text well attuned to recent developments and trends in this active field of contemporary research Numerical approximation schemes are an important component of any introductory course and the text covers the two most basic approaches finite differences and finite elements

Introduction to Partial Differential Equations with Applications E. C.

Zachmanoglou, Dale W. Thoe, 1986-01-01 This text explores the essentials of partial differential equations as applied to engineering and the physical sciences Discusses ordinary differential equations integral curves and surfaces of vector fields the Cauchy Kovalevsky theory more Problems and answers

An Introduction to Partial Differential Equations Michael

Renardy, Robert C. Rogers, 2004-01-08 Partial differential equations are fundamental to the modeling of natural phenomena The desire to understand the solutions of these equations has always had a prominent place in the efforts of mathematicians and has inspired such diverse fields as complex function theory functional analysis and algebraic topology This book meant for a beginning graduate audience provides a thorough introduction to partial differential equations

Introduction to

Partial Differential Equations David Borthwick, 2017-01-12 This modern take on partial differential equations does not require knowledge beyond vector calculus and linear algebra The author focuses on the most important classical partial differential equations including conservation equations and their characteristics the wave equation the heat equation function spaces and Fourier series drawing on tools from analysis only as they arise Within each section the author creates a narrative that answers the five questions What is the scientific problem we are trying to understand How do we model that with PDE What techniques can we use to analyze the PDE How do those techniques apply to this equation What information or insight did we obtain by developing and analyzing the PDE The text stresses the interplay between modeling and

mathematical analysis providing a thorough source of problems and an inspiration for the development of methods

Introduction to Partial Differential Equations Aslak Tveito, Ragnar Winther, 2004-10-04 This book teaches basic methods of partial differential equations and introduces related important ideas associated with the analysis of numerical methods for those partial differential equations Coverage details such topics as separation of variables Fourier analysis maximum principles and energy estimates The book introduces numerical methods in parallel to the classical theory and also includes many engaging exercises

Partial Differential Equations Michael Shearer, Rachel Levy, 2015-03-01 An accessible yet rigorous introduction to partial differential equations This textbook provides beginning graduate students and advanced undergraduates with an accessible introduction to the rich subject of partial differential equations PDEs It presents a rigorous and clear explanation of the more elementary theoretical aspects of PDEs while also drawing connections to deeper analysis and applications The book serves as a needed bridge between basic undergraduate texts and more advanced books that require a significant background in functional analysis Topics include first order equations and the method of characteristics second order linear equations wave and heat equations Laplace and Poisson equations and separation of variables The book also covers fundamental solutions Green's functions and distributions beginning functional analysis applied to elliptic PDEs traveling wave solutions of selected parabolic PDEs and scalar conservation laws and systems of hyperbolic PDEs Provides an accessible yet rigorous introduction to partial differential equations Draws connections to advanced topics in analysis Covers applications to continuum mechanics An electronic solutions manual is available only to professors An online illustration package is available to professors

Introduction To Partial Differential Equations (With Maple), An: A Concise Course Zhilin Li, Larry Norris, 2021-09-23 The book is designed for undergraduate or beginning level graduate students and students from interdisciplinary areas including engineers and others who need to use partial differential equations Fourier series Fourier and Laplace transforms The prerequisite is a basic knowledge of calculus linear algebra and ordinary differential equations The textbook aims to be practical elementary and reasonably rigorous the book is concise in that it describes fundamental solution techniques for first order second order linear partial differential equations for general solutions fundamental solutions solution to Cauchy initial value problems and boundary value problems for different PDEs in one and two dimensions and different coordinates systems Analytic solutions to boundary value problems are based on Sturm Liouville eigenvalue problems and series solutions The book is accompanied with enough well tested Maple files and some Matlab codes that are available online The use of Maple makes the complicated series solution simple interactive and visible These features distinguish the book from other textbooks available in the related area

An Introduction to Partial Differential Equations Daniel J. Arrigo, 2022-06-01 This book is an introduction to methods for solving partial differential equations PDEs After the introduction of the main four PDEs that could be considered the cornerstone of Applied Mathematics the reader is introduced to a variety of PDEs that come from a variety of fields in the Natural Sciences

and Engineering and is a springboard into this wonderful subject The chapters include the following topics First order PDEs Second order PDEs Fourier Series Separation of Variables and the Fourier Transform The reader is guided through these chapters where techniques for solving first and second order PDEs are introduced Each chapter ends with a series of exercises illustrating the material presented in each chapter The book can be used as a textbook for any introductory course in PDEs typically found in both science and engineering programs and has been used at the University of Central Arkansas for over ten years

