Fluid Mechanics

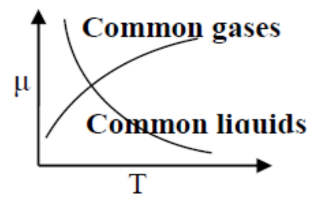
Asst. Lec. Safa Ali Hussein

Effect of temperature on viscosity

Viscosity is effected by temperature. The viscosity of liquids decreases but that of gases increases with increase in temperature. This is due to the reason that in liquids the shear stress is due to the inter-molecular cohesion which decreases with increase of temperature. In gases the inter-molecular cohesion is negligible and the shear stress is due to exchange of momentum of the molecules, normal to the direction of motion. The molecular activity increases with rise in temperature and so does the viscosity of gas.

$$\mu \propto T \quad \textit{for gases}$$

$$\mu \propto \frac{1}{T} \quad \textit{for liguids}$$

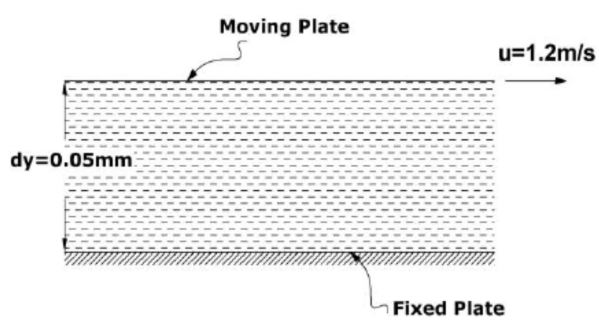


Effect of Pressure on viscosity

The viscosity under ordinary conditions is not appreciably affected by the changes in pressure. However, the viscosity of some oils has been found to increase with increase in pressure.

Example. **4//** plate 0.05mm distant from a fixed plate moves at 1.2m/s and requires a force of 2.2 N/m^2 to maintain this speed. Find the viscosity of the fluid between the plates.

Solution:



Velocity of the moving plate, $u = 1.2 m/s$

Distance between the plates, $dy = 0.05mm = 0.05 \times 10^{-3} m$

Force on the moving plate, $F = 2.2 N/m^2$

Viscosity of the fluid, μ?

$\tau = \mu . \frac{du}{dy}$, $\tau = F/_A = 2.2 N/m^2$

, du= change of velocity = $u - 0 = 1.2 m/s$

dy =change of distance = 0.05x10^{-3}m

$$\therefore 2.2 = \mu \times \frac{1.2}{0.05\times10^{-3}} \rightarrow \mu = \frac{2.2\times0.05\times10^{-3}}{1.2} = 9.16 \times 10^{-5}\, N.s/_{m^2}$$

$$\because 1\, poise = \frac{1}{10}\frac{N.s}{m^2} \qquad \therefore \mu = 9.16 \times 10^{-4} \text{ poise} \ldots\ldots\ldots\ldots (\text{Ans.})$$

Example 5// plate having an area of $0.6m^2$ is sliding down the inclined plane at 30^o to the horizontal with a velocity of a 0.36m/s. There is a cushion of fluid 1.8mm thick between the plane and the plate. Find the viscosity of the fluid if the weight of the plate is 280N.

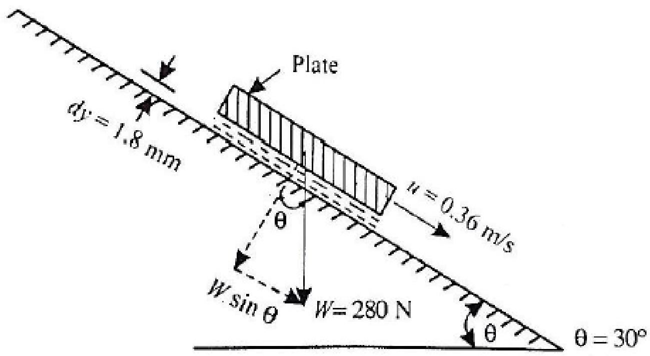
Solution: Area of plate, A=0.6m2
Weight of plate, W=280N
Velocity of plate, u=0.36m/s
Thickness of film, t=dy=1.8mm=1.8×10^{-3}m

Viscosity of the fluid, μ ?

