Fluid Mechanics

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1.5 Flow Characteristics Any state in which flow characteristics may be change from point to other or from time to other is named a flow characteristics; e.g., velocity (V), pressure (P), shear(Ʈ), discharge (Q), force (F), time (t), and acceleration(a).

1. Velocity(V):- It is the rate of displacement with respect to time.

The dimensions are: $L/_T = LT^{-1}$

The units are : $\left(m/_s\right) or \quad \left(cm/_s\right) or \quad \left(cm/_{\min}\right).$

2. Pressure(P):- It is the force distributed over an area, or the force per unit area. It exists wherever fluid exist, either at rest or in motion.

$$P = \frac{F(force)}{A(area)}$$

The dimensions are : $M/_{LT^2}$

The units of pressure are : $N/_{m^2} = \boldsymbol{Pa}$

The standard atmospheric pressure = 101.3 KPa = 1Bar.

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3. Discharge(Q):- It is the rate of movement or flux of fluid past a given point.

The dimensions are : $L^3/_T$

The units are : $m^3/_s = 1\ cumecs$

Or

$Litre/_s \quad where\ 1m^3/_s = 1000\,Litre/_s \qquad 1m^3 = 1000 litre \quad 1 litre = 1000 cm^3$

4. Acceleration(a):- It is the rate change of velocity through time.

The dimensions are : L/T^2

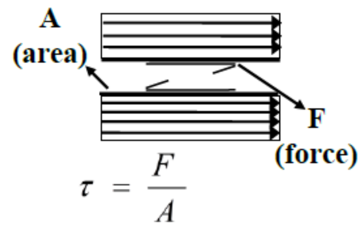
The units are : m/s^2

5. Shear (T) (tau):- A stress product due to sliding parts of fluid with respect to other in the direction parallel to there surface touching.

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

The dimensions: M/LT^2

Units : N/m^2



1.6 Fluid Properties :- Fluid properties are called to the constant fluid properties in which don't change on normal states from point to other or from time to other as the change of flow characteristics. Fluid properties include Density, specific weight (Unit weight), viscosity, compressibility, surface tension, and Vapor pressure. They are very important and have direct effect on the flow characteristics.

1.Density (mass density, specific mass) (ρ):- It is the mass, that is, the amount of matter, contained in a unit volume. It is a mass per unit volume at a standard temperature and pressure.

- It denoted by a symbol (roh ρ).
- It written as $\rho = \frac{Mass}{Volume} = \frac{m}{V}$
- The dimensions of(ρ) are $\left[\frac{M}{L^3}\right]$
- The units are $\left(\frac{Kg}{m^3}\right)$ or $\left(\frac{gr}{cm^3}\right)$
- The density of pure water= 1000 Kg/m^3 or $1\, gr/cm^3$

2. Weight Density (unit gravity force, specific weight, unit weight) (γ):-

It is the weight, that is, gravitational attractive force, acting on the matter in the unit volume. It is the weight per unit volume at a standard temperature and pressure.

- It denoted by a symbol (gamma γ).
- It written as $\left(\gamma = \frac{Weight}{volume} = \frac{W}{V}\right)$.

- **The dimensions of (γ) are $\left(\frac{F}{L^3}\right)$ or $\left(\frac{M}{L^2T^2}\right)$.**
- **The units are: $\left(N/m^3\right)$. Newton is the force required to accelerate (1Kg) of a mass for (1m) through (sec^2).** $N \equiv \frac{Kg \cdot m}{s^2}$
- **It is change as the gravitational system is change.**

$\gamma = \rho * g \qquad g = 9.81\, m/s^2 \qquad \gamma_W = \gamma_{Water} = 1000 * 9.81 = 9810\, N/m^3 \;\; or\; 9800\, N/m^3$

3.Relative Density (rd) or Specific Gravity (*s.g. or S*):- **It is a weight density of fluid to the specific (weight) density of pure water.**

- **It denoted by a symbol (r.d. & s.g. or *S*)**
- **It written as** $r.d. = \frac{\gamma_f}{\gamma_w} = \frac{\rho_f}{\rho_w}$
- **The dimensions of (*S*) : it is a dimensionless.**
- **The units : without units.**
- **s.g. for pure Water = 1**
- **s.g. for Mercury = 13.55**
- **The specific weight of liquids may be really calculated by:**

$$\gamma_f = (s.g.)_f * \gamma_w$$

$$\gamma = s.g. * 9810\, N/m^3$$

4.Specific Volume (s.v.):- **It is the reciprocal of the density(ρ). It is the volume occupied by unit mass of fluid.**

