Physics

JZL1001913C

summer semester

2020/2021

Wednesday, 18:20 - 19:50

Friday, 18:20 - 19:50

virtual room (ZOOM)

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Fluid Statics

- short rewiev

Pressure $P = F/S$	Unit $1 N/m^2 = 1\ kg/m/s^2 = 1$ Pascal
Density $d = \rho = m/V$	Unit $1\ kg/m^3$
Hydrostatic Pressure $P = h\rho g$	Unit $1m*kg/m^3*m/s^2 = 1\ kg/m/s^2 = 1$ Pa
Surface tension $\gamma = F/l$	Unit $1\ N/m$
Capillary action $h = \frac{2\gamma\cos\theta}{\rho g r}$	Unit 1 kg * J/kg = J

Quantities:

- Density
- Pressure
- Hydrostatic preassure
- Surface tension
- Contact angle

Pascal's Principle in Hydraulic System

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

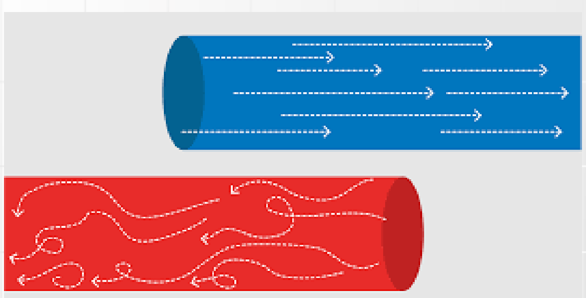
Archimedes' Principle

$$F_B = w_{fl}$$

https://www.youtube.com/watch?v=GuFHfQlgI1I

Fluids in motion

We have dealt with many situations in which fluids are static. But by their very definition, fluids flow. Examples come easily—a column of smoke rises from a camp fire, water streams from a fire hose, blood courses through your veins. Why does rising smoke curl and twist? How does a nozzle increase the speed of water emerging from a hose? How does the body regulate blood flow? The physics of fluids in motion—fluid dynamics—allows us to answer these and many other questions.



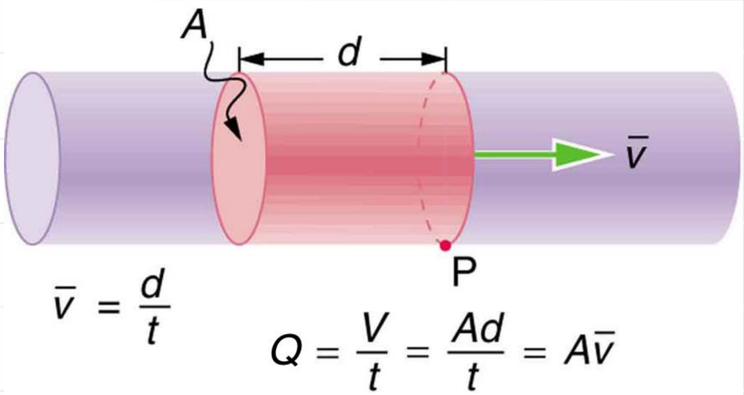
https://www.youtube.com/watch?v=G4CgOF4ccXk

Flow rate

Flow rate Q is defined to be the volume of fluid passing by some location through an area during a period of time

$$Q = \frac{V}{t}$$

where V is the volume and t is the elapsed time.



Flow rate is the volume of fluid per unit time flowing past a point through the area A. Here the shaded cylinder of fluid flows past point P in a uniform pipe in time t. The volume of the cylinder is Ad and the average velocity is v=d/t so that the flow rate is Q=Ad/t=Av.

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Example 1

Calculating Volume from Flow Rate: The Heart Pumps a Lot of Blood in a Lifetime

How many cubic meters of blood does the heart pump in a 75-year lifetime, assuming the average flow rate is 5.00 L/min?

Strategy

Time and flow rate Q are given, and so the volume V can be calculated from the definition of flow rate.

Solution

Solving $Q = V/t$ for volume gives

$$V = Qt$$

Substituting known values yields

$$V = \left(\frac{5.00L}{1\text{min}}\right)(75y)\left(\frac{1m^3}{10^3L}\right)\left(5.26 \times 10^5\,\frac{min}{y}\right) = 2.0 \times 10^5 m^3.$$

This amount is about 200,000 tons of blood. For comparison, this value is equivalent to about 200 times the volume of water contained in a 6-lane 50-m lap pool.

