

LAPLACE TRANSFORMS AND ITS APPLICATIONS

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Abstract Laplace transform is a very powerful mathematical tool applied in various areas of engineering and science. With the increasing complexity of engineering problems, Laplace transforms help in solving complex problems with a very simple approach just like the applications of transfer functions to solve ordinary differential equations. This paper will discuss the applications of Laplace transforms in the area of physics followed by the application to electric circuit analysis. A more complex application on Load frequency control in the area of power systems engineering is also discussed.

I. INTRODUCTION

Laplace transform is an integral transform method which is particularly useful in solving linear ordinary differential equations. It finds very wide applications in various areas of physics, electrical engineering, control engineering, optics, mathematics and signal processing. The Laplace transform can be interpreted as a transformation from the time domain where inputs and outputs are functions of time to the frequency domain where inputs and outputs are functions of complex angular frequency.

In order for any function of time $f(t)$ to be Laplace transformable, it must satisfy the following Dirichlet conditions [1]:

- $f(t)$ must be piecewise continuous which means that it must be single valued but can have a finite number of finite isolated discontinuities for $t > 0$.
- $f(t)$ must be exponential order which means that $f(t)$ must remain less than $Se^{-\alpha t}$ as t approaches ∞ where S is a positive constant and α_0 is a real positive number.

If there is any function $f(t)$ that satisfies the Dirichlet conditions, then,

$F(s) = \int_0^{\infty} f(t)e^{-st}dt$ written as $L\{f(t)\}$ is called the Laplace transformation of $f(t)$. Here, s can be either a real variable or a complex quantity.

The integral $\int_0^{\infty} f(t)e^{-st}dt$ converges if $\int_0^{\infty} |f(t)e^{-\sigma t}|dt < \infty, s = \sigma + j\omega$

A. Some Important Properties of Laplace Transforms

The Laplace transforms of different functions can be found in most of the mathematics and engineering books and hence, is not included in this paper. Some of the very important properties of Laplace transforms which will be used in its applications to be discussed later on are described as follows:[1][2]

• Linearity

The Laplace transform of the linear sum of two Laplace transformable functions $f(t) + g(t)$ is given by:

$$L\{f(t) + g(t)\} = F(s) + G(s)$$

• Differentiation

If the function $f(t)$ is piecewise continuous so that it has a continuous derivative $f^{(n-1)}(t)$ of order $n-1$ and a sectionally continuous derivative $f^{(n)}(t)$ in every finite interval $0 \leq t \leq T$, then let, $f(t)$ and all its derivatives through $f^{(n-1)}(t)$ be of exponential order $e^{\alpha t}$ as $t \rightarrow \infty$.

Then, the transform of $f^{(n)}(t)$ exists when $Re\{s\} > \alpha$ and has the following form:

$$L\{f^{(n)}(t)\} = s^n F(s) - s^{n-1}f(0+) - s^{n-2}f^{(1)}(0+) - \dots - s^{n-1}f^{(n-2)}(0+)$$

• Time delay

The substitution of $t - \lambda$ for the variable t in the transform $L\{f(t)\}$ corresponds to the multiplication of the function $F(s)$ by $e^{-s\lambda}$, that is

$$L\{f(t - \lambda)\} = e^{-s\lambda} F(s)$$

II. APPLICATIONS OF LAPLACE TRANSFORMS

This section describes the applications of Laplace transforms in the areas of science and engineering. At first, simple application in the area of Physics and Electric Circuit theory is presented which will be followed by a more complex application to power system which includes the description of Load Frequency Control (LFC) for transient stability studies.

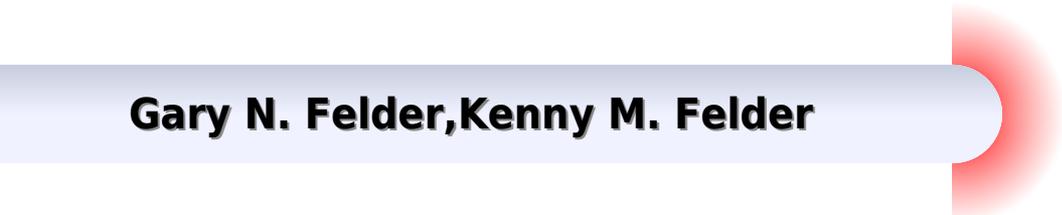
A. Application in Physics

A very simple application of Laplace transform in the area of physics could be to find out the harmonic vibration of a beam which is supported at its two ends [3].

