Chapter 1: Introduction to fluid mechanics:

1- Introduction:

The fluid mechanics is the study of laws of fluid flow. It is divided into two parts.

1- statics:

2- dynamics and Kinematics of fluid.

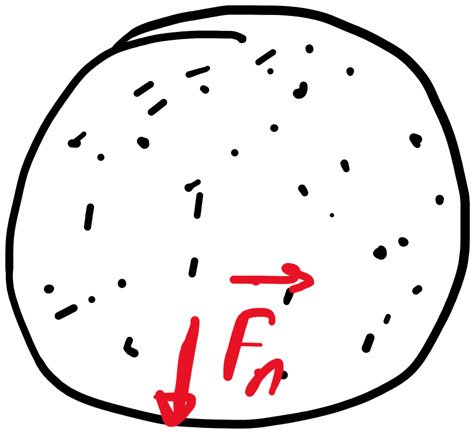
2- Types of fluids:

there are 2 types of fluids:

1- Newtonian: the viscosity of fluid depends only on temperature

2- Non-Newtonian fluid: the viscosity changes with the velocity of flow and other parameters.

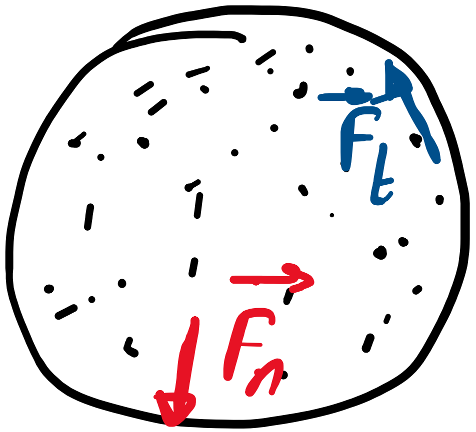
3.1 Ideal fluid:



the force exerted by ideal fluid on the wall of the tank is always perpendicular to the surface.

In ideal fluid the viscosity is 0.

3.2 - Real fluid.



the force exerted by ideal fluid on the wall of the tank has a tangential component to the wall surface.

the viscosity in this case does not equal to 0.

3.3 - Compressible and incompressible fluid.

⇒ incompressible fluid ⇒ $\rho =$ constant.

$$\frac{\partial \rho}{\partial t} = 0 \,.,$$

incompressible fluid (liquid fluid) water, oil, ---

Compressible fluid = (gas).

$$\frac{\partial \rho}{\partial t} \neq 0 .$$

4- Physical properties:

4.1 - density.

$$\rho = \frac{\text{mass of fluid}}{\text{volume of fluid}} = \left(\frac{Kg}{m^3}\right)$$

$\rho_{water} = 10^3 \ Kg/m^3$

$\rho_{air} = 1.2 \ Kg/m^3$

$\rho_{Mercury} = 13.546 \times 10^3 \ Kg/m^3$

$\rho_{gasoline} = 0.88 \times 10^3 \ Kg/m^3$

$$\rho_{oil} < \rho_{water}$$

relative density is the density of the fluid relative to water.
(specific gravity).

$$S.g = \frac{\rho_{fluid}}{\rho_{water}}$$

$$S.g_{gasoline} = \frac{880 \rightarrow \rho_{gasoline}}{1000 \rightarrow \rho_{water}} = 0.88.$$

4.2 - Specific weight.

$$\gamma = \frac{\text{weight of fluid}}{\text{volume of fluid}} = \frac{m\,g}{V} = \rho \cdot g \cdot \qquad \left(\frac{N}{m3}\right).$$

ideal:
gas:

$$\gamma = \rho \cdot g = \frac{m}{V} \cdot g = \frac{m\,g}{\frac{nRT}{P}} = \frac{P\,m}{nRT}\,g = \frac{P\,mg}{\frac{m}{M}RT}$$

$$\gamma = \frac{P\,g}{\frac{R}{M}T} = \frac{P\,g}{R'T} \qquad R' = \frac{R}{M} \qquad \frac{J}{K}\ \frac{}{g\,mol^{-1}}.$$

$$\rho = \frac{p}{R'T}$$

For air:

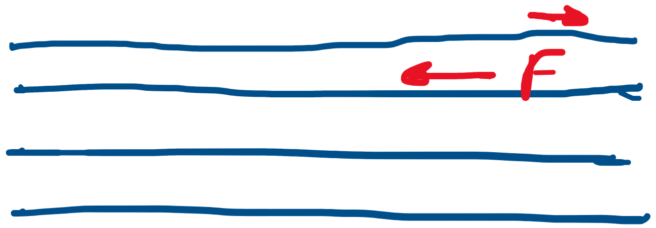
$$R' = 287 \ \frac{J}{kg \ K}$$

For oxygen:

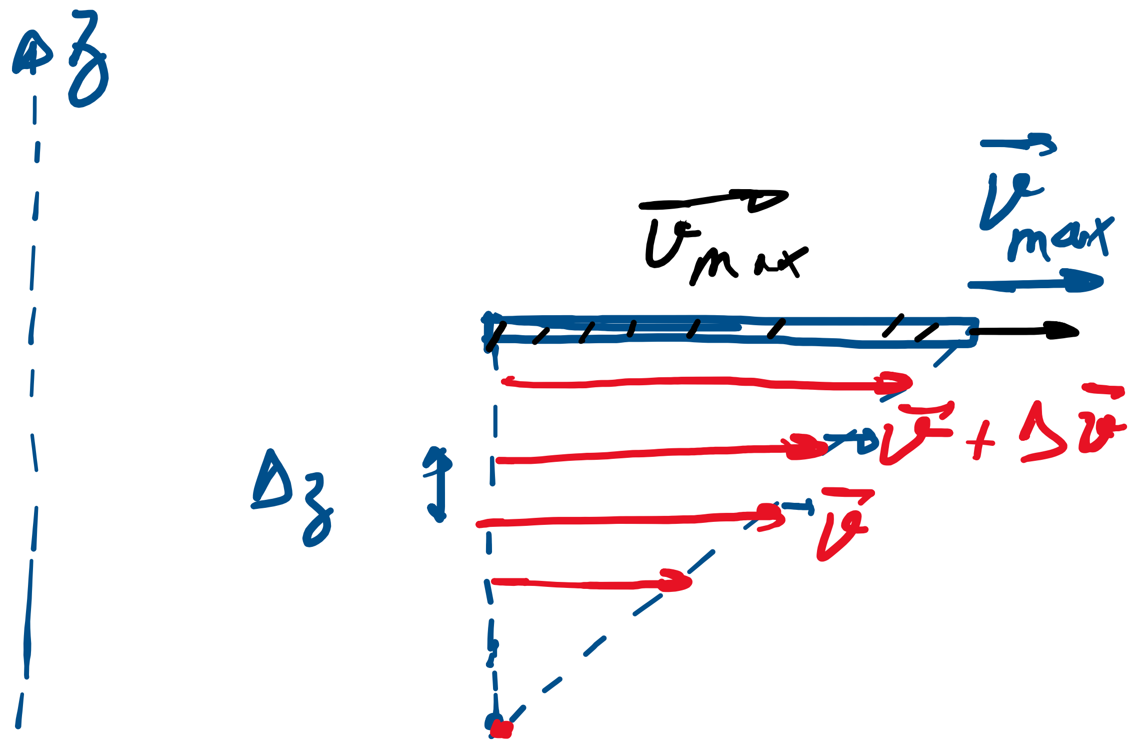
$$R' = 260 \ \frac{J}{kg \ K}.$$

4.3- Viscosity:

the viscosity is the parameter that describes the friction force between 2 layers of the same fluid.



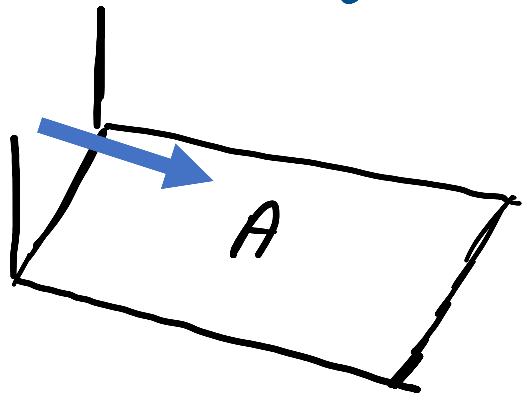
the velocity of flow depends on the depth z.



The force of friction between 2 layers is:

$$F = \mu \cdot A \cdot \frac{\Delta v}{\Delta z}$$

$N \quad \frac{N \cdot s}{m^2} \quad m^2 \quad \frac{1}{s}$

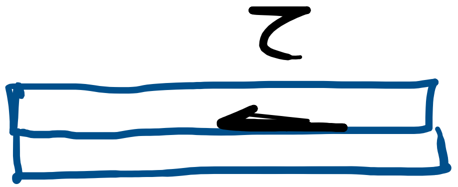


μ : dynamic viscosity. $\left(\frac{N}{m^2} \cdot s\right) = (Pa \cdot s) =$ Poise.

