Unit – 3

Fluid mechanics

- Most matter can exist as solid, liquid, gases. Liquid and gas are both fluid.
- Fluids moves or flow under the action of force b/c they lack of the ability to resist deformation.
- Fluid mechanics study of the fluid behavior at rest and in motion.
- Fluid mechanics has a wide range of application in mechanical, aerodynamics engineering, biological system and many more fields.

Fluid statics

Property of solid, liquid and gas

Solid

- ✓ Atoms in solid are in close contact.
- ✓ Atoms are vibrating not change position with neighboring atoms.
- ✓ Atoms in solid are arranged in pattern.
- ✓ Solid resist all types of stress.
- ✓ Solid cannot be easily deformed b/c the atom in solid is not moves freely.

Liquid

- ✓ In liquid intermolecular forces are weaker relative to solid but still strong relative to gas.
- ✓ Liquid deform easily when stressed do not back to original shape b/c the atoms free to slide.

Gases

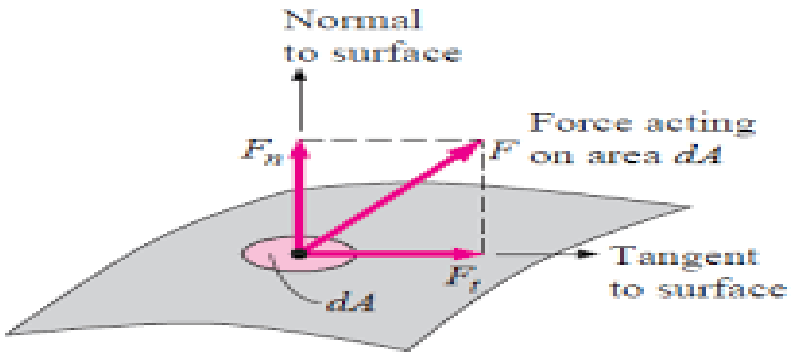
- ✓ Separations of atoms are large.
- ✓ The force b/n atoms very weak.
- ✓ Gases are easy to compressed b/c there is much space and little force b/n atoms.
- ✓ Gas can be expanding.

Fluid statics

- Fluid statics deals with the nature of fluid at rest.
- The fluid can be either gaseous or liquid.
- Hydrostatics when the fluid is liquid whereas aerostatics when fluid is gas.
- Fluid statics used to determine the force acting on floating or submerged bodies and force developed by device like hydraulic press and car jacks.
- Water dam and liquid storage tank requires determining force acting on their surface using fluid statics.

Pressure

- Pressure or stress defined as force per unit area.
- The normal component of a force acting a surface per unit area is called normal stress.
- The tangential component act on the surface per unit area is called shear stress.
- For fluid at rest the shear stress must be zero and only exist normal stress and is called pressure.
- $\mathbf{p = \frac{F}{A}}$



$$\text{Normal stress: } \sigma = \frac{F_n}{dA}$$

$$\text{Shear stress: } \tau = \frac{F_t}{dA}$$

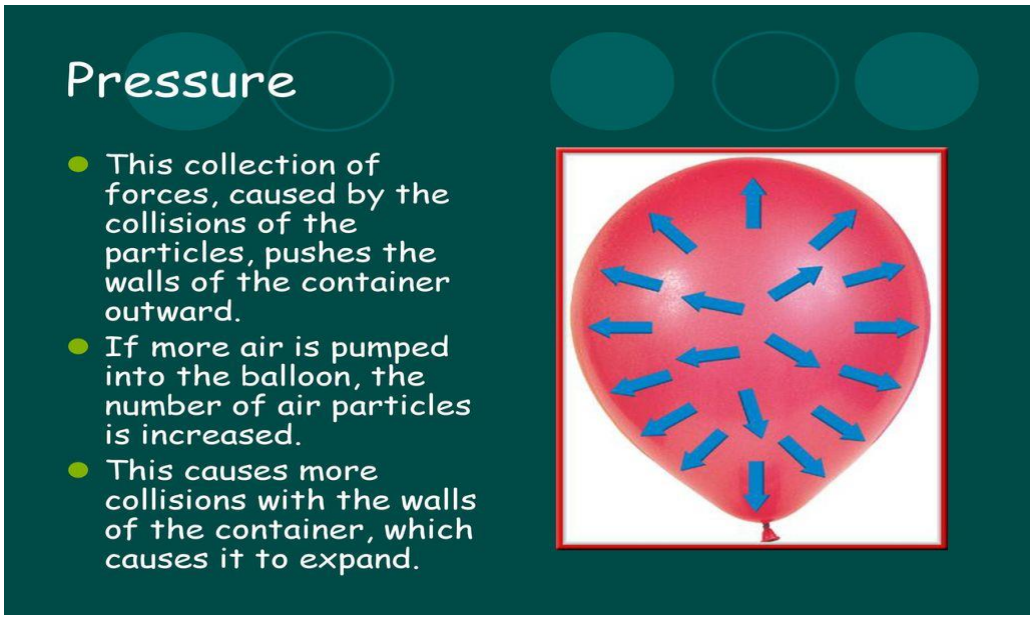
- The unit of pressure is $^{N}/_{m^2}$ in the SI system Pa is another SI unit of pressure.
- There are other units of pressure millimeter mercury (mmHg), torr, atmosphere (atm) and pounds per square inch (psi).
- to express pressure in other pressure unit we use this formula $\mathbf{P_{other} = \frac{P_{cons} \times P_{pascal}}{101.3kpa}}$

- $\mathbf{P_{cons}} = is\ constant\ value\ of\ pressure\ in\ other\ system\ excluded\ \ pascal$
- $\mathbf{P_{pascal}} = is\ given\ value\ of\ pressure.$
- $\boldsymbol{P_{other}} = is\ value\ of\ pressure\ in\ the\ new\ system.$

$$\mathbf{1atm = 760mmHg}$$
$$\mathbf{1atm = 14.7psi}$$
$$\mathbf{1atm = 760torr}$$

Pressure in gas

- Air particles moves randomly in space and collide with solid surface of any object in space.
- In each of these collision particle exerts an impulsive force on the object like tennis ball hitting a particle wall.
- In normal situation an extreme large number of gas particle collide each second with the surface each particle collision is impulsive the force consider as a single constant force.



