Solving PDEs using Laplace Transforms, Chapter 15

Given a function $u(x,t)$ defined for all $t > 0$ and assumed to be bounded we can apply the Laplace transform in t considering x as a parameter.

$$L(u(x,t)) = \int_0^\infty e^{-st} u(x,t)\,dt \equiv U(x,s)$$

In applications to PDEs we need the following:

$$L(u_t(x,t) = \int_0^\infty e^{-st} u_t(x,t)\,dt = e^{-st}u(x,t)]_0^\infty + s\int_0^\infty e^{-st}u(x,t)\,dt = sU(x,s) - u(x,0)$$

so we have

$$L(u_t(x,t) = sU(x,s) - u(x,0)$$

In exactly the same way we obtain

$$L(u_{tt}(x,t) = s^2U(x,s) - su(x,0) - u_t(x,0).$$

We also need the corresponding transforms of the x derivatives:

$$L(u_x(x,t)) = \int_0^\infty e^{-st} u_x(x,t)\,dt = U_x(x,s)$$

$$L(u_{xx}(x,t)) = \int_0^\infty e^{-st} u_{xx}(x,t)\,dt = U_{xx}(x,s)$$

Consider the following examples.

Example 1.

$$\frac{\partial u}{\partial x} + \frac{\partial u}{\partial t} = x, \quad x > 0, \quad t > 0,$$

with boundary and initial condition

$$u(0,t) = 0 \quad t > 0, \qquad \text{and} \quad u(x,0) = 0, \quad x > 0.$$

As above we use the notation $U(x,s) = L(u(x,t))(s)$ for the Laplace transform of u.
Then applying the Laplace transform to this equation we have

$$\frac{dU}{dx}(x,s) + sU(x,s) - u(x,0) = \frac{x}{s} \quad \Rightarrow \quad \frac{dU}{dx}(x,s) + sU(x,s) = \frac{x}{s}.$$

This is a constant coefficient first order ODE. We solve it by finding the integrating factor

$$\mu = e^{\int s\,dx} = e^{sx}$$

Thus we have

$$\frac{d}{dx}\left[e^{sx}U(x,s)\right] = e^{sx}\frac{x}{s}.$$

We integrate both sides to get

$$U(x,s) = \frac{e^{-sx}}{s}\left(\int e^{sr}r\,dr\right) + Ce^{-sx}.$$

Solving Pdes Using Laplace Transforms Chapter 15

Chao Zhang

Solving Pdes Using Laplace Transforms Chapter 15:

The Enigmatic Realm of **Solving Pdes Using Laplace Transforms Chapter 15**: Unleashing the Language is Inner Magic

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Table of Contents Solving Pdes Using Laplace Transforms Chapter 15

1. Understanding the eBook Solving Pdes Using Laplace Transforms Chapter 15
    - The Rise of Digital Reading Solving Pdes Using Laplace Transforms Chapter 15
    - Advantages of eBooks Over Traditional Books
2. Identifying Solving Pdes Using Laplace Transforms Chapter 15
    - 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 Solving Pdes Using Laplace Transforms Chapter 15
    - User-Friendly Interface
4. Exploring eBook Recommendations from Solving Pdes Using Laplace Transforms Chapter 15
    - Personalized Recommendations
    - Solving Pdes Using Laplace Transforms Chapter 15 User Reviews and Ratings
    - Solving Pdes Using Laplace Transforms Chapter 15 and Bestseller Lists

5. Accessing Solving Pdes Using Laplace Transforms Chapter 15 Free and Paid eBooks
    - Solving Pdes Using Laplace Transforms Chapter 15 Public Domain eBooks
    - Solving Pdes Using Laplace Transforms Chapter 15 eBook Subscription Services
    - Solving Pdes Using Laplace Transforms Chapter 15 Budget-Friendly Options
6. Navigating Solving Pdes Using Laplace Transforms Chapter 15 eBook Formats
    - ePub, PDF, MOBI, and More
    - Solving Pdes Using Laplace Transforms Chapter 15 Compatibility with Devices
    - Solving Pdes Using Laplace Transforms Chapter 15 Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Solving Pdes Using Laplace Transforms Chapter 15
    - Highlighting and Note-Taking Solving Pdes Using Laplace Transforms Chapter 15
    - Interactive Elements Solving Pdes Using Laplace Transforms Chapter 15
8. Staying Engaged with Solving Pdes Using Laplace Transforms Chapter 15
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Solving Pdes Using Laplace Transforms Chapter 15
9. Balancing eBooks and Physical Books Solving Pdes Using Laplace Transforms Chapter 15
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Solving Pdes Using Laplace Transforms Chapter 15
10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
11. Cultivating a Reading Routine Solving Pdes Using Laplace Transforms Chapter 15
    - Setting Reading Goals Solving Pdes Using Laplace Transforms Chapter 15
    - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Solving Pdes Using Laplace Transforms Chapter 15
    - Fact-Checking eBook Content of Solving Pdes Using Laplace Transforms Chapter 15
    - 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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