Introduction to Partial Differential Equations and Hilbert Space Methods Karl E. Gustafson,1999-01-01 This volume offers an excellent undergraduate level introduction to the main topics methods and applications of partial differential equations Chapter 1 presents a full introduction to partial differential equations and Fourier series as related to applied mathematics Chapter 2 begins with a more comprehensive look at the principal method for solving partial differential equations the separation of variables and then more fully develops that approach in the contexts of Hilbert space and numerical methods Chapter 3 includes an expanded treatment of first order systems a short introduction to computational methods and aspects of topical research on the partial differential equations of fluid dynamics With over 600 problems and exercises along with explanations examples and a comprehensive section of answers hints and solutions this superb easy to use text is ideal for a one semester or full year course It will also provide the mathematically inclined layperson with a stimulating review of the subject's essentials

Introduction to Partial Differential Equations Peter Olver,2013-11-30

Introduction to Partial Differential Equations Donald Greenspan,2012-05-04 Designed for use in a 1 semester course by seniors and beginning graduate students this rigorous presentation explores practical methods of solving differential equations plus the unifying theory underlying the mathematical superstructure Topics include basic concepts Fourier series 2nd order partial differential equations wave equation potential equation heat equation and more Includes exercises 1961 edition

Partial Differential Equations Vladimir A. Tolstykh,2020-06-08 This is a clear rigorous and self contained introduction to PDEs for a semester based course on the topic For the sake of smooth exposition the book keeps the amount of applications to a minimum focusing instead on the theoretical essentials and problem solving The result is an agile compendium of theorems and methods the ideal companion for any student tackling PDEs for the first time Vladimir Tolstykh is a professor of mathematics at Istanbul Arel University He works in group theory and model theoretic algebra Dr Tolstykh received his Ph D in Mathematics from the Ural Institute of Mathematics and Mechanics Ekaterinburg Russia in 1992 and his Doctor of Science degree in Mathematics from the Sobolev Institute of Mathematics Novosibirsk Russia in 2007

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chapters where techniques for solving first and second order PDEs are introduced Each chapter ends with series of exercises to facilitate learning as well as illustrate the material presented in each chapter

Partial Differential Equations Walter A. Strauss, 2007-12-21 Our understanding of the fundamental processes of the natural world is based to a large extent on partial differential equations PDEs The second edition of Partial Differential Equations provides an introduction to the basic properties of PDEs and the ideas and techniques that have proven useful in analyzing them It provides the student a broad perspective on the subject illustrates the incredibly rich variety of phenomena encompassed by it and imparts a working knowledge of the most important techniques of analysis of the solutions of the equations In this book mathematical jargon is minimized Our focus is on the three most classical PDEs the wave heat and Laplace equations Advanced concepts are introduced frequently but with the least possible technicalities The book is flexibly designed for juniors seniors or beginning graduate students in science engineering or mathematics

Introduction to Partial Differential Equations Peter Olver, 2013-11-20 This textbook is designed for a one year course covering the fundamentals of partial differential equations geared towards advanced undergraduates and beginning graduate students in mathematics science engineering and elsewhere The exposition carefully balances solution techniques mathematical rigor and significant applications all illustrated by numerous examples Extensive exercise sets appear at the end of almost every subsection and include straightforward computational problems to develop and reinforce new techniques and results details on theoretical developments and proofs challenging projects both computational and conceptual and supplementary material that motivates the student to delve further into the subject No previous experience with the subject of partial differential equations or Fourier theory is assumed the main prerequisites being undergraduate calculus both one and multi variable ordinary differential equations and basic linear algebra While the classical topics of separation of variables Fourier analysis boundary value problems Green's functions and special functions continue to form the core of an introductory course the inclusion of nonlinear equations shock wave dynamics symmetry and similarity the Maximum Principle financial models dispersion and solitons Huygens Principle quantum mechanical systems and more make this text well attuned to recent developments and trends in this active field of contemporary research Numerical approximation schemes are an important component of any introductory course and the text covers the two most basic approaches finite differences and finite elements Peter J Olver is professor of mathematics at the University of Minnesota His wide ranging research interests are centered on the development of symmetry based methods for differential equations and their manifold applications He is the author of over 130 papers published in major scientific research journals as well as 4 other books including the definitive Springer graduate text Applications of Lie Groups to Differential Equations and another undergraduate text Applied Linear Algebra A Solutions Manual for instructors is available by clicking on Selected Solutions Manual under the Additional Information section on the right hand side of this page

[Introduction to Partial Differential Equations with MATLAB](#) Jeffery M. Cooper, 2012-12-06