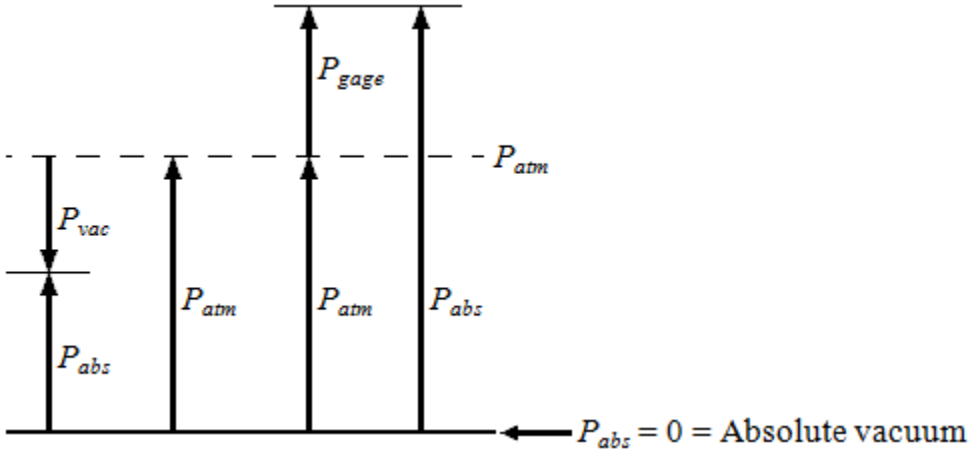
Absolute pressure: the actual pressure at a given position. It is measured relative to absolute zero pressure.

Gage pressure: it is the difference between the absolute pressure and the local atmospheric pressure.it can be positive or negative.

$$\boldsymbol{P_{gage} = P_{abs} - P_{atm}}$$

Vacuum pressure: it is the difference between atmospheric pressure and absolute pressure

$$\boldsymbol{P_{vac} = P_{atm} - P_{abs}}$$



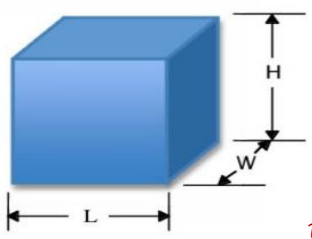
- The right tyre pressure of the car range from 32 - 35 psi

Density: it is important characteristics of substance determining whether an object sinks or float in a fluid.

- It measures how tightly packed the particle or molecule of materials are.
- It defined as the mass per unit volume.
- $\rho = \frac{m}{v}$
- The density of most gases is proportional to pressure and inversely proportional to temperature.
- Density allows us to answer equation like why does oil form a film on water.

Measuring density

1. Regular solid: to measure the density of regular shape we first measure their mass and volume by measuring dimension finally we determine density.



$v = L \times W \times H$

2. Irregular solid: to measure the density of irregular solids first measure the mass and the volume may be determine by measuring the volume of water the body displaces when it completely immersed in water.

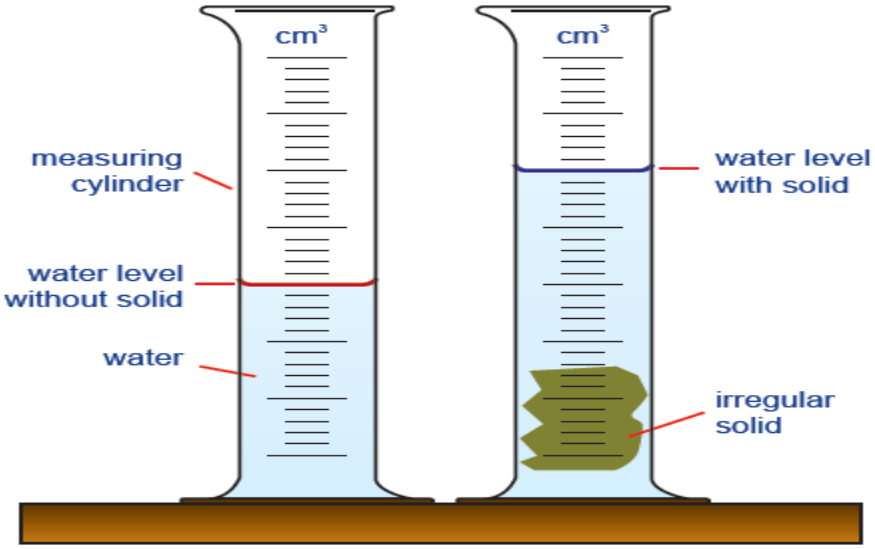


Fig. 4.3 Measuring the volume of an irregular solid

$$\rho = \frac{M}{V}$$

Relative density (specific gravity) : the density of substance is given relative to the density of another substance.it is define as the ratio of the density of substance to the density of some standard substance at specific temprature of water its value $1000\ {}^{kg}/_{m^3}$ if SG >1 body is sink if SG < 1 body is float.

$$SG = \frac{\rho}{\rho_{H_2O}}$$

Ideal gas euation from ideal gas equation there is a relation ship between density and presure.

- ✓ $pv = nRT = \frac{m}{M}RT = mR_{specific}T$
- ✓ $R_{specific} = 0.287 kpa.\frac{m^3}{kg.k}$ $= the\ specific\ gas\ constan\ different\ for\ different\ gases$

Pascal's principle state that achange in the pressure applied to static fluid is transmitted undiminished to every point of the fluid and to the walls of the container.

