Lecture 6

TOPICS

- **Density**
- **Pressure**
- **Variation of Pressure with Depth**
- **Pressure Measurements**
- **Buoyant Forces-Archimedes Principle**
- **Surface Tension (External source)**
- **Viscosity (External source)**
- **Equation of Continuity for Fluids**
- **Bernoulli's Equation**
- **Torricelli’s Law**

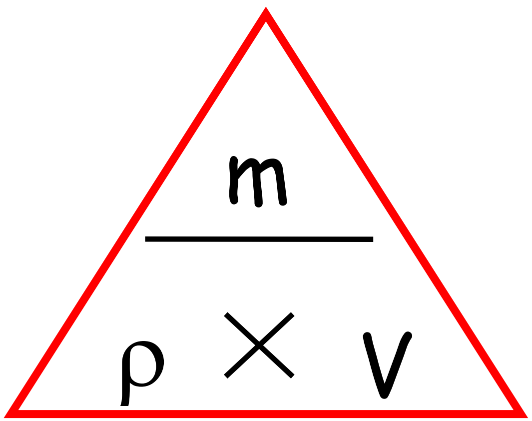
Density

g or kg

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

g .cm^{-3} or kg .m^{-3}

cm^3 or m^3



$$\rho = m \backslash V$$

- Density is defined as: amount of matter per unit volume
- In other word: is the **ratio** of mass to volume.

What is the mean of FLUID

- Matter is normally classified as being in one of four states: solid, liquid, gas, and plasma.

- All of liquids, gases, and plasma are fluids.

- A fluid is a collection of molecules that are randomly arranged and held together by weak cohesive forces and by forces exerted by the walls of a container.

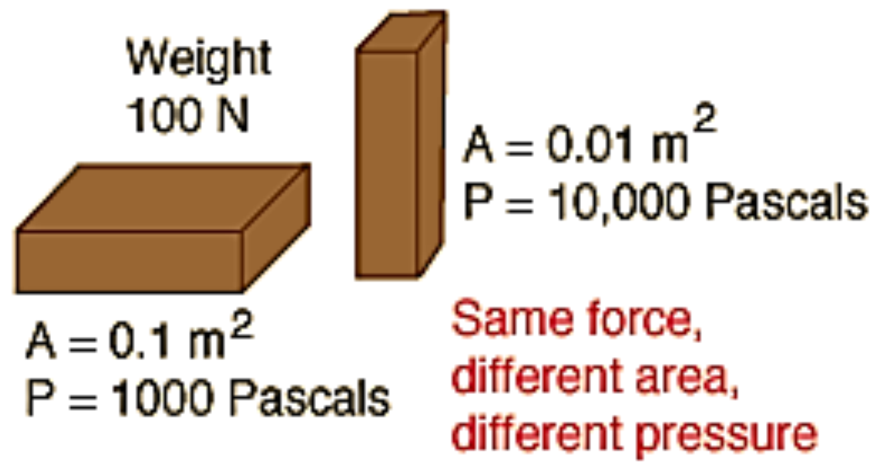
Fluid Mechanics

- ✓ Fluid mechanics is the study of how fluids move and the forces on them.
- ✓ Fluid mechanics can be divided into:
  - fluid statics, the study of fluids at rest.
    - fluid dynamics, the study of fluids in motion..

Pressure

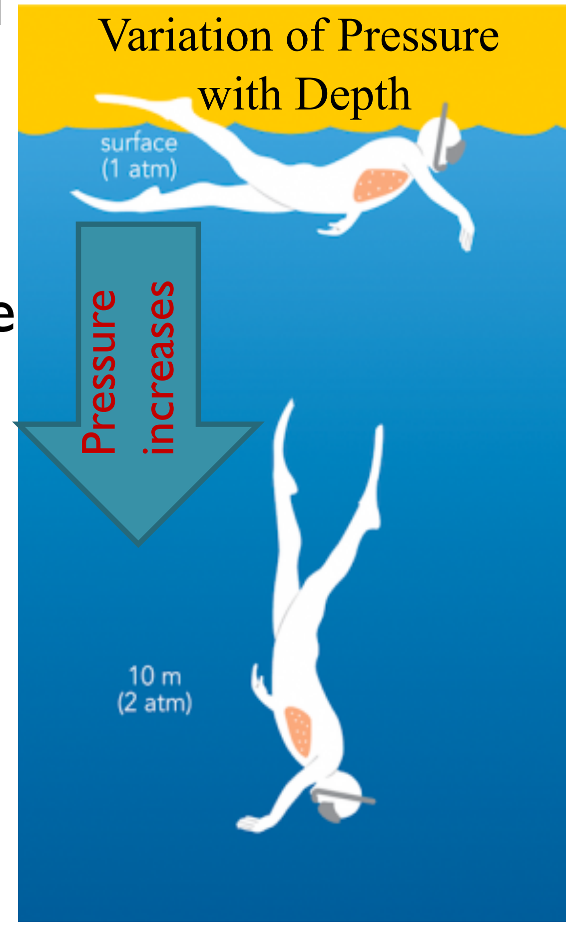
- ✓ Pressure is defined as force per unit area.
- ✓ The standard unit for pressure is the Pascal, which is a Newton per square meter.
- ✓ Pressure is a scalar quantity.