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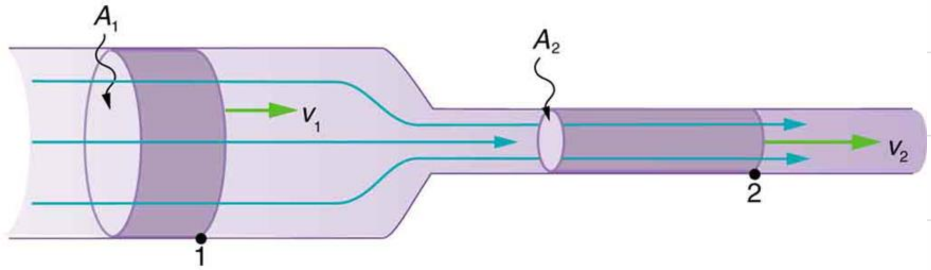
Example 2

Calculating Fluid Speed: Speed Increases When a Tube Narrows

A nozzle with a radius of 0.250 cm is attached to a garden hose with a radius of 0.900 cm. The flow rate through hose and nozzle is 0.500 L/s. Calculate the speed of the water in the hose.

Strategy
We can use the relationship between flow rate and speed to find both velocities. We will use the subscript 1 for the hose and 2 for the nozzle.



Solution
First, we solve $Q = A\bar{v}$ for v_1 and note that the cross-sectional area is $A = \pi r^2$, yielding

$$\bar{v}_1 = \frac{Q}{A_1} = \frac{Q}{\pi r_1^2}.$$

Substituting known values and making appropriate unit conversions yields

$$\bar{v}_1 = \frac{\left(\frac{0.500 L}{s}\right)\left(\frac{10^{-3} m^3}{L}\right)}{\pi (9.00 \times 10^{-3} m)^2} = 1.96 \frac{m}{s}.$$

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https://www.youtube.com/watch?v=wykn-JTnacE&t=197s

Continuity Equation

The continuity equation is simply a mathematical expression of the principle of conservation of mass. For a control volume that has a single inlet and a single outlet, the principle of conservation of mass states that, for steady-state flow, the mass flow rate into the volume must equal the mass flow rate out.

$$m_{in} = m_{out}$$
$$(\rho A v)_{in} = (\rho A v)_{out}$$

For a control volume with multiple inlets and outlets, the principle of conservation of mass requires that the sum of the mass flow rates into the control volume equal the sum of the mass flow rates out of the control volume.

$$\sum m_{in} = \sum m_{out}$$

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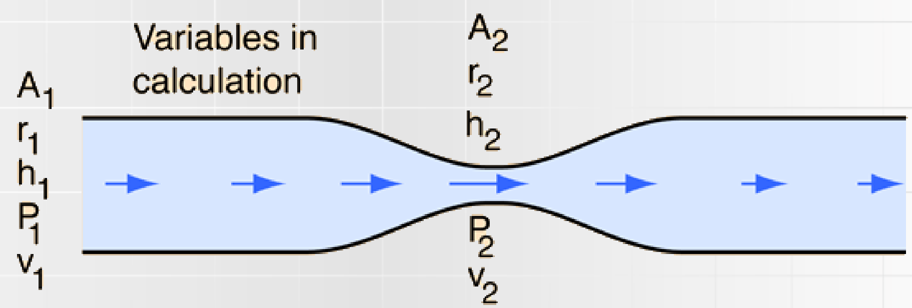
https://www.youtube.com/watch?v=DW4rItB20h4

Bernoulli's Equation

The relationship between pressure and velocity in fluids is described quantitatively by Bernoulli's equation, named after its discoverer, the Swiss scientist Daniel Bernoulli (1700–1782). Bernoulli's equation states that for an incompressible, frictionless fluid, the following sum is constant

$$P + \frac{1}{2}\rho v^2 + \rho g h = constant$$

where P is the absolute pressure, ρ is the fluid density, v is the velocity of the fluid, h is the height above some reference point, and g is the acceleration due to gravity.



$$P + \frac{1}{2}\rho v_1^2 = P + \frac{1}{2}\rho v_2^2$$

Situations in which fluid flows at a constant depth are so important that this equation is often called **Bernoulli's principle**.

