

## Fluid Mechanics Tutorial No 3 Boundary Layer Theory

The contents of this book covers the material required in the Fluid Mechanics Graduate Core Course (MEEN-621) and in Advanced Fluid Mechanics, a Ph. D-level elective course (MEEN-622), both of which I have been teaching at Texas A&M University for the past two decades. While there are numerous undergraduate fluid mechanics texts on the market for engineering students and instructors to choose from, there are only limited texts that comprehensively address the particular needs of graduate engineering fluid mechanics courses. To complement the lecture materials, the instructors more often recommend several texts, each of which treats special topics of fluid mechanics. This circumstance and the need to have a textbook that covers the materials needed in the above courses gave the impetus to provide the graduate engineering community with a coherent textbook that comprehensively addresses their needs for an advanced fluid mechanics text. Although this text book is primarily aimed at mechanical engineering students, it is equally suitable for aerospace engineering, civil engineering, other engineering disciplines, and especially those practicing professionals who perform CFD-simulation on a routine basis and would like to know more about the underlying physics of the commercial codes they use. Furthermore, it is suitable for self study, provided that the reader has a sufficient knowledge of calculus and differential equations. In the past, because of the lack of advanced computational capability, the subject of fluid mechanics was artificially subdivided into inviscid, viscous (laminar, turbulent), incompressible, compressible, subsonic, supersonic and hypersonic flows.

This powerful problem-solver gives you 2,500 problems in fluid mechanics and hydraulics, fully solved step-by-step! From Schaum's, the originator of the solved-problem guide, and students' favorite with over 30 million study guides sold—this timesaver helps you master every type of fluid mechanics and hydraulics problem that you will face in your homework and on your tests, from properties of fluids to drag and lift. Work the problems yourself, then check the answers, or go directly to the answers you need using the complete index. Compatible with any classroom text, Schaum's 2500 Solved Problems in Fluid Mechanics and Hydraulics is so complete it's the perfect tool for graduate or professional exam review!

This book presents a general nonlinear control design methodology for nonlinear uncertain dynamical systems. Specifically, a hierarchical nonlinear switching control framework is developed that provides a rigorous alternative to gain scheduling control for general nonlinear uncertain systems. The proposed switching control design framework accounts for actuator saturation constraints as well as system modeling uncertainty. The efficacy of the control design approach is extensively demonstrated on aeroengine propulsion systems. In particular, dynamic models for rotating stall and surge in axial and centrifugal flow compression systems that lend themselves to the application of nonlinear control design are developed and the hierarchical switching control framework is then applied to control the aerodynamic instabilities of rotating stall and surge. For the researcher who is entering the field of hierarchical switching robust control this book provides a plethora of new research directions. Alternatively, for researchers already active in the field of hierarchical control and hybrid systems, this book can be used as a reference to a significant body of recent work. Furthermore, control practitioners involved with nonlinear control design can immensely benefit from the novel nonlinear stabilization techniques presented in the book.

Through ten editions, Fox and McDonald's Introduction to Fluid Mechanics has helped students understand the physical concepts, basic principles, and analysis methods of fluid mechanics. This market-leading textbook provides a balanced, systematic approach to mastering

critical concepts with the proven Fox-McDonald solution methodology. In-depth yet accessible chapters present governing equations, clearly state assumptions, and relate mathematical results to corresponding physical behavior. Emphasis is placed on the use of control volumes to support a practical, theoretically-inclusive problem-solving approach to the subject. Each comprehensive chapter includes numerous, easy-to-follow examples that illustrate good solution technique and explain challenging points. A broad range of carefully selected topics describe how to apply the governing equations to various problems, and explain physical concepts to enable students to model real-world fluid flow situations. Topics include flow measurement, dimensional analysis and similitude, flow in pipes, ducts, and open channels, fluid machinery, and more. To enhance student learning, the book incorporates numerous pedagogical features including chapter summaries and learning objectives, end-of-chapter problems, useful equations, and design and open-ended problems that encourage students to apply fluid mechanics principles to the design of devices and systems.

