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First-order Second-degree Equations Related with Painlevé Equations

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Abstract. The first-order second-degree equations satisfying the Fuchs theorem concerning the absence of movable critical points, related with Painlevé equations, and one-parameter families of solutions which solve the first-order second-degree equations are investigated.
Keywords: Painlevé equations, Fuchs theorem.

1 Introduction

Painlevé equations, PI-PVI, which are second order first-degree equations $v'' = F(v', v, z)$ where F is rational in v', algebraic in v and locally analytic in z with the Painlevé property, which were first derived at the beginning of the 20^{th} century by Painlevé and his school [1]. A differential equation is said to have Painlevé property if all solutions are single valued around all movable singularities. Movable means that the position of the singularities varies as a function of initial values. Painlevé equations may be regarded as the nonlinear counterparts of some classical special functions. They also arise as reductions of solutions of soliton equations solvable by the inverse scattering method and may be studied as the compatibility condition of the isomonodromy deformation problem. Recently, there have been studies of integrable mappings and discrete systems, including discrete analogous of the Painlevé equations.

The Riccati equations is the only example for the first-order first-degree equation which has the Painlevé property. By Fuchs theorem, the irreducible form of the first order algebraic differential equation of the second-degree with Painlevé property is given as

$$(v')^2 = (A_2v^2 + A_1v + A_0)v' + B_4v^4 + B_3v^3 + B_2v^2 + B_1v + B_0, \tag{1}$$

where A_j, $j = 0, 1, 2$ and B_k, $j = 0, 1, 2, 3, 4$ are functions of z and set of parameters denoted by α [2]. Higher order ($n \geq 3$) and second order higher-degree ($k \geq 2$) with Painlevé property were subject to the articles [3, 4, 5]

Painlevé equations, PI-PVI, posses a rich internal structure. For example, for certain choice of the parameters PII-PVI admit one parameter families of solutions, rational, algebraic and expressible in terms of the classical transcendental functions: Airy, Bessel, Weber-Hermite, Whittcker, hypergeometric functions respectively. But, all the known one parameter families of solutions appear as the solutions of Riccati equations. In this article, we investigate the one parameter families of solutions of PII-PVI which solves the first-order second-degree equation of the form (1). Let $v(z)$ be a solution of one of the Painlevé equations

$$v'' = P_2(v')^2 + P_1v' + P_0. \tag{2}$$

where P_0, P_1, P_2 depend on v, z and set of parameters α. Differentiating equation (1) and using (2) to replace v'' and (1) to replace $(v')^2$, one gets

$$\Phi v' + \Psi = 0, \tag{3}$$

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E-mail address: mugan@fen.bilkent.edu.tr.

Painlev Equations And Related Topics Painlev Equations And Related Topics

Alexander D. Bruno,Alexander B. Batkhin

Painlev Equations And Related Topics Painlev Equations And Related Topics:

Painlevé Equations and Related Topics Alexander D. Bruno,Alexander B. Batkhin,2012-08-31 This is a proceedings of the international conference Painlev Equations and Related Topics which was taking place at the Euler International Mathematical Institute a branch of the Saint Petersburg Department of the Steklov Institute of Mathematics of the Russian Academy of Sciences in Saint Petersburg on June 17 to 23 2011 The survey articles discuss the following topics General ordinary differential equations Painlev equations and their generalizations Painlev property Discrete Painlev equations Properties of solutions of all mentioned above equations Asymptotic forms and asymptotic expansions Connections of asymptotic forms of a solution near different points Convergency and asymptotic character of a formal solution New types of asymptotic forms and asymptotic expansions Riemann Hilbert problems Isomonodromic deformations of linear systems Symmetries and transformations of solutions Algebraic solutions Reductions of PDE to Painlev equations and their generalizations Ordinary Differential Equations systems equivalent to Painlev equations and their generalizations Applications of the equations and the solutions Special Functions and Orthogonal Polynomials Richard Beals,Roderick Wong,2016-05-17 A comprehensive graduate level introduction to classical and contemporary aspects of special functions