- **It denoted by as symbol (s.v.)**
- **It written as** $s.v. = \frac{Volume}{Mass} = \frac{V}{m}$
- **The dimensions are:** $\left[\frac{L^3}{M}\right]$
- **The units are:** $\left[\frac{m^3}{Kg}\right]$
- **Density for liquids (ρ, γ) does not change with change of temperature and pressure.**

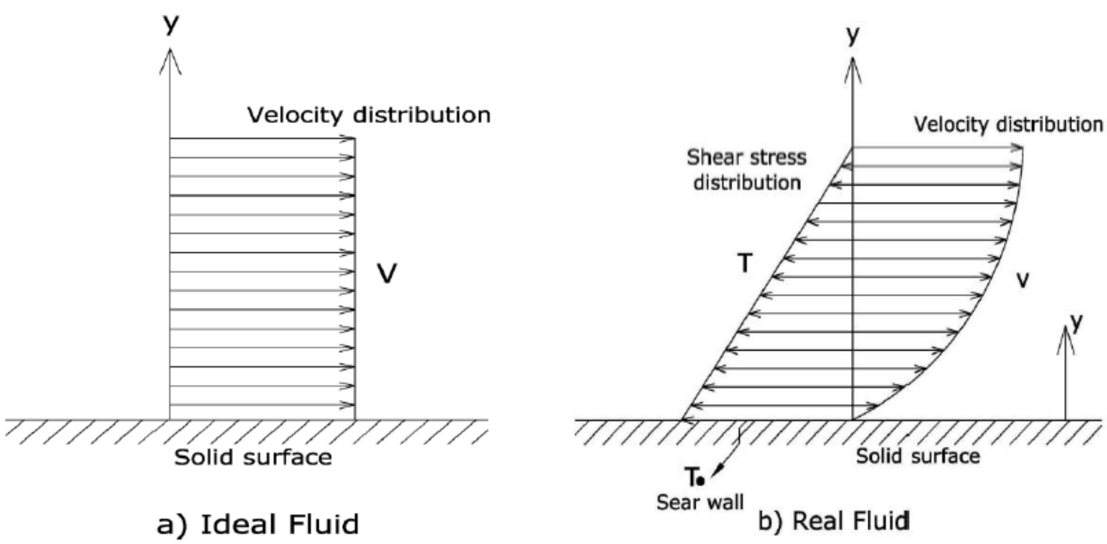
Example: 3 The specific weight of water at ordinary pressure and temperature is 9.81KN/m^3. The specific gravity of mercury is 13.55. Compute the density of water and the specific weight and density of mercury.

$$\rho_{water} = \frac{\gamma_{water}}{g} = \frac{9.81 \, KN/m^3}{9.81 \, m/s^2} = 1.00 \, Mg/m^3 = 1000 \, Kg/m^3 = 1.00 \, g/cm^3 \qquad Ans.$$

$$\gamma_{mercury} = s.g._{mercury} \times \gamma_{water} = 13.55(9.81) = 133 \, KN/m^3 \qquad Ans.$$

$$\rho_{mercury} = s.g._{mercury} \times \rho_{water} = 13.55(1.00) = 13.55 \, Mg/m^3 \qquad Ans.$$

5. Viscosity It is that a property of a fluid which determine its resistance to shearing stress. It is a measure of the internal fluid friction which causes resistance to flow. It is primarily due to cohesion and molecular momentum exchange between fluid layers, and as flow occurs, these effects appear as shearing stresses between the moving layers of fluid.



- **Shear stress & velocity gradient**

$$\tau \propto \frac{du}{dy}$$

$$\tau = \mu.\frac{du}{dy} \quad N/m^2 \quad (Newton's\,law\,of\,viscosity)$$

where: τ is a shear stress (called Tau); (N/m^2)

$\frac{du}{dy}$ **: Rate of shear stress or rate of shear deformation or velocity gradient; (m/sec/m)**

μ (mu): Constant of proportionality (viscosity coefficient). It is called dynamic viscosity or only viscosity; (pa. sec).

From shown figure: the viscosity μ may also be defined as the shear stress required to produce unit rate of shear strain.