This book gathers contributions to the 20th biannual symposium of the German Aerospace Aerodynamics Association (STAB) and the German Society for Aeronautics and Astronautics (DGLR). The individual chapters reflect ongoing research conducted by the STAB members in the field of numerical and experimental fluid mechanics and aerodynamics, mainly for (but not limited to) aerospace applications, and cover both nationally and EC-funded projects. Special emphasis is given to collaborative research projects conducted by German scientists and engineers from universities, research-establishments and industries. By addressing a number of cutting-edge applications, together with the relevant physical and mathematics fundamentals, the book provides readers with a comprehensive overview of the current research work in the field. Though the book's primary emphasis is on the aerospace context, it also addresses further important applications, e.g. in ground transportation and energy.

A step-by-step guide, containing tutorial examples that serve as models for all concepts presented. This text contains properties of nearly 50 fluids, including density and viscosity data for compressed water and superheated steam, and characteristics of areas, pipes and tubing.

Computational Fluid Dynamics: An Introduction grew out of a von Karman Institute (VKI) Lecture Series by the same title first presented in 1985 and repeated with modifications every year since that time. The objective, then and now, was to present the subject of computational fluid dynamics (CFD) to an audience unfamiliar with all but the most basic numerical techniques and to do so in such a way that the practical application of CFD would become clear to everyone. A second edition appeared in 1995 with updates to all the chapters and when that printing came to an end, the publisher requested that the editor and authors consider the preparation of a third edition. Happily, the authors received the request with enthusiasm. The third edition has the goal of presenting additional updates and clarifications while preserving the introductory nature of the material. The book is divided into three parts. John Anderson lays out the subject in Part I by first describing the governing equations of fluid dynamics, concentrating on their mathematical properties which contain the keys to the choice of the numerical approach. Methods of discretizing the equations are discussed and transformation techniques and grids are presented. Two examples of numerical methods close out this part of the book: source and vortex panel methods and the explicit method. Part II is devoted to four self-contained chapters on more advanced material. Roger Grundmann treats the boundary layer equations and methods of solution.

This book presents contributions to the 19th biannual symposium of the German Aerospace Aerodynamics Association (STAB) and the German Society for Aeronautics and Astronautics (DGLR). The individual chapters reflect ongoing research conducted by the STAB members in the field of numerical and experimental fluid mechanics and aerodynamics, mainly for (but not limited to)

aerospace applications, and cover both nationally and EC-funded projects. Special emphasis is given to collaborative research projects conducted by German scientists and engineers from universities, research-establishments and industries. By addressing a number of cutting-edge applications, together with the relevant physical and mathematics fundamentals, the book provides readers with a comprehensive overview of the current research work in the field. Though the book's primary emphasis is on the aerospace context, it also addresses further important applications, e.g. in ground transportation and energy.

Parallel CFD 2000, the Twelfth in an International series of meetings featuring computational fluid dynamics research on parallel computers, was held May 22-25, 2000 in Trondheim, Norway. Following the trend of the past conferences, areas such as numerical schemes and algorithms, tools and environments, load balancing, as well as interdisciplinary topics and various kinds of industrial applications were all well represented in the work presented. In addition, for the first time in the Parallel CFD conference series, the organizing committee chose to draw special attention to certain subject areas by organizing a number of special sessions. We feel the emphasis of the papers presented at the conference reflect the direction of the research within parallel CFD at the beginning of the new millennium. It seems to be a clear tendency towards increased industrial exploitation of parallel CFD. Several presentations also demonstrated how new insight is being achieved from complex simulations, and how powerful parallel computers now make it possible to use CFD within a broader interdisciplinary setting. Obviously, successful application of parallel CFD still rests on the underlying fundamental principles. Therefore, numerical algorithms, development tools, and parallelization techniques are still as important as when parallel CFD was in its infancy. Furthermore, the novel concepts of affordable parallel computing as well as metacomputing show that exciting developments are still taking place. As is often pointed out however, the real power of parallel CFD comes from the combination of all the disciplines involved: Physics, mathematics, and computer science. This is probably one of the principal reasons for the continued popularity of the Parallel CFD Conferences series, as well as the inspiration behind much of the excellent work carried out on the subject. We hope that the papers in this book, both on an individual basis and as a whole, will contribute to that inspiration. Further details of Parallel CFD'99, as well as other conferences in this series, are available at <http://www.parcfd.org>