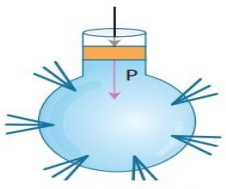
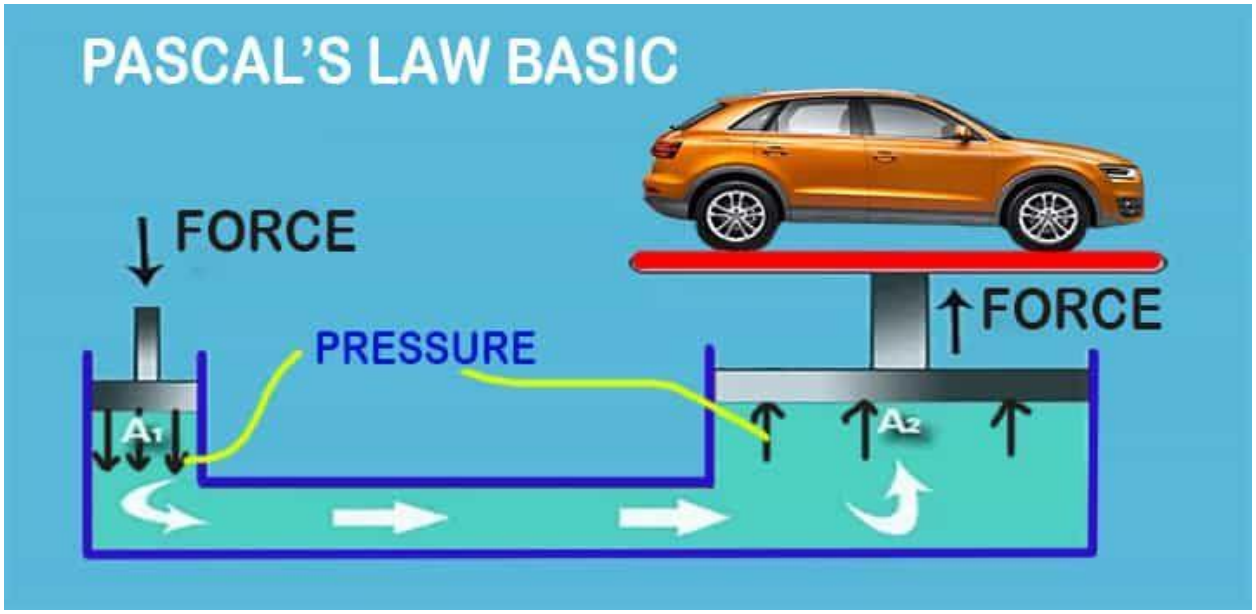


Figure 1.13 Demonstration of Pascal's Law

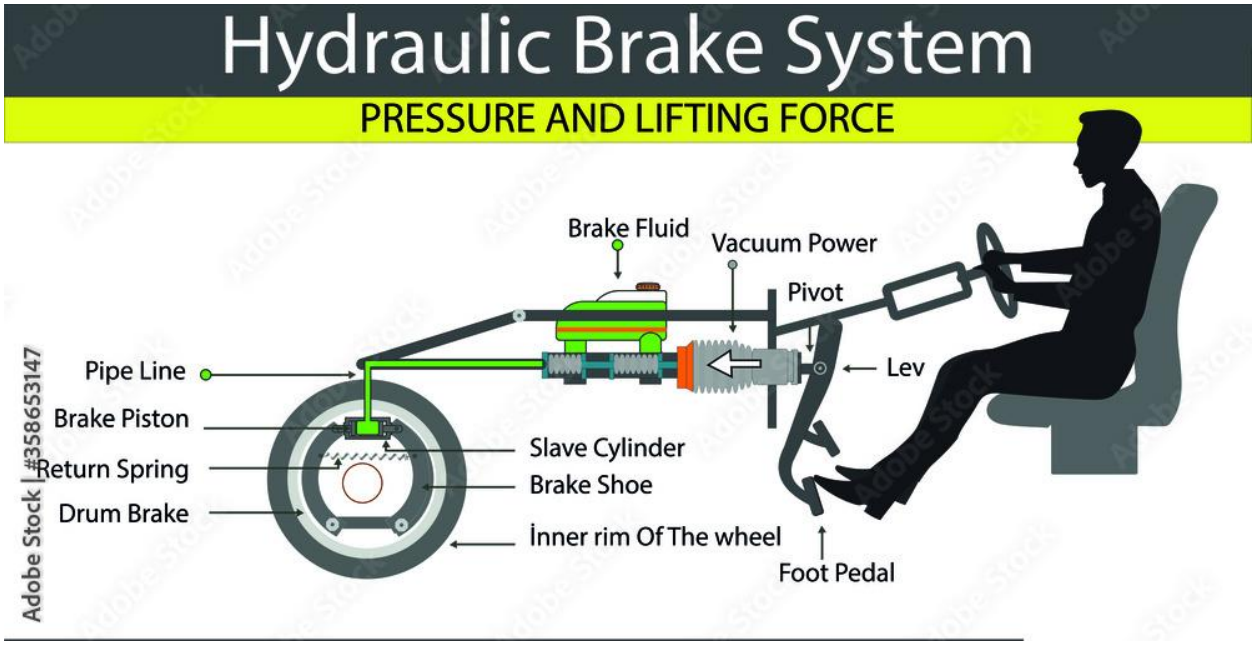
Hydrolic press is a simple machine that cinvert small force into large forces or vice versal which is one of the application of pascals principle



$$p_1 = p_2$$

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

The hydraulic brakes of an automobile are also a form of hydraulics press

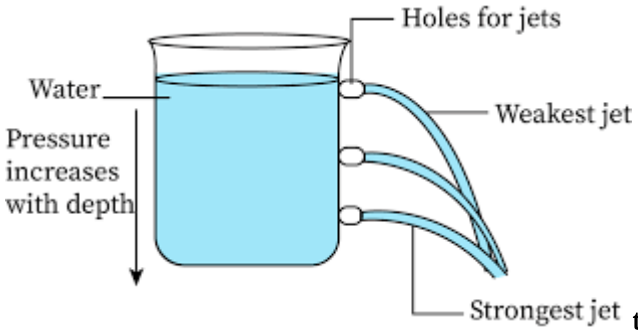


- Hydraulic press is a force multiplier machine. It reduced the amount of force needed to lift a load.

