Chapter 1
Properties of Fluids

- Definition of fluid
- Properties of fluids
- Calculations

Definition of Fluid

All matter can be divided into 2 major classes

1) Solid
2) Fluids

The difference between a solid and fluid can be defined by

1) The stress-strain relationship
2) The elasticity

The Stress-Strain Relationship

Solid

- requires external forces to cause it to deform.

Fluid

- will deform without the application of external forces.
- will take on the shape of the container in which they are held.

    -Ex. water, oil, gas etc.

The Elasticity Relationship

Solid

-When external forces stress and deform solids, the solid will regain their original shape when these external forces are removed [Elasticity].

Fluid

-Fluid will continue to change shape in time even after the removal of the external forces causing the deformation.

Ideal Fluid

Ideal fluid is a substance that is unable to resist internal shear and tensile forces.

Liquid and Gases

Fluids can be classified into 2 forms of matter

1) Liquids
2) Gases

The difference between a liquid and gas can be defined by

1) The compressibility
2) The continuity

Compressibility

:to compress something into a small space.

Liquids

- Liquids are considered to be incompressible.
- Liquids only change in volume even when subjected to very high pressure.

Gases

- Gases are very compressible.
- Their volume can increase/decrease when subjected to slight variation in pressure.

Continuity

: is the state of being continuous.

Liquids

- When a liquid is held in a container, its entire mass will arrange itself so as to be in contact with the bottom and the sides of that container, and a well-defined surface of the liquid will form.

Gases

- A gas held in a closed container will not form a well-defined surface and will tend to fill the entire container.

Properties of Fluids

Density (ρ)

Density is the mass of the fluid per unit volume

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

ρ = Density of fluid, kg/m^3

M = Mass of fluid, kg

V = Unit volume, m^3

The density of water at 4^0C = 1,000 kg/m^3

Properties of Fluids

Specific Weight/Unit Weight (γ)

The specific weight is the weight of the fluid per unit volume

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

γ = Specific weight, N/m^3
W = Weight of fluid, N (W=mg)
V = Unit volume, m^3

The specific weight of water at $4^0C = 9.81\ kN/m^3$

Properties of Fluids

Specific Gravity/Relative Gravity (S)

The specific gravity is the ratio of the density or specific weight of the fluid to the density or specific weight of water, at a temperature of 4°C

$$S = \frac{\rho}{\rho_w} = \frac{\gamma}{\gamma_w} \Rightarrow \text{Dimensionless}$$

Properties of Fluids

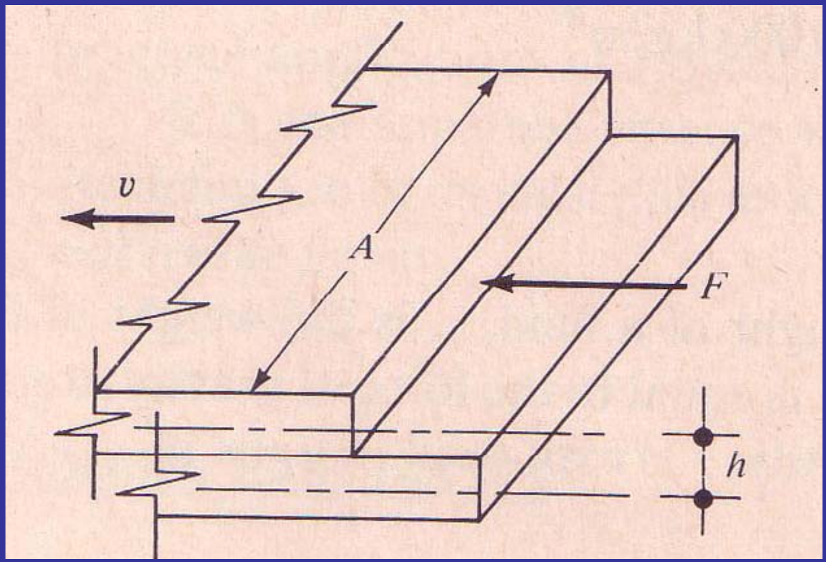
Dynamic Viscosity (μ)

