

# ON OPERATIONAL CALCULUS

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(Communicated by Dr. Ram Behari, M.A., Ph.D., Sc.D., F.N.I.)

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**Theorem 1.** If  $f(p) \doteq h(x)$ , then for  $\mu > 0$ ,  $R(\lambda) > -1$ ,

$$p^{\mu-\lambda} f(p^{-\mu}) \doteq F(x) = x^{\lambda} \int_0^{\infty} h(s) J_{\lambda}^{\mu}(sx^{\mu}) ds, \quad \dots \quad (0.1)$$

where \*

$$J_{\lambda}^{\mu}(x) = \sum_{r=0}^{\infty} \{ (-x)^r / r! \Gamma(1+\lambda+\mu r) \},$$

provided that

(i) as  $s \rightarrow 0$ ,  $h(s) = o(s^{-1+\epsilon})$ ,

(ii) as  $s \rightarrow \infty$ ,  $h(s) = o[s^{k(\lambda+1)-1-\epsilon'} \exp(-s^k + \epsilon'' \cos \pi k \cos \pi k)]$ ,

$k$  being equal to  $1/(\mu+1)$  and  $\epsilon, \epsilon', \epsilon''$  being arbitrarily small positive numbers and

(iii)  $\int_0^{\infty} e^{-\rho x} F(x) dx$

converges absolutely.

**PROOF.** By the definition of operational relationship

$$\begin{aligned} x^{\lambda} \int_0^{\infty} h(s) J_{\lambda}^{\mu}(sx^{\mu}) ds &\doteq p \int_0^{\infty} e^{-\rho x} x^{\lambda} dx \int_0^{\infty} h(s) J_{\lambda}^{\mu}(sx^{\mu}) ds \\ &= p \int_0^{\infty} h(s) ds \int_0^{\infty} x^{\lambda} e^{-\rho x} \sum_{r=0}^{\infty} \frac{(-sx^{\mu})^r}{r! \Gamma(1+\lambda+\mu r)} dx \quad \dots \quad (I_1) \end{aligned}$$

$$= p \int_0^{\infty} h(s) ds \sum_{r=0}^{\infty} \frac{(-s)^r}{r! \Gamma(1+\lambda+\mu r)} \int_0^{\infty} x^{\lambda+\mu r} e^{-\rho x} dx \quad \dots \quad (I_2)$$

$$= p \int_0^{\infty} h(s) \sum_{r=0}^{\infty} \frac{(-s)^r}{r! p^{1+\lambda+\mu r}} ds$$

$$= p^{\mu-\lambda} p^{-\mu} \int_0^{\infty} h(s) \exp(-p^{-\mu} s) ds$$

$$= p^{\mu-\lambda} f(p^{-\mu}), \text{ since } p \int_0^{\infty} h(x) e^{-\rho x} dx = f(p).$$

\* This is Maitland's generalised Bessel function. See Ref. 18.

# Operational Calculus

**R.G. Buschman**



## **Operational Calculus:**

Operational Calculus Jan Mikusinski, 2014-07-14 Pure and Applied Mathematics Volume 109 Operational Calculus Second Edition Volume I presents the foundations of operational calculus and its applications to physics and engineering This book introduces the operators algebraically as a kind of fractions Organized into three parts this volume begins with an overview of the concept as well as the characteristics of a convolution of continuous functions This text then examines the transitivity associativity and distributivity of convolution with regard to addition Other parts consider the methods of solving other difference equations particularly in the field of electrical engineering in which the variable runs over integer values only This book discusses as well the solution of differential equations under given initial conditions The final part deals with the characteristic properties of a derivative and provides the definition of algebraic derivative to any operators This book is a valuable resource for physicists electrical engineers mathematicians and research workers      **Operational Calculus and**

**Generalized Functions** Arthur Erdelyi, 2013-07-24 Suitable for advanced undergraduates and graduate students this brief monograph examines elementary and convergence theories of convolution quotients differential equations involving operator functions exponential functions of operators Solutions 1962 edition      **Operational Calculus** Āosip Zakharovych

Shtokalo, 1976      *Operational Calculus and Related Topics* A. P. Prudnikov, K.A. Skórnik, 2006-08-15 Even though the theories of operational calculus and integral transforms are centuries old these topics are constantly developing due to their use in the fields of mathematics physics and electrical and radio engineering Operational Calculus and Related Topics highlights the classical methods and applications as well as the recent advances      **Introduction To The Operational**

