

# A numerical computation of special functions with applications to physics

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## Abstract

Students of mathematical physics, engineering, natural and biological sciences sometimes need to use special functions that are not found in ordinary mathematical software. In this paper a simple universal numerical algorithm is developed to compute the Legendre function values of the first kind using the Legendre differential equation. The computed function values are compared to built-in values in *Mathcad14* and *Derive6*. Error analysis is performed to test the accuracy of the algorithm. Graphical residuals are found to be of order  $10^{-12}$ . Finally, some physical application is presented.

## 1 Introduction and motivation

Abramowitz and Stegun's Handbook of Mathematical Functions [1] is one of the most cited references in mathematics. According to Ludovic and Bruno [2] the formulas in this book on special functions were computed, written and proof-read by hand.

The method of separation of variables for the solution of partial differential equations often leads to ordinary differential equations (ODEs) with variable coefficients. The solutions are obtained in the form of infinite series or in terms of special functions. The Legendre and Bessel equations are some of the ordinary differential equations derived from the wave equation. These equations and their solutions play an important role in applied mathematics, electric field, heat conduction, fluid flow *et cetera* (see for example, Lebedev [9], Tikhonov and Samarskii [3]).

The main objective of this paper is to develop a simple numerical method using the Legendre differential equation:

$$(1-x^2) \frac{d^2 y}{dx^2} - 2x \frac{dy}{dx} + n(n+1)y = 0 \quad (0.1)$$

which could be re-written as:

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# Computation Of Special Functions

**Anthony S. Fauci**



## **Computation Of Special Functions:**

Computation of Special Functions Shanjie Zhang, Jian-Ming Jin, 1996-07-26 Computation of Special Functions is a valuable book software package containing more than 100 original computer programs for the computation of most special functions currently in use These include many functions commonly omitted from available software packages such as the Bessel and modified Bessel functions the Mathieu and modified Mathieu functions parabolic cylinder functions and various prolate and oblate spheroidal wave functions Also unlike most software packages this book disk set gives readers the latitude to modify programs according to the special demands of the sophisticated problems they are working on The authors provide detailed descriptions of the program s algorithms as well as specific information about each program s internal structure

Numerical Methods for Special Functions Amparo Gil, Javier Segura, Nico M. Temme, 2007-01-01 Special functions arise in many problems of pure and applied mathematics mathematical statistics physics and engineering This book provides an up to date overview of numerical methods for computing special functions and discusses when to use these methods depending on the function and the range of parameters Not only are standard and simple parameter domains considered but methods valid for large and complex parameters are described as well The first part of the book basic methods covers convergent and divergent series Chebyshev expansions numerical quadrature and recurrence relations Its focus is on the computation of special functions however it is suitable for general numerical courses Pseudoalgorithms are given to help students write their own algorithms In addition to these basic tools the authors discuss other useful and efficient methods such as methods for computing zeros of special functions uniform asymptotic expansions Pad approximations and sequence transformations The book also provides specific algorithms for computing several special functions like Airy functions and parabolic cylinder functions among others

**Calculation of Special Functions** C. G. van der Laan, N. M. Temme, 1984 *Orthogonal Polynomials and Special Functions* Francisco Marcellàn, Walter Van Assche, 2006-10-18 Special functions and orthogonal polynomials in particular have been around for centuries Can you imagine mathematics without trigonometric functions the exponential function or polynomials The present set of lecture notes contains seven chapters about the current state of orthogonal polynomials and special functions and gives a view on open problems and future directions

Mathematics of Computation 1943-1993: A Half-Century of Computational Mathematics Walter Gautschi, 1994 Proceedings of an International Conference held in Vancouver B C August 1993 to commemorate the 50th anniversary of the founding of the journal Mathematics of Computation It consisted of a Symposium on Numerical Analysis and a Minisymposium of Computational Number Theory This proceedings contains 14 invited papers including two not presented at the conference an historical essay on integer factorization and a paper on componentwise perturbation bounds in linear algebra The invited papers present surveys on the various subdisciplines covered by Mathematics of Computation in a historical perspective and in a language accessible to a wide audience The 46 contributed papers address contemporary specialized work Annotation

copyright by Book News Inc Portland OR      **Special Functions** Nico M. Temme,2011-03-01 This book gives an introduction to the classical well known special functions which play a role in mathematical physics especially in boundary value problems Calculus and complex function theory form the basis of the book and numerous formulas are given Particular attention is given to asymptotic and numerical aspects of special functions with numerous references to recent literature provided

**Symbolic Computation, Number Theory, Special Functions, Physics and Combinatorics** Frank G. Garvan,Mourad E.H. Ismail,2001-11-30 These are the proceedings of the conference Symbolic Computation Number Theory Special Functions Physics and Combinatorics held at the Department of Mathematics University of Florida Gainesville from November 11 to 13 1999 The main emphasis of the conference was Computer Algebra i e symbolic computation and how it related to the fields of Number Theory Special Functions Physics and Combinatorics A subject that is common to all of these fields is q series We brought together those who do symbolic computation with q series and those who need q series in cluding workers in Physics and Combinatorics The goal of the conference was to inform mathematicians and physicists who use q series of the latest developments in the field of q series and especially how symbolic computa tion has aided these developments Over 60 people were invited to participate in the conference We ended up having 45 participants at the conference including six one hour plenary speakers and 28 half hour speakers There were talks in all the areas we were hoping for There were three software demonstrations      Algorithms for the Computation of Mathematical Functions Yudell L. Luke,1977 Basic formulas Identification of functions General remarks on the algorithms and programs Chebyshev coefficients      *Orthogonal Polynomials and Special Functions* Francisco Marcellan,Walter van Assche,2006-01-01