Spectral Operator Theory and Related Topics Vladimir Aleksandrovich Marchenko,1994 The collection contains the papers of mathematicians who are participants of the seminar on Mathematical Physics in Kharkov Ukraine The papers are mainly devoted to nontraditional problems of spectral theory of disordered systems to the spectral aspects of homogenization and of properties of ergodic dynamical systems ABSTRACT **The Painlevé Property** Robert Conte,2012-12-06 The subject this volume is explicit integration that is the analytical as opposed to the numerical solution of all kinds of nonlinear differential equations ordinary differential partial differential finite difference Such equations describe many physical phenomena their analytic solutions particular solutions first integral and so forth are in many cases preferable to numerical computation which may be long costly and worst subject to numerical errors In addition the analytic approach can provide a global knowledge of the solution while the numerical approach is always local Explicit integration is based on the powerful methods based on an in depth study of singularities that were first used by Poincar and subsequently developed by Painlev in his famous Leons de Stockholm of 1895 The recent interest in the subject and in the equations investigated by Painlev dates back about thirty years ago arising from three apparently disjoint fields the Ising model of statistical physics and field theory propagation of solitons and dynamical systems The chapters in this volume based on courses given at Cargse 1998 alternate mathematics and physics they are intended to bring researchers entering the field to the level of present research

Stochastic Analysis and Related Topics Hayri Korezlioglu,Ali S. Ustunel,2006-11-14 The Silvri Workshop was divided into a short summer school and a working conference producing lectures and research papers on recent developments in stochastic analysis on Wiener space The topics treated in the lectures relate to the Malliavin calculus the Skorohod integral

and nonlinear functionals of white noise Most of the research papers are applications of these subjects This volume addresses researchers and graduate students in stochastic processes and theoretical physics *Painlevé Transcendents* Decio Levi,Pavel Winternitz,2013-11-11 The NATO Advanced Research Workshop Painleve Transcendents their Asymp totics and Physical Applications held at the Alpine Inn in Sainte Adele near Montreal September 2 7 1990 brought together a group of experts to discuss the topic and produce this volume There were 41 participants from 14 countries and 27 lectures were presented all included in this volume The speakers presented reviews of topics to which they themselves have made important contributions and also re sults of new original research The result is a volume which though multiauthored has the character of a monograph on a single topic This is the theory of nonlinear ordinary differential equations the solutions of which have no movable singularities other than poles and the extension of this theory to partial differential equations For short we shall call such systems equations with the Painleve property The search for such equations was a very topical mathematical problem in the 19th century Early work concentrated on first order differential equations One of Painleve s important contributions in this field was to develop simple methods applicable to higher order equations In particular these methods made possible a complete analysis of the equation f y y x where f is a rational function of y and y with coefficients that are analytic in x The fundamental result due to Painleve Acta Math Painleve Equations through Symmetry Masatoshi Noumi,2004-01-01 This book is devoted to the symmetry of Painleve equations especially those of types II and IV The author studies families of transformations for several types of Painleve equationsQthe so called Backlund transformationsQwhich transform solutions of a given Painleve equation to solutions of the same equation with a different set of parameters It turns out that these symmetries can be interpreted in terms of root systems associated to affine Weyl groups The author describes the remarkable combinatorial structures of these symmetries and shows how they are related to the theory of tau functions associated to integrable systems **An Introduction to Methods of Complex Analysis and Geometry for Classical Mechanics and Non-linear Waves** Daniel Benest,1994 Divergent Series, Summability and Resurgence III Eric Delabaere,2016-06-28 The aim of this volume is two fold First to show how the resurgent methods introduced in volume 1 can be applied efficiently in a non linear setting to this end further properties of the resurgence theory must be developed Second to analyze the fundamental example of the First Painlev equation The resurgent analysis of singularities is pushed all the way up to the so called bridge equation which concentrates all information about the non linear Stokes phenomenon at infinity of the First Painlev equation The third in a series of three entitled Divergent Series Summability and Resurgence this volume is aimed at graduate students mathematicians and theoretical physicists who are interested in divergent power series and related problems such as the Stokes phenomenon The prerequisites are a working knowledge of complex analysis at the first year graduate level and of the theory of resurgence as presented in volume 1 *Topological Algebras and their Applications* Alexander Katz,2018-05-07 Proceedings of the 8th International Conference of Topological Algebras and Their