**Calculus** Lothar Berg, 2013-07-19 Introduction to the Operational Calculus is a translation of Einführung in die Operatorenrechnung Second Edition This book deals with Heaviside's interpretation on the Laplace integral and on Jan Mikusinski's fundamental work Operational Calculus Throughout the book basic algebraic concepts appear as aids to understanding some relevant points of the subject An important field for research in analysis is asymptotic properties This text also discusses examples to show the potentialities in applying operational calculus that run beyond ordinary differential equations with constant coefficients In using operational calculus to solve more complicated problems than those of ordinary differential equations with constant coefficients the concept of convergence assumes a significant role in the field of operators This book also extends the Laplace transformation and applies it to non transformable functions This text also presents three methods in which operational calculus can be modified and become useful in solving specific ranges of problems These methods pertain to the finite Laplace transformation to partial differential equations and to the Volterra integral equations and ordinary differential equations with variable coefficients This book can prove valuable for mathematicians students and professors of calculus and advanced mathematics      *Integral Transformations, Operational Calculus and Their Applications* Hari Mohan Srivastava, 2021-01-20 This volume consists of a collection of 14 accepted

submissions including several invited feature articles to the Special Issue of MDPI's journal Symmetry on the general subject area of integral transformations operational calculus and their applications from many different parts around the world The main objective of the Special Issue was to gather review expository and original research articles dealing with the state of the art advances in integral transformations and operational calculus as well as their multidisciplinary applications together with some relevance to the aspect of symmetry Various families of fractional order integrals and derivatives have been found to be remarkably important and fruitful mainly due to their demonstrated applications in numerous diverse and widespread areas of mathematical physical chemical engineering and statistical sciences Many of these fractional order operators provide potentially useful tools for solving ordinary and partial differential equations as well as integral differintegral and integro differential equations fractional calculus analogues and extensions of each of these equations and various other problems involving special functions of mathematical physics and applied mathematics as well as their extensions and generalizations in one or more variables

Operational Calculus Kosaku Yosida, 2012-12-06 In the end of the last century Oliver Heaviside inaugurated an operational calculus in connection with his researches in electromagnetic theory In his operational calculus the operator of differentiation was denoted by the symbol  $p$  The explanation of this operator  $p$  as given by him was difficult to understand and to use and the range of the validity of his calculus remains unclear still now although it was widely noticed that his calculus gives correct results in general In the 1930s Gustav Doetsch and many other mathematicians began to strive for the mathematical foundation of Heaviside's operational calculus by virtue of the Laplace transform  $\int_0^\infty f(t) e^{-pt} dt$  However the use of such integrals naturally confronts restrictions concerning the growth behavior of the numerical function  $f(t)$  as  $t \rightarrow \infty$  At about the midcentury Jan Mikusinski invented the theory of convolution quotients based upon the Titchmarsh convolution theorem If  $f(t)$  and  $g(t)$  are continuous functions defined on  $[0, \infty)$  such that the convolution  $\int_0^t f(\tau) g(t-\tau) d\tau = 0$  then either  $f(t) = 0$  or  $g(t) = 0$  must hold The convolution quotients include the operator of differentiation  $s$  and related operators Mikusinski's operational calculus gives a satisfactory basis of Heaviside's operational calculus it can be applied successfully to linear ordinary differential equations with constant coefficients as well as to the telegraph equation which includes both the wave and heat equations with constant coefficients

Operational Calculus in Two Variables and Its Applications V.A. Ditkin, A.P. Prudnikov, 2017-06-15 Concise treatment of fundamental theory explores two dimensional Laplace transform and basic definitions theorems applications of operational calculus in two variables Includes tables of formulae for various categories of functions 1962 edition

**Operational Calculus** Thomas K. Boehme, 2014-08-01 Operational Calculus Volume II is a methodical presentation of operational calculus An outline of the general theory of linear differential equations with constant coefficients is presented Integral operational calculus and advanced topics in operational calculus including locally integrable functions and convergence in the space of operators are also discussed Formulas and tables are included Comprised of four sections this volume begins with a discussion on the general theory of linear

differential equations with constant coefficients focusing on such topics as homogeneous and non homogeneous equations and applications of operational calculus to partial differential equations The section deals with the integral of an operational function and its applications along with integral transformations A definition of operators in terms of abstract algebra is then presented Operators as generalized functions power series of operators and Laplace transform are also discussed Formulas of the operational calculus and tables of functions round out the book This monograph will be useful to engineers who regard the operational calculus merely as a tool in their work and readers who are interested in proofs of theorems and mathematical problems Heaviside's Operational Calculus as Applied to Engineering and Physics Ernst Julius Berg, 1929 Complex Variable & Operational Calculus with Technical Applications Norman William McLachlan, 1942

