1.3 FLUID PROPERTIES:

1.Density or Mass density(ρ) : Density or mass density of a fluid is defined as the ratio of the mass of a fluid to its volume. Thus mass per unit volume of a fluid is called density.

$$\therefore \quad \rho = \frac{Mass}{Volume}$$

$$\rho = \frac{M}{V} \text{ or } \frac{dM}{dV}$$

The unit of density in S.I. unit is kg/m^3. The value of density for water is 1000kg/m. With the increase in temperature volume of fluid increases and hence mass density decreases in case of fluids as the pressure increases volume decreases and hence mass density increases.

2.Specific weight or weight density (γ): Specific weight or weight density of a fluid isthe ratio between the weight of a fluid to its volume. The weight per unit volume of a fluid is called weight density.

$$\therefore \quad \gamma = \frac{Weight}{Volume} = \frac{W}{V} \text{ or } \frac{dW}{dV}$$

The unit of specific weight in S.I. units is N/m^3. The value of specific weight or weightdensity of water is 9810N/m^3.

With increase in temperature volume increases and hence specific weight decreases.

With increases in pressure volume decreases and hence specific weight increases.

Note: Relationship between mass density and weight density:

$$\text{We have } \gamma = \frac{Weight}{Volume}$$

$$\gamma = \frac{mass \ x \ g}{Volume}$$

$$\gamma = \rho \text{ x g}$$

3.Specific Volume ($\forall$): Specific volume of a fluid is defined as the volume of a fluidoccupied by a unit mass or volume per unit mass of a fluid.

$$\therefore \quad \forall = \frac{Volume}{mass} = \frac{V}{M} \; or \; \frac{dV}{dM}$$

As the temperature increases volume increases and hence specific volume increases. As the pressure increases volume decreases and hence specific volume decreases.

4.Specific Gravity(S): Specific gravity is defined as the ratio of the weight density of afluid to the weight density of a standard fluid.

$$S = \frac{\rho_{fluid}}{\rho_{standard\,fluid}}$$

Unit: It is a dimensionless quantity and has no unit.

In case of liquids water at 4°C is considered as standard liquid. ρ_{water} = 1000 kg/m^3

Problem1: Calculate specific weight, mass density, specific volume and specific gravity of a liquid having a volume of 4m^3 and weighing 29.43 kN. Assume missing data suitably.

$\gamma = ?$

$\rho = ?$

$\forall = ?$

$S = ?$

$V = 4\,m^3$

$W = 29.43\ kN$

$= 29.43 \times 10^3 N$

$$\gamma = \frac{W}{V}$$

$$= \frac{29.43X10^3}{4}$$

$$\gamma = 7357.58\ N/m^3$$

To find ρ - Method 1:

$W = mg$

$29.43 \times 10^3 = m \times 9.81$

$m = 3000\ kg$

$$\therefore \ \rho = \frac{m}{v} = \frac{3000}{4}$$

Method 2:

$\gamma = \rho\, g$

$7357.5 = \rho\ 9.81$

$\rho = 750\ kg/m^3$

$$\rho = 750 \ \text{kg/m}^3$$

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

$$\text{i)}\ \forall = \frac{V}{M}$$

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

$$= \frac{4}{3000}$$

$$\forall = \frac{1}{\rho} = \frac{1}{750}$$

$$\forall = 1.33 \text{ x } 10^{-3} \text{m}^3/\text{kg}$$

$$\forall = 1.33\text{X}10^{-3} \text{m}^3/\text{kg}$$

$$S = \frac{\gamma}{\gamma_{\text{Standard}}} \qquad S = \frac{\rho}{\rho_{\text{Standaard}}}$$

$$= \frac{7357.5}{9810} \quad \text{or} \quad S = \frac{750}{1000}$$

$$S = 0.75 \qquad S = 0.75$$

Problem2: Calculate specific weight, density, specific volume and specific gravity and if one liter of Petrol weighs 6.867N.

$$\gamma = \frac{W}{V}$$

$$V = 1 \text{Litre}$$

$$= \frac{6.867}{10^{-3}}$$

$$V = 10^{-3} \text{m}^3$$

$$W = 6.867\text{N}$$

$$\gamma = 6867 \text{N/m}^3$$

$$S = \frac{\gamma}{\gamma_{\text{Standard}}}$$

$$\rho = s\ g$$

$$= \frac{6867}{9810}$$

$$6867 = \rho \text{ x } 9.81$$

$$S = 0.7$$

$$\rho = 700 \text{kg/m}^3$$

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

$$= \frac{10^{-3}}{0.7}$$

$$\forall = 1.4x10^{-3} m^3 / kg$$

$$M = 6.867 \div 9.81$$

$$M = 0.7 \text{ kg}$$

***Problem* 3:** Specific gravity of a liquid is 0.7 Find i) Mass density ii) specific weight. Also find the mass and weight of 10 Liters of liquid.

