Click Here

Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. How can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Favorites

A ready section for the researcher to input the list abbreviations and symbols List of Greek Symbols The following album gives the PhD a hint to how a list of symbols should look like: Unless otherwise noted, all content on this site is @Copyright by Ahmed Al Makky 2012-2016 - 2025 Copyright. All Rights Reserved Privacy Policy Application Areas of Fluid Mechanics It is important to develop a good understanding of the basic principles of fluid mechanics, since fluid mechanics is widely used both in everyday activities and in the design of modern engineering systems from vacuum cleaners to supersonic aircraft. For example, fluid mechanics plays a vital role in the human body. The heart is constantly pumping blood to all parts of the human body through the arteries and veins, and the lungs are the sites of airflow in alternating directions. All artificial hearts, breathing machines, and dialysis systems are designed using fluid dynamics (Fig. 1–7). An ordinary house is, in some respects, an exhibition hall filled with applications of fluid mechanics. The piping systems for water, natural gas, and sewage for an individual house and the entire city are designed primarily on the basis of fluid mechanics. The same is also true for the piping and ducting network of heating and air-conditioning systems. A refrigerator involves tubes through which the refrigerant flows, a compressor that pressurizes the refrigerant, and two heat exchangers where the refrigerant absorbs and rejects heat. Fluid mechanics plays a major role in the design of all these components. Even the operation of ordinary faucets is based on fluid mechanics. We can also see numerous applications of fluid mechanics in an automobile. All components associated with the transportation of the fuel from the fuel tank to the cylinders—the fuel line, fuel pump, and fuel injectors or carburetors—as well as the mixing of the fuel and the air in the cylinders and the purging of combustion gases in exhaust pipes—are analyzed using fluid mechanics. Fluid mechanics is also used in the design of the heating and air-conditioning system, the hydraulic brakes, the power steering, the automatic transmission, the lubrication systems, the cooling system of the engine block including the radiator and the water pump, and even the tires. The sleek streamlined shape of recent model cars is the result of efforts to minimize drag by using extensive analysis of flow over surfaces. On a broader scale, fluid mechanics plays a major part in the design and analysis of aircraft, boats, submarines, rockets, jet engines, wind turbines, biomedical devices, cooling systems for electronic components, and transportation systems for moving water, crude oil, and natural gas. It is also considered in the design of buildings, bridges, and even billboards to make sure that the structures can withstand wind loading. Numerous natural phenomena such as the rain cycle, weather patterns, the rise of ground water to the tops of trees, winds, ocean waves, and currents in large water bodies are also governed by the principles of fluid mechanics (Fig. 1–8). THE NO-SLIP CONDITION Fluid flow is often confined by solid surfaces, and it is important to understand how the presence of solid surfaces affects fluid flow. We know that water in a river cannot flow through large rocks, and must go around them. That is, the water velocity normal to the rock surface must be zero, and water approaching the surface normally comes to a complete stop at the surface. What is not as obvious is that water approaching the rock at any angle also comes to a complete stop at the rock surface, and thus the tangential velocity of water at the surface is also zero. Consider the flow of a fluid in a stationary pipe or over a solid surface that is nonporous (i.e., impermeable to the fluid). All experimental observations indicate that a fluid in motion comes to a complete stop at the surfaceand assumes a zero velocity relative to the surface. That is, a fluid in direct contact with a solid "sticks" to the surface, and there is no slip. This is known as the no-s... CLASSIFICATION OF FLUID FLOWS Earlier we defined fluid mechanics as the science that deals with the behavior of fluids at rest or in motion, and the interaction of fluids with solids or other fluids at the boundaries. There is a wide variety of fluid flow problems encountered in practice, and it is usually