Dimensions of μ : $\left[\frac{F.T}{L^2}\right]$ **or** $\left[\frac{M}{LT}\right]$

- **kinematic viscosity:** is defined as the ratio between the dynamic viscosity and density of fluid. **It is denoted by ν** (nu).

$$\nu = \frac{Viscosity}{Density} = \frac{\mu}{\rho} \rightarrow \text{Units} \quad \upsilon \equiv \frac{Kg}{m.\sec.\frac{Kg}{m^3}} \equiv \frac{m^2}{\sec}$$

Note: Because of the dimensions of (υ) are length and time, and no has a force it's called a kinematic viscosity.

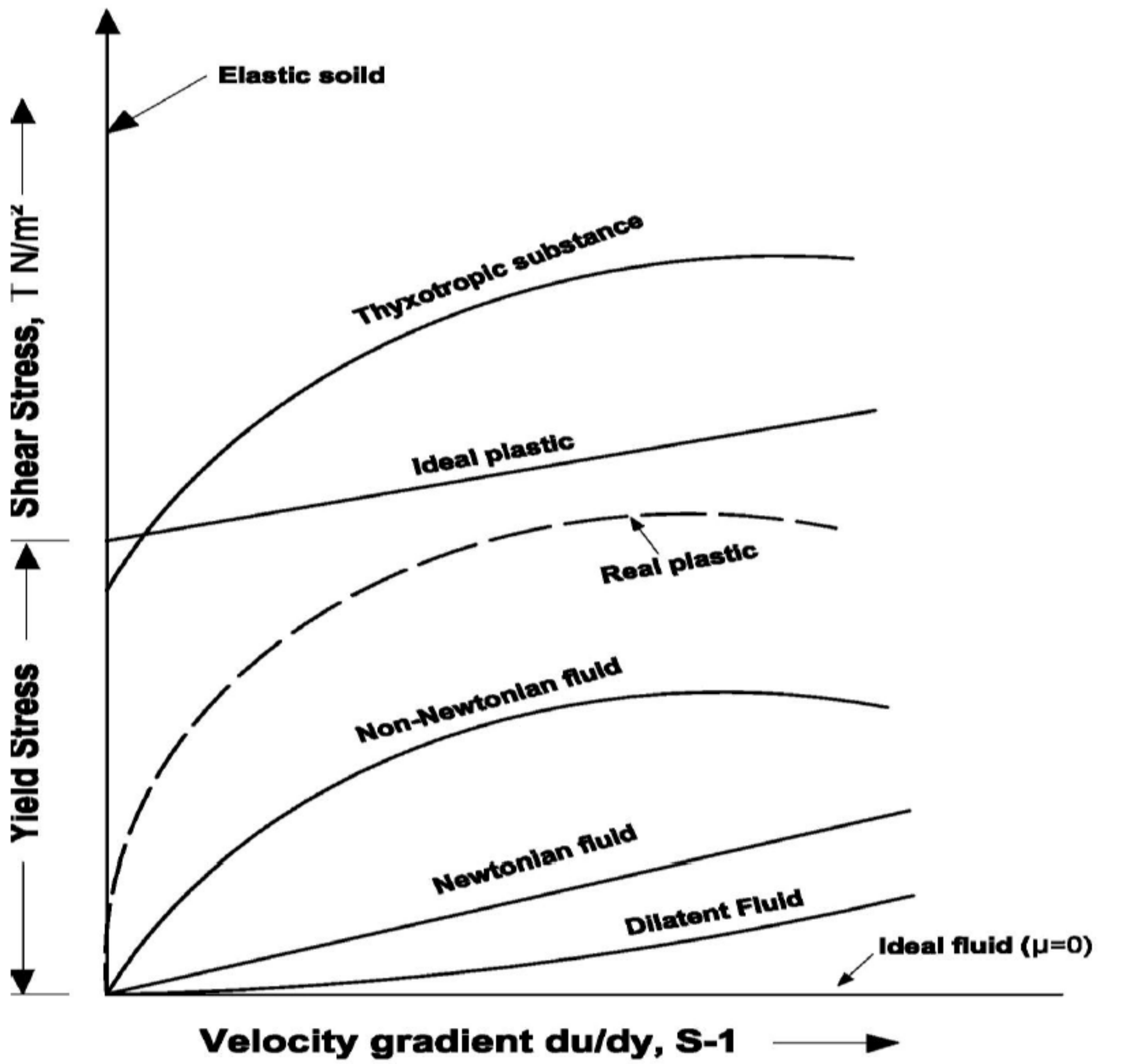


Diagram of types of fluid according to the viscosity