$$Pressure = \frac{Force}{Area} = \frac{F}{A}$$



Variation of Pressure with Depth

- One might guess that the deeper you go into a liquid or gas, the pressure on you from the surrounding fluid will be greater . The reason for the increased pressure is that the deeper into a fluid you go, the more fluid, and thus the more weight, you have over top of you.

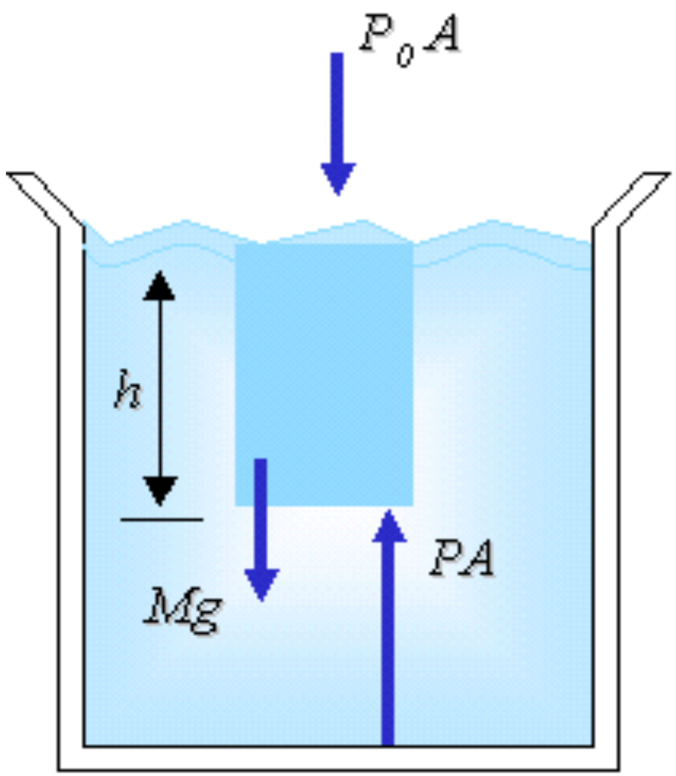


- We can calculate the variation of pressure with depth by considering a volume of fluid of height *h* and cross-sectional area *A*.

If the fluid is <u>open to the atmosphere of pressure</u> ,

<u>the pressure of the fluid at a depth is given by:</u>

$$P = P_0 + \rho g h$$



ρ **is the fluid density.**

g **is the acceleration of gravity.**

P_0 **is the atmospheric pressure & is usually**

$$P_0 = 1.01 \times 10^5\ Pa$$

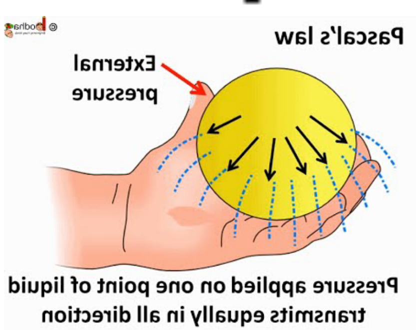
The pressure in a fluid changes linearly with depth.