convenient to classify them on the basis of some common characteristics to make it feasible to study them in groups. There are many ways to classify fluid flow problems, and here we present some general categorie Viscous versus Inviscid Regions of Flow When two fluid layers move relative to each other, a friction force develops between them and the slower layer tries to slow down the faster layer. This internal resistance to flow is quantified by the fluid property viscosity, which is a measure of internal stickiness of the fluid. Viscosity is caused by cohesive forces between the molecules in liquids and by molecular collisions in gases. There is no fluid with zero visc... Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Get full access to Fluid Mechanics and Hydraulic Machines and 60K+ other titles, with a free 10-day trial of O'Reilly. There are also live events, courses curated by job role, and more. Symbols Used SI units A, δA Surface area m2 B Body force N a Acoustic velocity m/s f Friction coefficient F Force N Fr Froude number = g Earth's gravity m/s2 h, H Head, distance m I Second moment of area m4 k Source/sink strength m2/s L Characteristic length m m, δm mass kg M Mach number = U/a N RPM rad/s p Pressure N/m2 r, R radial distance m Re Reynolds number = UL/n t Time s T Torque Nm u, v, w Velocity components m/s U Flow velocity m/s V, δV Volume of control volume m3 w, g Specific weight N/m3 x-, y-, z- Cartesian coordinates Greek letters ω Angular velocity, ... Get Fluid Mechanics and Hydraulic Machines now with the O'Reilly learning platform. O'Reilly members experience books, live events, courses curated by job role, and more from O'Reilly and nearly 200 top publishers. Get Mark Richards's Software Architecture Patterns ebook to better understand how to design components—and how they should interact. It's yours, free. Get it now Dive in for free with a 10-day trial of the O'Reilly learning platform—then explore all the other resources our members count on to build skills and solve problems every day. Start your free trial Become a member now 2025 Copyright. All Rights Reserved Privacy Policy Join TheConstructor to ask questions, answer questions, write articles, and connect with other people. When you join you get additional benefits. Have an account? Sign In 2025 Copyright. All Rights Reserved Privacy Policy Part of a series onContinuum mechanics J = − D d φ d x {\displaystyle J=-D{\frac {d\varphi }{dx}}} Fick's laws of diffusion Laws Conservations Mass Momentum Energy Inequalities Clausius–Duhem (entropy) Solid mechanics Deformation Elasticity linear Plasticity Hooke's law Stress Strain Finite strain Infinitesimal strain Compatibility Bending Contact mechanics frictional Material failure theory Fracture mechanics Fluid mechanics Fluids Statics · Dynamics Archimedes' principle · Bernoulli's principle Navier–Stokes equations Poiseuille equation · Pascal's law Viscosity (Newtonian · non-Newtonian) Buoyancy · Mixing · Pressure Liquids Adhesion Capillary action Chromatography Cohesion (chemistry) Surface tension Gases Atmosphere Boyle's law Charles's law Combined gas law Fick's law Gay-Lussac's law Graham's law Plasma Rheology Viscoelasticity Rheometry Rheometer Smart fluids Electrorheological Magnetorheological Ferrofluids Scientists Bernoulli Boyle Cauchy Charles Euler Fick Gay-Lussac Graham Hooke Newton Navier Noll Pascal Stokes Truesdell vte This article summarizes equations in the theory of fluid mechanics. Flux F through a surface, dS is the differential vector area element, n is the unit normal to the surface. Left: No flux passes in the surface, the maximum amount flows normal to the surface. Right: The reduction in flux passing through a surface can be visualized by reduction in F or dS equivalently (resolved into components, θ is angle to normal n). F•dS is the component of flux passing through the surface, multiplied by the area of the surface (see dot product). For this reason flux represents physically a flow per unit area. Here t ^ {\displaystyle \mathbf {\hat {t}} \,\!} is a unit vector in the direction of the flow/current/flux. Quantity (common name/s) (Common) symbol/s Defining equation SI units Dimension Flow velocity vector field u u = u (r , t) {\displaystyle \mathbf {u} =\mathbf {u} \left(\mathbf {r} ,t\right)\,\!} m s−1 [L][T]−1 Velocity pseudovector field ω ω = ∇ × v {\displaystyle {\boldsymbol {\omega }}=abla \times \mathbf {v} } s−1 [T]−1 Volume velocity, volume flux φV (no standard symbol) ϕ V = ∫ S u · d A {\displaystyle \phi _{V}=\int _{S}\mathbf {u} \cdot \mathrm {d} \mathbf {A} \,\!