Applications ICTAA 2014 held on May 26 30 2014 in Playa de Villas de Mar Beach dedicated to the memory of Anastasios Mallios Athens Greece This series of conferences started in 1999 in Tartu Estonia and were subsequently held in Rabat Moroco 2000 Oulu Finland 2001 Oaxaca Mexico 2002 Bedlewo Poland 2003 Athens Greece 2005 and Tartu Estonia 2008 and 2013 The topics of the conference include all areas of mathematics connected with preferably general topological algebras and their applications including all kinds of topological algebraic structures as topological linear spaces topological rings topological modules topological groups and semigroups bornological algebraic structures such as bornological linear spaces bornological algebras bornological groups bornological rings and modules algebraic and topological K theory topological module bundles sheaves and others Contents Some results on spectral properties of unital algebras and on the algebra of linear operators on a unital algebra Descriptions of all closed maximal one sided ideals in topological algebras On non self adjoint operators defined by Riesz bases in Hilbert and rigged Hilbert spaces Functional calculus on algebras of operators generated by a self adjoint operator in Pontryagin space 1 On Gelfand Naimark type Theorems for unital abelian complex and real locally C and locally JB algebras Multipliers and strictly real topological algebras Multipliers in some perfect locally m pseudo convex algebras Wedderburn structure theorems for two sided locally m convex H algebras Homologically best modules in classical and quantized functional analysis Operator Gr ss inequality Main embedding theorems for symmetric spaces of measurable functions Mapping class groups are linear Subnormable A convex algebras Commutative BP algebras and Gelfand Naimark s theorem Discrete nonclosed subsets in maximally nondiscrete topological groups Faithfully representable topological algebras some spectral properties On continuity of complementors in topological algebras Dominated ergodic theorem for isometries of non commutative Lp spaces 1 p p 2 Ranks and the approximate n th root property of C algebras Dense ideals in topological algebras some results and open problems *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 **Discrete Painlevé Equations** Nalini Joshi,2019-05-30 Discrete Painlev equations are nonlinear difference equations which arise from translations on crystallographic lattices The deceptive simplicity of this statement hides immensely rich mathematical properties connecting dynamical systems algebraic geometry Coxeter groups topology special functions theory and mathematical physics This book necessarily starts with introductory material to give the reader an accessible entry point to this vast subject matter It is based on lectures that the author presented as principal lecturer at a Conference Board of Mathematical Sciences and National Science Foundation conference in Texas in 2016 Instead of technical theorems or complete proofs the book relies on providing essential points of many arguments through explicit examples with the hope

that they will be useful for applied mathematicians and physicists **Special Functions 2000: Current Perspective and Future Directions** Joaquin Bustoz,Mourad E.H. Ismail,Sergei Suslov,2012-12-06 The Advanced Study Institute brought together researchers in the main areas of special functions and applications to present recent developments in the theory review the accomplishments of past decades and chart directions for future research Some of the topics covered are orthogonal polynomials and special functions in one and several variables asymptotic continued fractions applications to number theory combinatorics and mathematical physics integrable systems harmonic analysis and quantum groups Painlev classification **Painlevé Equations and Related Topics** Yasin Adjabi,Tatsyana K. Andreeva,Mikhail V. Babich,Natalia V. Batkhina,Yuliya P. Bibilo,Yurii V. Brezhnev,Pantelis A. Damianou,Rustem N. Garifullin,Valentina A. Golubeva,Renat R. Gontsov,Irina V. Goryuchkina,Evgenii Gricuk,Valerii Gromak,Pavlos Xenitidis,Davide Guzzetti,Peter Zograf,Kohei Iwaki,Alexander Ya. Kazakov,Arezki Kessi,Dmitry Korotkin,Vladimir P. Leksin,Ivan P. Martynov,Dmitrii P. Novikov,Yousuke Ohyama,Anastasya V. Parusnikova,Yoshikatsu Sasaki,Sergey Yu. Slavyanov,Kouichi Takemura,Vladimir Tsegelrsquo;nik,Ilya V. Vyugin,2012-09-04 This is a proceedings of the international conference Painleve Equations and Related Topics which was taking place at the Euler International Mathematical Institute a branch of the Saint Petersburg Department of the SteklovInstitute of Mathematicsof theRussian Academy of Sciences in Saint Petersburg on June 17 to 23 2011 The survey articles discuss the following topics general ordinary differentialequations Painleve equations and their generalizations Painleve property discrete Painleve equations properties of solutions of all mentioned above equations reductions ofpartial differential equationsto Painleve equations and their generalizations ordinary differentialequation systems equivalent to Painleve equations and their generalizations and applications of the equations and the solutions **Topics In Soliton Theory And Exactly Solvable Nonlinear Equations: Proceedings Of The Conference On Nonlinear Evolution Equations, Solitons And The Inverse Scattering Transform** Mark J Ablowitz,Benno Fuchssteiner,M Kruskal,1987-06-01 The focus of this volume is to show how the various successful models of nuclear structure complement one another and can be realised as approximations appropriate in different situations to an underlying non relativistic many nucleon theory of nuclei In common with the previous volume on Foundational Models it starts with a broad survey of the relevant nuclear structure data and proceeds with two dominant themes The first is to review the many body theories and successful phenomenological models with collective and nucleon degrees of freedom The second is to show how these models relate to the underlying many nucleon shell model in its various coupling schemes Algebraic and Analytic Aspects of Integrable Systems and Painleve Equations Anton Dzhamay,Kenichi Maruno,Christopher M. Ormerod,2015-10-28 This volume contains the proceedings of the AMS Special Session on Algebraic and Analytic Aspects of Integrable Systems and Painlev Equations held on January 18 2014 at the Joint Mathematics Meetings in Baltimore MD The theory of integrable systems has been at the forefront of some of the most important developments in mathematical physics in the last 50 years The techniques to

