CHAPTER (2)

FLUID PROPERTIES

SUMMARY

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FLUID PROPERTIES

System

Is defined as a given quantity of matter.

Extensive Property

Can be identified when it is Dependent on the total mass of the system such as Mass-(M) & Weight- (W).

Intensive Property

Can be identified when it is Independent of the total mass of the system such as Pressure (p), density (ρ)

FLUID PROPERTIES

Specific Weight =

$$\frac{Weight}{volume} = \frac{mg}{V} = \rho g = \gamma$$

Specific Gravity=S

$$\frac{specific\ weight\ of\ fluid}{specific\ weight\ of\ water} = \frac{\gamma_f}{\gamma_w} = \frac{(\rho g)_{fluid}}{(\rho g)_{water}} = \frac{\rho_f}{\rho_w}$$

FLUID PROPERTIES

Ideal Gas Law: (Equation of State)

$$PV = nR_uT$$

$$PV = (nR_uT)\frac{m}{m}$$

$$P = \left(\frac{nm}{V}\right)\left(\frac{R_u}{m}\right)T$$

$$P = \rho RT$$

Where: **n = Number of moles**

m = Molecular mass

(nm)=M=Mass of the gas

R_u = Universal gas constant

R = Gas Constant

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Specific Heat Capacity

The term originated primarily through the work of Scottish physicist Joseph Black

Specific Heat at Constant Volume= C_V

Is defined as the Amount of Heat required to raise the unit mass of a given substance by one degree at constant volume.

Specific Heat at Constant Pressure= C_p

Is defined as the Amount of Heat required to raise the unit mass of a given substance by one degree at constant pressure.

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Specific Enthalpy (h) / (J / kg K)

The enthalpy in a fluid is defined as:

$$h = u + \frac{p}{\rho}$$

The difference cp - cv is constant for an ideal gas.

$$cp - cv = R$$

The Ratio of Specific Heats

The Ratio of Specific Heats can be expressed as:

$$k = cp / cv$$

Where:
k = the ratio of specific heats

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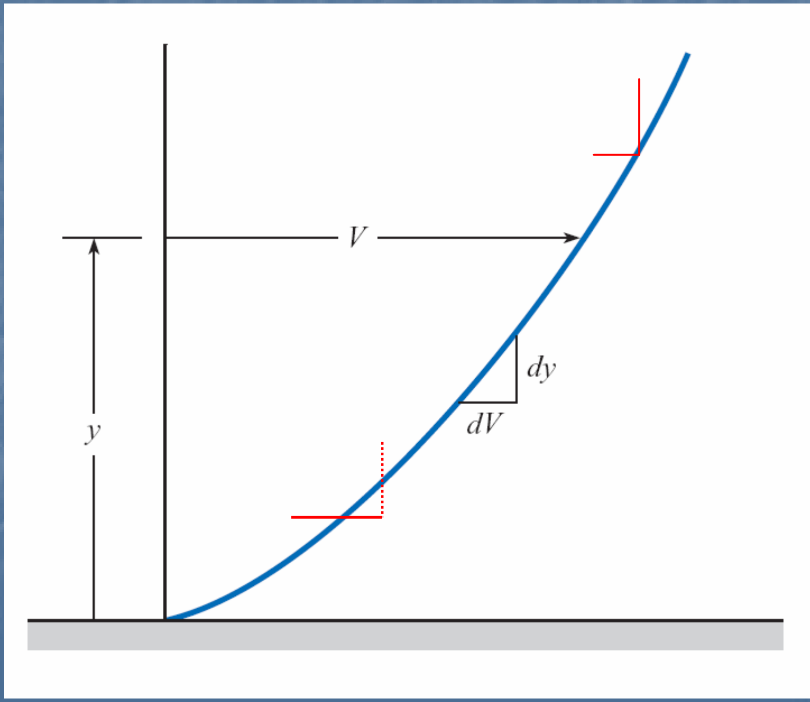
Consider the flow shown Fig. 1 where the velocity distribution is typical of a laminar flow next to a solid boundary. The following observation can be identified which are:

- **The velocity gradient at the boundary is finite.**
- **The velocity gradient** $\left(\frac{dV}{dy}\right)$ **, becomes smaller, with distance from the boundary.**
- **The velocity at the boundary is zero.**

By definition, $\tau \propto \frac{dV}{dy}$ **, Then** $\tau = \mu \frac{dV}{dy}$



Where:

$\tau =$ **Shear stress applied**

$\frac{dV}{dy} =$ **Velocity gradient (Shear Strain)**

FLUID PROPERTIES

Units of Viscosity:

$$\mu = \frac{\tau}{\left(\frac{dV}{dy}\right)} = \frac{N/m^2}{\frac{m/s}{m}} = \frac{N\,s}{m^2}$$

Common Unit for Viscosity is Poise. (1 poise = $0.1\frac{Ns}{m^2}$).