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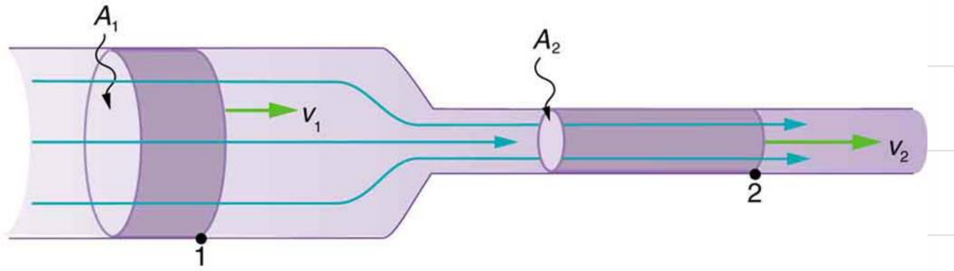
Example 3

Calculating Pressure: Pressure Drops as a Fluid Speeds Up

Let assume that the speed of water in a hose increased from 1.96 m/s to 25.5 m/s going from the hose to the nozzle. Calculate the pressure in the hose, given that the absolute pressure in the nozzle is $1.01\times10^5 N/m^2$ (atmospheric, as it must be) and assuming level, frictionless flow.



Strategy
Level flow means constant depth, so Bernoulli's principle applies. We use the subscript 1 for values in the hose and 2 for those in the nozzle. We are thus asked to find P_1.

Solution
Solving Bernoulli's principle for P_1 yields

$$P_1 = P_2 + \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho(v_2^2 - v_1^2).$$

Substituting known values,

$$P_1 = \frac{1.01\times10^5 N}{m^2} + \frac{1}{2}\left(10^3\,\frac{kg}{m^3}\right)\left[\left(25.5\,\frac{m}{s}\right)^2 - \left(1.96\,\frac{m}{s}\right)^2\right] = 4.24\times10^5\,\frac{N}{m^2}.$$

This absolute pressure in the hose is greater than in the nozzle, as expected since v is greater in the nozzle. The pressure P_2 in the nozzle must be atmospheric since it emerges into the atmosphere without other changes in conditions.

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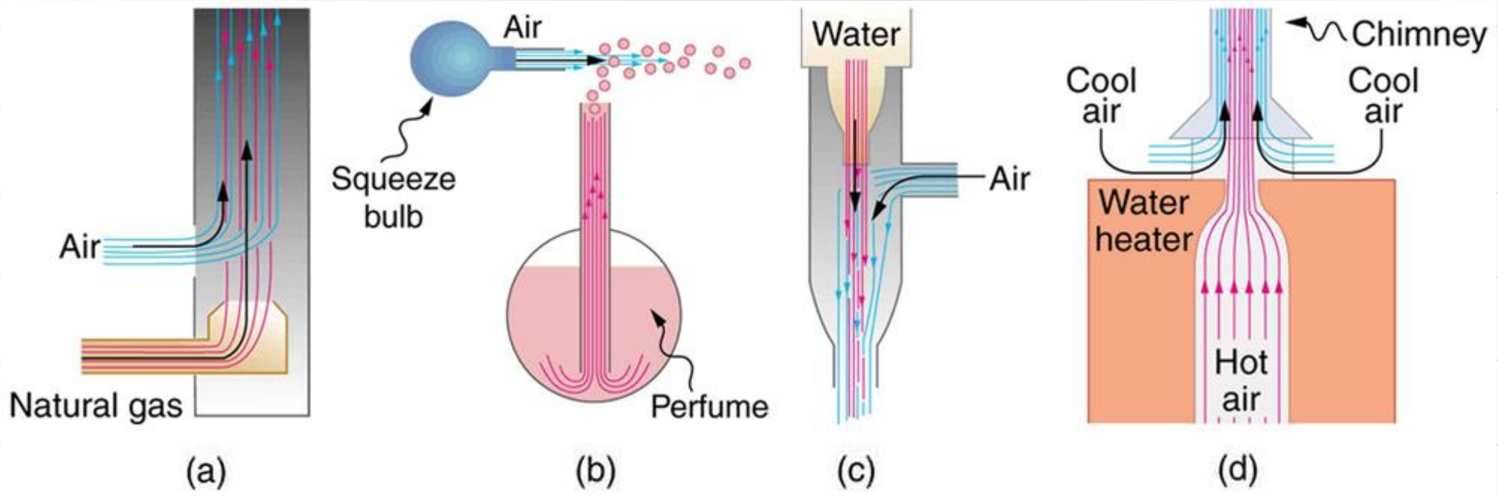
https://www.youtube.com/watch?v=fJefjG3xhW0
https://www.youtube.com/watch?v=E3i_XHlVCeU

