# INVARIANT OPERATORS AND UNIVALENT FUNCTIONS<sup>1</sup>

#### BY

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ABSTRACT. Necessary and sufficient conditions for univalence of meromorphic functions in certain domains in the complex plane are established in terms of some differential operators of degrees > 3, possessing the same invariance property as the Schwarzian derivative. Those operators include the derivatives of the Schwarzian derivative and Aharonov's invariants. Conditions for the existence of quasiconformal extensions are also achieved.

I. Introduction. Let  $\mathscr{C}(D)$  and  $\mathfrak{M}(D)$  denote the linear spaces of all the analytic and meromorphic functions, respectively, at a domain D in the complete complex plane  $\hat{\mathbb{C}} = \mathbb{C} \cup \{\infty\}$ , and let  $\mathfrak{M}_0(D)$  be the set of all univalent elements in  $\mathfrak{M}(D)$ . For every positive integer n let

$$(1.1^{\bullet}) \quad B_{n}^{\bullet}(D) = \left\{ \phi \in \mathscr{C}(D) \colon \|\phi\|_{n,D}^{\bullet} = \|\phi\|_{n}^{\bullet} = \sup_{z \in D} d(z, \partial D)^{n} |\phi(z)| < \infty \right\}$$

where  $d(z, \partial D)$  is the euclidean distance of z to the boundary  $\partial D$  of D. If D is a hyperbolic domain, with a hyperbolic density  $\rho_D(z) = \rho(z)$ , let

$$(1.1) B_n(D) = \left\{ \phi \in \mathcal{C}(D) \colon \|\phi\|_{\pi,D} = \|\phi\|_{\pi} = \sup_{z \in D} \rho(z)^{-n} |\phi(z)| < \infty \right\}.$$

(Here we consider the hyperbolic density  $\rho_D(z)$  with constant curvature -4, so that  $\rho_D(z) = (1 - |z|^2)^{-1}$  for the unit disc U.)

The Schwarzian differential operator

$$\mathfrak{M}(D)\ni f\mapsto \{f,z\}=\left[\left(\frac{f''}{f'}\right)'-\frac{1}{2}\left(\frac{f''}{f'}\right)^2\right](z)\in\mathfrak{M}(D)$$

is a typical invariant operator in the sense that

(1.2) 
$$\{g \circ f, z\} = \{f, z\}$$
 for every Möbius transformation  $g$ ,

and it has the following two remarkable properties:

(i) If 
$$f \in \mathfrak{R}_0(D)$$
 and  $\phi(z) = \{f, z\}$ , then  $\phi \in B_2^*(D)$  and

$$\|\phi\|_{2,D}^* \le 6$$

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<sup>&</sup>lt;sup>1</sup>This is a part of a Ph.D. Thesis, written at the Technion, Israel Institute of Technology, under the guidance of Professor Uri Srebro. My deepest thanks to Professor Uri Srebro for his useful remarks and valuable support.

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# **Univalent Functions Univalent Functions**

**Konstantin Ivanovich Babenko** 

#### **Univalent Functions Univalent Functions:**

Univalent Functions Derek K. Thomas, Nikola Tuneski, Allu Vasudevarao, 2018-04-09 The study of univalent functions dates back to the early years of the 20th century and is one of the most popular research areas in complex analysis This book is directed at introducing and bringing up to date current research in the area of univalent functions with an emphasis on the important subclasses thus providing an accessible resource suitable for both beginning and experienced researchers Contents Univalent Functions the Elementary Theory Definitions of Major Subclasses Fundamental Lemmas Starlike and Convex Functions Starlike and Convex Functions of Order Strongly Starlike and Convex Functions Alpha Convex Functions Gamma Starlike Functions Close to Convex Functions Bazilevi Functions B1 Bazilevi Functions The Class U Convolutions Meromorphic Univalent Functions Loewner Theory Other Topics Open Problems Univalent Functions. Fractional Calculus, and Their Applications H. M. Srivastava, Shigeyoshi Owa, 1989 <u>Univalent Functions - Selected Topics G.</u> Schober.2006-11-14 The Theory of Extremal Problems for Univalent Functions of Class S Konstantin Ivanovich Babenko, 1975 Discusses univalent functions and extremal problems Extremum Problems for Bounded Univalent Functions II O. Tammi.1978 Encyclopaedia of Mathematics Michiel Hazewinkel, 1993-01-31 This ENCYCLOPAEDIA OF MATHEMATICS aims to be a reference work for all parts of mathe matics It is a translation with updates and editorial comments of the Soviet Mathematical Encyclopaedia published by Soviet Encyclopaedia Publishing House in five volumes in 1977 1985 The annotated translation consists of ten volumes including a special index volume There are three kinds of articles in this ENCYCLOPAEDIA First of all there are survey type articles dealing with the various main directions in mathematics where a rather fme subdivi sion has been used The main requirement for these articles has been that they should give a reasonably complete up to date account of the current state of affairs in these areas and that they should be maximally accessible On the whole these articles should be understandable to mathematics students in their first specialization years to graduates from other mathematical areas and depending on the specific subject to specialists in other domains of science en gineers and teachers of mathematics These articles treat their material at a fairly general level and aim to give an idea of the kind of problems techniques and concepts involved in the area in question They also contain background and motivation rather than precise statements of precise theorems with detailed definitions and technical details on how to carry out proofs and constructions The second kind of article of medium length contains more detailed concrete problems results and techniques Topics in Hardy Classes and Univalent Functions Marvin Rosenblum, James Rovnyak, 2012-12-06 These notes are based on lectures given at the University of Virginia over the past twenty years They may be viewed as a course in function theory for nonspecialists Chapters 1 6 give the function theoretic background to Hardy Classes and Operator Theory Oxford Mathematical Monographs Oxford University Press New York 1985 These chapters were written first and they were originally intended to be a part of that book Half plane function theory continues to be useful for

applications and is a focal point in our account Chapters 5 and 6 The theory of Hardy and Nevanlinna classes is derived from proper ties of harmonic majorants of subharmonic functions Chapters 3 and 4 A selfcontained treatment of harmonic and subharmonic functions is included Chapters 1 and 2 Chapters 7 9 present concepts from the theory of univalent functions and Loewner families leading to proofs of the Bieberbach Robertson and Milin conjectures Their purpose is to make the work of de Branges accessible to students of operator theory These chapters are by the second author There is a high degree of independence in the chapters allowing the material to be used in a variety of ways For example Chapters 5 6 can be studied alone by readers familiar with function theory on the unit disk Chapters 7 9 have been used as the basis for a one semester topics course **Extremum Problems for Bounded Univalent Functions** Olli Tammi, 2006-11-15 <u>Univalent functions</u> Christian Pommerenke, Gerd Jensen, 1975

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