$$S = 0.7$$
$$V = ?$$
$$\rho = ?$$
$$M = ?$$
$$W = ?$$
$$V = 10 \text{ litre}$$
$$= 10x10^{-3} m^3$$

$$S = \frac{\gamma}{\gamma_{Standard}}$$

$$0.7 = \frac{\gamma}{9810}$$

$$\gamma = 6867 N / m^3$$

$$\gamma = \rho g$$

$$6867 = \rho \text{ x } 9.81$$

$$\rho = 700 \text{ kg} / m^3$$

$$S = \frac{\rho}{\rho_{Standard}}$$

$$0.7 = \frac{\rho}{1000}$$

$$\rho = 700 \text{kg} / m^3$$

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

$$700 = \frac{M}{10x10^{-3}}$$

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

$$700 = \frac{M}{10x10^{-3}}$$

$$M = 7 \text{kg}$$

5.Viscosity: Viscosity is the property by virtue of which fluid offers resistance against the flow or shear deformation. In other words, it is the reluctance of the fluid to flow. Viscous force is that force of resistance offered by a layer of fluid for the motion of another layer over it.

In case of liquids, viscosity is due to cohesive force between the molecules of adjacent layers of liquid. In case of gases, molecular activity between adjacent layers is the cause of viscosity.

Newton's law of viscosity:

Let us consider a liquid between the fixed plate and the movable plate at a distance 'Y' apart, 'A' is the contact area (Wetted area) of the movable plate, 'F' is the force required to move the plate with a velocity 'U' According to Newton's law shear stress is proportional to shear strain.

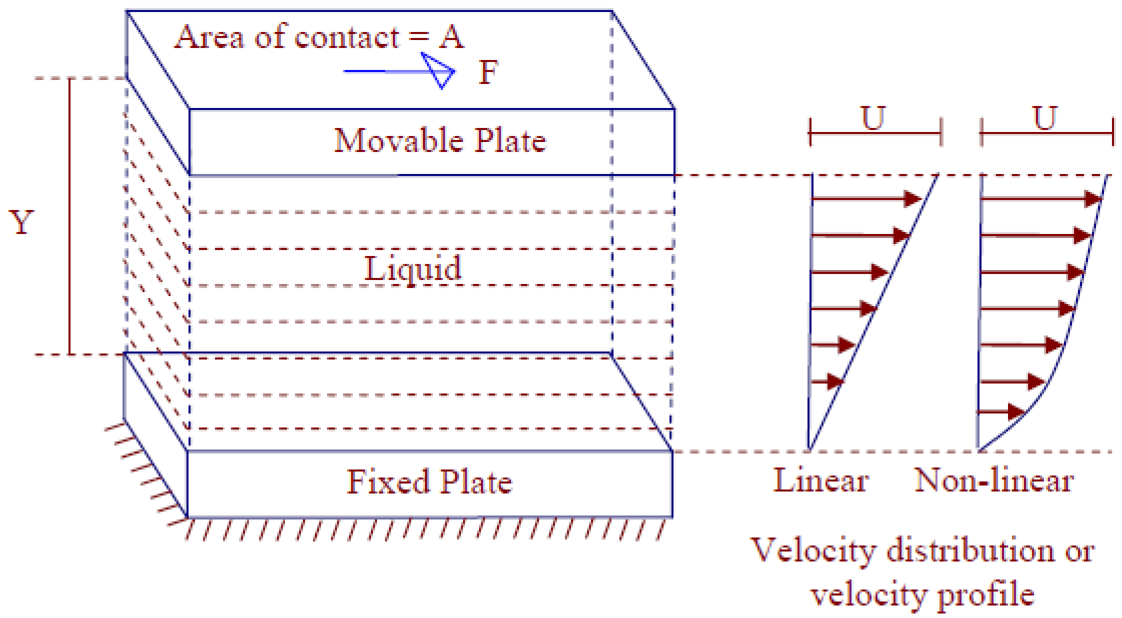


Figure 1.3.1 Definition diagram of Liquid viscosity

[Source: "https://en.wikiversity.org/wiki/Fluid_Mechanics_for_Mechanical_Engineers/fluid Properties"*]*

- $F \alpha \ A$
- $F \alpha \ \frac{1}{Y}$
- $F \alpha U$

$$\therefore F \alpha \frac{AU}{Y}$$

$$F = \mu . \frac{AU}{Y}$$

'μ' is the constant of proportionality called Dynamic Viscosity or Absolute Viscosity or Coefficient of Viscosity or Viscosity of the fluid.

$$\frac{F}{A} = \mu.\frac{U}{Y} \longrightarrow \therefore \tau = \mu\frac{U}{Y}$$

'τ' is the force required; Per Unit area called 'Shear Stress'. The above equation is called Newton's law of viscosity.

Velocity gradient or rate of shear strain:

It is the difference in velocity per unit distance between any two layers.

If the velocity profile is linear then velocity gradient is given by U/Y . If the velocity profile is non – linear then it is given by du/dy

Unit of force (F): N

- Unit of distance between the twp plates (Y): m
- Unit of velocity (U): m/s
- Unit of velocity gradient : $\frac{U}{Y} = \frac{m/s}{m} = /s = s^{-1}$
- Unit of dynamic viscosity (τ): $\tau = \mu\frac{u}{y}$

$$\mu = \frac{\tau y}{U}$$

$$\Rightarrow \frac{N/m^2 . m}{m/s}$$

$$\mu \Rightarrow \frac{N\text{-}sec}{m^2} \quad \text{or} \quad \mu \Rightarrow P_a\text{-}S$$

NOTE: In CGS system unit of dynamic viscosity is $\frac{dyne . S}{Cm^2}$ and is called poise (P).