$\frac{\Delta v}{\Delta z}$: change of velocity with respect to z. $\left(\frac{m/s}{m}\right)$

A: Area of layer. (m^3)

τ = shear stress : pressure exerted by friction parallel to the layer.



$$\tau = \frac{F}{A} = \mu \frac{\Delta v}{\Delta z} = \mu \frac{dv}{dz}.$$

*) Kinematic viscosity: $\underset{nu}{\nu} = \dfrac{\mu}{\rho}$

$$\frac{\frac{N}{m^2}\cdot s}{\frac{kg}{m^3}} = \frac{\frac{\cancel{kg}\,\frac{m}{\cancel{s^2}}\cdot \cancel{s}}{m^2}}{\frac{\cancel{kg}}{m^3}} = \frac{\frac{1}{m}\,\frac{1}{s}}{\frac{1}{m^3}} = \frac{1}{\frac{1}{m^2}\,s} = \frac{m^2}{s}$$

unit ν is stokes (st) $1\,st = 10^{-4}\,\dfrac{m^2}{s}$.

Example:

Two parallel plates seperated by 5 mm of glycerin at T =20 °C . The friction force applied on the upper plate is 26 N per 1 m² of area. Find the velocity of the upper plate.

$\mu_{glyc} = 1.49$ Pa.s

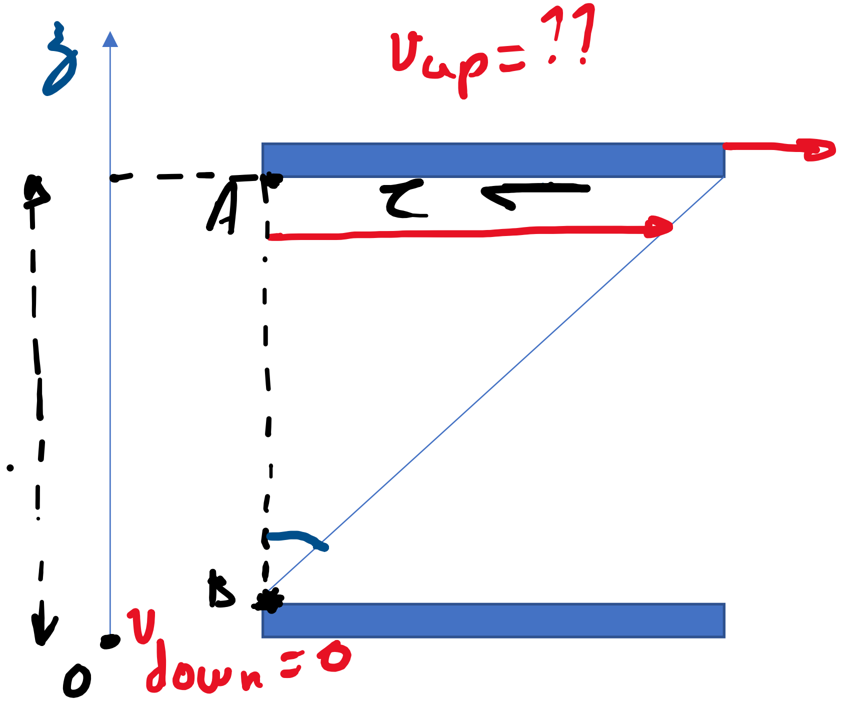
$\tau = 26 \ \frac{N}{m^2} = 26$ Pa.

$\frac{v_A - v_B}{z_A - z_B}$

$\tau = \mu \ \frac{\Delta V}{\Delta z} \Rightarrow 26 = 1.49 \ \frac{V_{up} - 0}{5 \times 10^{-3} - 0}$

5mm

$= 5 \times 10^{-3}$ m.



$$v_{up} = \frac{26}{1.49} \times 5 \times 10^{-3} = 0.087 \ m/s.$$

μ = dynamic viscosity (Pa.s). $\tau = \mu \dfrac{\Delta v}{\Delta z}$

ν = Kinematic viscosity $\left(\dfrac{m^2}{s}\right)$. $\left[\nu = \dfrac{\mu}{\rho} . \right]$