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:

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

so we have

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

In exactly the same way we obtain

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

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

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

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

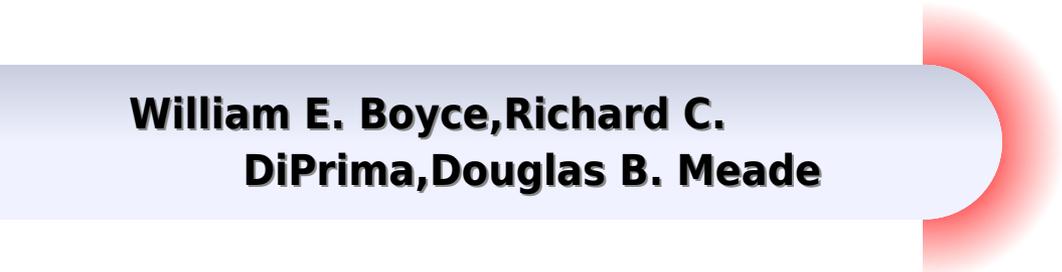$$\mu = e^{\int s\, dx} = e^{sx}$$

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

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Solving Pdes Using Laplace Transforms Chapter 15:

Advanced Numerical and Semi-Analytical Methods for Differential Equations Snehashish Chakraverty,Nisha Mahato,Perumandla Karunakar,Tharasi Dilleswar Rao,2019-04-10 Examines numerical and semi analytical methods for differential equations that can be used for solving practical ODEs and PDEs This student friendly book deals with various approaches for solving differential equations numerically or semi analytically depending on the type of equations and offers simple example problems to help readers along Featuring both traditional and recent methods Advanced Numerical and Semi Analytical Methods for Differential Equations begins with a review of basic numerical methods It then looks at Laplace Fourier and weighted residual methods for solving differential equations A new challenging method of Boundary Characteristics Orthogonal Polynomials BCOPs is introduced next The book then discusses Finite Difference Method FDM Finite Element Method FEM Finite Volume Method FVM and Boundary Element Method BEM Following that analytical semi analytic methods like Akbari Ganji s Method AGM and Exp function are used to solve nonlinear differential equations Nonlinear differential equations using semi analytical methods are also addressed namely Adomian Decomposition Method ADM Homotopy Perturbation Method HPM Variational Iteration Method VIM and Homotopy Analysis Method HAM Other topics covered include emerging areas of research related to the solution of differential equations based on differential quadrature and wavelet approach combined and hybrid methods for solving differential equations as well as an overview of fractal differential equations Further uncertainty in term of intervals and fuzzy numbers have also been included along with the interval finite element method This book Discusses various methods for solving linear and nonlinear ODEs and PDEs Covers basic numerical techniques for solving differential equations along with various discretization methods Investigates nonlinear differential equations using semi analytical methods Examines differential equations in an uncertain environment Includes a new scenario in which uncertainty in term of intervals and fuzzy numbers has been included in differential equations Contains solved example problems as well as some unsolved problems for self validation of the topics covered Advanced Numerical and Semi Analytical Methods for Differential Equations is an excellent text for graduate as well as post graduate students and researchers studying various methods for solving differential equations numerically and semi analytically *Advanced Engineering Mathematics with MATLAB* Dean G. Duffy,2010-10-26 Taking a practical approach to the subject Advanced Engineering Mathematics with MATLAB Third Edition continues to integrate technology into the conventional topics of engineering mathematics The author employs MATLAB to reinforce concepts and solve problems that require heavy computation MATLAB scripts are available for download at www crcpres **Mathematical Methods in the Physical Sciences** Mary L. Boas,1983-04-20 Updates the original comprehensive introduction to the areas of mathematical physics encountered in advanced courses in the physical sciences Intuition and computational abilities are stressed Original material on DE and multiple integrals has been expanded **Advanced Engineering Mathematics** Dennis G.

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