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# Functional Equations

## Part II

SHUBORNO DAS

In Part I, I explained the different techniques to solve functional equations. In most cases, the steps to solve them are similar to those in solving algebraic equations. However there is one scenario where using the algebraic method to solve a functional equation may lead to an incomplete solution; i.e., only a subset of functions that solve the FE may be identified and not the complete list. This error is known as pointwise trap. In Part II of the two-part article on functional equations, we discuss the notion of pointwise trap and learn different ways to overcome it.

### Pointwise Trap

**What is a 'pointwise trap'?** Consider the following example:

Find all functions  $f: \mathbb{R} \rightarrow \mathbb{R}$  such that  $f(x)^2 = xf(x)$ .

Factorising the equation  $f(x)^2 - xf(x) = 0$  gives  $f(x)(f(x) - x) = 0$ . Solving it like a normal equation would yield  $f(x) = 0$  for all  $x$  or  $f(x) = x$  for all  $x$ .

Is this the complete list of functions that solve the FE?

Consider a function  $f(x)$  defined as follows:  $f(x) = x$  for all  $x$  except  $f(5) = 0$ . If  $x \neq 5$ , then  $f(x) - x = 0 \implies f(x)^2 = xf(x)$ . If  $x = 5$ , then  $f(x) = 0 \implies f(x)^2 = xf(x)$ . So clearly this function also satisfies the FE. This proves that our earlier list of functions that satisfy the FE was incomplete.

It is not too difficult to deduce that there are infinitely many solutions to this FE. Refer Figure 1 as another example of such a function that satisfies the FE.

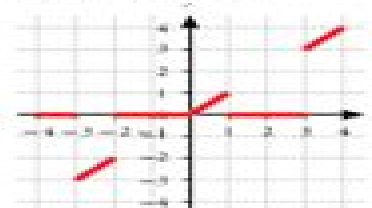


Figure 1. Example of a function solving the equation  $f(x)^2 = xf(x)$

*Keywords:* Functional equation, function, domain, range, injective, surjective, even, odd, continuous, pointwise trap, solution

# On Functions And Functional Equations

**J. Aczel, Hansjorg Oser**



## **On Functions And Functional Equations:**

**On Functions and Functional Equations** Smítal, 1988-01-01 On Functions and Functional Equations introduces the main topics in iteration theory and the theory of functional equations with emphasis on applications in the fields of mathematics physics biology chemistry and electronics and mechanical engineering The book contains many classical results as well as important more recent results It also includes numerous exercise and some problems that have yet to be resolved The book is accessible to readers having a secondary level mathematical education Lectures on Functional Equations and Their Applications J. Aczel, Hansjörg Oser, 2006-02-01 Numerous detailed proofs highlight this treatment of functional equations Starting with equations that can be solved by simple substitutions the book then moves to equations with several unknown functions and methods of reduction to differential and integral equations Also includes composite equations equations with several unknown functions of several variables vector and matrix equations more 1966 edition *Functional Equations and Modelling in Science and Engineering* Enrique Castillo, 1992-05-27 Provides engineers and applied scientists with some selected results of functional equations and their applications with the intention of changing the way they think about mathematical modelling Many of the proofs are simplified or omitted so as not to bore or confuse engineers Functional equati

**Functional Equations and How to Solve Them** Christopher G. Small, 2006-11-14 Many books have been written on the theory of functional equations but very few help readers solve functional equations in mathematics competitions and mathematical problem solving This book fills that gap Each chapter includes a list of problems associated with the covered material These vary in difficulty with the easiest being accessible to any high school student who has read the chapter carefully The most difficult will challenge students studying for the International Mathematical Olympiad or the Putnam Competition An appendix provides a springboard for further investigation of the concepts of limits infinite series and continuity