Applications of Bernoulli's Principle



Examples of entrainment devices that use increased fluid speed to create low pressures, which then entrain one fluid into another. (a) A Bunsen burner uses an adjustable gas nozzle, entraining air for proper combustion. (b) An atomizer uses a squeeze bulb to create a jet of air that entrains drops of perfume. Paint sprayers and carburetors use very similar techniques to move their respective liquids. (c) A common aspirator uses a high-speed stream of water to create a region of lower pressure. Aspirators may be used as suction pumps in dental and surgical situations or for draining a flooded basement or producing a reduced pressure in a vessel. (d) The chimney of a water heater is designed to entrain air into the pipe leading through the ceiling.

Laminar Flow and Viscosity

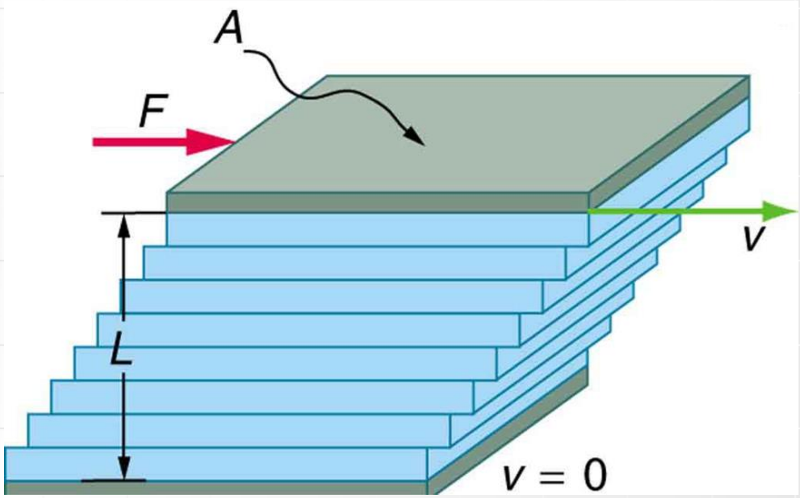
Flow Regimes
All fluid flow is classified into one of two broad categories or regimes. These two flow regimes are laminar flow and turbulent flow. The flow regime, whether laminar or turbulent, is important in the design and operation of any fluid system. The amount of fluid friction, which determines the amount of energy required to maintain the desired flow, depends upon the mode of flow. This is also an important consideration in certain applications that involve heat transfer to the fluid.

Laminar Flow
Laminar flow is also referred to as streamline or viscous flow. These terms are descriptive of the flow because, in laminar flow, (1) layers of water flowing over one another at different speeds with virtually no mixing between layers, (2) fluid particles move in definite and observable paths or streamlines, and (3) the flow is characteristic of viscous (thick) fluid or is one in which viscosity of the fluid plays a significant part.

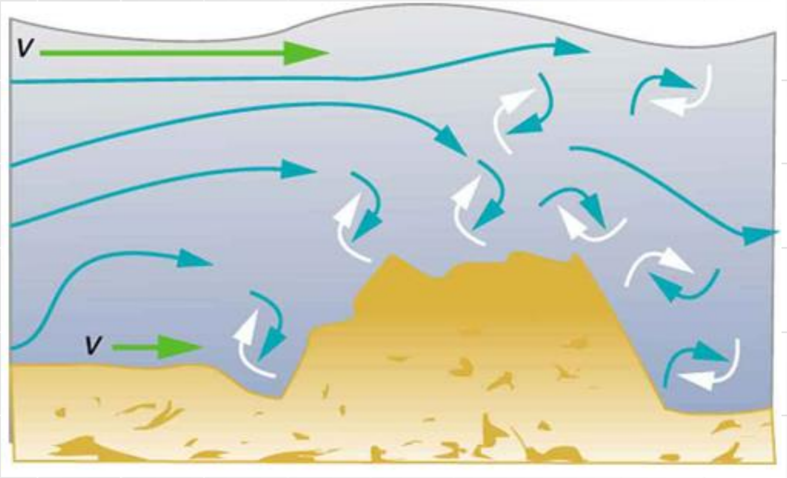
Turbulent Flow
Turbulent flow is characterized by the irregular movement of particles of the fluid. There is no definite frequency as there is in wave motion. The particles travel in irregular paths with no observable pattern and no definite layers.

https://www.youtube.com/watch?v=9A-uUG0WR0w

Laminar Flow and Viscosity



The graphic shows **laminar flow** of fluid between two plates of area A. The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.