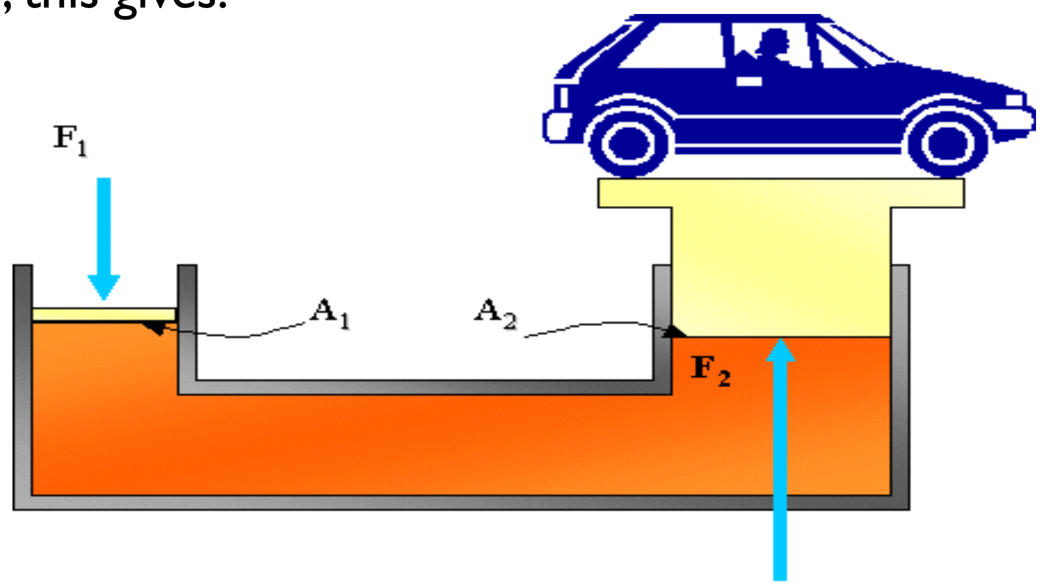
Pascal's principle:

" A change in the pressure applied to an enclosed liquid is transmitted undiminished to every point of the liquid and to the walls of the container. "

In the case of hydraulic press, if the force at one piston of area A_1 is F_1 , this pressure is transmitted through a liquid to the other piston of area . This produces a force at the other piston. Since the pressure is the same at both pistons, this gives:

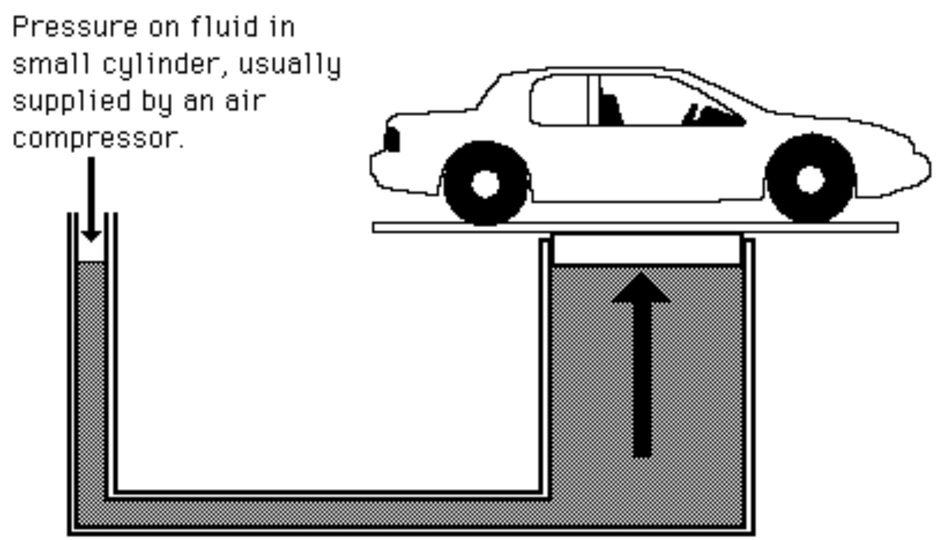
$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$





Example: The Car Lift

In a car lift used in a service station, compressed air exerts force on a small piston that has a circular cross section and a radius of 5.00 cm. This pressure is transmitted by a liquid to a piston that has a radius of 15.0 cm. What force must the compressed air exert to lift a car weighing 13300 N? What air pressure produces this forces?



