

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.

Partial Differential Equations An Introduction

RJ Shavelson



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Table of Contents Partial Differential Equations An Introduction

1. Understanding the eBook Partial Differential Equations An Introduction
 - The Rise of Digital Reading Partial Differential Equations An Introduction
 - Advantages of eBooks Over Traditional Books
2. Identifying Partial Differential Equations An Introduction
 - 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 eBook Platform
 - User-Friendly Interface
4. Exploring eBook Recommendations from Partial Differential Equations An Introduction
 - Personalized Recommendations
 - eBook Platform User Reviews and Ratings
 - eBook Platform and Bestseller Lists

5. Accessing Partial Differential Equations An Introduction Free and Paid eBooks
 - Partial Differential Equations An Introduction Public Domain eBooks
 - Partial Differential Equations An Introduction eBook Subscription Services
 - Partial Differential Equations An Introduction Budget-Friendly Options
6. Navigating Partial Differential Equations An Introduction eBook Formats
 - ePub, PDF, MOBI, and More
 - Partial Differential Equations An Introduction Compatibility with Devices
 - Partial Differential Equations An Introduction Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Partial Differential Equations An Introduction
 - Highlighting and Note-Taking Partial Differential Equations An Introduction
 - Interactive Elements Partial Differential Equations An Introduction
8. Staying Engaged with Partial Differential Equations An Introduction
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Partial Differential Equations An Introduction
9. Balancing eBooks and Physical Books Partial Differential Equations An Introduction
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Partial Differential Equations An Introduction
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Partial Differential Equations An Introduction
 - Setting Reading Goals Partial Differential Equations An Introduction
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Partial Differential Equations An Introduction
 - Fact-Checking eBook Content of Partial Differential Equations An Introduction
 - 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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