

# Laminar viscous flow

**Definition:**  $\eta$  = viscosity (Pa-s)

How can you measure it?

**Stokes' law:**

$$F = 6\pi\eta r_{\text{sphere}} v$$

Force required to move a sphere through a viscous fluid with velocity  $v$ .

**Falling sphere:**

$$v_{\text{terminal}} = 2(\rho_{\text{sphere}} - \rho_{\text{fluid}})(r_{\text{sphere}})^2 g / (9\eta)$$

Consequences?

**Poiseuille's law** gives rate at which a fluid flows through a hose or a pipe.

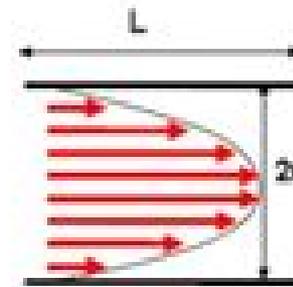
$$Q = \pi \Delta P r^4 / (8\eta L)$$

$Q$  = volume flow rate

$\Delta P$  = pressure difference across  $L$  of the pipe

$r$  = radius of the pipe

A thin boundary layer of fluid next to a walls does not move at all.



Ideal Flow



Viscous flow

# Laminar Viscous Flow

**Yong Kweon Suh**



## **Laminar Viscous Flow:**

*Laminar Viscous Flow* V.N. Constantinescu, 2012-12-06 Mechanical engineering an engineering discipline born of the needs of the industrial revolution is once again asked to do its substantial share in the call for industrial renewal The general call is urgent as we face profound issues of productivity and competitiveness that require engineering solutions among others The Mechanical Engineering Series is a series featuring graduate texts and research monographs intended to address the need for information in contemporary areas of mechanical engineering The series is conceived as a comprehensive one that covers a broad range of concentrations important to mechanical engineering graduate education and research We are fortunate to have a distinguished roster of consulting editors each an expert in one of the areas of concentration The names of the consulting editors are listed on the following page of this volume The areas of concentration are applied mechanics biomechanics computational mechanics dynamic systems and control energetics mechanics of materials processing thermal science and tribology Professor Winer the consulting editor for tribology and I are pleased to present this volume of the series *Laminar Viscous Flow* by Professor Constantinescu The selection of this volume underscores again the interest of the Mechanical Engineering Series to provide our readers with topical monographs as well as graduate texts

*Viscous Flow Theory* Shih-I. Pai, 1956      **Viscous Flow Theory: Laminar flow** Shiyi Bai, 1956      *On Laminar Viscous Flow in a Corner* Yong Kweon Suh, 1986      **Viscous Flow Theory, Vol.1. Laminar Flow** S-I. Pai, 1956      **Laminar Viscous Flow in Flexible-elastic Tubes** Melvin Richard Brashears, 1969      *Homogenous Turbulence and Laminar Viscous Flow* J. R. A. Pearson, University of Cambridge, 1957      **Viscous Fluid Flow** Frank M. White, 1974 Frank White's *Viscous Fluid Flow* Third Edition continues to be the market leader in this course area The text is for a senior graduate level elective in Mechanical Engineering and has a strong professional and international appeal Author Frank White is has a strong reputation in the field his book is accurate conceptually strong and contains excellent problem sets Many of the problems are new to this third edition a rarity among senior and graduate level textbooks The references found in the text have been updated and reflect the most current information available Users will also be interested to find explanations of and references to ongoing controversies and trends in this course area Topically speaking the text contains modern information on technological advances such as Micro and Nano technology Turbulence Modeling Computational Fluid Dynamics CFD and Unsteady Boundary Layers