- The work done by the the two pistone is the same.

Variation of pressure with depth

- Pressure of the liquid depend on the depth as well as the density of liquid.



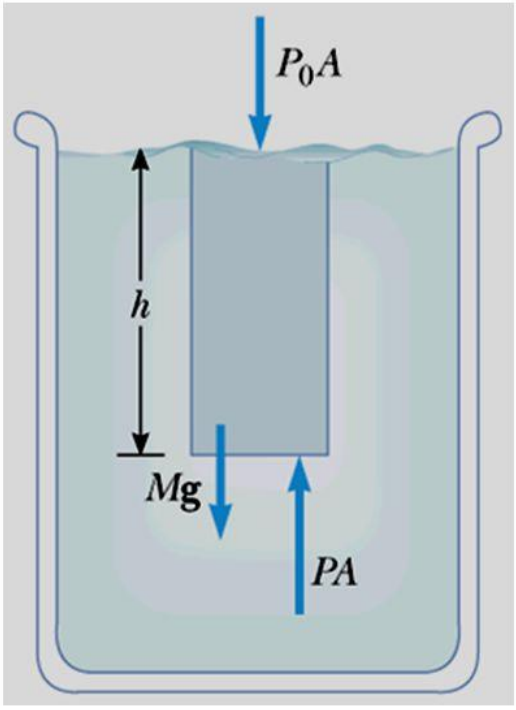
the total pressure is $p_{abs} = p_{atm} + \rho gh$

Variation of pressure with depth

$$P \equiv P_0 + \rho \cdot g \cdot h$$

The pressure P at a depth h below the surface of a liquid open to the atmosphere is *greater* then the atmospheric pressure by an amount ρ·g·h

ρ… density of liquid



i.e. added pressure corresponds to weight of fluid column of height h.

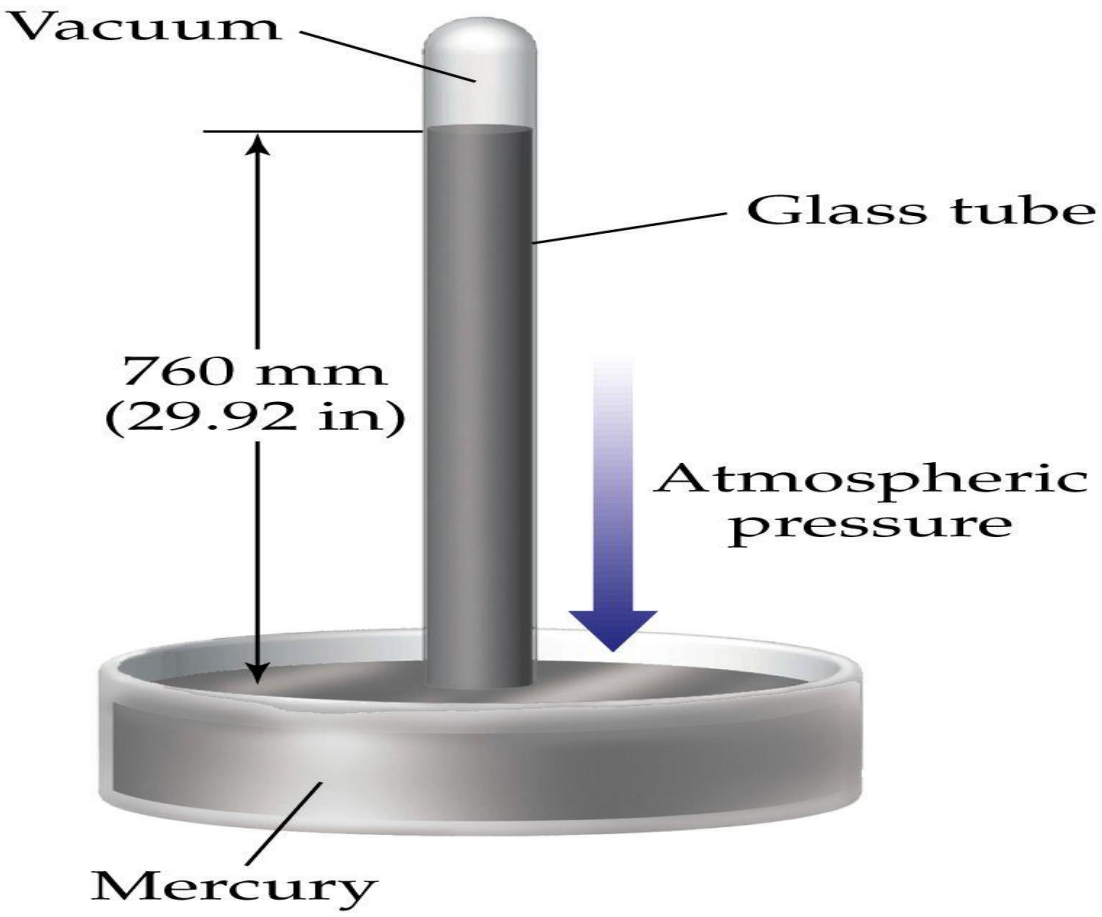
- The pressure due depth of liquid is independent of the shape and the size of the container only depend on the depth.

Atmospheric pressure

- Most gas molocules in the atomospher are pulled by close to earth surface by gravity as the result air posseses weight which enables it to exert pressure on the bodies this pressure is called atmospheric pressure.
- The depth (distance from top to bottom) of the atmossphere is greatest at sea level and decrease at higher altitude.
- Cooking takes longer time at high altitude than lower altitude.

Measuring atmospheric pressure

- Atmospheric pressure is measured by an insturument is called barometer.
- The mercury barometer a glass tube about 80cm long is completely filled with a clean dry mercury. It is then inverted in a bath of mercury leaving the open end under the surface of mercury.
- The level of mercury in the tube fall leaving an empty space or vaccum at the top.