} m3 s−1 [L]3 [T]−1 Mass current per unit volume s (no standard symbol) s = d ρ / d t {\displaystyle s=\mathrm {d} \rho /\mathrm {d} t\,\!} kg m−3 s−1 [M] [L]−3 [T]−1 Mass current, mass flow rate Im I m = d m / d t {\displaystyle I_{\mathrm {m} }=\mathrm {d} m/\mathrm {d} t\,\!} kg s−1 [M][T]−1 Mass current density jm I m = ∫∫ j m · d S {\displaystyle I_{\mathrm {m} }=\iint \mathbf {j} _{\mathrm {m} }\cdot \mathrm {d} \mathbf {S} \,\!} kg m−2 s−1 [M][L]−2[T]−1 Momentum current Ip I p = d | p | / d t {\displaystyle I_{\mathrm {p} }=\mathrm {d} \left|\mathbf {p} \right|/\mathrm {d} t\,\!} kg m s−2 [M][L][T]−2 Momentum current density jp I p = ∫∫ j p · d S {\displaystyle I_{\mathrm {p} }=\iint \mathbf {j} _{\mathrm {p} }\cdot \mathrm {d} \mathbf {S} } kg m s−2 [M][L][T]−2 Physical situation Nomenclature Equations Fluid statics,pressure gradient r = Position ρ = ρ(r) = Fluid density at gravitational equipotential containing r g = g(r) = Gravitational field strength at point r ∇P = Pressure gradient ∇ P = ρ g {\displaystyle abla P=\rho \mathbf {g} \,\!} Buoyancy equations ρf = Mass density of the fluid Vimm = Immersed volume of body in fluid Fb = Buoyant force Fg = Gravitational force Wapp = Apparent weight of immersed body W = Actual weight of immersed body Buoyant force F b = − ρ f V i m m g = − F g {\displaystyle \mathbf {F} _{\mathrm {b} }=-\rho _{f}V_{\mathrm {imm} }\mathbf {g} =-\mathbf {F} _{\mathrm {g} }\,\!} Apparent weight W a p p = W − F b {\displaystyle \mathbf {W} _{\mathrm {app} }=\mathbf {W} -\mathbf {F} _{\mathrm {b} }\,\!} Bernoulli's equation pconstant is the total pressure at a point on a streamline p + ρ u 2 / 2 + ρ g y = p c o n s t a n t {\displaystyle p+\rho u^{2}/2+\rho gy=p_{\mathrm {constant} }\,\!} Euler equations ρ = fluid mass density u is the flow velocity vector E = total volume energy density U = internal energy per unit mass of fluid p = pressure ⊗ {\displaystyle \otimes } denotes the tensor product ∂ ρ ∂ t + ∇ · (ρ u) = 0 {\displaystyle {\frac {\partial \rho }{\partial t}}+abla \cdot (\rho \mathbf {u})=0\,\!} ∂ ρ u ∂ t + ∇ · (u ⊗ (ρ u)) + ∇ p = 0 {\displaystyle {\frac {\partial \rho {\mathbf {u} }}{\partial t}}+abla \cdot \left(\mathbf {u} \otimes \left(\rho \mathbf {u} \right)\right)+abla p=0\,\!} ∂ E ∂ t + ∇ · (u (E + p)) = 0 {\displaystyle {\frac {\partial E}{\partial t}}+abla \cdot \left(\mathbf {u} \left(E+p\right)\right)=0\,\!} E = ρ (U + 1 2 u 2) {\displaystyle E=\rho \left(U+{\frac {1}{2}}\mathbf {u} ^{2}\right)\,\!} Convective acceleration a = (u · ∇) u {\displaystyle \mathbf {a} =\left(\mathbf {u} \cdot abla \right)\mathbf {u} } Navier–Stokes equations TD = Deviatoric stress tensor f {\displaystyle \mathbf {f} } = volume density of the body forces acting on the fluid ∇ {\displaystyle abla } here is the del operator. ρ (∂ u ∂ t + u · ∇ u) = − ∇ p + ∇ · T D + f {\displaystyle \rho \left({\frac {\partial \mathbf {u} }{\partial t}}+\mathbf {u} \cdot abla \mathbf {u} \right)=-abla p+abla \cdot \mathbf {T} _{\mathrm {D} }+\mathbf {f} } Defining equation (physical chemistry) List of electromagnetism equations List of equations in classical mechanics List of equations in gravitation List of equations in nuclear and particle physics List of equations in quantum mechanics List of photonics equations List of relativistic equations Table of thermodynamic equations P.M. Whelan, M.J. Hodgeson (1978). Essential Principles of Physics (2nd ed.). John Murray. ISBN 0-7195-3382-1. G. Woan (2010). The Cambridge Handbook of Physics Formulas. Cambridge University Press. ISBN 978-0-521-57507-2. A. Halpern (1988). 3000 Solved Problems in Physics, Schaum Series. Mc Graw Hill. ISBN 978-0-07-025734-4. R.G. Lerner, G.L. Trigg (2005). Encyclopaedia of Physics (2nd ed.). VHC Publishers, Hans Warlimont, Springer. pp. 12–13. ISBN 978-0-07-025734-4. C.B. Parker (1994). McGraw Hill Encyclopaedia of Physics (2nd ed.). McGraw Hill. ISBN 0-07-051400-3. P.A. Tipler, G. Mosca (2008). Physics for Scientists and Engineers: With Modern Physics (6th ed.). W.H. Freeman and Co. ISBN 978-1-4292-0265-7. L.N. Hand, J.D. Finch (2008). Analytical Mechanics. Cambridge University Press. ISBN 978-0-521-57572-0. T.B. Arkill, C.J. Millar (1974). Mechanics, Vibrations and Waves. John Murray. ISBN 0-7195-2882-8. H.J. Pain (1983). The Physics of Vibrations and Waves (3rd ed.). John Wiley & Sons. ISBN 0-471-90182-2. L.H. Greenberg (1978). Physics with Modern Applications. Holt-Saunders International W.B. Saunders and Co. ISBN 0-7216-4247-0. J.B. Marion, W.F. Hornyak (1984). Principles of Physics. Holt-Saunders International Saunders College. ISBN 4-8337-0195-2. A. Beiser (1987). Concepts of Modern Physics (4th ed.). McGraw-Hill (International). ISBN 0-07-100144-1. H.D. Young, R.A. Freedman (2008). University Physics – With Modern Physics (12th ed.). Addison-Wesley (Pearson International). ISBN 978-0-321-50130-1. Retrieved from " Fluid Kinematics Fluid Kinematics deals with the motion of fluids such as displacement, velocity, acceleration, and other aspects. This topic is useful in terms of the exam and the knowledge of the candidate. Kinematics is the branch of classical mechanics that describes the motion of bodies and systems without consideration of the forces the cause the motion. Types of Fluid Flows Fluid flow may be classified under the following headings; Steady & Unsteady Flow Uniform & Non-uniform Flow Steady uniform flow Conditions do not change with position in the stream or with time. E.g. flow of water in a pipe of constant diameter at a constant velocity. Steady non-uniform flow Conditions change from point to point in the stream but do not change with time. E.g. Flow in a tapering pipe with the constant velocity at the inlet. Unsteady uniform flow At a given instant in time the conditions at every point are the same but will change with time. E.g. A pipe of constan... Expression for capillary rise and capillary fall - Jurin's law Expression for height in Capillary rise Consider a narrow glass tube of diameter of d dipped in a liquid (say water). Water in the tube will rise above the adjacent liquid level. It is called capillary rise. Let σ = Surface tension of liquid. Θ = Angle of contact between the glass tube and the liquid surface. h = Height of liquid column in glass tube. Under equilibrium, two forces are acting on the water inside. The first one is weight of water column and second is the upward force acting on water due to surface tension. The weight of liquid of height h should be balanced by the force at liquid surface. This force at surface of liquid is due to surface tension. The weight of liquid of height h in the tube = Volume x ρ x g = (π/4)d 2 x h x ρ x g Here ρ = density of liquid g = acceleration due to gravity. The vertical component of surface tensile force = surface tension x circumference x cosΘ = σ x πd x cosΘ At eq... A liquid of density ρ ρ and surface tension σ σ rises in a capillary of inner radius r r to a height h = 2 σ cos θ ρ g r h = 2 σ cos θ ρ g r where θ θ is the contact angle made by the liquid meniscus with the capillary's surface. The liquid rises due to the forces of adhesion, cohesion, and surface tension. If adhesive force (liquid-capillary) is more than the cohesive force (liquid-liquid) then liquid rises as in case of water rise in a glass capillary. In this case, the contact angle is less than 90 deg and the meniscus is concave. If adhesive force is less than the cohesive force then liquid depresses as in case of mercury in a glass capillary. In this case, the contact angle is greater than 90 deg and the meniscus is convex. The formula for capillary rise can be derived by balancing forces on the liquid column. The weight of the liquid (π r 2 h ρ g π r 2 h ρ g) is balanced by the upward force due to surface tension (2 π r σ cos θ ... Branch of physics Part of a series onContinuum mechanics J = − D d φ d x {\displaystyle J=-D{\frac {d\varphi }{dx}}} Fick's laws of diffusion Laws Conservations Mass Momentum Energy Inequalities Clausius–Duhem (entropy) Solid mechanics Deformation Elasticity linear Plasticity Hooke's law Stress Strain Finite strain Infinitesimal strain Compatibility Bending Contact mechanics frictional Material failure theory Fracture mechanics Fluid mechanics Fluids Statics · Dynamics Archimedes' principle · Bernoulli's principle Navier–Stokes equations Poiseuille equation · Pascal's law Viscosity (Newtonian · non-Newtonian) Buoyancy · Mixing · Pressure Liquids Adhesion Capillary action Chromatography Cohesion (chemistry) Surface tension Gases Atmosphere Boyle's law Charles's law Combined gas law Fick's law Gay-Lussac's law Graham's law Plasma Rheology Viscoelasticity Rheometry Rheometer Smart fluids Electrorheological Magnetorheological Ferrofluids Scientists Bernoulli Boyle Cauchy Charles Euler Fick Gay-Lussac Graham Hooke Newton Navier Noll Pascal Stokes Truesdell vte Fluid mechanics is the branch of physics concerned with the mechanics of fluids (liquids, gases, and plasmas) and the forces on them.