If the value of μ is given in poise, multiply it by 0.1 to get it in $\frac{NS}{m^2}$.

1 Centipoises = 10^{-2} Poise.

- ***Effect of Pressure on Viscosity of fluids:***

Pressure has very little or no effect on the viscosity of fluids.

- ***Effect of Temperature on Viscosity of fluids:***
  - *Effect of temperature on viscosity of liquids:* Viscosity of liquids is due to cohesive force between the molecules of adjacent layers. As the temperature

increases cohesive force decreases and hence viscosity decreases.

- *Effect of temperature on viscosity of gases:* Viscosity of gases is due to molecular activity between adjacent layers. As the temperature increases molecular activity increases and hence viscosity increases.

Kinematics Viscosity: It is the ratio of dynamic viscosity of the fluid to its mass density.

$$\therefore \text{Kinematic Viscosity} = \frac{\mu}{\rho}$$

Unit of Kinematics Viscosity

$$KV \Rightarrow \frac{\mu}{\rho}$$

$$\Rightarrow \frac{NS/m^2}{kg/m^3}$$

$$= \frac{NS}{m^2} x \frac{m^3}{kg}$$

$$= \left(\frac{kg\,m}{s^2}\right) x \frac{s}{m^2} x \frac{m^3}{kg} = m^2/s$$

$$F = ma$$

$$N = Kg.m/s^2$$

$\therefore$ Kinematic Viscosity $= m^2/s$

NOTE: Unit of kinematics Viscosity in CGS system is cm^2/s and is called stoke (S)

If the value of KV is given in stoke, multiply it by 10^{-4} to convert it into m^2/s.

***Problem* 4:** Viscosity of water is 0.01poise. Find its kinematics viscosity if specific gravity is 0.998.

Kinematics viscosity = ?

$S = 0.998$

$$S = \frac{\rho}{\rho_{standrad}}$$

$$0.998 = \frac{\rho}{1000}$$

$$\rho = 998 \ kg/m^3$$

$\mu = 0.01P$

$= 0.01x0.1$

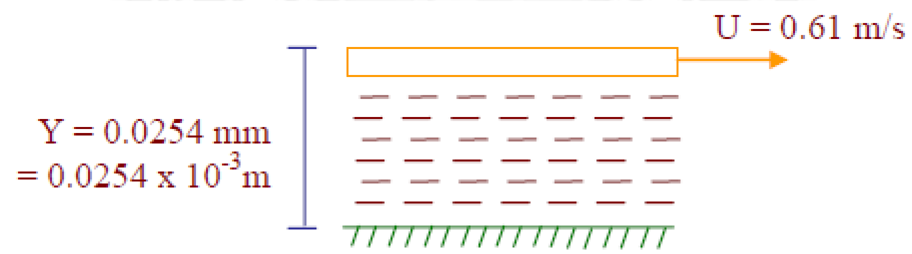
$$\mu = 0.001 \ \frac{NS}{m^2}$$

$$\therefore \text{Kinmetic Viscosity} = \frac{\mu}{\rho}$$

$$= \frac{0.001}{998}$$

$$KV = 1 \ x \ 10^{6} m^2/s$$

***Problem* 5:** A Plate at a distance 0.0254mm from a fixed plate moves at 0.61m/s and requires a force of 1.962N/m^2 area of plate. Determine dynamic viscosity of liquid between the plates.



$$\tau = 1.962 \ N/m^2$$

$$\mu = ?$$

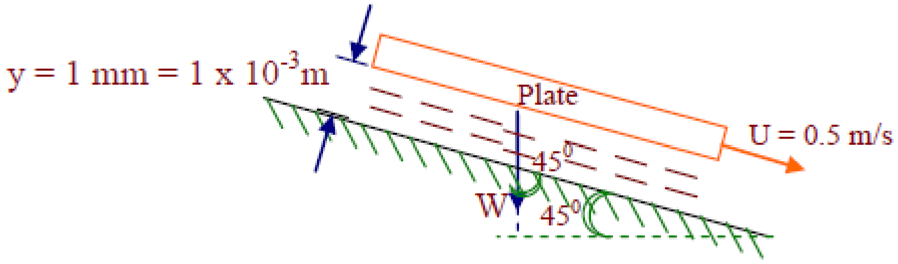
Assuming linear velocity distribution

$$\tau = \mu \frac{U}{Y}$$

$$1.962 = \mu \ x \ \frac{0.61}{0.0254 \ x \ 10^{-3}}$$

$$\mu = 8.17 \ x \ 10^{-5} \frac{NS}{m^2}$$

***Problem* 6 :** A plate having an area of $1m^2$ is dragged down an inclined plane at 45^0 to horizontal with a velocity of 0.5m/s due to its own weight. Three is a cushion of liquid 1mm thick between the inclined plane and the plate. If viscosity of oil is 0.1 PaS find the weight of the plate.