Solution Because the pressure exerted by the compressed air is transmitted undiminished throughout the liquid, we have

$$F_1 = \left(\frac{A_1}{A_2}\right) F_2 = \frac{\pi(5.00 \times 10^{-2}\ \mathrm{m})^2}{\pi(15.0 \times 10^{-2}\ \mathrm{m})^2}(1.33 \times 10^4\ \mathrm{N})$$

$$= \boxed{1.48 \times 10^3\ \mathrm{N}}$$

The air pressure that produces this force is

$$P = \frac{F_1}{A_1} = \frac{1.48 \times 10^3\ \mathrm{N}}{\pi(5.00 \times 10^{-2}\ \mathrm{m})^2}$$

$$= \boxed{1.88 \times 10^5\ \mathrm{Pa}}$$

PRESSURE MEASUREMENTS

1- MANOMETER

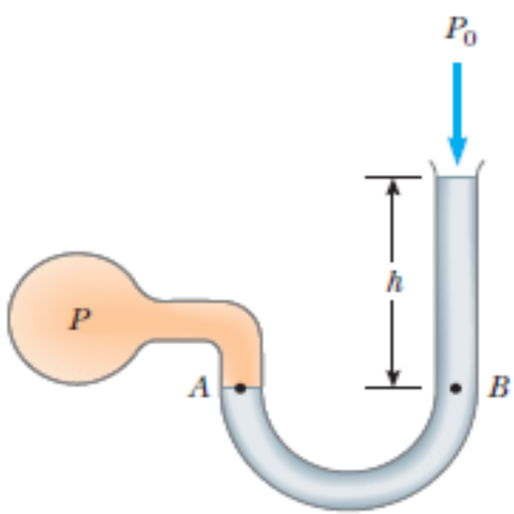
A simple device for measuring pressure is the open-tube manometer. One end of a U-shaped tube containing a liquid is open to the atmosphere, and the other end is connected to a system of unknown pressure *P*.

The pressure at point *B equals*

$$P_0 + \rho g h$$

The pressure at B, however, equals the pressure at A, which is also the unknown pressure P. We conclude that

$$P = P_0 + \rho g h.$$

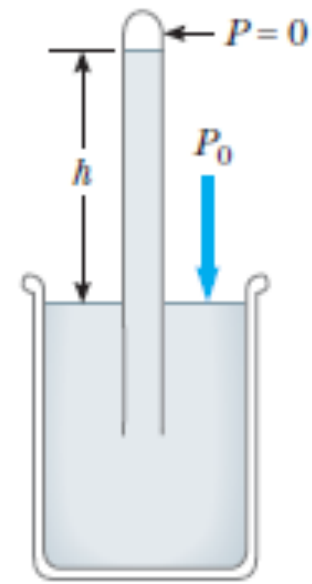


PRESSURE MEASUREMENTS

2- BAROMETER

https://www.youtube.com/watch?v=WXe0TIV3vVc

A long tube closed at one end is filled with mercury and then inverted into a dish of mercury. The closed end of the tube is nearly a vacuum, so its pressure can be taken to be zero. It follows that



(b)

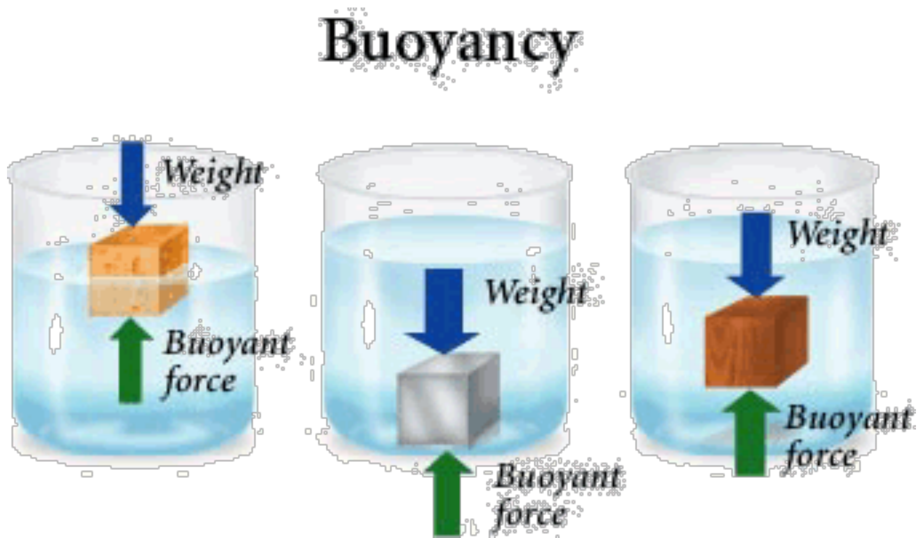
$$P_0 = \rho g h$$

Note that **the barometer measures the pressure of the atmosphere, however, the manometer measures pressure in an enclosed fluid.**

Buoyant Forces

The behavior of an object submerged in a fluid is governed by *Archimedes Principle*. Archimedes determined that a body which is completely or partially submerged in a fluid experiences an upward force called the **Buoyant Force, *B***, which is equal in magnitude to the weight of the fluid displaced by the object.