Special Functions and Wave Propagation Donald Ludwig, Frank W. J. Olver,1970      **Advances in Difference Equations** Saber N. Elaydi,I. Gyori,G. Ladas,1998-01-29 The recent surge in research activity in difference equations and applications has been driven by the wide applicability of discrete models to such diverse fields as biology engineering physics economics chemistry and psychology The 68 papers that make up this book were presented by an international group of experts at the Second International Conference on Difference Equations held in Veszpr m Hungary in August 1995 Featuring contributions on such topics as orthogonal polynomials control theory asymptotic behavior of solutions stability theory special functions numerical analysis oscillation theory models of vibrating string models of chemical reactions discrete competition systems the Liouville Green WKB method and chaotic phenomena this volume offers a comprehensive review of the state of the art in this exciting field      Walter Gautschi, Volume 3 Claude Brezinski,Ahmed Sameh,2013-10-24 Walter Gautschi has written extensively on topics ranging from special functions quadrature and orthogonal polynomials to difference and differential equations software implementations and the history of mathematics He is world renowned for his pioneering work in numerical analysis and constructive orthogonal polynomials including a definitive textbook in the former and a monograph in the latter area This three volume set Walter Gautschi Selected Works with Commentaries is a compilation of Gautschi s most

influential papers and includes commentaries by leading experts The work begins with a detailed biographical section and ends with a section commemorating Walter's prematurely deceased twin brother This title will appeal to graduate students and researchers in numerical analysis as well as to historians of science Selected Works with Commentaries Vol 1 Numerical Conditioning Special Functions Interpolation and Approximation Selected Works with Commentaries Vol 2 Orthogonal Polynomials on the Real Line Orthogonal Polynomials on the Semicircle Chebyshev Quadrature Kronrod and Other Quadratures Gauss type Quadrature Selected Works with Commentaries Vol 3 Linear Difference Equations Ordinary Differential Equations Software History and Biography Miscellanea Works of Werner Gautschi

**Arithmetic and Algebraic Circuits** Antonio Lloris Ruiz, Encarnación Castillo Morales, Luis Parrilla Roure, Antonio García Ríos, María José Lloris Meseguer, 2021-02-23 This book presents a complete and accurate study of arithmetic and algebraic circuits The first part offers a review of all important basic concepts it describes simple circuits for the implementation of some basic arithmetic operations it introduces theoretical basis for residue number systems and describes some fundamental circuits for implementing the main modular operations that will be used in the text Moreover the book discusses floating point representation of real numbers and the IEEE 754 standard The second and core part of the book offers a deep study of arithmetic circuits and specific algorithms for their implementation It covers the CORDIC algorithm and optimized arithmetic circuits recently developed by the authors for adders and subtractors as well as multipliers dividers and special functions It describes the implementation of basic algebraic circuits such as LFSRs and cellular automata Finally it offers a complete study of Galois fields showing some exemplary applications and discussing the advantages in comparison to other methods This dense self contained text provides students researchers and engineers with extensive knowledge on and a deep understanding of arithmetic and algebraic circuits and their implementation

**Sharpening Mathematical Analysis Skills** Alina Sîntămărian, Ovidiu Furdui, 2021-10-25 This book gathers together a novel collection of problems in mathematical analysis that are challenging and worth studying They cover most of the classical topics of a course in mathematical analysis and include challenges presented with an increasing level of difficulty Problems are designed to encourage creativity and some of them were especially crafted to lead to open problems which might be of interest for students seeking motivation to get a start in research The sets of problems are comprised in Part I The exercises are arranged on topics many of them being preceded by supporting theory Content starts with limits series of real numbers and power series extending to derivatives and their applications partial derivatives and implicit functions Difficult problems have been structured in parts helping the reader to find a solution Challenges and open problems are scattered throughout the text being an invitation to discover new original methods for proving known results and establishing new ones The final two chapters offer ambitious readers splendid problems and two new proofs of a famous quadratic series involving harmonic numbers In Part II the reader will find solutions to the proposed exercises Undergraduate students in mathematics physics

and engineering seeking to strengthen their skills in analysis will most benefit from this work along with instructors involved in math contests individuals who want to enrich and test their knowledge in analysis and anyone willing to explore the standard topics of mathematical analysis in ways that aren't commonly seen in regular textbooks *Mathematical Tables and Other Aids to Computation*, 1954 **Punched Card Methods in Scientific Computation** Wallace John Eckert, 1940

*The Special Functions and Their Approximations* Yudell L. Luke, 1969 These volumes are designed to provide scientific workers with a self contained and unified development for many of the mathematical functions which arise in applied problems as well as the attendant mathematical theory for their approximations These functions are often called the special functions of mathematical physics or more simply the special functions *The Collected Mathematical Works of George William Hill ...* George William Hill, 1906 *Special Functions & Their Applications* N. N. Lebedev, 2012-04-30 Famous Russian work discusses the application of cylinder functions and spherical harmonics gamma function probability integral and related functions Airy functions hypergeometric functions more Translated by Richard Silverman **Vistas of Special Functions** Shigeru Kanemitsu, Haruo Tsukada, 2007 1 The theory of Bernoulli and allied polynomials 2 The theory of the gamma and related functions 3 The theory of the Hurwitz Lerch zeta functions 4 The theory of Bernoulli polynomials via zeta functions 5 The theory of the gamma and related functions via zeta functions 6 The theory of Bessel functions and the Epstein zeta functions 7 Fourier series and Fourier transforms 8 Around Dirichlet's L functions

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