$A = 1m^2$

$U = 0.5m/s$

$Y = 1x10^{-3}m$

$\mu = 0.1NS/m^2$

$W = ?$

$F = W \times \cos 45^0$

$= W \times 0.707$

$F = 0.707W$

$$\tau = \frac{F}{A}$$

$$\tau = \frac{0.707W}{1}$$

$\tau = 0.707WN/m^2$

Assuming linear velocity distribution,

$$\tau = \mu.\frac{U}{Y}$$

$$0.707W = 0.1 \times \frac{0.5}{1 \times 10^{-3}}$$

$$W = 70.72\,N$$

***Problem* 7:** A flat plate is sliding at a constant velocity of 5 m/s on a large horizontal table. A thin layer of oil (of absolute viscosity = 0.40 N-s/m^2) separates the plate from the table. Calculate the thickness of the oil film (mm) to limit the shear stress in the oil layer to 1 kPa.

Given : τ = 1 kPa = 1000 N/m2; U = 5m/s; μ = 0.4 N-s/m^2

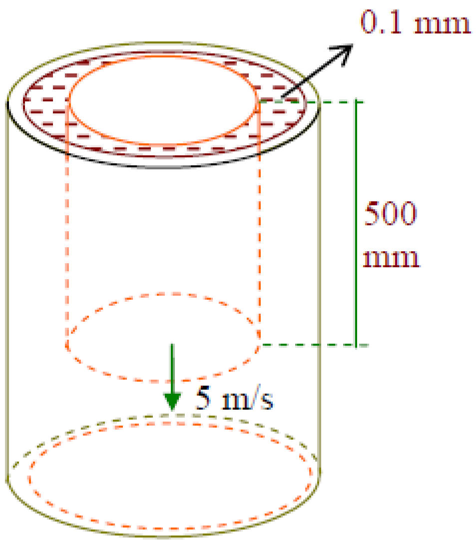
Applying Newton's Viscosity law for the oil film -

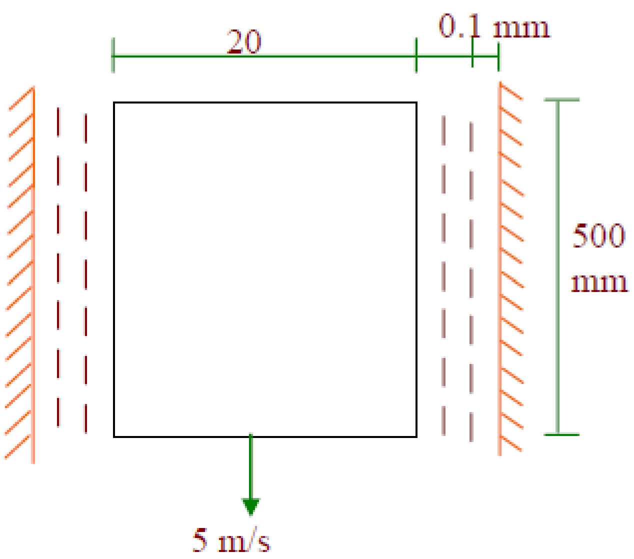
$$\tau = \mu \frac{du}{dy} = \mu \frac{U}{y}$$

$$1000 = 0.4 \frac{5}{y}$$

$$y = 2 \times 10^{-3} = 2 \text{ mm}$$

***Problem* 8:** A shaft of ϕ 20mm and mass 15kg slides vertically in a sleeve with a velocity of 5 m/s. The gap between the shaft and the sleeve is 0.1mm and is filled with oil. Calculate the viscosity of oil if the length of the shaft is 500mm.





$D = 20mm = 20x10^{-3}m$

$M = 15\ kg$

$W = 15x\ 9.81$

$W = 147.15N$

$y = 0.1mm$

$y = 0.1\ x\ 10^{-3}mm$

$U = 5m/s$

$F = W$

$F = 147.15N$

$\mu = ?$

$A = \Pi\ D\ L$

$A = \Pi\ \ x\ 20\ x\ 10^{-3}\ x\ 0.5$

$A = 0.031\ m^2$

$$\tau = \mu.\frac{U}{Y}$$

$$4746.7 = \mu\, x \frac{5}{0.1x10^{-3}}$$

$$\mu = 0.095\ \frac{NS}{m^2}$$

$$\tau = \frac{F}{A}$$

$$= \frac{147.15}{0.031}$$

$$\tau = 4746.7N/m^2$$

***Problem* 9 :** If the equation of velocity profile over 2 plate is $V= 2y^{2/3}$ in which 'V' is the velocity in m/s and 'y' is the distance in 'm' . Determine shear stress at (i) y = 0 (ii) y = 75mm. Take $\mu = 8.35P$.