[1]:3 Originally applied to water (hydromechanics), it found applications in a wide range of disciplines, including mechanical, aerospace, civil, chemical, and biomedical engineering, as well as geophysics, oceanography, meteorology, astrophysics, and biology. It can be divided into fluid statics, the study of various fluids at rest; and fluid dynamics, the study of the effect of forces on fluid motion.[1]:3 It is a branch of continuum mechanics, a subject which models matter without using the information that it is made out of atoms; that is, it models matter from a macroscopic viewpoint rather than from microscopic. Fluid mechanics, especially fluid dynamics, is an active field of research, typically mathematically complex. Many problems are partly or wholly unsolved and are best addressed by numerical methods, typically using computers. A modern discipline, called computational fluid dynamics (CFD), is devoted to this approach.[2] Particle image velocimetry, an experimental method for visualizing and analyzing fluid flow, also takes advantage of the highly visual nature of fluid flow. Main article: History of fluid mechanics For a chronological guide, see Timeline of fluid and continuum mechanics. The study of fluid mechanics goes back at least to the days of ancient Greece, when Archimedes investigated fluid statics and buoyancy and formulated his famous law known now as the Archimedes' principle, which was published in his work On Floating Bodies—generally considered to be the first major work on fluid mechanics. Iranian scholar Abu Rayhan Biruni and later Al-Khazini applied experimental scientific methods to fluid mechanics.[3] Rapid advancement in fluid mechanics began with Leonardo da Vinci (observations and experiments), Evangelista Torricelli (invented the barometer), Isaac Newton (investigated viscosity) and Blaise Pascal (researched hydrostatics, formulated Pascal's law), and was continued by Daniel Bernoulli with the introduction of mathematical fluid dynamics in Hydrodynamica (1739). Inviscid flow was further analyzed by various mathematicians (Jean le Rond d'Alembert, Joseph Louis Lagrange, Pierre-Simon Laplace, Siméon Denis Poisson) and viscous flow was explored by a multitude of engineers including Jean Léonard Marie Poiseuille and Gotthilf Hagen. Further mathematical justification was provided by Claude-Louis Navier and George Gabriel Stokes in the Navier–Stokes equations, and boundary layers were investigated (Ludwig Prandtl, Theodore von Kármán), while various scientists such as Osborne Reynolds, Andrey Kolmogorov, and Geoffrey Ingram Taylor advanced the understanding of fluid viscosity and turbulence. Main article: Fluid statics Fluid statics or hydrostatics is the branch of fluid mechanics that studies fluids at rest. It embraces the study of the conditions under which fluids are at rest in stable equilibrium; and is contrasted with fluid dynamics, the study of fluids in motion. Hydrostatics offers physical explanations for many phenomena of everyday life, such as why atmospheric pressure changes with altitude, why wood and oil float on water, and why the surface of water is always level whatever the shape of its container. Hydrostatics is fundamental to hydraulics, the engineering of equipment for storing, transporting and using fluids. It is also relevant to some aspects of geophysics and astrophysics (for example, in understanding plate tectonics and anomalies in the Earth's gravitational field), to meteorology, to medicine (in the context of blood pressure), and many other fields. Main article: Fluid dynamics Fluid dynamics is a subdiscipline of fluid mechanics that deals with fluid flow—the science of liquids and gases in motion.[4] Fluid dynamics offers a systematic structure—which underlies these practical disciplines—that embraces empirical and semi-empirical laws derived from flow measurement and used to solve practical problems. The solution to a fluid dynamics problem typically involves calculating various properties of the fluid, such as velocity, pressure, density, and temperature, as functions of space and time. It has several subdisciplines itself, including aerodynamics[5][6][7][8] (the study of air and other gases in motion) and hydrodynamics[9][10] (the study of liquids in motion). Fluid dynamics has a wide range of applications, including calculating forces and movements on aircraft, determining the mass flow rate of petroleum through pipelines, predicting evolving weather patterns, understanding nebulae in interstellar space and modeling explosions. Some fluid-dynamical principles