The graphic shows an obstruction in the vessel, which produces turbulence. **Turbulent flow** mixes the fluid. There is more interaction, greater heating, and more resistance than in laminar flow..

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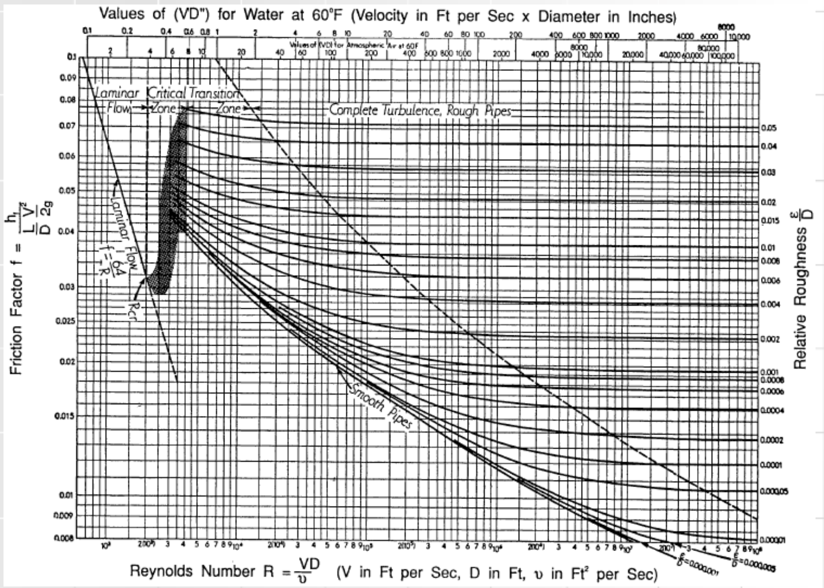
Reynolds Number

The flow regime (either laminar or turbulent) is determined by evaluating the Reynolds number of the flow. The Reynolds number, based on studies of Osborn Reynolds, is a dimensionless number comprised of the physical characteristics of the flow. Below equation is used to calculate the Reynolds number (NR) for fluid flow.

$$N_R = \frac{\rho\, vD}{\mu g}$$

where:

NR	=	Reynolds number (unitless)
v	=	average velocity (m/s)
D	=	diameter of pipe (m)
μ	=	absolute viscosity of fluid (Pa*s)
ρ	=	fluid mass density (lbm/m^3)
g	=	gravitational constant (m/s^2)



https://www.youtube.com/watch?v=wn6eRMIOJ1k

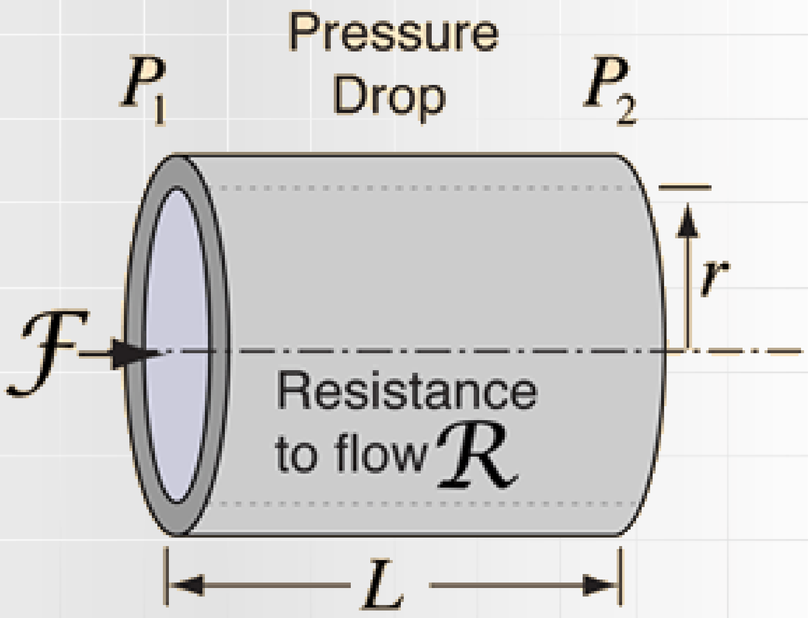
Poiseuille's law

The laminar flow rate of an incompressible fluid along a pipe is proportional to the fourth power of the pipe's radius

$$Q = \frac{(P_2 - P_1)\pi r^4}{8\mu l}$$

where P_2 - P_1 is pressure difference, fluid viscosity μ, r is radius of a tube, and l is its length.