a. at y = 0
b. at y = 75mm

$= 75\ x\ 10^{-3}m$

$$\tau = 8.35\ P$$

$$= 8.35 \text{ x } 0.1\ \frac{NS}{m^2}$$

$$= 0.835\ \frac{NS}{m^2}$$

$$V = 2y^{2/3}$$

$$\frac{dv}{dy} = 2x\frac{2}{3}y^{2/3-1}$$

$$= \frac{4}{3}y^{-1/3}$$

$$\text{at, } y = 0, \frac{dv}{dy} = 3\frac{4}{\sqrt[3]{0}} = \infty$$

$$\text{at, } y = 75x10^{-3}\text{m}, \frac{dv}{dy} = 3\frac{4}{\sqrt[3]{75x10^{-3}}}$$

$$\frac{dv}{dy} = 3.16/s$$

$$\tau = \mu.\frac{dv}{dy}$$

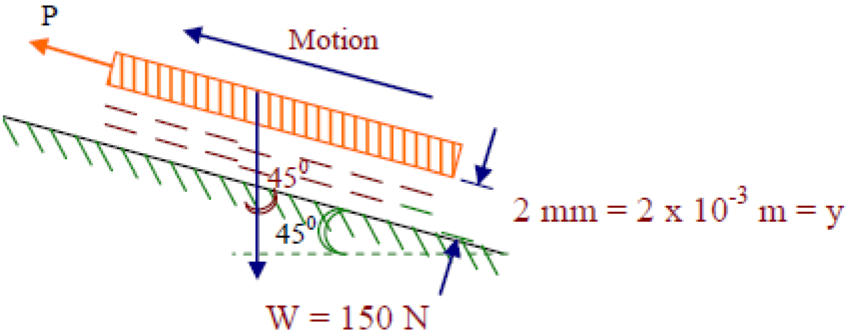
$$at, y = 0,\ \ \tau = 0.835x\infty$$

$$\tau = \infty$$

$$at, y = 75x10^{-3}m, \tau = 0.835\ x\ 3.16$$

$$\tau = 2.64\ N/m^2$$

***Problem* 10 :** A circular disc of 0.3m dia and weight 50 N is kept on an inclined surface with a slope of 45^0. The space between the disc and the surface is 2 mm and is filled with oil of dynamics viscosity $1N/Sm^2$.What force will be required to pull the disk up the inclined plane with a velocity of 0.5m/s.



D = 0.3m

$$A = \frac{\Pi \ x \ 0.3m^2}{4}$$

$A = 0.07m^2$

W = 50N

$$\mu = 1 \ \frac{NS}{m^2}$$

$$F = P - 50\cos 45$$

$$F = (P - 35{,}35)$$

$$y = 2x10^{-3}m$$

$$U = 0.5m/s$$

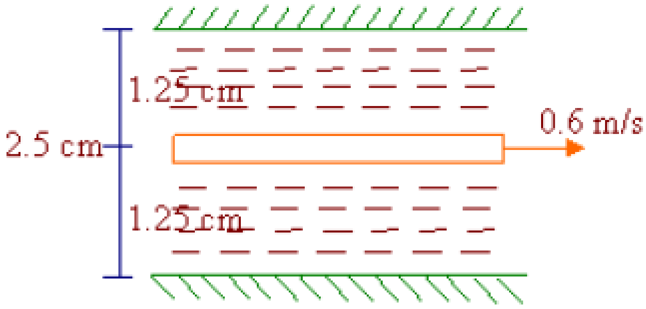
$$\upsilon = \frac{(P - 35.35)}{0.07} N/m^2$$

$$\tau = \mu . \frac{U}{Y}$$

$$\left(\frac{P - 35{,}35}{0.07}\right) = 1x \ \frac{0.5}{2x10^{-3}}$$

$$P = 52.85N$$

***Problem* 10 :** Two large surfaces are 2.5 cm apart. This space is filled with glycerin of absolute viscosity 0.82 NS/m^2. Find what force is required to drag a plate of area 0.5m^2 between the two surfaces at a speed of 0.6m/s. (i) When the plate is equidistant from the surfaces, (ii) when the plate is at 1cm from one of the surfaces.



$$U = \frac{\Pi DN}{60}$$

$$= \frac{\Pi \text{ x } 0.4 \text{ x } 190}{60}$$

$$U = 3.979 \text{ m/s}$$

$$\tau = \mu.\frac{U}{Y}$$

$$= 0.6 \text{ x } \frac{3.979}{1.5 \text{ x } 10^{-3}}$$

$$\tau = 1.592 \text{ x } 10^{3} \text{ N/m}^{2}$$

$$\frac{F}{A} = 1.59 \text{ x } 10^{3}$$

$$F = 1.591 \text{x } 10^{3} \text{ x } 0.11$$

$$F = 175.01 \text{ N}$$

$$\boldsymbol{T = F \; x \; R}$$

$$= 175.01 x 0.2$$

$$\boldsymbol{T} = 35 \boldsymbol{Nm}$$

$$\boldsymbol{P} = \frac{2\Pi \boldsymbol{NT}}{60{,}000}$$

$$\boldsymbol{P} = 0.6964 \boldsymbol{KW}$$

$$\boldsymbol{P} = 696.4 \boldsymbol{W}$$

Let F_1 be the force required to overcome viscosity resistance of liquid above the plate and F_2 be the force required to overcome viscous resistance of liquid below the plate. In this case $F_1 = F_2$. Since the liquid is same on either side or the plate is equidistant from the surfaces.