are used in traffic engineering and crowd dynamics. Fluid mechanics is a subdiscipline of continuum mechanics, as illustrated in the following table. Continuum mechanicsThe study of the physics of continuous materials Solid mechanicsThe study of the physics of continuous materials with a defined rest shape. ElasticityDescribes materials that return to their rest shape after applied stresses are removed. PlasticityDescribes materials that permanently deform after a sufficient applied stress. RheologyThe study of materials with both solid and fluid characteristics. Fluid mechanicsThe study of the physics of continuous materials which deform when subjected to a force. Non-Newtonian fluidDo not undergo strain rates proportional to the applied shear stress. Newtonian fluids undergo strain rates proportional to the applied shear stress. In a mechanical view, a fluid is a substance that does not support shear stress; that is why a fluid at rest has the shape of its containing vessel. A fluid at rest has no shear stress. Balance for some integrated fluid quantity in a control volume enclosed by a control surface. The assumptions inherent to a fluid mechanical treatment of a physical system can be expressed in terms of mathematical equations. Fundamentally, every fluid mechanical system is assumed to obey: Conservation of mass Conservation of energy Conservation of momentum The continuum assumption For example, the assumption that mass is conserved means that for any fixed control volume (for example, a spherical volume)—enclosed by a control surface—the rate of change of the mass contained in that volume is equal to the rate at which mass is passing through the surface from outside to inside, minus the rate at which mass is passing from inside to outside. This can be expressed as an equation in integral form over the control volume.[11]:74 The continuum assumption is an idealization of continuum mechanics under which fluids can be treated as continuous, even though, on a microscopic scale, they are composed of molecules. Under the continuum assumption, macroscopic (observed/measurable) properties such as density, pressure, temperature, and bulk velocity are taken to be well-defined at "infinitesimal" volume elements—small in comparison to the characteristic length scale of the system, but large in comparison to molecular length scale. Fluid properties can vary continuously from one volume element to another and are average values of the molecular properties. The continuum hypothesis can lead to inaccurate results in applications like supersonic speed flows, or molecular flows on nano scale.[12] Those problems for which the continuum hypothesis fails can be solved using statistical mechanics. To determine whether or not the continuum hypothesis applies, the Knudsen number, defined as the ratio of the molecular mean free path to the characteristic length scale, is evaluated. Problems with Knudsen numbers below 0.1 can be evaluated using the continuum hypothesis, but molecular approach (statistical mechanics) can be applied to find the fluid motion for larger Knudsen numbers. Main article: Navier–Stokes equations The Navier–Stokes equations (named after Claude-Louis Navier and George Gabriel Stokes) are differential equations that describe the force balance at a given point within a fluid. For an incompressible fluid with vector velocity field u {\displaystyle \mathbf {u} } , the Navier–Stokes equations are[13][14][15][16] ∂ u ∂ t + (u · ∇) u = − 1 ρ ∇ p + ν ∇ 2 u {\displaystyle {\frac {\partial \mathbf {u} }{\partial t}}+(\mathbf {u} \cdot abla)\mathbf {u} =-{\frac {1}{\rho }}abla p+u abla ^{2}\mathbf {u} } . These differential equations are the analogues for deformable materials to Newton's equations of motion for particles – the Navier–Stokes equations describe changes in momentum (force) in response to pressure p {\displaystyle p} and viscosity, parameterized by the kinematic viscosity ν {\displaystyle u } . Occasionally, body forces, such as the gravitational force or Lorentz force are added to the equations. Solutions of the Navier–Stokes equations for a given physical problem must be sought with the help of calculus. In practical terms, only the simplest cases can be solved exactly in this way. These cases generally involve non-turbulent, steady flow in which the Reynolds number is small. For more complex cases, especially those involving turbulence, such as global weather systems, aerodynamics, hydrodynamics and many more, solutions of the Navier–Stokes equations can currently only be found with the help of computers. This branch of science is called computational fluid dynamics.