Overview The subject of partial differential equations has an unchanging core of material but is constantly expanding and evolving The core consists of solution methods mainly separation of variables for boundary value problems with constant coefficients in geometrically simple domains Too often an introductory course focuses exclusively on these core problems and techniques and leaves the student with the impression that there is no more to the subject Questions of existence uniqueness and well posedness are ignored In particular there is a lack of connection between the analytical side of the subject and the numerical side Furthermore nonlinear problems are omitted because they are too hard to deal with analytically Now however the availability of convenient powerful computational software has made it possible to enlarge the scope of the introductory course My goal in this text is to give the student a broader picture of the subject In addition to the basic core subjects I have included material on nonlinear problems and brief discussions of numerical methods I feel that it is important for the student to see nonlinear problems and numerical methods at the beginning of the course and not at the end when we usually run out of time Furthermore numerical methods should be introduced for each equation as it is studied not lumped together in a final chapter

Introduction to Partial Differential Equations Arne Broman, 2012-04-27 The self contained treatment covers Fourier series orthogonal systems Fourier and Laplace transforms Bessel functions and partial differential equations of the first and second orders 266 exercises with solutions 1970 edition

An Introduction to Partial Differential Equations with MATLAB Matthew P. Coleman, Vladislav Bukshtynov, 2024-08-01 The first two editions of *An Introduction to Partial Differential Equations with MATLAB* gained popularity among instructors and students at various universities throughout the world Plain mathematical language is used in a friendly manner to provide a basic introduction to partial differential equations PDEs Suitable for a one or two semester introduction to PDEs and Fourier series the book strives to provide physical mathematical and historical motivation for each topic Equations are studied based on method of solution rather than on type of equation This third edition of this popular textbook updates the structure of the book by increasing the role of the computational portion compared to previous editions The redesigned content will be extremely useful for students of mathematics physics and engineering who would like to focus on the practical aspects of the study of PDEs without sacrificing mathematical rigor The authors have maintained flexibility in the order of topics In addition students will be able to use what they have learned in some later courses for example courses in numerical analysis optimization and PDE based programming Included in this new edition is a substantial amount of material on reviewing computational methods for solving ODEs symbolically and numerically visualizing solutions of PDEs using MATLAB s symbolic programming toolbox and applying various schemes from numerical analysis along with suggestions for topics of course projects Students will use sample MATLAB or Python codes available online for their practical experiments and for completing computational lab assignments and course projects

An Introduction to Partial Differential Equations with MATLAB, Second Edition Matthew P. Coleman, 2013-06-26 *An Introduction to Partial Differential Equations with*

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Introduction to Partial Differential Equations K. Sankara Rao, 2010-07-30 Provides students with the fundamental concepts the underlying principles and various well known mathematical techniques and methods such as Laplace and Fourier transform techniques the variable separable method and Green's function method to solve partial differential equations It is supported by miscellaneous examples to enable students to assimilate the fundamental concepts and the techniques for solving PDEs with various initial and boundary conditions

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Table of Contents Introduction To Partial Differential Equations

1. Understanding the eBook Introduction To Partial Differential Equations
 - The Rise of Digital Reading Introduction To Partial Differential Equations
 - Advantages of eBooks Over Traditional Books
2. Identifying Introduction To Partial Differential Equations
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Introduction To Partial Differential Equations
 - User-Friendly Interface
4. Exploring eBook Recommendations from Introduction To Partial Differential Equations
 - Personalized Recommendations
 - Introduction To Partial Differential Equations User Reviews and Ratings
 - Introduction To Partial Differential Equations and Bestseller Lists
5. Accessing Introduction To Partial Differential Equations Free and Paid eBooks
 - Introduction To Partial Differential Equations Public Domain eBooks
 - Introduction To Partial Differential Equations eBook Subscription Services

- Introduction To Partial Differential Equations Budget-Friendly Options
- 6. Navigating Introduction To Partial Differential Equations eBook Formats
 - ePub, PDF, MOBI, and More
 - Introduction To Partial Differential Equations Compatibility with Devices
 - Introduction To Partial Differential Equations Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Introduction To Partial Differential Equations
 - Highlighting and Note-Taking Introduction To Partial Differential Equations
 - Interactive Elements Introduction To Partial Differential Equations
- 8. Staying Engaged with Introduction To Partial Differential Equations
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Introduction To Partial Differential Equations
- 9. Balancing eBooks and Physical Books Introduction To Partial Differential Equations
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Introduction To Partial Differential Equations
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Introduction To Partial Differential Equations
 - Setting Reading Goals Introduction To Partial Differential Equations
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Introduction To Partial Differential Equations
 - Fact-Checking eBook Content of Introduction To Partial Differential Equations
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

-
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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