

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:

- partial integration,
- first and second order partial differentiation — as explained in Chapter 34, and
- 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

Mike Jess



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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 Partial Differential Equations: An Introduction With Mathematica And Maple Ioannis P Stavroulakis, Stepan A Tersian, 1999-12-13 This textbook is a self contained introduction to partial differential equations It is designed for undergraduate and first year graduate students who are mathematics physics engineering or in general science majors The goal is to give an introduction to the basic equations of mathematical physics and the properties of their solutions based on classical calculus and ordinary differential equations Advanced concepts such as weak solutions and discontinuous solutions of nonlinear conservation laws are also considered The material is illustrated with model examples Mathematics software products such as Mathematica and Maple in ScientificWorkPlace are used in both graphical and computational aspects *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 **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** Yehuda Pinchover, Jacob Rubinstein, 2005-05-12 A complete introduction to partial differential equations this is a textbook aimed at students of

mathematics physics and engineering *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* Aslak Tveito, Ragnar Winther, 2005-09-15 Mathematics is playing an ever more important role in the physical and biological sciences provoking a blurring of boundaries between scientific disciplines and a resurgence of interest in the modern as well as the classical techniques of applied mathematics This renewal of interest both in research and teaching has led to the establishment of the series Texts in Applied Mathematics TAM The development of new courses is a natural consequence of a high level of excitement on the research frontier as newer techniques such as numerical and symbolic computer systems dynamical systems and chaos mix with and reinforce the traditional methods of applied mathematics Thus the purpose of this textbook series is to meet the current and future needs of these advances and encourage the teaching of new courses TAM will publish textbooks suitable for use in advanced undergraduate and beginning graduate courses and will complement the Applied Mathematical Sciences AMS series which will focus on advanced textbooks and research level monographs Preface It is impossible to exaggerate the extent to which modern applied

mathematics has been shaped and fueled by the general availability of fast computers with large memories. Their impact on mathematics both applied and pure is comparable to the role of the telescopes in astronomy and microscopes in biology. Peter Lax, *Siam Rev* Vol 31 No 4. Congratulations! You have chosen to study partial differential equations. **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 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*** 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. ***An Introduction to Partial Differential Equations with MATLAB*** Matthew P. Coleman, Vladislav Bukshytynov, 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.

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