Component of W along the plate= $W\ sin\theta = 280sin30^0 = 140$∴

∴ shear force on the bottom surface of the plate, $F = 140N$

and shear stress, $\tau = \frac{F}{A} = \frac{140}{0.6} = 233.33N/m^2 \rightarrow \tau = \mu.\frac{du}{dy} \rightarrow \tau = \mu.\frac{u-0}{t} \rightarrow$



$233.33 = \mu.\frac{0.36}{1.8\times10^{-3}}$ ∴ $233.33 = \mu.\frac{0.36}{1.8\times10^{-3}} \rightarrow$

$\mu = \frac{233.33\times1.8\times10^{-3}}{0.36} = 1.66\ N.\frac{s}{m^2} = 11.66\ poise$ .... Ans.

1.7 Thermodynamic Properties

The thermodynamic properties need to be considered when a fluid is influenced by change of temperature. The following equation, known as the characteristic ***equation of a state of a perfect gas***, is used for this purpose

$$pV = \text{mRT}$$

$$p = \frac{m}{V}RT \rightarrow \ p = \rho RT$$ .... Perfect gas law

Where: p =Absolute pressure, m =Mass of gas, V =Volume of m Kg of gas,
T = Absolute temperature in Kelvin (K= C^0 + 273),
R = Characteristic gas constant

Example: 6// The pressure and temperature of carbon-dioxide in a vessel are $600 kN/m^2$ abs. and $30C^0$ respectively. Find its mass density, specific weight and specific volume.

Solution: Given→ Pressure of CO_2= $600kN/m^2$ abs.

Temperature of CO_2=30+273=303K

Molecular weight of CO_2=12+2x16=44

Universal gas constant, R_0 = 8314.3Nm/mole K

∴ Characteristic gas constant, $R = \frac{R_0}{M} = \frac{8314.3}{44} = 189 \;\; Nm/kg\,K$

i. **Mass density, ρ:**

$$pV = mRT \rightarrow \frac{m}{V} = \frac{p}{RT} \rightarrow \rho = \frac{p}{RT} = \frac{600\times10^3}{189\times313} = 10.14\,kg/m^3 \rightarrow$$

$$\rho = 10.14\,kg/m^3$$ ....(Ans.)

ii. **Specific weight, γ:**

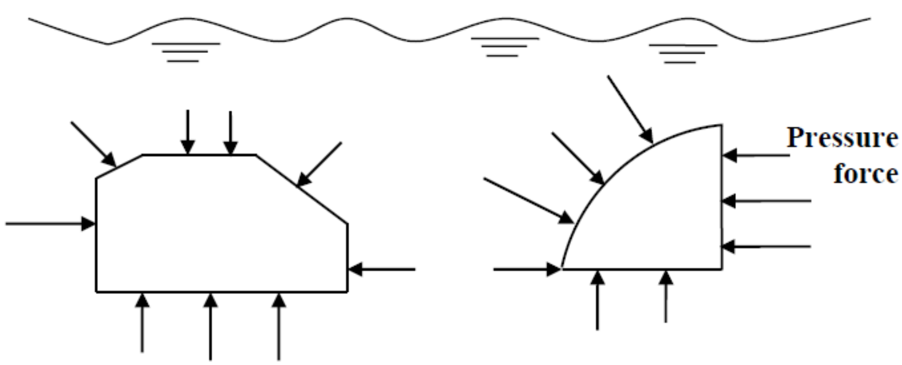
$$\gamma = \rho g = 10.14 \times 9.81 = 99.47\,N/m^3$$ ....(Ans.)

iii. **Specific volume, *s.v.* :**

$$s.v. = \frac{1}{\rho} = \frac{1}{10.14} = 0.0986\,m^3/kg$$ ....(Ans.)