Applied Research in Hydraulics and Heat Flow covers modern subjects of mechanical engineering such as fluid mechanics, heat transfer, and flow control in complex systems as well as new aspects related to mechanical engineering education. The chapters help to enhance the understanding of both the fundamentals of mechanical engineering and their application to the solution of problems in modern industry. The book includes the most popular applications-oriented approach to engineering fluid mechanics and heat transfer. It offers a clear and practical presentation of all basic principles of fluid mechanics and heat transfer, tying theory directly to real devices and systems used in mechanical and chemical engineering. It presents new procedures for problem-solving and design, including measurement devices and computational fluid mechanics and heat transfer. This book is suitable for students, both in upper-level undergraduate and graduate mechanical engineering courses. The book also serves as a useful reference for academics, hydraulic engineers, and professionals in fields related to mechanical engineering who want to review

basic principles and their applications in hydraulic engineering systems. This fundamental treatment of engineering hydraulics balances theory with practical design solutions to common engineering problems. The authors examine the most common topics in hydraulics, including hydrostatics, pipe flow, pipelines, pipe networks, pumps, hydraulic structures, water measurement devices, and hydraulic similitude and model studies. A glossary of terms, case studies, list of abbreviations, and recent references are included.

The first volume of CFD Review was published in 1995. The purpose of this new publication is to present comprehensive surveys and review articles which provide up-to-date information about recent progress in computational fluid dynamics, on a regular basis. Because of the multidisciplinary nature of CFD, it is difficult to cope with all the important developments in related areas. There are at least ten regular international conferences dealing with different aspects of CFD. It is a real challenge to keep up with all these activities and to be aware of essential and fundamental contributions in these areas. It is hoped that CFD Review will help in this regard by covering the state-of-the-art in this field. The present book contains sixty-two articles written by authors from the US, Europe, Japan and China, covering the main aspects of CFD. There are five sections: general topics, numerical methods, flow physics, interdisciplinary applications, parallel computation and flow visualization. The section on numerical methods includes grids, schemes and solvers, while that on flow physics includes incompressible and compressible flows, hypersonics and gas kinetics as well as transition and turbulence. This book should be useful to all researchers in this fast-developing field.

Written in a clear and simple style, this textbook on fluid mechanics gives equal emphasis to both geophysical and engineering fluid mechanics. For physicists, it contains chapters on geophysical fluid mechanics and gravity waves; for engineers, it has chapters on aerodynamics and compressible flow. Of common interest are chapters on governing equations, laminar flows, boundary layers, instability, and turbulence. This book also presents topics of recent interest, such as deterministic chaos, and double-diffusive instability.

- Gives equal treatment to topics in both engineering and geophysical fluid dynamics
- Suitable as an intermediate or graduate course textbook for students in their senior year or above
- Treats topics of recent interest such as deterministic chaos, double diffusive instability and soliton
- Extensively illustrated
- Contains fully worked examples in each chapter as well as end-of-chapter problems
- An instructor's manual is available

Fluid mechanics, the study of how fluids behave and interact under various forces and in various applied situations—whether in the liquid or gaseous state or both—is introduced and comprehensively covered in this widely adopted text. Fully revised and updated with the addition of a new chapter on biofluid mechanics, Fluid Mechanics, Fourth Edition is suitable for both a first or second course in fluid mechanics at the graduate or advanced undergraduate level. The leading advanced general text on fluid mechanics, Fluid Mechanics, 4e guides students from the fundamentals to the analysis and application of fluid mechanics, including compressible flow and such diverse applications as hydraulics and aerodynamics. Updates to several chapters and sections, including Boundary Layers, Turbulence, Geophysical Fluid Dynamics, Thermodynamics and Compressibility. Fully revised and updated chapter on Computational Fluid Dynamics. New chapter on Biofluid Mechanics by Professor Portonovo

Ayyaswamy, the Asa Whitney Professor of Dynamical Engineering at the University of Pennsylvania. New Visual Resources appendix provides a list of fluid mechanics films available for viewing online. Additional worked-out examples and end-of-chapter problems. Updated online Solutions Manual for adopting instructors.