**Three-Dimensional Attached Viscous Flow** Ernst Heinrich Hirschel, Jean Cousteix, Wilhelm Kordulla, 2013-10-29 Viscous flow is treated usually in the frame of boundary layer theory and as two dimensional flow Books on boundary layers give at most the describing equations for three dimensional boundary layers and solutions often only for some special cases This book provides basic principles and theoretical foundations regarding three dimensional attached viscous flow Emphasis is put on general three dimensional attached viscous flows and not on three dimensional boundary layers This wider scope is necessary in view of the theoretical and practical problems to be mastered in practice The topics

are weak strong and global interaction the locality principle properties of three dimensional viscous flow thermal surface effects characteristic properties wall compatibility conditions connections between inviscid and viscous flow flow topology quasi one and two dimensional flows laminar turbulent transition and turbulence Though the primary flight speed range is that of civil air transport vehicles flows past other flying vehicles up to hypersonic speeds are also considered Emphasis is put on general three dimensional attached viscous flows and not on three dimensional boundary layers as this wider scope is necessary in view of the theoretical and practical problems that have to be overcome in practice The specific topics covered include weak strong and global interaction the locality principle properties of three dimensional viscous flows thermal surface effects characteristic properties wall compatibility conditions connections between inviscid and viscous flows flow topology quasi one and two dimensional flows laminar turbulent transition and turbulence Detailed discussions of examples illustrate these topics and the relevant phenomena encountered in three dimensional viscous flows The full governing equations reference temperature relations for qualitative considerations and estimations of flow properties and coordinates for fuselages and wings are also provided Sample problems with solutions allow readers to test their understanding

**Solutions to Three Laminar Viscous Flow Problems by an Implicit Finite-difference Method** Wei Jao Chyu,1965

**Fundamentals of Fluid Mechanics** Joseph A. Schetz,Allen E. Fuhs,1999 Basic fluid dynamic theory and applications in a single authoritative reference The growing capabilities of computational fluid dynamics and the development of laser velocimeters and other new instrumentation have made a thorough understanding of classic fluid theory and laws more critical today than ever before Fundamentals of Fluid Mechanics is a vital repository of essential information on this crucial subject It brings together the contributions of recognized experts from around the world to cover all of the concepts of classical fluid mechanics from the basic properties of liquids through thermodynamics flow theory and gas dynamics With answers for the practicing engineer and real world insights for the student it includes applications from the mechanical civil aerospace chemical and other fields Whether used as a refresher or for first time learning Fundamentals of Fluid Mechanics is an important new asset for engineers and students in many different disciplines *Homogeneous turbulence and laminar viscous flow* J. R. A. Pearson,1957

**Fundamentals of Ship Hydrodynamics** Lothar Birk,2019-06-10 Fundamentals of Ship Hydrodynamics Fluid Mechanics Ship Resistance and Propulsion Lothar Birk University of New Orleans USA Bridging the information gap between fluid mechanics and ship hydrodynamics Fundamentals of Ship Hydrodynamics is designed as a textbook for undergraduate education in ship resistance and propulsion The book provides connections between basic training in calculus and fluid mechanics and the application of hydrodynamics in daily ship design practice Based on a foundation in fluid mechanics the origin use and limitations of experimental and computational procedures for resistance and propulsion estimates are explained The book is subdivided into sixty chapters providing background material for individual lectures The unabridged treatment of equations and the extensive use of figures and examples enable students to study

details at their own pace Key features Covers the range from basic fluid mechanics to applied ship hydrodynamics Subdivided into 60 succinct chapters In depth coverage of material enables self study Around 250 figures and tables Fundamentals of Ship Hydrodynamics is essential reading for students and staff of naval architecture ocean engineering and applied physics The book is also useful for practicing naval architects and engineers who wish to brush up on the basics prepare for a licensing exam or expand their knowledge

**Study of Laminar Incompressible Viscous Flow Near the Sharp Trailing Edge** U. C. Paek, CALIFORNIA UNIV BERKELEY DIV OF AERONAUTICAL SCIENCES., 1969 The region around the sharp corner in laminar viscous flow is studied for high Reynolds number In order to avoid handling the full Navier Stokes equations the flow variables are expressed in the form of the asymptotic expansions the first terms of which are solutions to separate local governing equations for each region To reduce the computational details the Blasius boundary layer approaching the corner is approximated by a simple shear flow The rotational inviscid flow region surrounding the corner becomes a well posed boundary value problem for an elliptic partial differential equation The thin viscous sub layer lying inside the rotational inviscid region can be solved by Thwaites approximate method to calculate such parameters as skin friction and momentum thickness In the immediate vicinity of the corner point Weinbaum s theory is used to investigate the nature of the flow Author *Engineering Fluid Mechanics* William Graebel, 2001-01-19 Fluid mechanics is a core component of many undergraduate engineering courses It is essential for both students and lecturers to have a comprehensive highly illustrated textbook full of exercises problems and practical applications to guide them through their study and teaching *Engineering Fluid Mechanics* By William P Grabel is that book The ISE version of this comprehensive text is especially priced for the student market and is an essential textbook for undergraduates particularly those on mechanical and civil engineering courses designed to emphasis the physical aspects of fluid mechanics and to develop the analytical skills and attitudes of the engineering student Example problems follow most of the theory to ensure that students easily grasp the calculations step by step processes outline the procedure used so as to improve the students problem solving skills An Appendix is included to present some of the more general considerations involved in the design process The author also links fluid mechanics to other core engineering courses an undergraduate must take heat transfer thermodynamics mechanics of materials statistics and dynamics wherever possible to build on previously learned knowledge