**Introduction to Functional Equations** Costas Efthimiou, 2011-10-13 Functions and their properties have been part of the rigorous precollege curriculum for decades And functional equations have been a favorite topic of the leading national and international mathematical competitions Yet the subject has not received equal attention by authors at an introductory level The majority of the books on the topic remain unreachable to the curious and intelligent precollege student The present book is an attempt to eliminate this disparity The book opens with a review chapter on functions which collects the relevant foundational information on functions plus some material potentially new to the reader The next chapter presents a working definition of functional equations and explains the difficulties in trying to systematize the theory With each new chapter the author presents methods for the solution of a particular group of equations Each chapter is complemented with many solved examples the majority of which are taken from mathematical competitions and professional journals The book ends with a chapter of unsolved problems and some other auxiliary material The book is an invaluable resource for precollege and college students who want to deepen their knowledge of functions and their properties for

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**Functional Equations in Economics** Wolfgang Eichhorn, 1978

**Functional Equations and Inequalities** Themistocles M. Rassias, 2000-07-31

Functional Equations and Inequalities provides an extensive study of some of the most important topics of current interest in functional equations and inequalities Subjects dealt with include a Pythagorean functional equation a functional definition of trigonometric functions the functional equation of the square root spiral a conditional Cauchy functional equation an iterative functional equation the Hille type functional equation the polynomial like iterative functional equation distribution of zeros and inequalities for zeros of algebraic polynomials a qualitative study of Lobachevsky's complex functional equation functional inequalities in special classes of functions replicativity and function spaces normal distributions some difference equations finite sums decompositions of functions harmonic functions set valued quasiconvex functions the problem of expressibility in some extensions of free groups Aleksandrov problem and mappings which preserve distances Ulam's problem stability of some functional equation for generalized trigonometric functions Hyers Ulam stability of Hosszil's equation superstability of a functional equation and some demand functions in a duopoly market with advertising It is a pleasure to express my deepest appreciation to all the mathematicians who contributed to this volume Finally we wish to acknowledge the superb assistance provided by the staff of Kluwer Academic Publishers June 2000 Themistocles M Rassias xi

ON THE STABILITY OF A FUNCTIONAL EQUATION FOR GENERALIZED TRIGONOMETRIC FUNCTIONS ROMAN BADORA Instytut Matematyki Uniwersytet Śląski ul Bankowa 14 PL 40 007 Katowice Poland e mail robadora@gate.math.us.edu.pl

Abstract In the present paper the stability result concerning a functional equation for generalized trigonometric functions is presented

**Functional Equations On Groups** Henrik Stetkaer, 2013-07-15 This volume provides an accessible and coherent introduction to some of the scientific progress on functional equations on groups in the last two decades It presents the latest methods of treating the topic and contains new and transparent proofs Its scope extends from the classical functional equations on the real line to those on groups in particular non abelian groups This volume presents in careful detail a number of illustrative examples like the cosine equation on the Heisenberg group and on the group  $SL(2)$  Some of the examples are not even seen in existing monographs Thus it is an essential source of reference for further investigations

**Introduction to Functional Equations** Prasanna K. Sahoo, Palaniappan Kannappan, 2011-02-08 Introduction to Functional Equations grew out of a set of class notes from an introductory graduate level course at the University of Louisville This introductory text communicates an elementary exposition of valued functional equations where the unknown functions take on real or complex values In order to make the presentation as manageable as possible

**Functional Equations and Inequalities with**

**Applications** Palaniappan Kannappan, 2009-06-10 *Functional Equations and Inequalities with Applications* presents a comprehensive nearly encyclopedic study of the classical topic of functional equations. Nowadays the field of functional equations is an ever growing branch of mathematics with far reaching applications; it is increasingly used to investigate problems in mathematical analysis, combinatorics, biology, information theory, statistics, physics, the behavioral sciences, and engineering. This self contained monograph explores all aspects of functional equations and their applications to related topics such as differential equations, integral equations, the Laplace transformation, the calculus of finite differences, and many other basic tools in analysis. Each chapter examines a particular family of equations and gives an in depth study of its applications as well as examples and exercises to support the material. The book is intended as a reference tool for any student, professional researcher, or mathematician studying in a field where functional equations can be applied. It can also be used as a primary text in a classroom setting or for self study. Finally, it could be an inspiring entrance into an active area of mathematical exploration for engineers and other scientists who would benefit from this careful, rigorous exposition.