A groundbreaking textbook on twenty-first-century fluids and elastic solids and their applications Kip Thorne and Roger Blandford's monumental Modern Classical Physics is now available in five stand-alone volumes that make ideal textbooks for individual graduate or advanced undergraduate courses on statistical physics; optics; elasticity and fluid dynamics; plasma physics; and relativity and cosmology. Each volume teaches the fundamental concepts, emphasizes modern, real-world applications, and gives students a physical and intuitive understanding of the subject. Elasticity and Fluid Dynamics provides an essential introduction to these subjects. Fluids and elastic solids are everywhere—from Earth's crust and skyscrapers to ocean currents and airplanes. They are central to modern physics, astrophysics, the Earth sciences, biophysics, medicine, chemistry, engineering, and technology, and this centrality has intensified in recent years—so much so that a basic understanding of the behavior of elastic solids and fluids should be part of the repertoire of every physicist and engineer and almost every other natural scientist. While both elasticity and fluid dynamics involve continuum physics and use similar mathematical tools and modes of reasoning, each subject can be readily understood without the other, and the book allows them to be taught independently, with the first two chapters introducing and covering elasticity and the last six doing the same for fluid dynamics. The book also can serve as supplementary reading for many other courses, including in astrophysics, geophysics, and aerodynamics. Includes many exercise problems Features color figures, suggestions for further reading, extensive cross-references, and a detailed index Optional "Track 2" sections make this an ideal book for a one-quarter or one-semester course in elasticity, fluid dynamics, or continuum physics An online illustration package is available to professors The five volumes, which are available individually as paperbacks and ebooks, are Statistical Physics; Optics; Elasticity and Fluid Dynamics; Plasma Physics; and Relativity and Cosmology.

This book offers timely insights into research on numerical and experimental fluid mechanics and aerodynamics, mainly for (but not limited to) aerospace applications. It reports on findings by members of the STAB (German Aerospace Aerodynamics Association) and DGLR (German Society for Aeronautics and Astronautics) and covers both nationally and EC-funded projects. Continuing on the tradition of the previous volumes, the book highlights innovative solutions, promoting translation from fundamental research to industrial applications. It addresses academics and professionals in the field of aeronautics, astronautics, ground transportation, and energy alike. .

This book is for engineers and students to solve issues concerning the fluidized bed systems. It presents an analysis that focuses directly on the problem of predicting the fluid dynamic behavior which empirical data is limited or unavailable. The second objective is to provide a treatment of computational fluidization dynamics that is readily accessible to the non-

specialist. The approach adopted in this book, starting with the formulation of predictive expressions for the basic conservation equations for mass and momentum using kinetic theory of granular flow. The analyses presented in this book represent a body of simulations and experiments research that has appeared in numerous publications over the last 20 years. This material helps to form the basis for university course modules in engineering and applied science at undergraduate and graduate level, as well as focused, post-experienced courses for the process, and allied industries. It is a long way from the first edition in 1976 to the present sixth edition in 1995. This edition is dedicated to the memory of Prof. S.P. Luthra (Once Head, Applied Mechanics Director, IIT Delhi) who wrote the foreword to its first edition. So many faculty members and students from different parts of the country and from abroad have accepted the text and contributed to its development. The book has been improved and updated with every edition.

Fluid Mechanics Elsevier

If you want top grades and excellent understanding of fluid mechanics and hydraulics, this powerful study tool is the best tutor you can have! It takes you step-by-step through the subject and gives you accompanying related problems with fully worked solutions. You also get hundreds of additional problems to solve on your own, working at your own speed. This superb Outline clearly presents every aspect of fluid mechanics and hydraulics. Famous for their clarity, wealth of illustrations and examples, and lack of dreary minutiae, Schaum's Outlines have sold more than 30 million copies worldwide. Compatible with any textbook, this Outline is also perfect for self-study. For better grades in courses covering fluid mechanics and hydraulics—*you can't do better than this Schaum's Outline!*

Basic knowledge about fluid mechanics is required in various areas of water resources engineering such as designing hydraulic structures and turbomachinery. The applied fluid mechanics laboratory course is designed to enhance civil engineering students' understanding and knowledge of experimental methods and the basic principle of fluid mechanics and apply those concepts in practice. The lab manual provides students with an overview of ten different fluid mechanics laboratory experiments and their practical applications. The objective, practical applications, methods, theory, and the equipment required to perform each experiment are presented. The experimental procedure, data collection, and presenting the results are explained in detail. LAB

Summary and general methods of constructing static and dynamic equations, dealing with the laws of mechanics for heated elastic solids, forms of aerodynamic operators, structural operators, much more. 1962 edition.