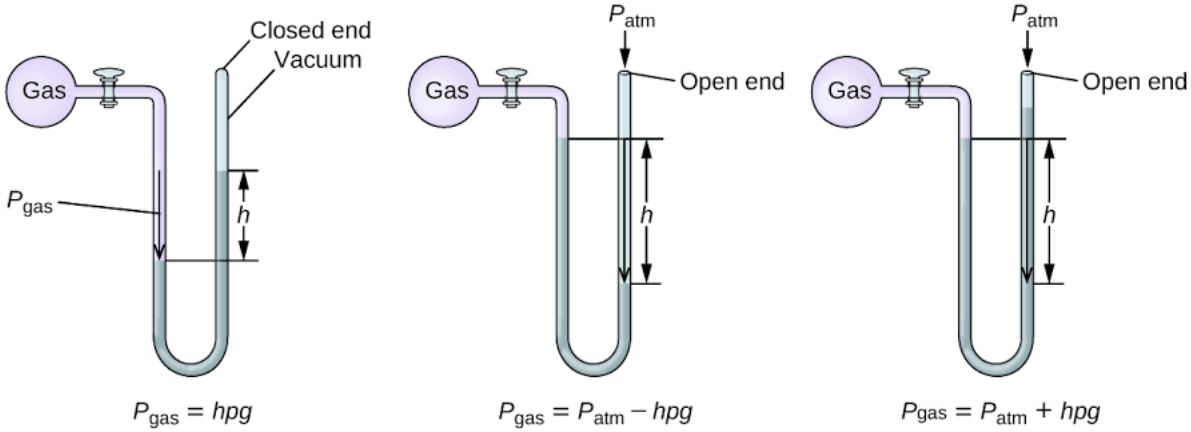


- Standard atmospheric pressure is taken to support a colun of mercury 76cm high at sea level.
- $\mathbf{p_a = 13600\frac{kg}{m^3} \times 0.76cm \times 9.8\frac{m}{s^2} = 101.3kpa}$
- Experimentally observed that for a rise of every 120m above sea level near the earth surface the height of the column of mercury in a barometer decrease by 1cm so that atmospheric pressure decreasees at higher altitude. $\mathbf{Altitude = \frac{76cm-h}{1cm} \times 120m}$

- The length or the cross section area of the tube has no effect on the height of the fluid coulmen barometer.the tube diameter is large enough to avoid surface tension or capillary effect.

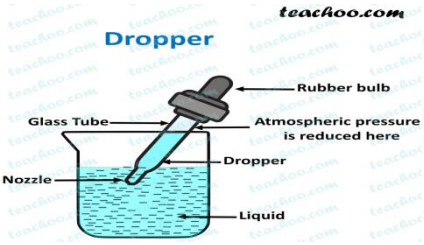
The manometer

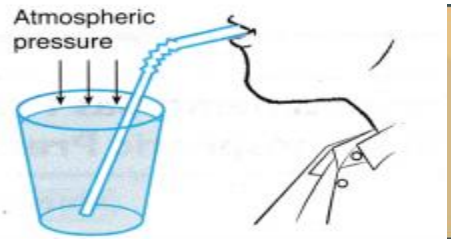
- Manometer is another device which used to measure the pressure of gas supplies.
- It consist of a U- shaped glass tube containing some liquid. The liquid may be oil ,water or mercury.

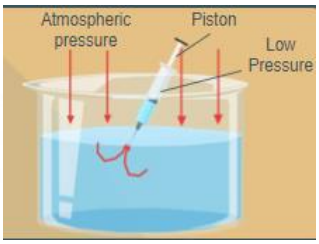


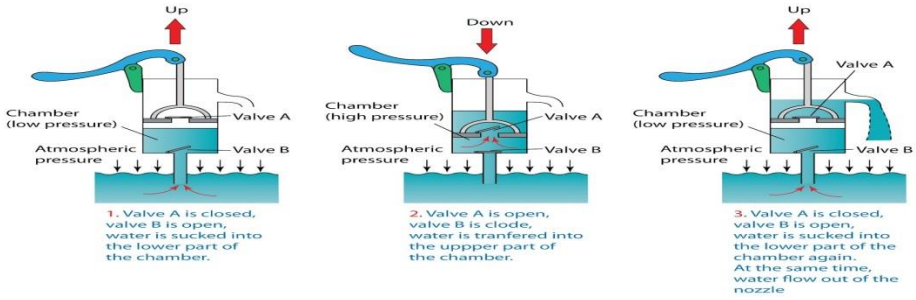
Some application of atmosheric pressure

- There are different device that oprate under atmosheric pressure.
  - ✓ Syringe.
  - ✓ Water pump.
  - ✓ Dropper.
  - ✓ Drinking with strow.oprate under theaction of atmospheric pressure.