$$\tau_1 = \mu_1 \frac{U}{Y}$$

$$\tau_1 = 0.82 \text{x} \frac{0.6}{0.0125}$$

$$\tau_1 = 39.36 N/m^2$$

$$\frac{F_1}{A} = 39.36$$

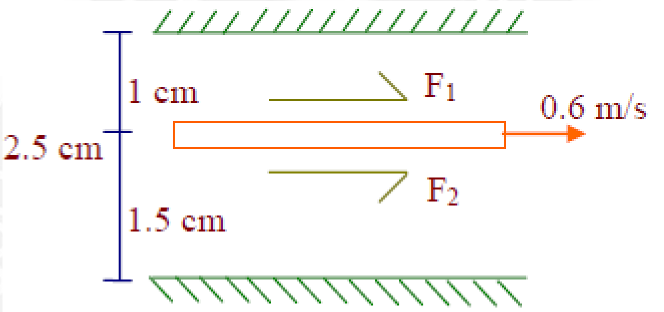
$$F_1 = 19.68 N$$

Total force required to drag the plate $= F_1 + F_2 = 19.68 + 19.68$

$F = 39.36N$

Case (ii) when the plate is at 1cm from one of the surfaces

Here $F_1 \neq F_2$



$F/A = 49.2$

$F_1 = 49.2 \times 0.5$

$F_1 = 24.6N$

$F_2/A = 32.8$

$F_2 = 32.8 \times 0.5$

$F_2 = 16.4N$

Total Force $F = F_1 + F_2 = 24.6 + 16.4$

$F = 41N$

6.Capillarity :

Capillarity is the phenomena by which liquids will rise or fall in a tube of small diameter dipped in them. Capillarity is due to cohesion adhesion and surface tension of liquids. If adhesion is more than cohesion then there will be capillary rise. If cohesion is greater than adhesion then will be capillary fall or depression. The surface tensile force supports capillary rise or depression.

$$h = \frac{4\sigma \cos\theta}{\gamma D}$$

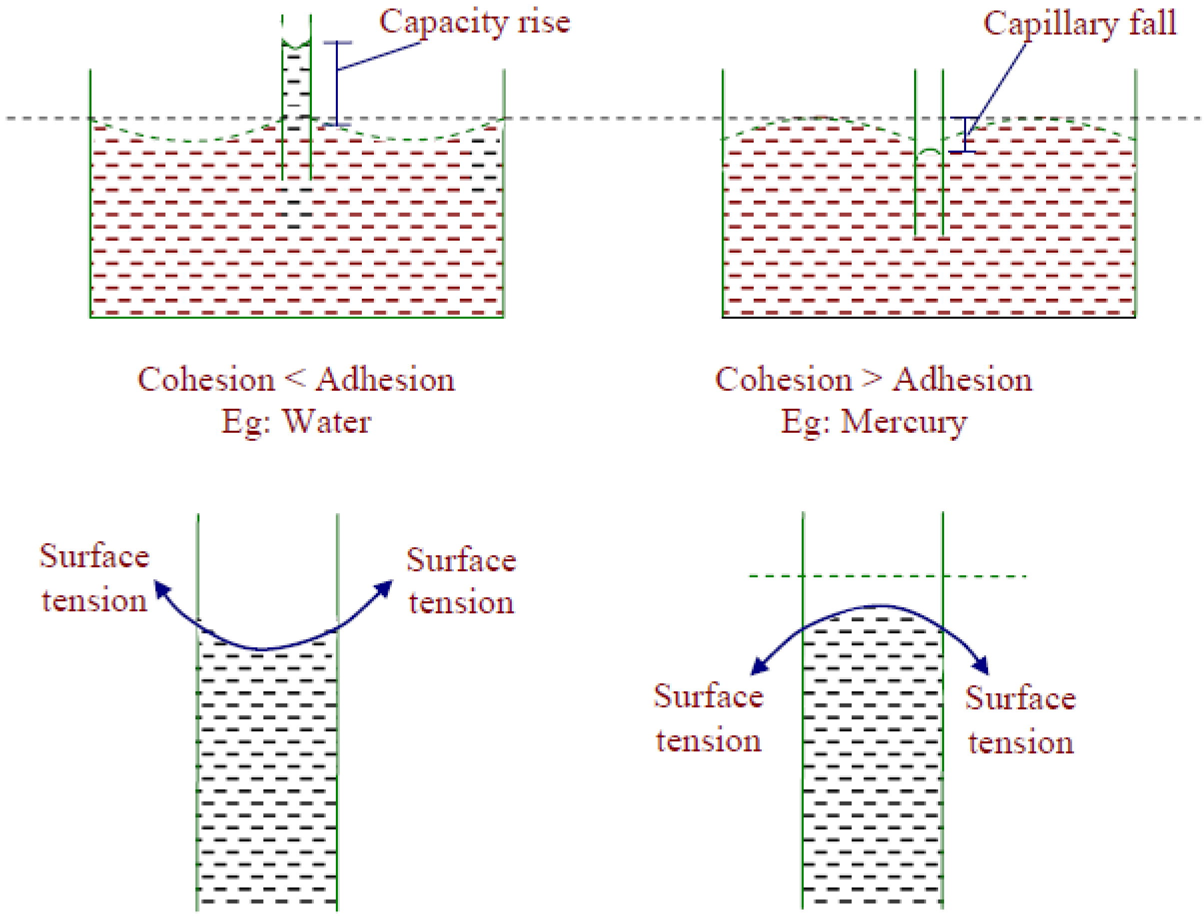


Figure 1.3.2 Capillarity

*[Source: "*https://en.wikiversity.org/wiki/Fluid_Mechanics_for_Mechanical_Engineers/fluid Properties*"]*