This volume contains notes for 21 of the 22 major 16-mm sound films prepared under the direction of the NCFMF and covering nearly all of the fundamental phenomena of fluid motions.

The book aims at providing to master and PhD students the basic knowledge in fluid mechanics for chemical engineers. Applications to mixing

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and reaction and to mechanical separation processes are addressed. The first part of the book presents the principles of fluid mechanics used by chemical engineers, with a focus on global theorems for describing the behavior of hydraulic systems. The second part deals with turbulence and its application for stirring, mixing and chemical reaction. The third part addresses mechanical separation processes by considering the dynamics of particles in a flow and the processes of filtration, fluidization and centrifugation. The mechanics of granular media is finally discussed.

We inhabit a world of fluids, including air (a gas), water (a liquid), steam (vapour) and the numerous natural and synthetic fluids which are essential to modern-day life. Fluid mechanics concerns the way fluids flow in response to imposed stresses. The subject plays a central role in the education of students of mechanical engineering, as well as chemical engineers, aeronautical and aerospace engineers, and civil engineers. This textbook includes numerous examples of practical applications of the theoretical ideas presented, such as calculating the thrust of a jet engine, the shock- and expansion-wave patterns for supersonic flow over a diamond-shaped aerofoil, the forces created by liquid flow through a pipe bend and/or junction, and the power output of a gas turbine. The first ten chapters of the book are suitable for first-year undergraduates. The latter half covers material suitable for fluid-mechanics courses for upper-level students. Although knowledge of calculus is essential, this text focuses on the underlying physics. The book emphasizes the role of dimensions and dimensional analysis, and includes more material on the flow of non-Newtonian liquids than is usual in a general book on fluid mechanics — a reminder that the majority of synthetic liquids are non-Newtonian in character.

With this second revised and extended edition, the readers have a solid source of information for designing state-of-the-art turbomachinery components and systems at hand. Based on fundamental principles of turbomachinery thermo-fluid mechanics, numerous CFD based calculation methods are being developed to simulate the complex 3-dimensional, highly unsteady turbulent flow within turbine or compressor stages. The objective of this book is to present the fundamental principles of turbomachinery fluid-thermodynamic design process of turbine and compressor components, power generation and aircraft gas turbines in a unified and compact manner. The book provides senior undergraduate students, graduate students and engineers in the turbomachinery industry with a solid background of turbomachinery flow physics and performance fundamentals that are essential for understanding turbomachinery performance and flow complexes. While maintaining the unifying character of the book structure in this second revised and extended edition all chapters have undergone a rigorous update and enhancement. Accounting for the need of the turbomachinery community, three chapters have been added, that deal with computationally relevant aspects of turbomachinery design such as boundary layer transition, turbulence and boundary layer.

"Fluid Machinery and Fluid Mechanics: 4th International Symposium (4th ISFMFE)" is the proceedings of 4th International Symposium on Fluid Machinery and Fluid Engineering, held in Beijing November 24-27, 2008. It contains 69 highly informative technical papers presented at the Mei Lecture session and the technical sessions of the symposium. The Chinese Society of Engineering Thermophysics (CSET) organized the First, the Second and the Third International Symposium on Fluid Machinery and Fluid Engineering (1996, 2000 and 2004). The purpose of the 4th Symposium is to provide a common forum for exchange of scientific and technical information worldwide on fluid machinery and fluid engineering for scientists and engineers. The main subject of this symposium is "Fluid Machinery for Energy Conservation". The "Mei Lecture" reports on the most recent developments of fluid machinery in commemoration of the late professor Mei Zuyan. The book is intended for researchers and engineers in fluid machinery and fluid engineering. Jianzhong Xu is a professor at the Chinese Society of Engineering Thermophysics, Chinese Academy of Sciences, Beijing.

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Modern Fluid Dynamics, Second Edition provides up-to-date coverage of intermediate and advanced fluids topics. The text emphasizes fundamentals and applications, supported by worked examples and case studies. Scale analysis, non-Newtonian fluid flow, surface coating, convection heat transfer, lubrication, fluid-particle dynamics, microfluidics, entropy generation, and fluid-structure interactions are among the topics covered. Part A presents fluids principles, and prepares readers for the applications of fluid dynamics covered in Part B, which includes computer simulations and project writing. A review of the engineering math needed for fluid dynamics is included in an appendix.

