# On Value Distribution Theory of Second Order Periodic ODEs, Special Functions and Orthogonal Polynomials

*Dedicated to the memory of Noel Baker, a dear friend.*

## Yik-Man Chiang and Mourad E. H. Ismail

*Abstract:* We show that the value distribution (complex oscillation) of solutions of certain periodic second order ordinary differential equations studied by Bank, Laine and Langley is closely related to confluent hypergeometric functions, Bessel functions and Bessel polynomials. As a result, we give a complete characterization of the zero–distribution in the sense of Nevanlinna theory of the solutions for two classes of the ODEs. Our approach uses special functions and their asymptotics. New results concerning finiteness of the number of zeros (finite-zeros) problem of Bessel and Coulomb wave functions with respect to the parameters are also obtained as a consequence. We demonstrate that the problem for the remaining class of ODEs not covered by the above "special function approach" can be described by a classical Heine problem for differential equations that admit polynomial solutions.

## 1 Introduction and Main Results

We consider value distribution problems of the solutions of certain ordinary differential equations of the form

$$(1.1) \qquad f''(z) + A(z)f(z) = 0,$$

where

$$(1.2) \qquad A(z) = B(e^z), \qquad B(\zeta) = \frac{K_3}{\zeta^t} + \cdots + K_0 + \cdots + K_1 \zeta^t, \qquad K_t K_3 \neq 0.$$

Such equations always admit entire solutions. We recall that the *order of* $f$ is defined by $\sigma(f) = \limsup_{r \to \infty} \log \log M(r, f) / \log r$, where $M(r, f) = \max_{|z|=r} |f(z)|$ denotes the maximum modulus of $f$. The "density" of the zeros of $f$ is given by $\lambda(f) = \limsup_{r \to \infty} \log n(r, f) / \log r$, known as the *exponent of convergence* of $f$, where $n(r, f)$ denote the number of the zeros of $f$ in $|z| < r$. It is elementary to use Nevanlinna theory [25, 34] to deduce that any solution $f$ of (1.1), where $A(z)$ can

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**Harry Bateman**

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**Selected Papers on Differential Equations and Analysis** ,2005 Contains translations of papers that originally appeared in the Japanese journal Sugaku This book covers a variety of topics including differential equations with free boundary singular integral operators and operator algebras It is suitable for graduate students and research mathematicians interested in analysis and differential equations     Manifolds and Modular Forms Friedrich Hirzebruch,Thomas Berger,Rainer Jung,2013-06-29 This book provides a comprehensive introduction to the theory of elliptic genera due to Ochanine Landweber Stong and others The theory describes a new cobordism invariant for manifolds in terms of modular forms The book evolved from notes of a course given at the University of Bonn After providing some background material elliptic genera are constructed including the classical genera signature and the index of the Dirac operator as special cases Various properties of elliptic genera are discussed especially their behaviour in fibre bundles and rigidity for group actions For stably almost complex manifolds the theory is extended to elliptic genera of higher level The text is in most parts self contained The results are illustrated by explicit examples and by comparison with well known theorems The relevant aspects of the theory of modular forms are derived in a seperate appendix providing also a useful reference for mathematicians working in this field     Conjectures in Arithmetic Algebraic Geometry Wilfred W. J. Hulsbergen,2013-06-29 In this expository text we sketch some interrelations between several famous conjectures in number theory and algebraic geometry that have intrigued math ematicians for a long period of time Starting from Fermat s Last Theorem one is naturally led to introduce L functions the main motivation being the calculation of class numbers In partic ular Kummer showed that the class numbers of cyclotomic fields play a decisive role in the corroboration of Fermat s Last Theorem for a large class of exponents Before Kummer Dirichlet had already successfully applied his L functions to the proof of the theorem on arithmetic progressions Another prominent appearance of an L function is Riemann s paper where the now famous Riemann Hypothesis was stated In short nineteenth century number theory showed that much if not all of number theory is reflected by properties of L functions Twentieth century number theory class field theory and algebraic geome try only strengthen the nineteenth century number theorists s view We just mention the work of E H cke E Artin A Weil and A Grothendieck with his collaborators Heeke generalized Dirichlet s L functions to obtain results on the distribution of primes in number fields Artin introduced his L functions as a non abelian generalization of Dirichlet s L functions with a generalization of class field theory to non abelian Galois extensions of number fields in mind     Introduction to the Theory of Distributions William M. Robertson,1962     **Selected Papers on Analysis, Probability, and Statistics** Katsumi Nomizu,1994 This book presents papers in the general area of mathematical analysis as it pertains to probability and statistics dynamical systems differential equations and analytic function theory Among the topics discussed are stochastic differential equations spectra of the Laplacian and Schr dinger operators nonlinear partial differential equations which generate dissipative dynamical systems

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