Fluid Statics: **It is the study of fluid problems in which there is no relative motion between fluid elements (there is no velocity gradient so shear stress can't be exist.**

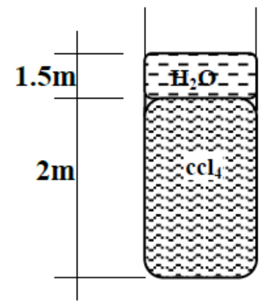
- **Since there is no motion of a fluid layer relative to adjacent layer, there are no shear stresses in the fluid. Hence all forces acting on their surface.**



$P = \gamma h$ hydrostatics law

Example 7// **An open vessel contains carbon tetrachloride to a depth of (2m) and water on the carbon tetrachloride to a depth of 1.5m. what is the pressure at bottom of the vessel? The s.g. for ccl_4 is (1.59).**

Solution:-



$$\gamma_w = 9810\, N/m^3$$

$$\gamma_{ccl_4} = s.g.(\gamma_w) = 1.59(9810) = 15598\, N/m^3$$

$$P = \gamma_w . h_w + \gamma_{ccl_4} . h_{ccl_4} = 9810(1.5) + 15598(2) = 45911\, N/m^3$$

Example 8// **How many millimeters of mercury are equivalent to standard atmospheric pressure? How many meters of water?**

Solution:-

$$P = \gamma h$$

$$a)\ 101.3 \times 10^3 = 13.6(9810)h$$

$$h = 0.76m = 76cm = 760mmHg$$

$$b) 101.3 \times 10^3 = 9810h$$

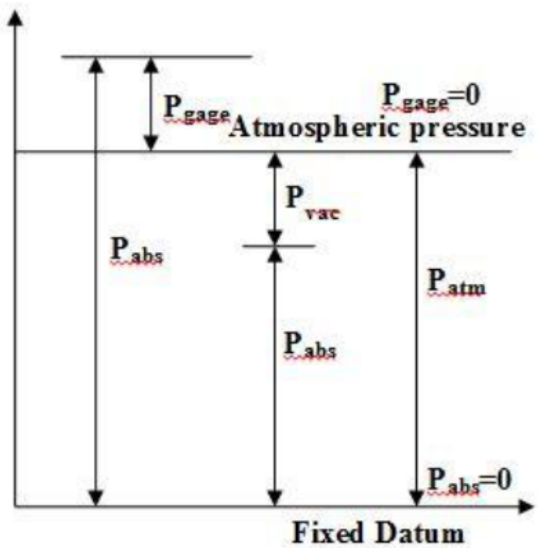
$$h = 10.33\, mH_2O$$

- **The pressure may be expressed in terms of a column of fluid rather than in force per unit area for the purpose of the hydrostatic law may be written as:**

$$\frac{P}{\gamma} = h$$

where P/γ is called the pressure head.

Absolute, vacuum and gage pressure



- **Atmospheric pressure P_{atm}:** the pressure that applied on the surfaces in contact with air. It is also known as "Barometric pressure". The atmospheric pressure at sea level (above absolute zero) is called "Standard atmospheric pressure".
  - **Gage pressure (P_{gage}):** it is the pressure, measured with help of pressure measuring instrument, in which the atmospheric pressure is taken as datum. The atmospheric pressure on the scale is marked as zero.
  - **Vacuum pressure (P_{vac})**: is the different between the absolute and the atmospheric pressure when the first is lower than the second. Or it is the negative pressure relative to the gage pressure.
- **Absolute pressure (P_{abs}):** is the pressure relative to the absolute vacuum pressure.

$$P_{abs} = P_{atm} + P_{gage} \qquad P_{abs} = P_{atm} - P_{vac}$$

Where P_{gage} may be positive or negative (vacuum, suction).

Table of decimal complictions/parts for physical quantities

Name	Symbol	Decimal complictions or parts
Mega	**M**	**10^6**
Kilo	**K**	**10^3**
Hecto	**H**	**10^2**
Deca	**Da**	**10**
Deci	**D**	**10^{-1}**
Centi	**C**	**10^{-2}**
Milli	**m**	**10^{-3}**
micro	**µ**	**10^{-6}**