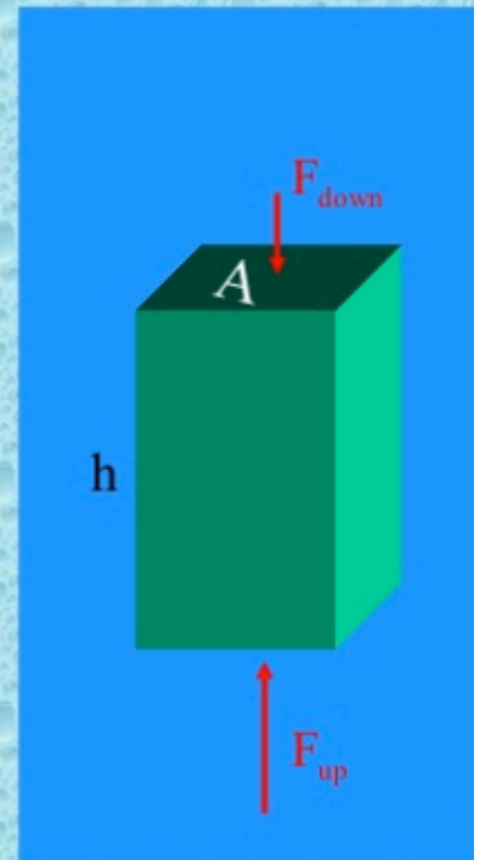
This principle can be used to explain why ships, loaded with millions of kilograms of cargo, are able to float.



Law of Archimedes:
The buoyant force is equal to
the weight of the replaced liquid or gas.

The fluid is pressing on the box on all sides. The horizontal forces cancel out. The buoyant force is given by $F_B = F_{up} - F_{down}$. $F_{up} > F_{down}$ since the pressure is lower at the top by the amount $\rho g h$, where ρ is the density of the fluid.

So, $F_B = \rho g h A = \rho g V$, where V is the volume of the box. But ρV is the mass of the fluid that the box displaces, so $\rho g V$ is the weight of fluid displaced. Thus, the buoyant force = the weight of displaced fluid.

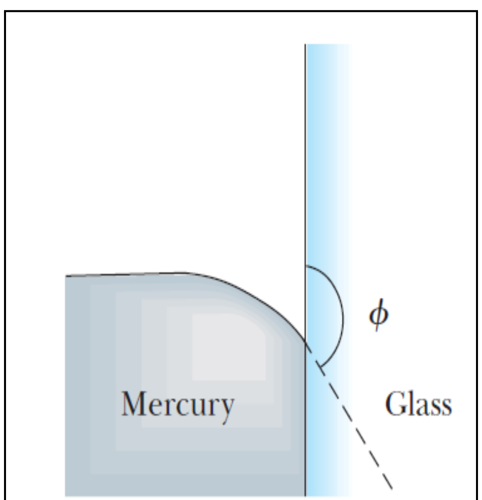


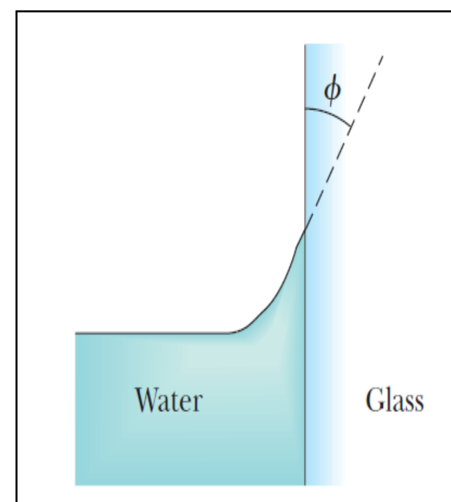
$$F_{B=}V\rho g = mg = W$$

THE SURFACE OF LIQUID

In general terms, forces between like molecules, such as the forces between water molecules, are called cohesive forces.

and forces between unlike molecules, such as those exerted by glass on water, are called adhesive forces.