Viscosity is the measure of a fluid's resistance to internal shear stresses.

$$\mu = \frac{\tau h}{v}$$

μ = Dynamic viscosity, $N.s/m^2$ or Pa.s
τ = Internal shear stress, N (τ =F/A)
v = Velocity, m/s

Properties of Fluids



A thin layer of fluid

Let
-A = the horizontal area of each layer
-h = the vertical distance between their centerlines
-F = internal shear force

The top layer is acted upon by F

The top layer will move with a velocity, v relative to the bottom layer

Properties of Fluids

Ideal Fluid :

-is unable to resist F

-the relative velocity would remain constant, even F is removed

Real Fluid :

-is able to resist F due to

1) internal molecular activity

2) friction between the layers

Properties of Fluids

$$F = \mu \frac{vA}{h}$$

$$\tau = F/A$$

$$\Rightarrow \mu = \frac{\tau h}{v} \Rightarrow \tau = \mu \frac{v}{h}$$

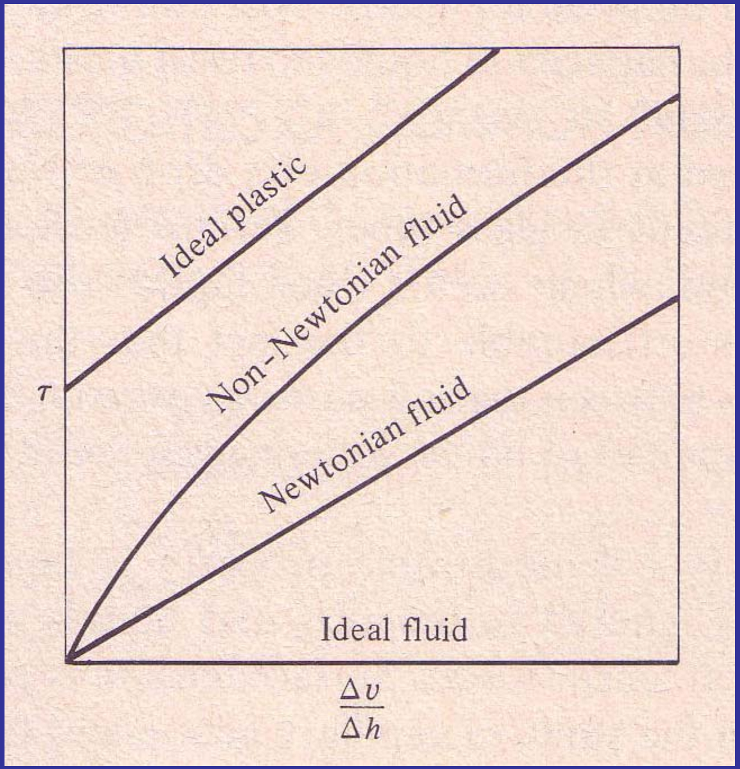
If $h \to 0$ $\quad \tau = \mu \frac{\Delta v}{\Delta h}$

⇑

Instantaneous rate of deformation of fluid

⇓

Newton's Law of Viscosity



Properties of Fluids

Kinematic Viscosity (ν)

The kinematic viscosity of a fluid is the ratio of its dynamic viscosity to its density.

$$\nu = \frac{\mu}{\rho}$$

ν = kinematic viscosity, m^2/s

μ = Dynamic viscosity, $N.s/m^2$ or Pa.s

ρ = Density of fluid, kg/m^3

Properties of Fluids

Surface Tension (σ)

The capacity of liquids to resist tensile stresses at their surface is called surface tensile.