**Computations of the Magnus Effect for Slender Bodies in Supersonic Flow** Walter B. Sturek, Lewis B. Schiff, 1981 A recently reported Parabolized Navier Stokes code has been employed to compute the supersonic flow field about spinning cone ogive cylinder and boattailed bodies of revolution at moderate incidence The computations were performed for flow conditions where extensive measurements for wall pressure boundary layer velocity profiles and Magnus force had been obtained Comparisons between the computational results and experiment indicate excellent agreement for angles of attack up to 6 deg The comparisons for Magnus effects show that the code accurately predicts the effects of body shape and Mach

number for the selected models for the selected models for 2      *Boundary Element Methods in Nonlinear Fluid Dynamics* P.K. Banerjee, L. Morino, 1990-05-31 This volume demonstrates that boundary element methods are both elegant and efficient in their application to time dependent time harmonic problems in engineering and therefore worthy of considerable development

**Fluid Mechanics** Kamlesh Purohit, S.P. Harsha, R.K. Purohit, 2012-01-01 The material in the book has been presented in a very simple but effective language in order to enable students to master the subject matter thoroughly without coming across the hurdle of highly technical language Needless to emphasise this book has been designed as a self learning capsule With this aim the material has been organised in a logical order with lots of illustrative examples to enable students to thoroughly master the subject

*A User's Guide to Vacuum Technology* John F. O'Hanlon, 2005-02-18 In the decade and a half since the publication of the Second Edition of *A User's Guide to Vacuum Technology* there have been many important advances in the field including spinning rotor gauges dry mechanical pumps magnetically levitated turbo pumps and ultraclean system designs These along with improved cleaning and assembly techniques have made contamination free manufacturing a reality Designed to bridge the gap in both knowledge and training between designers and end users of vacuum equipment the Third Edition offers a practical perspective on today's vacuum technology With a focus on the operation understanding and selection of equipment for industrial processes used in semiconductor optics packaging and related coating technologies *A User's Guide to Vacuum Technology* Third Edition provides a detailed treatment of this important field While emphasizing the fundamentals and touching on significant topics not adequately covered elsewhere the text avoids topics not relevant to the typical user

**Introduction to Fluid Mechanics** James A. Fay, 1994 *Introduction to Fluid Mechanics* is a mathematically efficient introductory text for a basal course in mechanical engineering More rigorous than existing texts in the field it is also distinguished by the choice and order of subject matter its careful derivation and explanation of the laws of fluid mechanics and its attention to everyday examples of fluid flow and common engineering applications Beginning with the simple and proceeding to the complex the text introduces the principles of fluid mechanics in orderly steps At each stage practical engineering problems are solved principally in engineering systems such as dams pumps turbines pipe flows propellers and jets but with occasional illustrations from physiological and meteorological flows The approach builds on the student's experience with everyday fluid mechanics showing how the scientific principles permit a quantitative understanding of what is happening and provide a basis for designing engineering systems that achieve the desired objectives *Introduction to Fluid Mechanics* differs from most engineering texts in several respects The derivations of the fluid principles especially the conservation of energy are complete and correct but concisely given through use of the theorems of vector calculus This saves considerable time and enables the student to visualize the significance of these principles More attention than usual is given to unsteady flows and their importance in pipe flow and external flows Finally the examples and exercises illustrate real engineering situations including physically realistic values of the problem variables

Many of these problems require calculation of numerical values giving the student experience in judging the correctness of his or her numerical skills

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