[17][18][19][20][21] An inviscid fluid has no viscosity, ν = 0 {\displaystyle u =0} . In practice, an inviscid flow is an idealization, one that facilitates mathematical treatment. In fact, purely inviscid flows are only known to be realized in the case of superfluidity. Otherwise, fluids are generally viscous, a property that is often most important within a boundary layer near a solid surface,[22] where the flow must match onto the no-slip condition at the solid. In some cases, the mathematics of a fluid mechanical system can be treated by assuming that the fluid outside of boundary layers is inviscid, and then matching its solution onto that for a thin laminar boundary layer. For fluid flow over a porous boundary, the fluid velocity can be discontinuous between the free fluid and the fluid in the porous media (this is related to the Beavers and Joseph condition). Further, it is useful at low subsonic speeds to assume that gas is incompressible—that is, the density of the gas does not change even though the speed and static pressure change. A Newtonian fluid (named after Isaac Newton) is defined to be a fluid whose shear stress is linearly proportional to the velocity gradient in the direction perpendicular to the plane of shear. This definition means regardless of the forces acting on a fluid, it continues to flow. For example, water is a Newtonian fluid, because it continues to display fluid properties no matter how much it is stirred or mixed. A slightly less rigorous definition is that the drag of a small object being moved slowly through the fluid is proportional to the force applied to the object. (Compare friction). Important fluids, like water as well as most gasses, behave—to good approximation—as a Newtonian fluid under normal conditions on Earth.[11]:145 By contrast, stirring a non-Newtonian fluid can leave a "hole" behind. This will gradually fill up over time—this behavior is seen in materials such as pudding, oobleck, or sand (although sand isn't strictly a fluid). Alternatively, stirring a non-Newtonian fluid can cause the viscosity to decrease, so the fluid appears "thinner" (this is seen in non-drip paints). There are many types of non-Newtonian fluids, as they are defined to be something that fails to obey a particular property—for example, most fluids with long molecular chains can react in a non-Newtonian manner.[11]:145 Main article: Newtonian fluid The constant of proportionality between the viscous stress tensor and the velocity gradient is known as the viscosity. A simple equation to describe incompressible Newtonian fluid behavior is τ = − μ d u d n {\displaystyle \tau =-\mu {\frac {\mathrm {d} u}{\mathrm {d} n}}} where τ {\displaystyle \tau } is the shear stress exerted by the fluid ("drag"), μ {\displaystyle \mu } is the fluid viscosity—a constant of proportionality, and d u d n {\displaystyle {\frac {\mathrm {d} u}{\mathrm {d} n}}} is the velocity gradient perpendicular to the direction of shear. For a Newtonian fluid, the viscosity, by definition, depends only on temperature, not on the forces acting upon it. If the fluid is incompressible the equation governing the viscous stress (in Cartesian coordinates) is τ i j = μ (∂ v i ∂ x j + ∂ v j ∂ x i) {\displaystyle \tau _{ij}=\mu \left({\frac {\partial v_{i}}{\partial x_{j}}}+{\frac {\partial v_{j}}{\partial x_{i}}}\right)} where τ i j {\displaystyle \tau _{ij}} is the shear stress on the i t h {\displaystyle i^{th}} face of a fluid element in the j t h {\displaystyle j^{th}} direction v i {\displaystyle v_{i}} is the velocity in the i t h {\displaystyle i^{th}} direction x j {\displaystyle x_{j}} is the j t h {\displaystyle j^{th}} direction coordinate. If the fluid is not incompressible the general form for the viscous stress in a Newtonian fluid is τ i j = μ (∂ v i ∂ x j + ∂ v j ∂ x i − 2 3 δ i j ∇ · v) + κ δ i j ∇ · v {\displaystyle \tau _{ij}=\mu \left({\frac {\partial v_{i}}{\partial x_{j}}}+{\frac {\partial v_{j}}{\partial x_{i}}}-{\frac {2}{3}}\delta _{ij}abla \cdot \mathbf {v} \right)+\kappa \delta _{ij}abla \cdot \mathbf {v} } where κ {\displaystyle \kappa } is the second viscosity coefficient (or bulk viscosity). If a fluid does not obey this relation, it is termed a non-Newtonian fluid, of which there are several types. Non-Newtonian fluids can be either plastic, Bingham plastic, pseudoplastic, dilatant, thixotropic, rheopectic, viscoelastic. In some applications, another rough broad