study such systems have solid foundations in algebraic geometry differential geometry and group representation theory Many important special solutions of continuous and discrete integrable systems can be written in terms of special functions such as hypergeometric and basic hypergeometric functions The analytic tools developed to study integrable systems have numerous applications in random matrix theory statistical mechanics and quantum gravity One of the most exciting recent developments has been the emergence of good and interesting discrete and quantum analogues of classical integrable differential equations such as the Painlev equations and soliton equations Many algebraic and analytic ideas developed in the continuous case generalize in a beautifully natural manner to discrete integrable systems The editors have sought to bring together a collection of expository and research articles that represent a good cross section of ideas and methods in these active areas of research within integrable systems and their applications *Asymptotic Methods for Wave and Quantum Problems* M. V. Karasev,2003 The collection consists of four papers in different areas of mathematical physics united by the intrinsic coherence of the asymptotic methods used The papers describe both the known results and most recent achievements as well as new concepts and ideas in mathematical analysis of quantum and wave problems In the introductory paper Quantization and Intrinsic Dynamics a relationship between quantization of symplectic manifolds and nonlinear wave equations is described and discussed from the viewpoint of the weak asymptotics method asymptotics in distributions and the semiclassical approximation method It also explains a hidden dynamic geometry that arises when using these methods Three other papers discuss applications of asymptotic methods to the construction of wave type solutions of nonlinear PDE s to the theory of semiclassical approximation in particular the Whitham method for nonlinear second order ordinary differential equations and to the study of the Schrodinger type equations whose potential wells are sufficiently shallow that the discrete spectrum contains precisely one point All the papers contain detailed references and are oriented not only to specialists in asymptotic methods but also to a wider audience of researchers and graduate students working in partial differential equations and mathematical physics **Painlevé Transcendents** Athanassios S. Fokas,Alexander R. Its,Andrei A. Kapaev,Victor Yu. Novokshenov,2023-11-20 At the turn of the twentieth century the French mathematician Paul Painlev and his students classified second order nonlinear ordinary differential equations with the property that the location of possible branch points and essential singularities of their solutions does not depend on initial conditions It turned out that there are only six such equations up to natural equivalence which later became known as Painlev I VI Although these equations were initially obtained answering a strictly mathematical question they appeared later in an astonishing and growing range of applications including e g statistical physics fluid mechanics random matrices and orthogonal polynomials Actually it is now becoming clear that the Painlev transcendents i e the solutions of the Painlev equations play the same role in nonlinear mathematical physics that the classical special functions such as Airy and Bessel functions play in linear physics The explicit formulas relating the asymptotic behaviour of the classical special functions at different critical points play a crucial role in