Let us consider a beam of length l and uniform cross section parallel to the yz plane so that the normal deflection $w(x,t)$ is measured downward if the axis of the beam is towards x axis. The basic equation defining this phenomenon is as given below:

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Engineering Applications of the Laplace Transform Y.H. Gangadharaiyah,N. Sandeep,2021-08-25 This book is devoted to one of the most critical areas of applied mathematics namely the Laplace transform technique for linear time invariance systems arising from the fields of electrical and mechanical engineering It focuses on introducing Laplace transformation and its operating properties finding inverse Laplace transformation through different methods and describing transfer function applications for mechanical and electrical networks to develop input and output relationships It also discusses solutions of initial value problems the state variables approach and the solution of boundary value problems connected with partial differential equations

Laplace Transforms and Their Applications Alexander Apelblat,2012-05-01 There is a lot of literature devoted to operational calculus which includes the analysis of properties and rules of integral transformations and illustrates their usefulness in different fields of applied mathematics engineering and natural sciences The integral transform technique is one of most useful tools of applied mathematics employed in many branches of science and engineering Typical applications include the design and analysis of transient and steady state configurations of linear systems in electrical mechanical and control engineering and heat transfer diffusion waves vibrations and fluid motion problems The Laplace transformation receives special attention in literature because of its importance in various applications and therefore is considered as a standard technique in solving linear differential equations For this reason this book is centered on the Laplace transformation

Laplace Transforms and Their Applications to Differential Equations N.W. McLachlan,2014-11-19 This introduction to modern operational calculus offers a classic exposition of Laplace transform theory and its application to the solution of ordinary and partial differential equations The treatment is addressed to graduate students in engineering physics and applied mathematics and may be used as a primary text or supplementary reading Chief topics include the theorems or rules of the operational calculus evaluation of integrals and establishment of mathematical relationships derivation of Laplace transforms of various functions the Laplace transform for a finite interval and other subjects Many problems and illustrative examples appear throughout the book which is further augmented by helpful Appendixes Dover 2014 republication of the 1962 Dover revised edition of *Modern Operational Calculus with Applications in Technical Mathematics* Macmillan London 1948 See every Dover book in print at www.doverpublications.com

Introduction to the Laplace Transformation John Conrad Jaeger,1946 *Application of Integral Transforms in Mathematical Physics and Engineering* Dr. Sarita Poonia,Dr. Rafia Begum ,Dr. Mahadev Biradar,Dr. G. C.

Basavaraju,2023-04-14 In this book readers will explore the fundamental concepts and applications of integral transformations including Laplace Fourier and Mellin transforms among others With clear explanations and real world examples this book provides a deep understanding of the power and versatility of integral transformations Whether you re a student researcher or practitioner in the fields of mathematics or engineering physics this book is an invaluable resource for

understanding and applying integral transformations to a wide range of problems Integral Transforms and Their Applications Lokenath Debnath, 1995-07-03 Integral Transforms and Their Applications provides a systematic comprehensive review of the properties of integral transforms and their applications to the solution of boundary and initial value problems Over 750 worked examples exercises and applications illustrate how transform methods can be used to solve problems in applied mathematics mathematical physics and engineering The specific applications discussed include problems in differential integral and difference equations electric circuits and networks vibrations and wave propagation heat conduction fractional derivatives and fractional integrals dynamical systems signal processing quantum mechanics atmosphere and ocean dynamics physical chemistry mathematical biology and probability and statistics Integral Transforms and Their Applications includes broad coverage the standard material on integral transforms and their applications along with modern applications and examples of transform methods It is both an ideal textbook for students and a sound reference for professionals interested in advanced study and research in the field Transform Methods Eginhard J. Muth, 1977 Good No Highlights No Markup all pages are intact Slight Shelfwear may have the corners slightly dented may have slight color changes slightly damaged spine Introductory Laplace Transform with Applications Dalpatadu, Singh, 2015-07-17 One of the first applications of the modern Laplace transform was by Bateman in 1910 who used it to transform Rutherfords equations in his work on radioactive decay The modeling of complex engineering and physical problems by linear differential equations has made the Laplace transform an indispensable mathematical tool for engineers and scientists The method of Laplace transform for solving linear differential equations is very popular in the disciplines of electrical engineering environmental engineering hydrology and petroleum engineering This book presents some applications of Laplace transforms in these disciplines Algorithms for the numerical inversion of Laplace transform are given and a computer program in R for the Stehfest algorithm is included **Applied Laplace Transforms and z-Transforms for Scientists and Engineers** Urs Graf, 2012-12-06 The theory of Laplace transformation is an important part of the mathematical background required for engineers physicists and mathematicians Laplace transformation methods provide easy and effective techniques for solving many problems arising in various fields of science and engineering especially for solving differential equations What the Laplace transformation does in the field of differential equations the z transformation achieves for difference equations The two theories are parallel and have many analogies Laplace and z transformations are also referred to as operational calculus but this notion is also used in a more restricted sense to denote the operational calculus of Mikusinski This book does not use the operational calculus of Mikusinski whose approach is based on abstract algebra and is not readily accessible to engineers and scientists The symbolic computation capability of Mathematica can now be used in favor of the Laplace and z transformations The first version of the Mathematica Package LaplaceAndzTransforms developed by the author appeared ten years ago The Package computes not only Laplace and z transforms but also includes many routines from various domains of

applications Upon loading the Package about one hundred and fifty new commands are added to the built in commands of Mathematica The code is placed in front of the already built in code of Laplace and z transformations of Mathematica so that built in functions not covered by the Package remain available The Package substantially enhances the Laplace and z transformation facilities of Mathematica The book is mainly designed for readers working in the field of applications