Units of Kinematic Viscosity:

$$\nu = \frac{\mu}{\rho} = \frac{Ns/m^2}{kg/m^3} = \frac{m^2}{s}$$

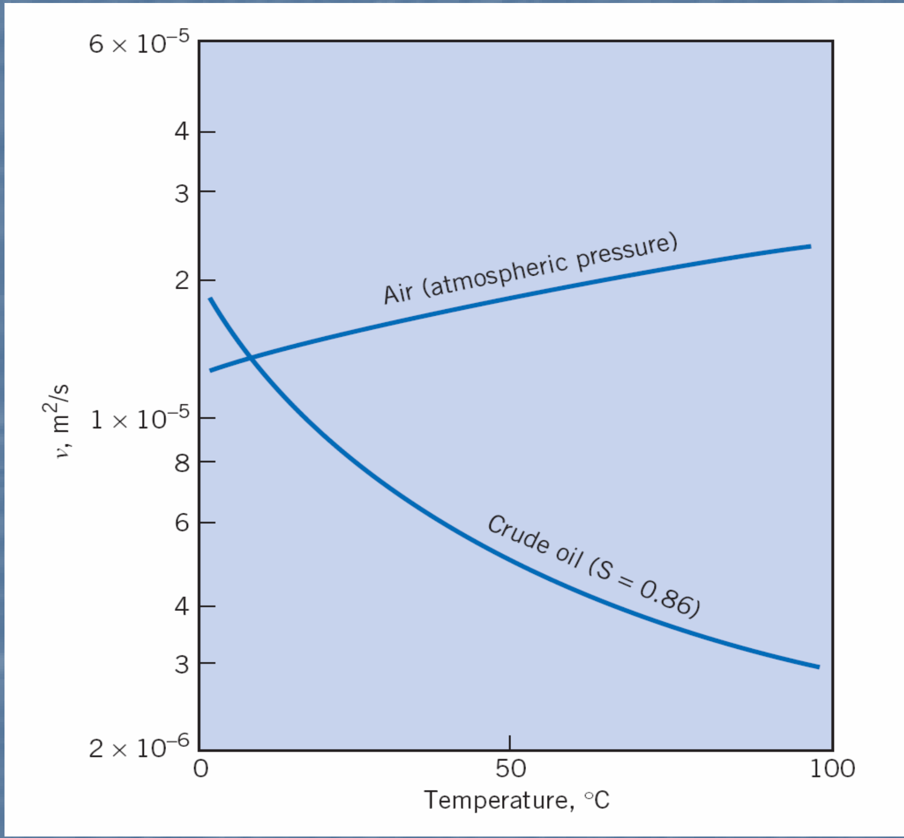
Kinematic Velocity = $\nu = \frac{\mu}{\rho} (\frac{m^2}{s})$

1. Variation of viscosity with temperature for gases

Sutherland Constant

$$\frac{\mu}{\mu_0} = \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T+S}{T_0+S}\right)$$

(S) are found from Table (A.2)



2. Variation of viscosity with pressure for gases

Viscosity is **minmal** for pressure less **than 10 atmospheres**

FLUID PROPERTIES

3. Variation of viscosity with temperature For Liquids

$$\mu = Ce^{b/T}$$

The variation of ***Dynamic Viscosity*** for fluids with temperature is given in **(Fig. A.2)** in the Appendix of the text book.