**Operational Calculus** Gregors Krabbe, 1970 Since the publication of an article by G DoETSCH in 1927 it has been known that the Laplace transform procedure is a reliable substitute for HEAVISIDE's operational calculus However the Laplace transform procedure is unsatisfactory from several viewpoints some of these will be mentioned in this preface the most obvious defect the procedure cannot be applied to functions of rapid growth such as the  $2$  function  $\text{tr exp } t$  In 1949 JAN MIKUSINSKI indicated how the unnecessary restrictions required by the Laplace transform can be avoided by a direct approach thereby gaining in notational as well as conceptual simplicity this approach is carefully described in MIKUSINSKI's textbook Operational Calculus M 1 The aims of the present book are the same as MIKUSINSKI's M 1 a direct approach requiring no unnecessary restrictions The present operational calculus is essentially equivalent to the calcul symbolique of distributions having left bounded support see 6 52 below and pp 171 to 180 of the textbook Theorie des distributions by LAURENT SCHWARTZ Integral Transforms and Operational Calculus Vitalii Arsen'evich Ditkin, Anatoliï Platonovich Prudnikov, 1965 Fourier transforms Laplace transforms Bessel transforms Other integral transforms Operational calculus Summary of notation for special functions and certain constraints Fourier cosine transforms Fourier sine transforms Laplace Carson transforms Mellin transforms Bessel transforms Other integral transforms **Modern Operational Calculus** Norman William McLachlan, 1948 **Operational Calculus and Generalized Functions** Arthur Erdélyi, 1962 Problems

after each chapter **Operational Calculus** Gregors Krabbe, 1975-12 Students who daily must face the need to use calculus for solving problems in engineering or mathematics will find Professor Krabbe's text books a refreshing departure from other sources Because it is addressed equally to engineering and mathematics students Operational Calculus concentrates on examples that illustrate the practical usefulness of the theory In fact the author emphasizes that all the theoretical material included was selected by the standard of practical applicability With the aid of seventy nine detailed diagrams he presents a system that is distinguished for its validity in solving not only traditional types of problems but the so called non standard problems as well He endorses and expands Jan Mikusinski's 1949 method of direct approach which succeeds in avoiding the unnecessary restriction of the Laplace transform method and therefore gains in both notational and

conceptual simplicity      **Operational Calculus** Jan Mikusiński, Thomas K. Boehme, 1983      **Integral Transformations, Operational Calculus, and Generalized Functions** R.G. Buschman, 2013-11-27

It is not the object of the author to present comprehensive coverage of any particular integral transformation or of any particular development of generalized functions for there are books available in which this is done. Rather this consists more of an introductory survey in which various ideas are explored. The Laplace transformation is taken as the model type of an integral transformation and a number of its properties are developed. Later the Fourier transformation is introduced. The operational calculus of Mikusinski is presented as a method of introducing generalized functions associated with the Laplace transformation. The construction is analogous to the construction of the rational numbers from the integers. Further on generalized functions associated with the problem of extension of the Fourier transformation are introduced. This construction is analogous to the construction of the reals from the rationals by means of Cauchy sequences. A chapter with sections on a variety of transformations is adjoined. Necessary levels of sophistication start low in the first chapter but they grow considerably in some sections of later chapters. Background needs are stated at the beginnings of each chapter. Many theorems are given without proofs which seems appropriate for the goals in mind. A selection of references is included. Without showing many of the details of rigor it is hoped that a strong indication is given that a firm mathematical foundation does actually exist for such entities as the Dirac delta function.

**Operational Calculus** Balthasar van der Pol, H. Bremmer, 1987. From the Preface: Primarily this book is intended for application of the operational calculus to mathematics, physics and technical problems. We have therefore given not only the basic principles, ideas and theorems as clearly as possible and rather extensively but also many worked out problems from purely mathematical and physical as well as from technical fields. Some of the deeper theorems have been omitted and for these the reader is referred to the mathematical literature. Nonetheless it is believed that the purely mathematical treatment is more advanced than is usual in books devoted primarily to practical applications. It is therefore hoped that the book may be of value to those pure mathematicians who are interested in a rapid and simple derivation of complicated and unexpected relations between various mathematical functions as well as to the engineer in search for example of a very simple treatment of transient phenomena in electrical networks such as filters. In both cases the operational calculus appears to its best advantage.

**Operational Calculus Based on the Two-sided Laplace Integral** Balthasar van der Pol, H. Bremmer, 1959

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web located a mile and a half outside of stratford upon avon in shottery anne hathaway's cottage is a thatched house nestled in an idyllic cottage garden the building was the childhood home of william shakespeare's wife anne hathaway

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web shakespeare s wife is a book by feminist academic germaine greer which was first published in 2007 by Bloomsbury the book is a biography of Anne Hathaway the wife of English poet and playwright William Shakespeare who was born in Shottery a former small village within Stratford-upon-Avon

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