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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.

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Waves And Rays In Elastic Continua (3rd Edition) Michael A Slawinski, 2014-12-15 The present book which is the third significantly revised edition of the textbook originally published by Elsevier Science emphasizes the interdependence of mathematical formulation and physical meaning in the description of seismic phenomena Herein we use aspects of continuum mechanics wave theory and ray theory to explain phenomena resulting from the propagation of seismic waves The book is divided into three main sections Elastic Continua Waves and Rays and Variational Formulation of Rays There is also a fourth part which consists of appendices In Elastic Continua we use continuum mechanics to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such a material In Waves and Rays we use these equations to identify the types of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua we invoke the concept of a ray In Variational Formulation of Rays we show that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary traveltimes Consequently many seismic problems in elastic continua can be conveniently formulated and solved using the calculus of variations In the Appendices we describe two mathematical concepts that are used in the book namely homogeneity of a function and Legendre's transformation This

section also contains a list of symbols

Supplementary Material and Solutions Manual for Mathematical Modeling in the Environment Charles R. Hadlock, 2020-05-05 This manual is meant to provide supplementary material and solutions to the exercises used in Charles Hadlock's textbook *Mathematical Modeling in the Environment*. The manual is invaluable to users of the textbook as it contains complete solutions and often further discussion of essentially every exercise the author presents in his book. This includes both the mathematical/computational exercises as well as the research questions and investigations. Since the exercises in the textbook are very rich in content rather than simple mechanical problems and cover a wide range, most readers will not have the time to work out every one on their own. Readers can thus still benefit greatly from perusing solutions to problems they have at least thought about briefly. Students using this manual still need to work out solutions to research questions using their own sources and adapting them to their own geographic locations or to numerical problems using their own computational schemes, so this manual will be a useful guide to students in many course contexts. Enrichment material is included on the topics of some of the exercises. Advice for teachers who lack previous environmental experience but who want to teach this material is also provided and makes it practical for such persons to offer a course based on these volumes. This book is the essential companion to *Mathematical Modeling in the Environment*.

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a flipped classroom model The availability of a computer algebra system is not assumed but there are many opportunities to incorporate the use of one

Functional Differential Equations Constantin Corduneanu, Yizeng Li, Mehran Mahdavi, 2016-04-11 Features new results and up to date advances in modeling and solving differential equations Introducing the various classes of functional differential equations Functional Differential Equations Advances and Applications presents the needed tools and topics to study the various classes of functional differential equations and is primarily concerned with the existence uniqueness and estimates of solutions to specific problems The book focuses on the general theory of functional differential equations provides the requisite mathematical background and details the qualitative behavior of solutions to functional differential equations The book addresses problems of stability particularly for ordinary differential equations in which the theory can provide models for other classes of functional differential equations and the stability of solutions is useful for the application of results within various fields of science engineering and economics Functional Differential Equations Advances and Applications also features Discussions on the classes of equations that cannot be solved to the highest order derivative and in turn addresses existence results and behavior types Oscillatory motion and solutions that occur in many real world phenomena as well as in man made machines Numerous examples and applications with a specific focus on ordinary differential equations and functional differential equations with finite delay An appendix that introduces generalized Fourier series and Fourier analysis after periodicity and almost periodicity An extensive Bibliography with over 550 references that connects the presented concepts to further topical exploration Functional Differential Equations Advances and Applications is an ideal reference for academics and practitioners in applied mathematics engineering economics and physics The book is also an appropriate textbook for graduate and PhD level courses in applied mathematics differential and difference equations differential analysis and dynamics processes

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YIZENG LI PhD is Professor in the Department of Mathematics at Tarrant County College USA He is a member of the Society for Industrial and Applied Mathematics

MEHRAN MAHDAVI PhD is Professor in the Department of Mathematics at Bowie State University USA The author of numerous journal articles he is a member of the American Mathematical Society Society for Industrial and Applied Mathematics and the Mathematical Association of America

Introductory Differential Equations Martha L. Abell, James P. Braselton, 2010-04-20 This text is for courses that are typically called Introductory Differential Equations Introductory Partial Differential Equations Applied Mathematics and Fourier Series Differential Equations is a text that follows a traditional approach and is appropriate for a first course in ordinary differential equations including Laplace transforms and a second course in Fourier series and boundary value

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Differential Equations and Numerical Solutions Mr. Rohit Manglik, 2024-06-24 Studies differential equations and numerical methods focusing on solving ODEs and PDEs with applications in physics engineering and modeling

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Basic Partial Differential Equations David. Bleecker, 2018-01-18 Methods of solution for partial differential equations PDEs used in mathematics science and engineering are clarified in this self contained source The reader will learn how to use PDEs to predict system behaviour from an initial state of the system and from external influences and enhance the success of endeavours involving reasonably smooth predictable changes of measurable quantities This text enables the reader to not only find solutions of many PDEs but also to interpret and use these solutions It offers 6000 exercises ranging from routine to challenging The palatable motivated proofs enhance understanding and retention of the material Topics not usually found in books at this level include but examined in this text the application of linear and nonlinear first order PDEs to the evolution of population densities and to traffic shocks convergence of numerical solutions of PDEs and implementation on a computer convergence of Laplace series on spheres quantum mechanics of the hydrogen atom solving PDEs on manifolds The text requires some knowledge of calculus but none on differential equations or linear algebra

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