FLUID PROPERTIES

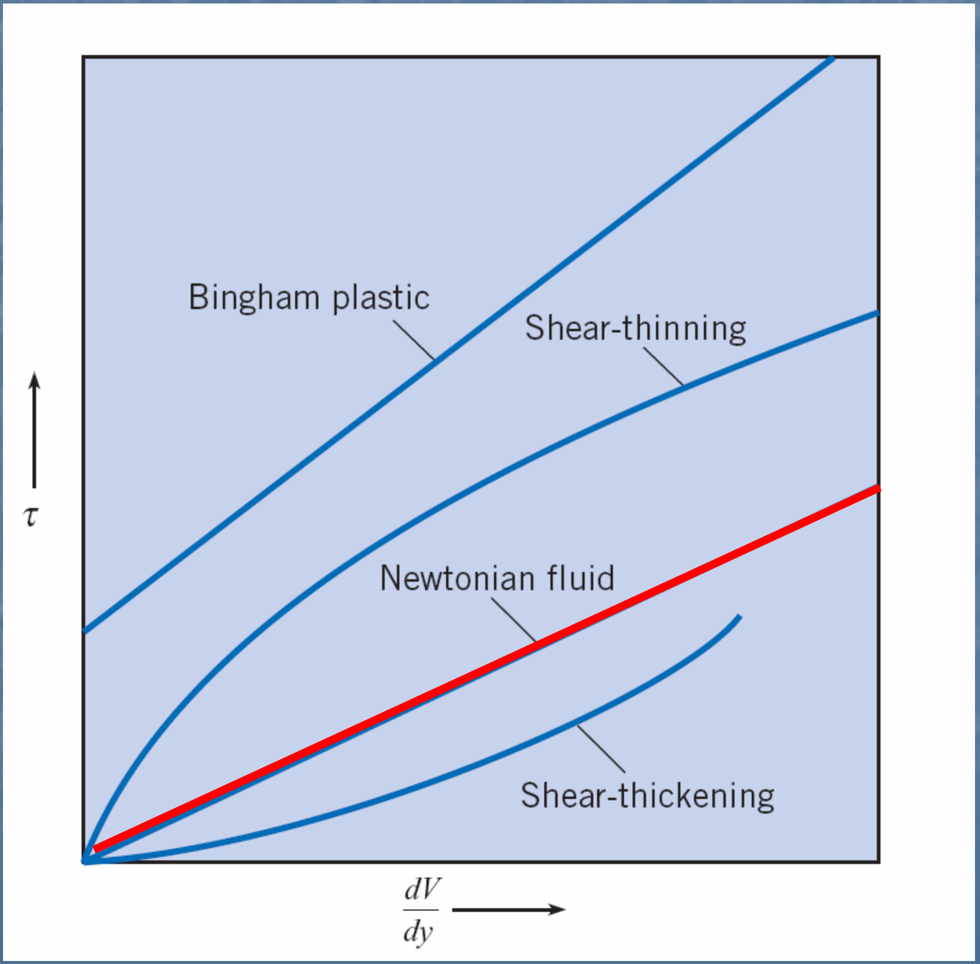
The variation of *Kinematic Viscosity* for fluids with temperature is given in (Fig. A.3) in the Appendix of the text book.

FLUID PROPERTIES

Newtonian and Non-Newtonian Fluids

Newtonian fluids are identified when only $\tau \; \alpha \left(\frac{dV}{dy} \right)$

- Shear Thinning: (paints, printer ink)
- Shear thickening: (gypsum-water mixture)



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Elasticity

The elasticity of a fluid is related to the amount of deformation (expansion or contraction) ***for a given pressure change***.

Expressing this in a mathematical form,

$$dp \;\alpha\; \frac{dV}{V}$$

Then

$$dp = -E_V \frac{dV}{V}$$

Where E_V = Degree of Elasticity

For an Adiabatic process (No heat transfer)

$$E_V = kp$$

Where

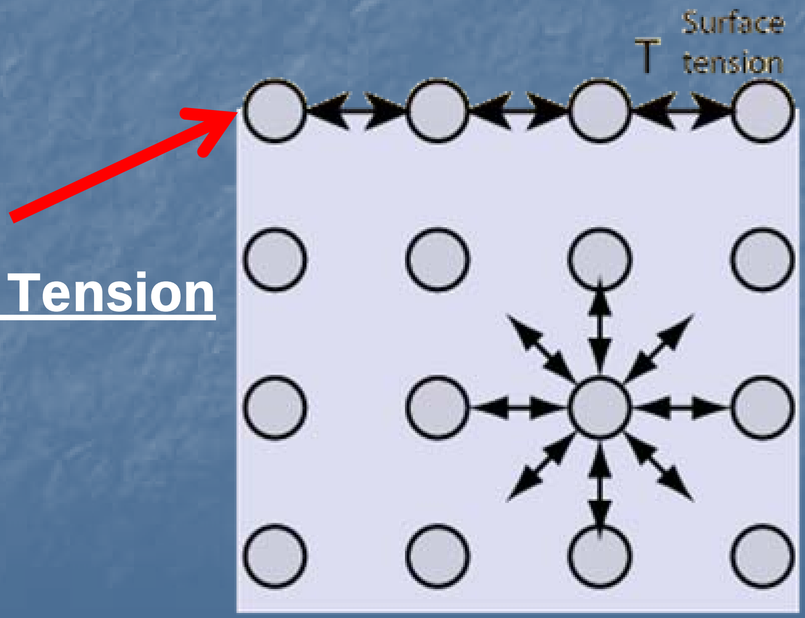
$$K = \frac{C_P}{C_V}$$

$$E_V = \rho\frac{dp}{d\rho} = \rho RT = p$$

FLUID PROPERTIES

surface Tension

The cohesive forces between molecules down into a liquid are shared with all neighboring atoms. Those on the surface have no neighboring atoms above, and exhibit stronger attractive forces upon their nearest neighbors on the surface. This enhancement of the intermolecular attractive forces at the surface is called Surface Tension