***Problem* 11 :** Capillary tube having an inside diameter 5mm is dipped in water at 20^0. Determine the heat of water which will rise in tube. Take σ=0.0736N/m at 20^0 C.

$$h = \frac{4\sigma\cos\theta}{\gamma D}$$

$$= \frac{4 \text{ x } 0.0736 \text{ x } \cos\theta}{9810 \text{ x } 5 \text{ x } 10^{-3}}$$

$$\theta = 0^0 \text{ (assumed)}$$

$$\gamma = 9810 N/m^3$$

$$h = 6 \text{ x } 10^{-3} m$$

***Problem* 12 :** Calculate capillary rise in a glass tube when immersed in Hg at 20⁰C. Assume σ for Hg at 20⁰C as 0.51N/m. The diameter of the tube is 5mm. $\theta = 130^0$c.

$$S = \frac{\gamma}{\gamma_{Standard}}$$

$$h = \frac{4\sigma\cos\theta}{\gamma D}$$

$$13.6 = \frac{\gamma}{9810}$$

$$h = -1.965 \text{ x} 10^{-3} m$$

$\gamma = 133.416 \text{ x } 10^3 \text{N} / \text{m}^3$

-ve sign indicates capillary depression.

***Problem* 13:** Calculate the capillary effect in millimeters a glass tube of 4mm diameter, when immersed in (a) water (b) mercury. The temperature of the liquid is 20^0 C and the values of the surface tension of water and mercury at 20^0 C in contact with air are 0.073575 and 0.51 N/m respectively. The angle of contact for water is zero that for mercury 130^0. Take specific weight of water as 9790 N / m^3..

Given:

Diameter of tube $\Rightarrow$ d = 4 mm = $4 \times 10^{-3} m$

Capillary effect (rise or depression) $\Rightarrow$ $h = \dfrac{4\sigma \cos\theta}{p \times g \times d}$

$\sigma =$ Surface tension in kg f/m

$\theta =$ Angle of contact and p = density

Capillary effect for water

$\sigma = 0.073575 \ N/m, \quad \theta = 0^0$

$p = 998 \ kg/m^3 \ @ \ 20^0 c$

$$h = \frac{4 \times 0.73575 \times Cos 0^0}{998 \times 9.81 \times 4 \times 10^{-3}} = 7.51 \times 10^{-3} m$$

= 7.51 mm.

Capillary effect for mercury:

$\sigma = 0.51 \ N/m, \qquad \theta = 130^0$

$p = sp \ gr \times 1000 = 13.6 \times 1000 = 13600 kg/m^3$

= - 2.46 mm.

-Ve indicates capillary depression.

7.Surface Tension:

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two two immiscible liquids such that the contact surface behaves like a membrane under tension

Excess Pressure inside a Water Droplet:

Pressure inside a Liquid droplet: Liquid droplets tend to assume a spherical shape since a sphere has the smallest surface area per unit volume.

The pressure inside a drop of fluid can be calculated using a free-body diagram of a spherical shape of radius R cut in half, as shown in Figure below and the force developed around the edge of the cut sphere is 2πRσ. This force must be balance with the difference between the internal pressure pi and the external pressure Δp acting on the circular area of the cut. Thus,

$$2\pi R\sigma = \Delta p \pi R^2$$

$$\Delta p = \left(p_{\text{int ernal}} - p_{external}\right) = \frac{2 \times \sigma}{R} = \frac{4 \times \sigma}{D}$$

Figure 1.3.3 Surface Tension inside a Water Droplet

*[Source: "*https://en.wikiversity.org/wiki/Fluid_Mechanics_for_Mechanical_Engineers/fluid Properties*"]*

The excess pressure within a Soap bubble:

The fact that air has to be blown into a drop of soap solution to make a bubble should suggest that the pressure within the bubble is greater than that outside. This is in fact the case: this excess pressure creates a force that is just balanced by the inward pull of the soap film of the bubble due to its surface tension.