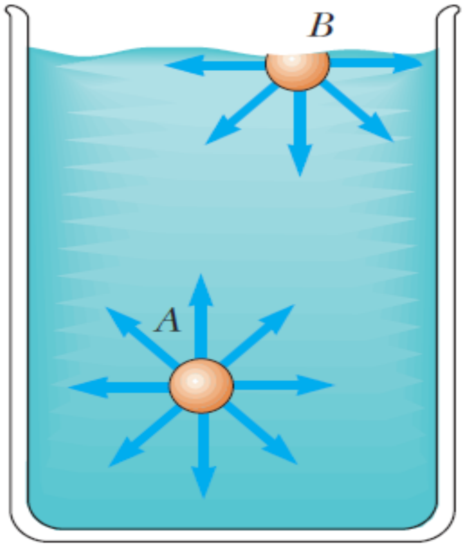




SURFACE TENSION

The drop takes spherical shape because of a property of liquid surfaces called surface tension.

The net effect of the pull on all the surface molecules is to make the surface of the liquid contract and, consequently, to make the surface area of the liquid as small as possible.

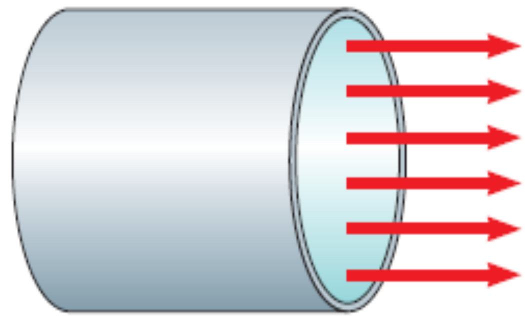


Drops of water take on a spherical shape because a sphere has the smallest surface area for a given volume.

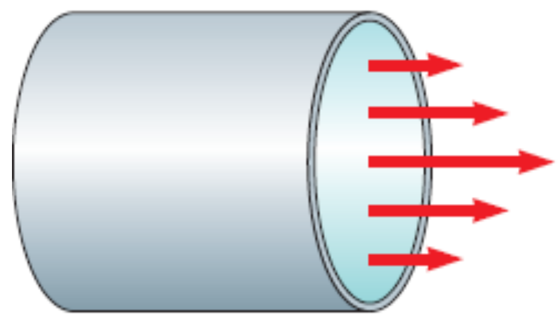
Viscous Fluid Flow

Viscosity refers to the internal friction of a fluid.

- When nonviscous fluid (an ideal fluid) flows through a pipe, the fluid layers slide past one another with no resistance. If the pipe has a uniform cross section, each layer has the same velocity.



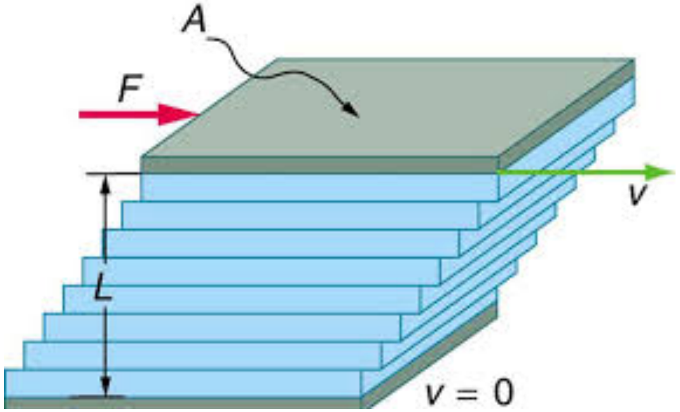
- When a viscous fluid flows through a pipe,the fluid layers have different velocities. The fluid has the greatest velocity at the center of the pipe, whereas the layer next to the wall doesn't move because of adhesive forces between molecules and the wall surface.



Viscosity

How does viscosity is measured for a fluid?