Poiseuille's law can be used to calculate volume flowrate only in the case of laminar flow.



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Viscosity

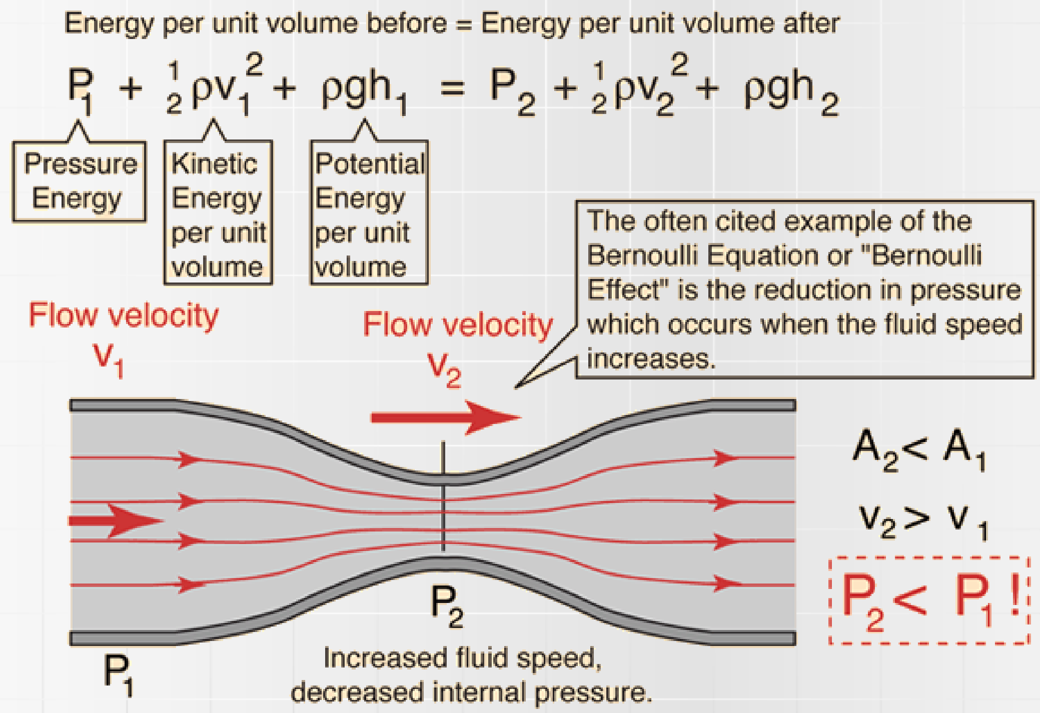
Viscosity is a fluid property that measures the resistance of the fluid to deforming due to a shear force. Viscosity is the internal friction of a fluid which makes it resist flowing past a solid surface or other layers of the fluid. Viscosity can also be considered to be a measure of the resistance of a fluid to flowing. A thick oil has a high viscosity; water has a low viscosity. The unit of measurement for absolute viscosity is:

$$\mu = absolute\ viscosity\ of\ fluid\ (Ns/m^2)$$

The viscosity of a fluid is usually significantly dependent on the temperature of the fluid and relatively independent of the pressure. For most fluids, as the temperature of the fluid increases, the viscosity of the fluid decreases. An example of this can be seen in the lubricating oil of engines. When the engine and its lubricating oil are cold, the oil is very viscous, or thick. After the engine is started and the lubricating oil increases in temperature, the viscosity of the oil decreases significantly and the oil seems much thinner.

Motion phenomena - Hydrodynamics

All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter.



Quizz

Kahoot link: https://kahoot.it/challenge/07689838?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23_1619368057925

Deadline: 5th May 2021, 18:00

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Closer look at calendar

	FEBRUARY	MARCH					APRIL				MAY					JUNE			JULY	
MON	22	1	8	15	22	29	5	12 Mon O	19	26	3	10	17	24	31	7	14	21	28	5
TUE	23	2	9	16	23	30 Fri E	6	13	20	27	4	11	18	25	1	8	15	22	29	6
											Q7	Q8	Q9	Q10						
WED	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2 Thu E	9	16	23	30	7
THU	25	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8
FRI	26	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9
SAT	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10
SUN	28	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11
E - EVEN O - ODD	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E

Lecture
Exercise
Revision/exam

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