*On Applications and Theory of Functional Equations* J. Aczél, 2014-05-12 *On Applications and Theory of Functional Equations* focuses on the principles and advancement of numerical approaches used in functional equations. The publication first offers information on the history of functional equations, noting that the research on functional equations originated in problems related to applied mathematics. The text also highlights the influence of J d'Alembert, S D Poisson, E Picard, and A L Cauchy in promoting the processes of numerical analyses involving functional equations. The role of vectors in solving functional equations is also noted. The book ponders on the international Fifth Annual Meeting on Functional Equations held in Waterloo, Ontario, Canada, on April 24-30, 1967. The meeting gathered participants from America, Asia, Australia, and Europe. One of the topics presented at the meeting focuses on the survey of materials dealing with the progress of approaches in the processes and methodologies involved in solving problems dealing with functional equations. The influence, works, and contributions of A L Cauchy, G Darboux, and G S Young to the field are also underscored. The publication is a valuable reference for readers interested in functional equations.

**Linear Functional Equations. Operator Approach** Anatolij Antonevich, 2012-12-06 In this book we shall study linear functional equations of the form  $m \sum_{k=1}^n U_k(x) f_k(x)$  where  $U$  is an unknown function from a given space  $F(X)$  of functions on a set  $X$ ,  $U_k, X$  are given mappings,  $a_k$  and  $f$  are given functions. Our approach is based on the investigation of the operators given by the left hand side of equation 1. In what follows such operators will be called functional operators. We will pay special attention to the spectral properties of functional operators, first of all to invertibility and the Noether property. Since the set  $X$ , the space  $F(X)$ , the mappings  $U_k$ , and the coefficients  $a_k$  are arbitrary, the class of operators of the form 1 is very rich and some of its individual representatives are related with problems arising in various areas of mathematics and its applications. In addition to the classical theory of functional equations, among such areas one can indicate the theory of functional differential equations with deviating argument, the theory of nonlocal

problems for partial differential equations the theory of boundary value problems for the equation of a vibrating string and equations of mixed type a number of problems of the general theory of operator algebras and the theory of dynamical systems the spectral theory of automorphisms of Banach algebras and other problems     *Functional Equations* David Leigh-Lancaster, 2006 Functional equations provides mathematics teachers with an introduction to elementary aspects of functional equations These equations are linked to function in various topics of the senior secondary mathematics curriculum including transformations identities difference equations and mathematical modelling     **Functional Equations in Several Variables** J. Aczél, J. Dhombres, 1989 This treatise deals with modern theory of functional equations in several variables and their applications to mathematics information theory and the natural behavioural and social sciences The authors have chosen to emphasize applications though not at the expense of theory so they have kept the prerequisites to a minimum

Functional Equations: History, Applications and Theory J. Aczél, 2001-11-30 Approach your problems from It isn't that they can't see the right end and begin with the solution It is that they the answers Then one day can't see the problem perhaps you will find the G K Chesterton The Scandal of final question Father Brown The Point of a Pin The Hermit Clad n Crane Feathers in R van Gulik's The Chinese Haze Murders Growing specialization and diversification have brought a host of monographs and textbooks on increasingly specialized topics However the tree of knowledge of mathematics and related fields does not grow only by putting forth new branches It also happens quite often in fact that branches which were thought to be completely disparate are suddenly seen to be related Further the kind and level of sophistication of mathematics applied in various sciences has changed drastically in recent years measure theory is used non trivially n regional and theoretical economics algebraic geometry interacts with physics the Minkowsky lemma coding theory and the structure of water meet one another in packing and covering theory quantum fields crystal defects and mathematical programming profit from homotopy theory Lie algebras are relevant to filtering and prediction and electrical engineering can use Stein spaces And in addition to this there are such new emerging subdisciplines as completely integrable systems chaos synergetics and large scale order which are almost impossible to fit into the existing classification schemes They draw upon widely different sections of mathematics     **Short Course on Functional Equations** J. Aczél, 1987 Reviews this book is not only an impressive example how mathematics can be applied to problems arising in the social and behavioral sciences but also on outstanding course on functional equations This course is short as the title says but leads astonishingly far since the material is presented very economically I am convinced that every reader will enjoy this book greatly Zeitschrift für Operations Research June 1989