division among fluids is made: ideal and non-ideal fluids. An ideal fluid is non-viscous and offers no resistance whatsoever to a shearing force. An ideal fluid really does not exist, but in some calculations, the assumption is justifiable. One example of this is the flow far from solid surfaces. In many cases, the viscous effects are concentrated near the solid boundaries (such as in boundary layers) while in regions of the flow field far away from the boundaries the viscous effects can be neglected and the fluid there is treated as it were inviscid (ideal flow). When the viscosity is neglected, the term containing the viscous stress tensor τ {\displaystyle \mathbf {\tau } } in the Navier–Stokes equation vanishes. The equation reduced in this form is called the Euler equation. Physics portal Transport phenomena Aerodynamics Applied mechanics Bernoulli's principle Communicating vessels Computational fluid dynamics Compressor map Secondary flow Different types of boundary conditions in fluid dynamics Fluid–structure interaction Immersed boundary method Stochastic Eulerian Lagrangian method Stokesian dynamics Smoothed-particle hydrodynamics ^ a b White, Frank M. (2011). Fluid Mechanics (7th ed.). McGraw-Hill. ISBN 978-0-07-352934-9. ^ Tu, Jiyuan; Yeoh, Guan Heng; Liu, Chaoqun (Nov 21, 2012). Computational Fluid Dynamics: A Practical Approach. Butterworth-Heinemann. ISBN 978-0080982434. ^ Mariam Rozhanskaya and I. S. Levinova (1996), "Statics", p. 642, ^ Batchelor, C. K., & Batchelor, G. K. (2000). An introduction to fluid dynamics. Cambridge University Press. ^ Bertin, J. J., & Smith, M. L. (1998). Aerodynamics for engineers (Vol. 5). Upper Saddle River, NJ: Prentice Hall. ^ Anderson Jr, J. D. (2010). Fundamentals of aerodynamics. Tata McGraw-Hill Education. ^ Houghton, E. L., & Carpenter, P. W. (2003). Aerodynamics for engineering students. Elsevier. ^ Milne-Thomson, L. M. (1973). Theoretical aerodynamics. Courier Corporation. ^ Milne-Thomson, L. M. (1996). Theoretical hydrodynamics. Courier Corporation. ^ Birkhoff, G. (2015). Hydrodynamics. Princeton University Press. ^ a b c Batchelor, George K. (1967). An Introduction to Fluid Dynamics. Cambridge University Press. p. 74. ISBN 0-521-66396-2. ^ Greenkorn, Robert (3 October 2018). Momentum, Heat, and Mass Transfer Fundamentals. CRC Press. p. 18. ISBN 978-1-4822-9297-8. ^ Constantin, P., & Foias, C. (1988). Navier-stokes equations. University of Chicago Press. ^ Temam, R. (2001). Navier-Stokes equations: theory and numerical analysis (Vol. 343). American Mathematical Society. ^ Foias, C., Manley, O., Rosa, R., & Temam, R. (2001). Navier-Stokes equations and turbulence (Vol. 83). Cambridge University Press. ^ Girault, V., & Raviart, P. A. (2012). Finite element methods for Navier-Stokes equations: theory and algorithms (Vol. 5). Springer Science & Business Media. ^ Anderson, J. D., & Wendt, J. (1995). Computational fluid dynamics (Vol. 206). New York: McGraw-Hill. ^ Chung, T. J. (2010). Computational fluid dynamics. Cambridge University Press. ^ Blazek, J. (2015). Computational fluid dynamics: principles and applications. Butterworth-Heinemann. ^ Wesseling, P. (2009). Principles of computational fluid dynamics (Vol. 29). Springer Science & Business Media. ^ Anderson, D., Tannehill, J. C., & Pletcher, R. H. (2016). Computational fluid mechanics and heat transfer. Taylor & Francis. ^ Kundu, Pijush K.; Cohen, Ira M.; Dowling, David R. (27 March 2015). "10". Fluid Mechanics (6th ed.). Academic Press. ISBN 978-0124059351. Falkovich, Gregory (2011), Fluid Mechanics (A short course for physicists), Cambridge University Press, doi:10.1017/CBO9780511794353, ISBN 978-1-107-00575-4 Kundu, Pijush K.; Cohen, Ira M. (2008), Fluid Mechanics (4th revised ed.), Academic Press, ISBN 978-0-12-373735-9 Currie, I. G. (1974), Fundamental Mechanics of Fluids, McGraw-Hill, Inc., ISBN 0-07-015000-1 Massey, B.; Ward-Smith, J. (2005), Mechanics of Fluids (8th ed.), Taylor & Francis, ISBN 978-0-415-36206-1 Nazarenko, Sergey (2014), Fluid Dynamics via Examples and Solutions, CRC Press (Taylor & Francis group), ISBN 978-1-43-988882-7 Fluid mechanics at Wikipedia's sister projects Media from CommonsQuotations from WikiquoteTextbooks from WikibooksResources from Wikiversity Free Fluid Mechanics books Annual Review of Fluid Mechanics. Archived 2009-01-19 at the Wayback Machine. CFDWiki – the Computational Fluid Dynamics reference wiki. Educational Particle Image Velocimetry Archived 2017-08-03 at the Wayback Machine – resources and demonstrations Retrieved from "