Written by experts in the field, this book, "Boundary Layer Flows - Theory, Applications, and Numerical Methods" provides readers with the opportunity to explore its theoretical and experimental studies and their importance to the nonlinear theory of boundary layer flows, the theory of heat and mass transfer, and the dynamics of fluid. With the theory's importance for a wide variety of applications, applied mathematicians, scientists, and engineers - especially those in fluid dynamics - along with engineers of aeronautics, will undoubtedly welcome this authoritative, up-to-date book.

Exploring new variations of classical methods as well as recent approaches appearing in the field, Computational Fluid Dynamics demonstrates the extensive use of numerical techniques and mathematical models in fluid mechanics. It presents various numerical methods, including finite volume, finite difference, finite element, spectral, smoothed particle hydrodynamics (SPH), mixed-element-volume, and free surface flow. Taking a unified point of view, the book first introduces the basis of finite volume, weighted residual, and spectral approaches. The contributors present the SPH method, a novel approach of computational fluid dynamics based on the mesh-free technique, and then improve the method using an arbitrary Lagrange Euler (ALE) formalism. They also explain how to improve the accuracy of the mesh-free integration procedure, with special emphasis on the finite volume particle method (FVPM). After describing numerical algorithms for compressible computational fluid dynamics, the text discusses the prediction of turbulent complex flows in environmental and engineering problems. The last chapter explores the modeling and numerical simulation of free surface flows, including future behaviors of glaciers. The diverse applications discussed in this book illustrate the importance of numerical methods in fluid mechanics. With research continually evolving in the field, there is no doubt that new techniques and tools will emerge to offer greater accuracy and speed in solving and analyzing even more fluid flow problems.

The multidisciplinary field of fluid mechanics is one of the most actively developing fields of physics, mathematics and engineering. In this book, the fundamental ideas of fluid mechanics are presented from a physics perspective. Using examples taken from everyday life, from hydraulic jumps in a kitchen sink to Kelvin–Helmholtz instabilities in clouds, the book provides readers with a better understanding of the world around them. It teaches the art of fluid-mechanical estimates and shows how the ideas and methods developed to study the mechanics of fluids are used to analyze other systems with many degrees of freedom in statistical physics and field theory. Aimed at undergraduate and graduate



students, the book assumes no prior knowledge of the subject and only a basic understanding of vector calculus and analysis. It contains 32 exercises of varying difficulties, from simple estimates to elaborate calculations, with detailed solutions to help readers understand fluid mechanics.

This collection of over 200 detailed worked exercises adds to and complements the textbook "Fluid Mechanics" by the same author, and, at the same time, illustrates the teaching material via examples. The exercises revolve around applying the fundamental concepts of "Fluid Mechanics" to obtain solutions to diverse concrete problems, and, in so doing, the students' skill in the mathematical modelling of practical problems is developed. In addition, 30 challenging questions WITHOUT detailed solutions have been included. While lecturers will find these questions suitable for examinations and tests, students themselves can use them to check their understanding of the subject.

This is the most comprehensive introductory graduate or advanced undergraduate text in fluid mechanics available. It builds from the fundamentals, often in a very general way, to widespread applications to technology and geophysics. In most areas, an understanding of this book can be followed up by specialized monographs and the research literature. The material added to this new edition will provide insights gathered over 45 years of studying fluid mechanics. Many of these insights, such as universal dimensionless similarity scaling for the laminar boundary layer equations, are available nowhere else. Likewise for the generalized vector field derivatives. Other material, such as the generalized stream function treatment, shows how stream functions may be used in three-dimensional flows. The CFD chapter enables computations of some simple flows and provides entrée to more advanced literature. \*New and generalized treatment of similar laminar boundary layers. \*Generalized treatment of streamfunctions for three-dimensional flow. \*Generalized treatment of vector field derivatives. \*Expanded coverage of gas dynamics. \*New introduction to computational fluid dynamics. \*New generalized treatment of boundary conditions in fluid mechanics. \*Expanded treatment of viscous flow with more examples.

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