Surface Tension

The surface tension Force is given by

$$F_s = \sigma L$$

FLUID PROPERTIES

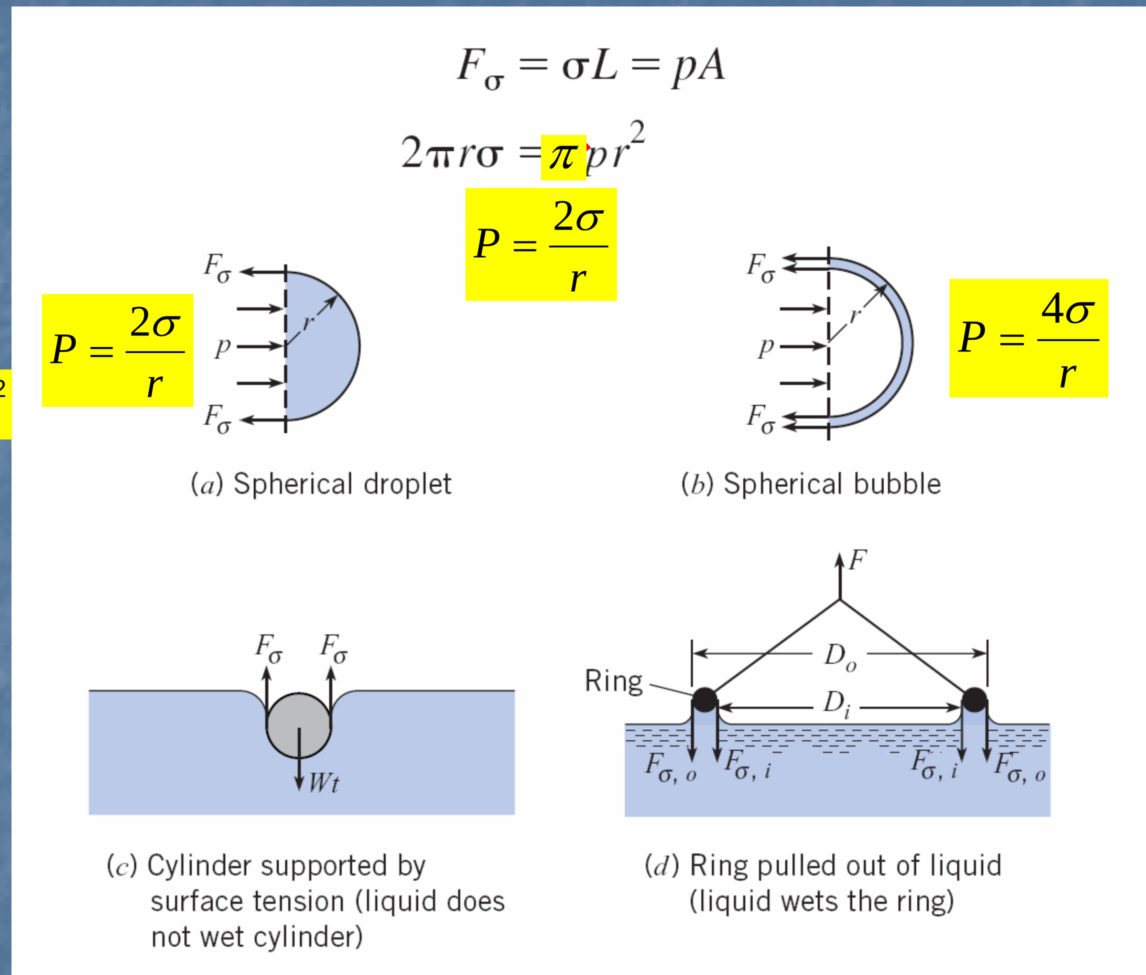
Surface Tension

Forces

Case (b) $2F_{\sigma} = 2\sigma 2\pi r = p\pi r^{2}$

Case (c) $2F_{\sigma} = 2\sigma L = Wt$

Case (d $F_{\sigma} = F_{\sigma,i} + F_{\sigma,o}$



(*a*) Spherical droplet

(*b*) Spherical bubble

(*c*) Cylinder supported by surface tension (liquid does not wet cylinder)

(*d*) Ring pulled out of liquid (liquid wets the ring)

FLUID PROPERTIES

Vapour Pressure

The pressure exerted by a vapor; often understood to mean saturated vapor pressure (the vapor pressure of a vapor in contact with its liquid form and increases with temperature).

Vapor pressure depends on various factors which are:

- **The nature of the liquid.**
- **Temperature.**
- **The presence of dissolved substances.**

END OF SUMMARY

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