**Functional Equations in Probability Theory** Ramachandran Balasubrahmanyam, Ka-Sing Lau, 2014-05-12 Functional Equations in Probability Theory deals with functional equations in probability theory and covers topics ranging from the integrated Cauchy functional equation ICfE to stable and semistable laws The problem of identical distribution of two linear forms in independent and identically distributed random variables is also considered with particular

reference to the context of the common distribution of these random variables being normal Comprised of nine chapters this volume begins with an introduction to Cauchy functional equations as well as distribution functions and characteristic functions The discussion then turns to the nonnegative solutions of ICFE on  $\mathbb{R}$  ICFE with a signed measure and application of ICFE to the characterization of probability distributions Subsequent chapters focus on stable and semistable laws ICFE with error terms on  $\mathbb{R}$  independent identically distributed linear forms and the normal laws and distribution problems relating to the arc sine the normal and the chi square laws The final chapter is devoted to ICFE on semigroups of  $\mathbb{R}^d$  This book should be of interest to mathematicians and statisticians

Stability of Functional Equations in Several Variables D.H. Hyers, G. Isac, Themistocles Rassias, 2012-12-06 The notion of stability of functional equations of several variables in the sense used here had its origins more than half a century ago when S Ulam posed the fundamental problem and Donald H Hyers gave the first significant partial solution in 1941 The subject has been revised and developed by an increasing number of mathematicians particularly during the last two decades Three survey articles have been written on the subject by D H Hyers 1983 D H Hyers and Th M Rassias 1992 and most recently by G L Forti 1995 None of these works included proofs of the results which were discussed Furthermore it should be mentioned that wider interest in this subject area has increased substantially over the last years yet the presentation of research has been confined mainly to journal articles The time seems ripe for a comprehensive introduction to this subject which is the purpose of the present work This book is the first to cover the classical results along with current research in the subject An attempt has been made to present the material in an integrated and self contained fashion In addition to the main topic of the stability of certain functional equations some other related problems are discussed including the stability of the convex functional inequality and the stability of minimum points A sad note During the final stages of the manuscript our beloved co author and friend Professor Donald H Hyers passed away

Functional Equations in Applied Sciences Enrique Castillo, Andres Iglesias, Reyes Ruiz-Cobo, 2004-11-04 The book provides the reader with the different types of functional equations that s he can find in practice showing step by step how they can be solved A general methodology for solving functional equations is provided in Chapter 2 The different types of functional equations are described and solved in Chapters 3 to 8 Many examples coming from different fields as geometry science engineering economics probability statistics etc help the reader to change his her mind in order to state problems as functional equations as an alternative to differential equations and to state new problems in terms of functional equations or systems An interesting feature of the book is that it deals with functional networks a powerful generalization of neural networks that allows solving many practical problems The second part of the book Chapters 9 to 13 is devoted to the applications of this important paradigm The book contains many examples and end of chapter exercises that facilitates the understanding of the concepts and applications A general methodology for solving functional equations is provided in Chapter 2 It deals with functional networks a powerful generalization of neural networks Many examples coming from

different fields as geometry science engineering economics probability statistics etc illustrate the concept of functional equation Functional equations are presented as a powerful alternative to differential equations The book contains end of chapter exercises     *Analytic Solutions Of Functional Equations* Sui Sun Cheng,Wenrong Li,2008-03-14 This book presents a self contained and unified introduction to the properties of analytic functions Based on recent research results it provides many examples of functional equations to show how analytic solutions can be found Unlike in other books analytic functions are treated here as those generated by sequences with positive radii of convergence By developing operational means for handling sequences functional equations can then be transformed into recurrence relations or difference equations in a straightforward manner Their solutions can also be found either by qualitative means or by computation The subsequent formal power series function can then be asserted as a true solution once convergence is established by various convergence tests and majorization techniques Functional equations in this book may also be functional differential equations or iterative equations which are different from the differential equations studied in standard textbooks since composition of known or unknown functions are involved



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this present chapter deals with the

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