Advanced Engineering Mathematics with MATLAB Dean G. Duffy, 2016-12-12 *Advanced Engineering Mathematics with MATLAB* Fourth Edition builds upon three successful previous editions It is written for today's STEM science technology engineering and mathematics student Three assumptions underlie its structure 1 All students need a firm grasp of the traditional disciplines of ordinary and partial differential equations vector calculus and linear algebra 2 The modern student must have a strong foundation in transform methods because they provide the mathematical basis for electrical and communication studies 3 The biological revolution requires an understanding of stochastic random processes The chapter on Complex Variables positioned as the first chapter in previous editions is now moved to Chapter 10 The author employs MATLAB to reinforce concepts and solve problems that require heavy computation Along with several updates and changes from the third edition the text continues to evolve to meet the needs of today's instructors and students Features Complex Variables formerly Chapter 1 is now Chapter 10 A new Chapter 18 It's Stochastic Calculus Implements numerical methods using MATLAB updated and expanded Takes into account the increasing use of probabilistic methods in engineering and the physical sciences Includes many updated examples exercises and projects drawn from the scientific and engineering literature Draws on the author's many years of experience as a practitioner and instructor Gives answers to odd numbered problems in the back of the book Offers downloadable MATLAB code at www.crcpress.com [Laplace Transforms for Electronic Engineers](#) James G. Holbrook, 2014-05-16 *Laplace Transforms for Electronic Engineers* Second Revised Edition details the theoretical concepts and practical application of Laplace transformation in the context of electrical engineering The title is comprised of 10 chapters that cover the whole spectrum of Laplace transform theory that includes advancement concepts methods logic and application The book first covers the functions of a complex variable and then proceeds to tackling the Fourier series and integral the Laplace transformation and the inverse Laplace transformation The next chapter details the Laplace transform theorems The subsequent chapters talk about the various applications of the Laplace transform theories such as network analysis transforms of special waveshapes and pulses electronic filters and other specialized applications The text will be of great interest to electrical engineers and technicians [An Introduction to the Laplace Transformation](#) John Conrad Jaeger, 1949 *A Functional Description of the Edvac [an Automatically-sequence Serial Binary Electronic Digital Computer]* Moore School of Electrical Engineering, 1949 **Integral Transforms and Their Applications** Lokenath Debnath, Dambaru Bhatta, 2014-11-07 *Integral Transforms and Their Applications* Third Edition covers advanced mathematical methods for many applications in science and engineering The book is suitable as a textbook

for senior undergraduate and first year graduate students and as a reference for professionals in mathematics engineering and applied sciences It presents a systematic *An introduction to the Laplace transformation* John C. Jaeger,1966

Mathematical Methods in Engineering and Physics Gary N. Felder,Kenny M. Felder,2015-04-13 This text is intended for the undergraduate course in math methods with an audience of physics and engineering majors As a required course in most departments the text relies heavily on explained examples real world applications and student engagement Supporting the use of active learning a strong focus is placed upon physical motivation combined with a versatile coverage of topics that can be used as a reference after students complete the course Each chapter begins with an overview that includes a list of prerequisite knowledge a list of skills that will be covered in the chapter and an outline of the sections Next comes the motivating exercise which steps the students through a real world physical problem that requires the techniques taught in each chapter Calculus and Ordinary Differential Equations Dr. Navneet Kumar Lamba,Dr. R.Srija,Dr. Suryakant S.

Charjan,Dr. Payal Hiranwar,2024-10-17 *Calculus and Ordinary Differential Equations* a comprehensive introduction to two fundamental areas of mathematics calculus and ordinary differential equations ODEs The explores core concepts of differentiation integration and limits alongside the theory and methods for solving first order and higher order differential equations Through a blend of theory examples and applications it aims to equip readers with essential mathematical tools for analyzing dynamic systems modeling real world phenomena and understanding the mathematical foundations of science and engineering **An Introduction to the Laplace Transformations** John Conrad Jaeger,1959 An introduction to the laplace transformation John Conrad Jaeger,1969 An Introduction to the Laplace Transformation John Conrad Jaeger,1959

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