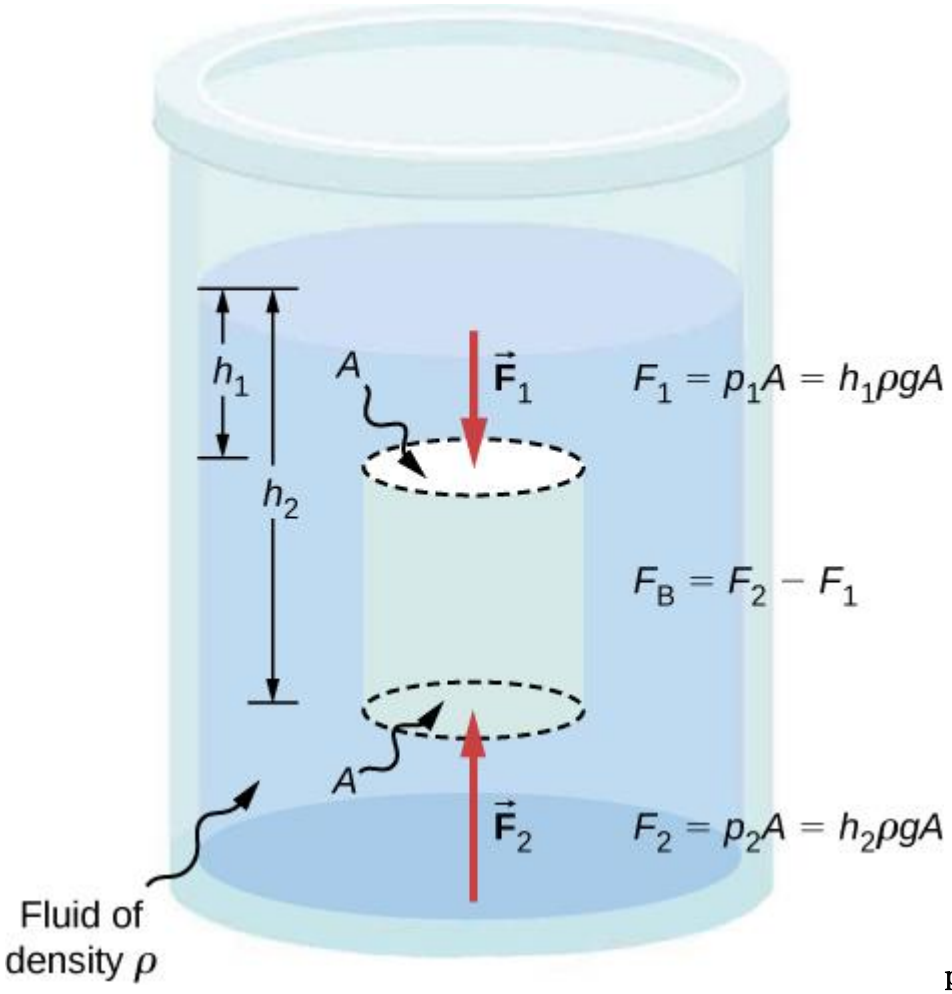


Archimedes' principle

- Which stated as" when a body is totally or partially immersed in a fluid it expriences an up ward force whhich is equal to the weight of the fluid displeced."

Buoyant force

- The upward force exerted by a fluid on any immersed object.
- Buoyant force comes from pressure increase with depth in a fluid. This means that the upward force on the bottom of an object in a fluid is greater than the downward force on the top of the object.
- $F_b = W - W'$ **where W = actual weight and W′ = apparent weight.**
- $F_b = \rho_{fluid} \times g \times V_{disp}$ **where** $\rho_f V_{dis}$ **= mass of fluid displeced the object.**



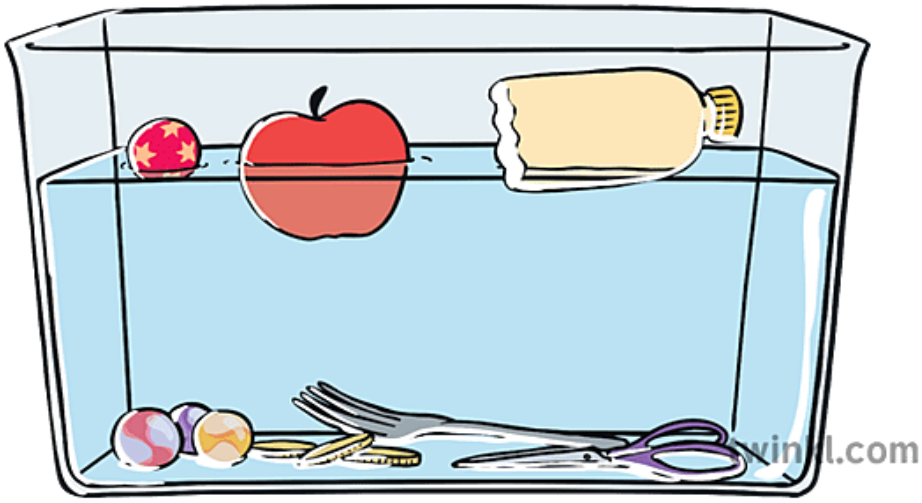
pressure variation with the depth result a buoyant force. $F_b = W_{fluid}$

Totally submerged object

- When an object is totally submerged in a fluid density the volume of the displeced fluid is equal to the volume of the object ; so the magnetude of the buoyant force is $F_b = \rho_f \times g \times V_{obj}$.
- If the object has mass M and density ρ_{obj} its weight $F_g = Mg = \rho_{obj} \times g \times V_{obj}$.
- The net force on the object is $F_b - F_g = (\rho_f - \rho_{obj})gV_{obj}$
- If the density of submerged object equal to the density of fluid the net force on the object is zero.
- If the density of the object is less tha the density of fluid then unsupported object accelerated upward.
- If the upward force less than the downward gravitational force unsupported object sink.
- The diraction of motion of an object submerged in a fluid is determined only by the density of the object and the fluid.

Floating object

- The principle of floatation state that a body that floats in a fluid displeced a volume of fluid which has the same weight as the body.
- A boat constructed in such a way that it has a large volume it displeced a lot of water when it float on water.
- The object is float the upward buoyant force balanced by the downward gravitational force acting on the object.
- If displeced volume is the volume of the fluid displeced by the object or this volume is the same as the volume of that part of the object beneath the surface of the fluid.
- $F_b = \rho_f \times g \times V_{dis}$ **and weight of object** $F_g = \rho_{obj} \times g \times V_{obj}$
- $F_g = F_g$ ***the the ratio of volume and density is*** $\frac{V_{dis}}{V_{obj}} = \frac{\rho_{obj}}{\rho_f}$



- What do you think the level of water in the ocean if all icebergs presently floating in the ocean melt ?

Conclusion

- ✓ If the ice is made up of pure water melt in an ocean of pure water sea level does not change.
- ✓ If ice made pure water melt in salty ocean sea level rise.
- ✓ If ice made up of salty water melt in oscean of pure water the level is goese down.
- ✓ If an ice made up of salty water melt in salty oscean the sea level does not change.