the applications of these functions It is shown in this book that even though the six Painlev equations are nonlinear it is still possible using a new technique called the Riemann Hilbert formalism to obtain analogous explicit formulas for the Painlev transcendents This striking fact apparently unknown to Painlev and his contemporaries is the key ingredient for the remarkable applicability of these nonlinear special functions The book describes in detail the Riemann Hilbert method and emphasizes its close connection to classical monodromy theory of linear equations as well as to modern theory of integrable systems In addition the book contains an ample collection of material concerning the asymptotics of the Painlev functions and their various applications which makes it a good reference source for everyone working in the theory and applications of Painlev equations and related areas Algebraic Analysis of Differential Equations T. Aoki,H. Majima,Y. Takei,N. Tose,2009-03-15 This volume contains 23 articles on algebraic analysis of differential equations and related topics most of which were presented as papers at the conference Algebraic Analysis of Differential Equations from Microlocal Analysis to Exponential Asymptotics at Kyoto University in 2005 This volume is dedicated to Professor Takahiro Kawai who is one of the creators of microlocal analysis and who introduced the technique of microlocal analysis into exponential asymptotics

Recent Progress in Special Functions Galina Filipuk,2024-11-02 This volume contains a collection of papers that focus on recent research in the broad field of special functions The articles cover topics related to differential equations dynamic systems integrable systems billiards and random matrix theory Linear classical special functions such as hypergeometric functions Heun functions and various orthogonal polynomials and nonlinear special functions e g the Painlev transcendents and their generalizations are studied from different perspectives This volume serves as a useful reference for a large audience of mathematicians and mathematical physicists interested in modern theory of special functions It is suitable for both graduate students and specialists in the field

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Table of Contents Painlev Equations And Related Topics Painlev Equations And Related Topics

1. Understanding the eBook Painlev Equations And Related Topics Painlev Equations And Related Topics
    - The Rise of Digital Reading Painlev Equations And Related Topics Painlev Equations And Related Topics
    - Advantages of eBooks Over Traditional Books
2. Identifying Painlev Equations And Related Topics Painlev Equations And Related Topics
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Painlev Equations And Related Topics Painlev Equations And Related Topics
    - User-Friendly Interface
4. Exploring eBook Recommendations from Painlev Equations And Related Topics Painlev Equations And Related Topics
    - Personalized Recommendations

- Painlev Equations And Related Topics Painlev Equations And Related Topics User Reviews and Ratings
- Painlev Equations And Related Topics Painlev Equations And Related Topics and Bestseller Lists

5. Accessing Painlev Equations And Related Topics Painlev Equations And Related Topics Free and Paid eBooks
   - Painlev Equations And Related Topics Painlev Equations And Related Topics Public Domain eBooks
   - Painlev Equations And Related Topics Painlev Equations And Related Topics eBook Subscription Services
   - Painlev Equations And Related Topics Painlev Equations And Related Topics Budget-Friendly Options
6. Navigating Painlev Equations And Related Topics Painlev Equations And Related Topics eBook Formats
   - ePub, PDF, MOBI, and More
   - Painlev Equations And Related Topics Painlev Equations And Related Topics Compatibility with Devices
   - Painlev Equations And Related Topics Painlev Equations And Related Topics Enhanced eBook Features
7. Enhancing Your Reading Experience
   - Adjustable Fonts and Text Sizes of Painlev Equations And Related Topics Painlev Equations And Related Topics
   - Highlighting and Note-Taking Painlev Equations And Related Topics Painlev Equations And Related Topics
   - Interactive Elements Painlev Equations And Related Topics Painlev Equations And Related Topics
8. Staying Engaged with Painlev Equations And Related Topics Painlev Equations And Related Topics
   - Joining Online Reading Communities
   - Participating in Virtual Book Clubs
   - Following Authors and Publishers Painlev Equations And Related Topics Painlev Equations And Related Topics
9. Balancing eBooks and Physical Books Painlev Equations And Related Topics Painlev Equations And Related Topics
   - Benefits of a Digital Library
   - Creating a Diverse Reading Collection Painlev Equations And Related Topics Painlev Equations And Related Topics
10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
11. Cultivating a Reading Routine Painlev Equations And Related Topics Painlev Equations And Related Topics
    - Setting Reading Goals Painlev Equations And Related Topics Painlev Equations And Related Topics
    - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Painlev Equations And Related Topics Painlev Equations And Related Topics

- Fact-Checking eBook Content of Painlev Equations And Related Topics Painlev Equations And Related Topics
- Distinguishing Credible Sources

13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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