Example 1

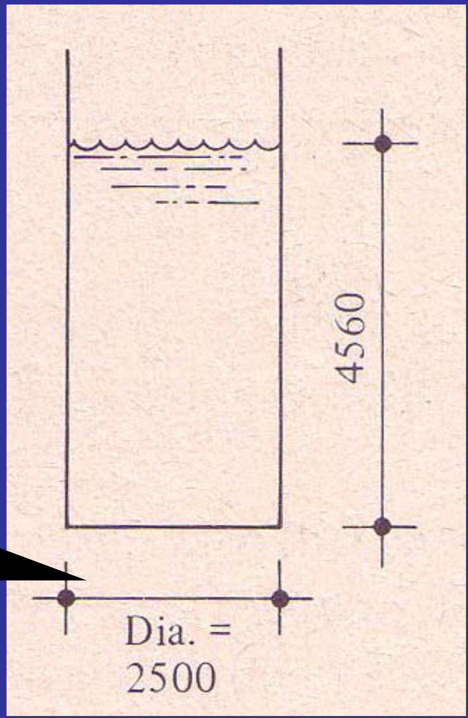
Determine the total mass and weight of the fluid in the container in the figure if the fluid is

a) water

b) mercury, with S=13.6

M_w=22,400 kg, W_w=220 kN

M_m=304,600 kg, W_w=2,990 kN

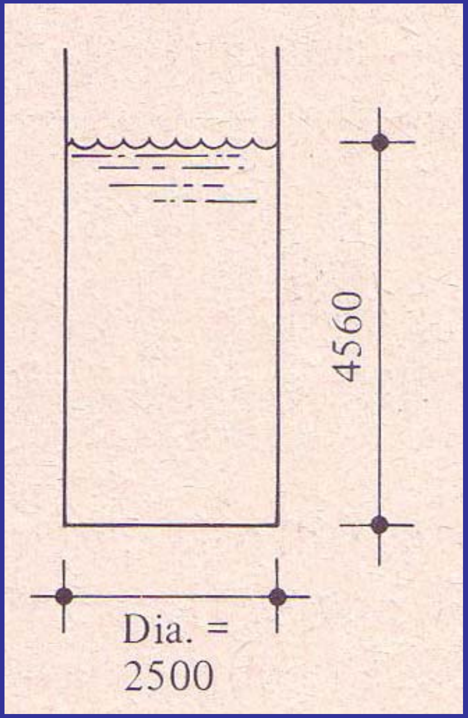


Example 2

If the total weight of the liquid in the figure is 505 KN, determine the height of liquid if it is

a) water

b) oil, with s=0.85



h=10.5 m

h=12.3 m

Example 3

Determine the dynamic viscosity of an oil with a kinematic viscosity of 0.352×10^{-5} m^2/s and a relative density of 0.88.

$\mu = 310 \times 10^{-5}$ Pa.s

Example 4

A fluid has a specific weight of 9.345 kN/m^3 and a dynamic viscosity of 3.31x10^{-2} Pa.s. Determine its relative and mass density and its kinematic viscosity.

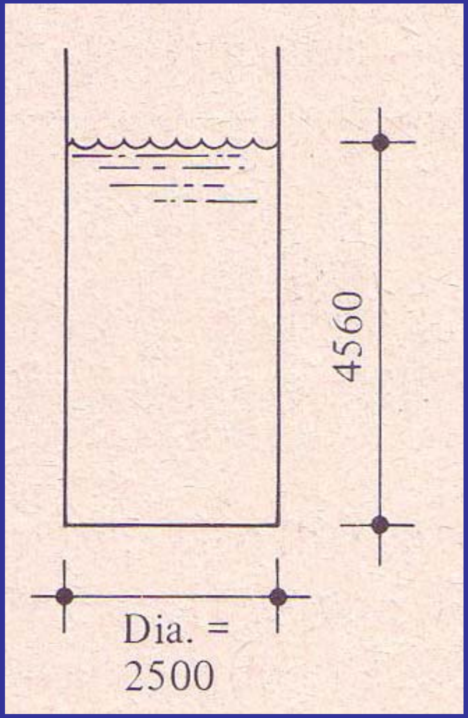
S=0.95

ρ=950 kg/m^3

ν=3.48x10^{-5} m^2/s

Example 5

The fluid of the container in the figure has a total weight of 319 kN and a dynamic viscosity of 91×10^{-5} Pa.s. Determine its relative and mass density and kinematic viscosity.



$S = 1.45$

$\rho = 1,450\ kg/m^3$

$\nu = 6.3 \times 10^{-7}\ m^2/s$