Two parallel plates with **A** area have the specific fluid between them. The bottom plate is held fixed, while the top plate is moved to the right, dragging fluid with it. The layer of fluid in contact with either plate does not move relative to the plate, and so the top layer moves at ***v*** while the bottom layer remains at rest. Each successive layer from the top down exerts a force **F** on the one below it, trying to drag it along, producing a continuous variation in speed from ***v***



$$F \alpha \frac{Av}{L}$$

Viscosity

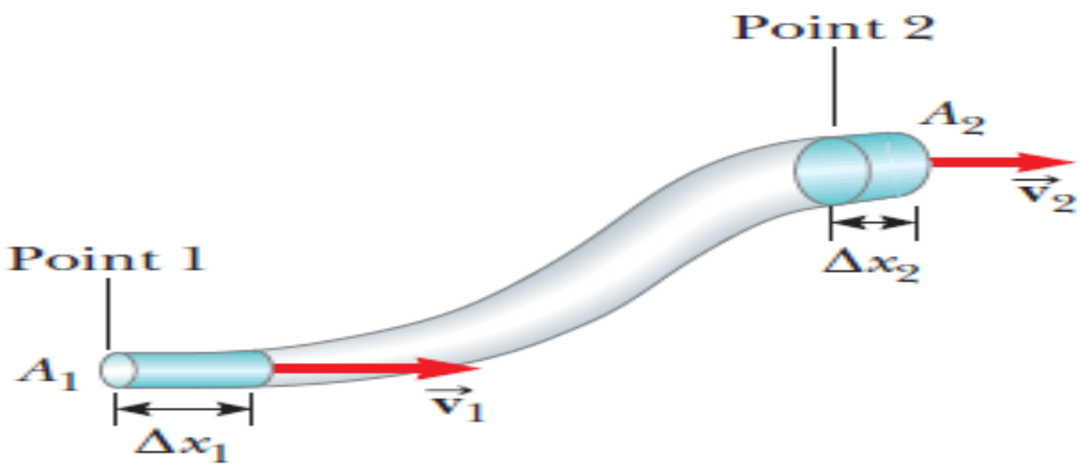
The viscosity force *F* is given as :

$$F = \eta \frac{Av}{L}$$

where A is the surface area.
v is the velocity.
d is the distance between the two plates.
η is the viscosity coefficient.

Fluid Dynamics

Equation of Continuity



The equation of continuity for fluids states that:

The product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.

$$A_1 \upsilon_1 = A_2 \upsilon_2 = const.$$

Bernoulli's Equation

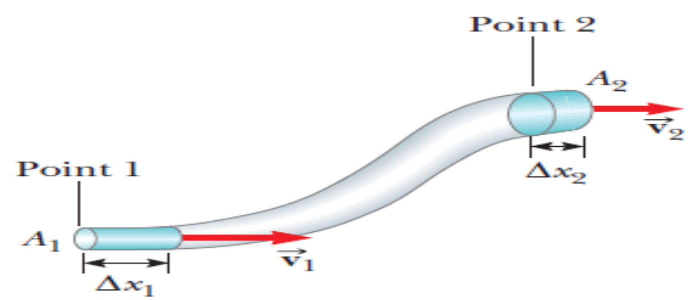
The relationship between fluid speed v, pressure P, and elevation h
was first derived by the Swiss physicist Daniel Bernoulli.

The Bernoulli's equation is often expressed as:

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

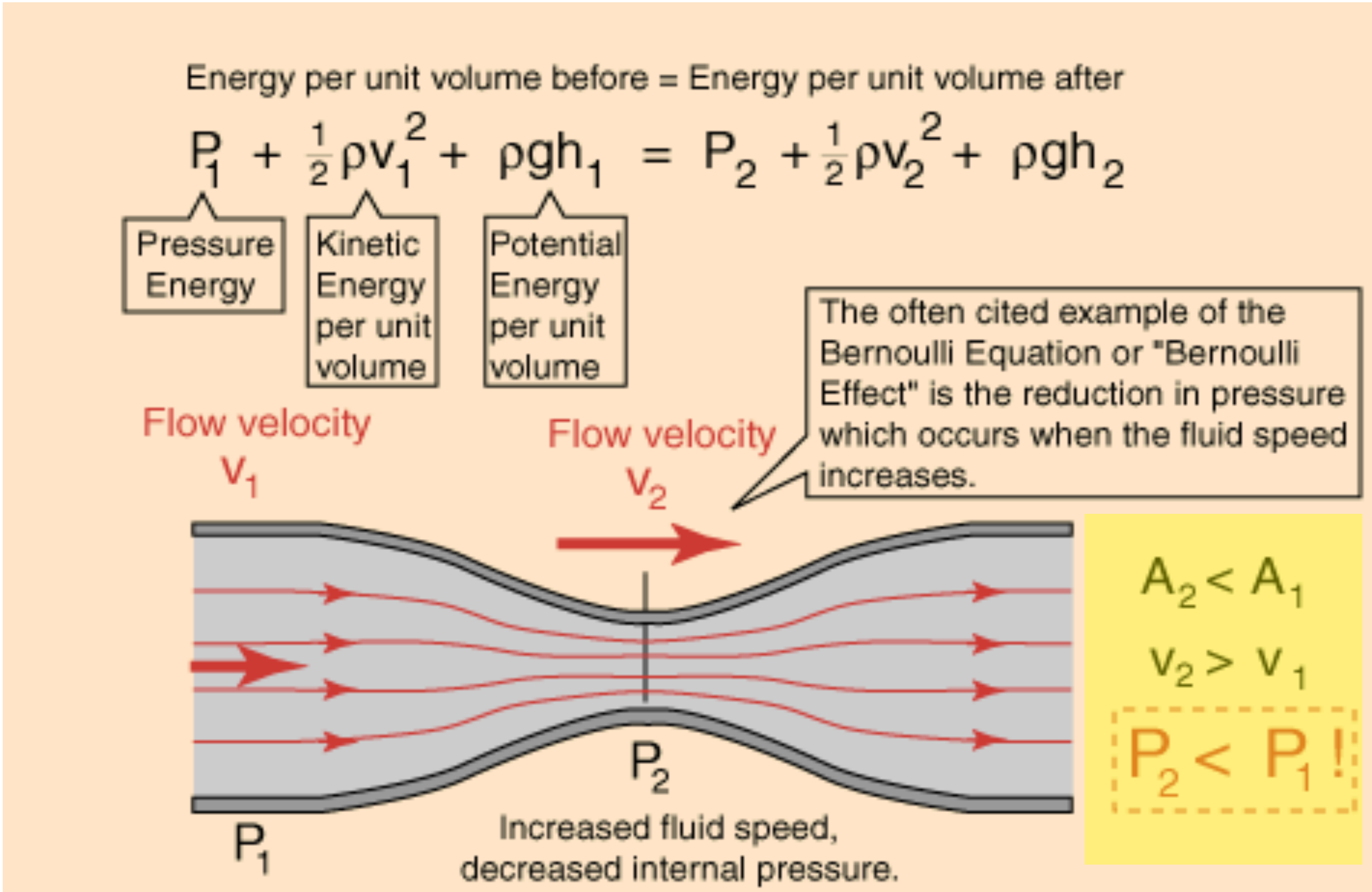
Where P is the pressure, ρ is the density, v is the velocity, h is the elevation, and g is the gravitational acceleration.

where
- points 1 and 2 lie on a streamline,
- the fluid has constant density,
- the flow is steady, and
- there is no friction.



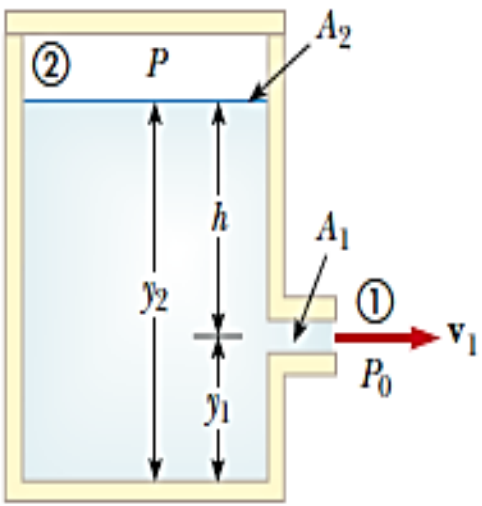
*** This expression shows that the pressure of a fluid decreases as the speed of the fluid increases.
In addition, the pressure decreases as the elevation increases.

Bernoulli's Equation



Torricelli's Law

Torricelli's law, also known as Torricelli's theorem, is relating the speed of fluid flowing out of an opening to the height of fluid above the opening.



If the tank is open to the atmosphere, then

$P = P_0$ and $v_1 = \sqrt{2gh}$. In other words,

for an open tank, the speed of liquid coming out through a hole with a distance h below the surface is equal to the speed acquired by an object falling freely through a vertical distance h. This phenomenon is known as Torricelli's law.