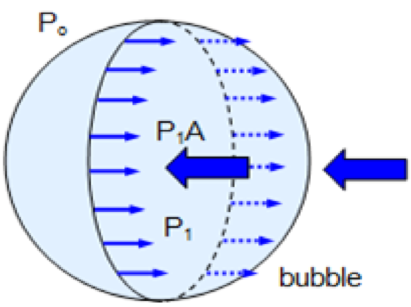


Figure 1.3.4 Surface Tension within a Soap bubble

*[Source: "*https://en.wikiversity.org/wiki/Fluid_Mechanics_for_Mechanical_Engineers/fluid Properties*"]*

Consider a soap bubble of radius r as shown in Figure 1. Let the external pressure be

P_o and the internal pressure P_1. The excess pressure ΔP within the bubble is therefore given by: Excess pressure $\Delta P = (P_1 - P_0)$

Consider the left-hand half of the bubble. The force acting from right to left due to the internal excess pressure can be shown to be PA, where A is the area of a section through the centre of the bubble. If the bubble is in equilibrium this force is balanced by a force due to surface tension acting from left to right. This force is $2x2\pi r\sigma$ (the factor of 2 is necessary because the soap film has two sides) where 'σ' is the coefficient of surface tension of the soap film. Therefore

$2x2\pi r\sigma = \Delta pA = \Delta p\pi r^2$ giving:

Excess pressure in a soap bubble (P) = $4\sigma/r$

8.Compressibility:

Compressibility is the reciprocal of the bulk modulus of elasticity, Kwhich is defined as the ratio of compressive stress to volumetric strain.

Bulk Modulus (K):

When a solid or fluid (liquid or gas) is subjected to a uniform pressure all over the surface, such that the shape remains the same, then there is a change in volume.

Then the ratio of normal stress to the volumetric strain within the elastic limits is called as Bulk modulus. This is denoted by K.

$$K = \frac{\text{Normal stress}}{\text{volumetric strain}}$$

$$K = \frac{F/A}{-\Delta V/V} = \frac{-pV}{\Delta V}$$

where p = increase in pressure; V = original volume; ΔV = change in volume

The negative sign shows that with increase in pressure p, the volume decreases by ΔV i.e. if p is positive, ΔV is negative. The reciprocal of bulk modulus is called compressibility.

$$C = Compressibility = \frac{1}{K} = \frac{\Delta V}{pV}$$

S.I. unit of compressibility is $N^{-1}m^2$ and C.G.S. unit is $dyne^{-1}\ cm^2$.

***Problem* 13:** The surface tension of water in contact with air at 20°C is 0.0725 N/m. The pressure inside a droplet of water is to be 0.02 N/cm^2 greater than the outside pressure. Calculate the diameter of the droplet of water.

Given: Surface Tension of Water σ =0.0725 N/m, Δp= 0.02 N/cm^2 = 0.02×10^{-4}N/m^2

Let 'D' be the diameter of jet

$$\Delta p = \frac{4\sigma}{D}$$

$$0.02 \times 10^{-4} = \frac{4 \times 0.0725}{D}$$

$$D = 0.00145\text{m} = 1.45\text{mm}$$

***Problem* 14:** Find the surface tension in a soap bubble of 40mm diameter when inside pressure is 2.5 N/m^2 above the atmosphere.

Given: D = 40mm = 0.04 m, Δp = 2.5 N/m^2

Let 'σ' be the surface tension of soap bubble

$$\Delta p = \frac{8\sigma}{D}$$

$$2.5 = \frac{4\sigma}{0.04}$$

$$\sigma = 0.0125\ \text{N/m}$$

9.Vapour Pressure

Vapour pressure is a measure of the tendency of a material to change into the gaseous or vapour state, and it increases with temperature. The temperature at which the vapour pressure at the surface of a liquid becomes equal to the pressure exerted by the surroundings is called the boiling point of the liquid.

Vapor pressure is important to fluid flows because, in general, pressure in a flow decreases as velocity increases. This can lead to ***cavitation***, which is generally destructive and undesirable. In particular, at high speeds the local pressure of a liquid sometimes drops below the vapor pressure of the liquid. In such a case, ***cavitation*** occurs. In other words, a "cavity" or bubble of vapor appears because the liquid vaporizes or boils at the location where the pressure dips below the local vapor pressure.

Cavitation is not desirable for several reasons. First, it causes noise (as the cavitation bubbles collapse when they migrate into regions of higher pressure). Second, it can lead to inefficiencies and reduction of heat transfer in pumps and turbines (turbo machines). Finally, the collapse of these cavitation bubbles causes pitting and corrosion of blades and other surfaces nearby. The left figure below shows a cavitating propeller in a water tunnel, and the right figure shows cavitation damage on a blade.

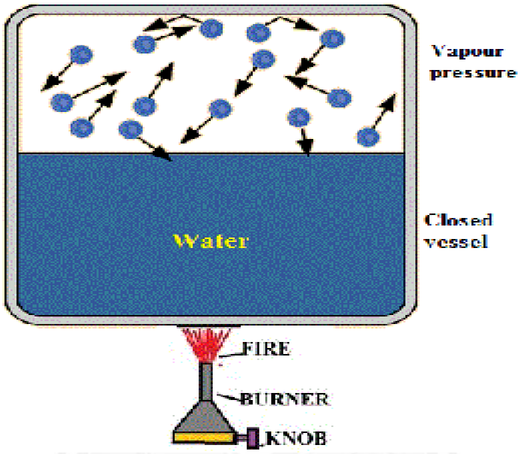


Figure 1.3.5 Vapour Pressure

*[Source: "*https://www.hkdivedi.com/2017/12/vapour-pressure-and-cavitation.html*"]*