Fluid dynamics

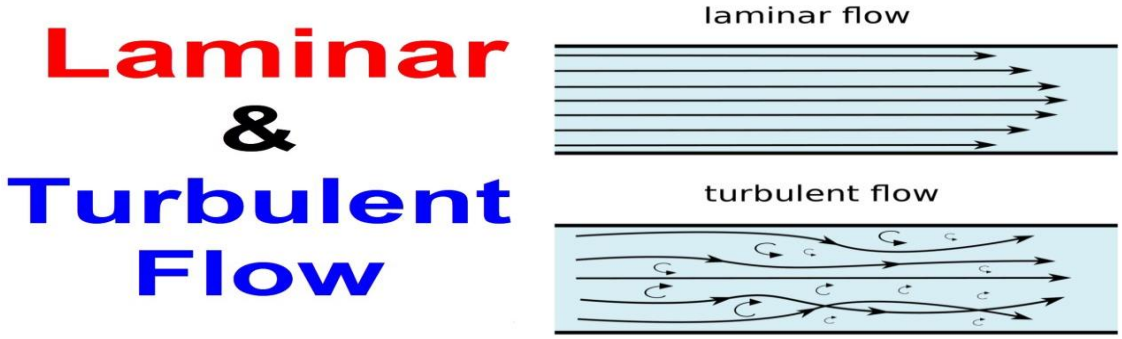
Fluid flow

- ➢ Fluid flow is caused by the difference in pressure.
- ➢ When the pressure in one region of the fluid is lower than in another region the fluid tends to flow higher pressure to lower pressure.
- ➢ Example of fluid flow
  - ✓ A river flow down a mountain.
  - ✓ Air passing over a birds wing.
  - ✓ Blood moving thrugh circulatory system
  - ✓ Fuel moving through the engine.

- ➢ There are three fluid flow regimes.
  - ✓ Laminar(steady) flow.
  - ✓ Turbulent flow.
  - ✓ Transition flow.

Laminar or steady flow

- ➢ Laminar flow occurs when the fluid flow in infinitesmal parallel layer with no disurption b/n them.
- ➢ Fluid layer slides in parallel with no eddies swirl.
- ➢ Travel smoothly in ragular path.
- ➢ Evry fluid particles arriving at a given point in space has the same velocity.
- ➢ Always occurs when the fluid flow with low velocity and in small diameter of pipe.



Turbulent flow

- a type of fluid flow in which the fluid undergoese irregular flactuation.
- The velocity of the fluid at a point continuously changes in both magnatude and diraction.
- The fluid travel in irregular path moves randomly in zigzag manner.
- Occurs when the velocity of the fluid is high and it flows through large diameter pipes.
- Turbulent flow boundary layer has more energy than laminar flow layer so it with stand an adverse pressure gradien longer.
- When two adjecent layers of fluid try to move relative to each other viscosity causes part of the fluid kinetic energy to be transformed to internal energy.
- The path taken by a fluid particle under steady flow is called a streamline.

Definition of Streamlines

Glenn Research Center

Airfoil

Moving with the object.

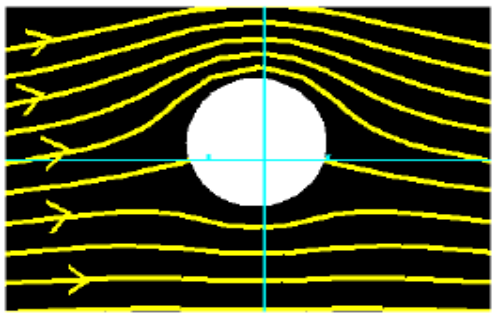
Flow goes from left to right.

Steady, two-dimensional flow.

Streamline is a path traced out by a massless particle moving with the flow.

Velocity is tangent to streamline at every point.

Mass does not cross streamlines.

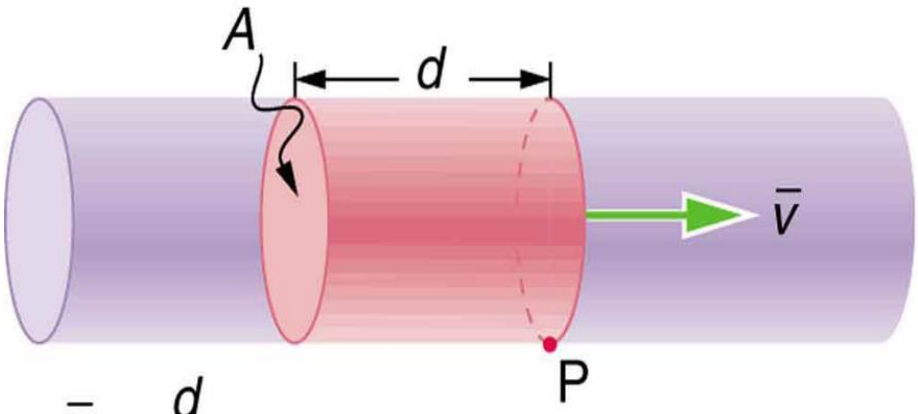


Cylinder

Flow rate

- Flow rate is defined as the quantity of fluid that is passing through a cross – section of pipe in a specific period of time.
- It is the volume of fluid per time the fluid has flowed.

$$Q = \frac{volume}{time}$$



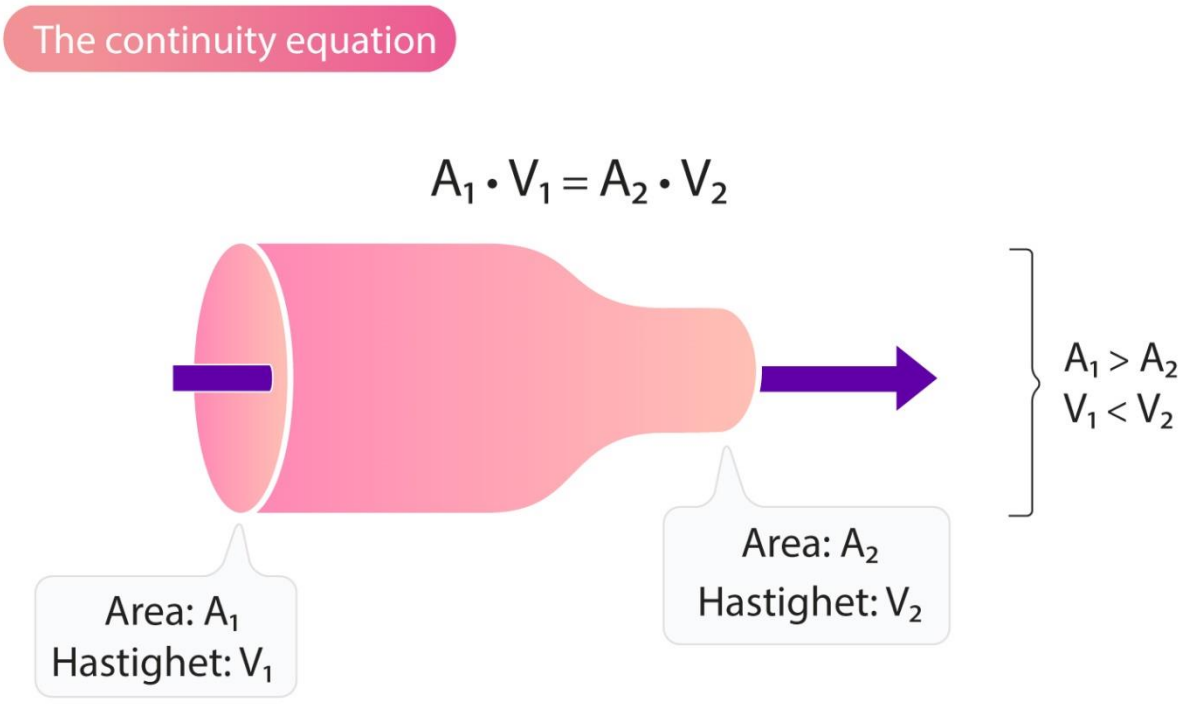
$$\bar{v} = \frac{d}{t}$$

$$Q = \frac{V}{t} = \frac{Ad}{t} = A\bar{v}$$

Equation of continuity

- According to the continuity equation the product of cross – section area of the pipe and the velocity of the fluid at any given point along the pipe is constan.
- The volume flow rate intering the pipe is the same as the volume flow rate leave out.
- Thhis valid for any incompressible fluid.

$$Q_1 = Q_2$$
$$A_1V_1 = A_2V_2$$

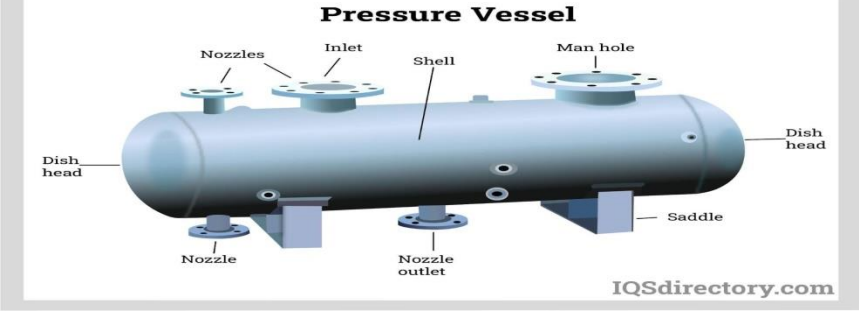


Safty and high pressure

- Pressure for greater than one atm most of the time greater than 50 atm considered as high pressure.
- High pressure used for many application
  - ✓ Used thermal power plant to generat power example velox boiler.
  - ✓ Cookers atre used high pressure in a kichen to cook food.
  - ✓ Gas cylinder used to seal d/t types of gas at high pressure for laboratory or medical.
  - ✓ Used for tire inflater.
  - ✓ High pressure washer.
  - ✓ In biological microorganism activity is diminished by the process of pascalization it used incrrease the shelf lives prishable foodstuffs juice,fish,meat and dry product.
- High pressure equipment consist of
  - High pressure compressor or pump
  - High pressure piping (fitting,seals,tubing and valves)
  - High pressure vessels
  - Steam generator
  - Safty acessory
  - High pressure instrumentation.

High pressure copressor : a compressor is a mechanical device that increase the pressure of the gas by reducing the volume.it can transport the fluid through the pipe.

High pressure vessels : it is a housing designed and built to contain fluids under pressure including its diract attachement upto the coupling point connected to other equipment.



Sefty accessories : these accessories include safety valve and brusting discsas well as limiting devices.limiting device can either activate the means for correction or shut down pressure switches and tempreture switch.

High pressure instrumentation : it is availebe for purpuses like pressure tempreture flow and level measurments.

Safty for high pressure equipment

- If the pressure system or equipment fails and bursts violently it ca seriously injure or kill people and causse serius damage to property.
- Common cause of pressure system and equipment risk include
    - Damaged equipment or system design.
    - Poor or no maintenace
    - An safe system of work.
    - Oprate error due to lack of training or supervision
    - Incorrect installation
    - Inadequate repair
- The safty measure to be taken to avoid the risk depend on the nature of high pressure system.

For high pressure gas cylinder : it filled with liquefied petroleum gas or LPG are sealed at high pressure

Safty measure to be taken

- ✓ Keep the gas cylinder in vertical position placed proper ventilated area.
- ✓ Make sure there are no inflammable materials and fuel it can cause an explosion
- ✓ Always turn off the knop on the gas cylinder after use.
- ✓ Keep the gase knopout of reach children.
- ✓ Do not use cylinder for long hours whle cooking.

High pressure washer : used in industry or our home used us to clean large area it also used to clean automobile motorcycle boat etc....

Safty measures are taken

- ✓ Wear safty glasses or goggle.
- ✓ Use work boots
- ✓ Wear proper safty glaves
- ✓ Wear ear protection.
- ✓ Never point your pressure washer at pet or people.
- ✓ Stand properly when using pressure washer.

End tank you