Properties of Fluids Dr.Abdulkareem A.Wahab

Problem 1.1 /

Calculate the mass density (ρ), specific weight (weight density γ), specific gravity (relative density S) of volume(V) is 10^{-3} m^3 of a liquid which weighs (W) is 7 N ?

Solution:

$w = m\,g$ (Newton second law, F = ma)

$$m = \frac{w}{g} = \frac{7}{9.8} = 0.714 \text{ kg.}$$

$$\rho = \frac{m}{v} = \frac{0.714}{10^{-3}} = 714 \text{ kg / m}^3 \quad \text{(mass density)}$$

$$\gamma = \frac{w}{v} = \frac{7}{10^{-3}} = 7000 \text{ N/ m}^3 \quad \text{(specific weight or weight density)}$$

$$S_L = \frac{\rho_l}{\rho_w} = \frac{714}{1000} = 0.714 \quad \text{(specific gravity or relative density of Liquid)}$$

Problem 1.2 /

Calculate the mass density (ρ), specific weight (γ) and weight(W) of volume (V) 10^{-3} m^3 of petrol of specific gravity (S_L) is 0.7?

Solution:

$$S_L = \frac{\rho_l}{\rho_w}$$

$$\rho_L = S_L . \rho_w = 0.7 \times 1000 = 700 \text{ kg / m}^3 \quad \text{(mass density)}$$

$$\gamma_L = \rho_L\, g = 700 \times 9.8 = 6860 \text{ N/ m}^3 \quad \text{(specific weight)}$$

$$\gamma = \frac{w}{v}$$

$$w = \gamma\, v = 6860 \times 10^{-3} = 6.86 \text{ N} \quad \text{(weight)}$$

A distance between the moving plate and fixed plate (dy) is 0.025 mm, the velocity of moving plate (du) is 0.6 m /s, requires of 2 N /m^2 (shear stress τ). Determine the dynamic viscosity of fluid (μ) between the plates?

Solution:

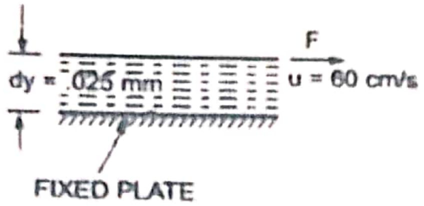


Fig. 1.3

$$\tau = \mu \frac{du}{dy}$$

$du = 0.6$ m /s

$dy = 0.025$ mm $= 0.025 \times 10^{-3}$ m

$\tau = 2$ N / m^2

$$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{2\times10^{-3}}{0.6/0.025} = 8.33 \times 10^{-5} \text{ N.s / m}^2$$

$$= 8.33\times 10^{-5} \times 10 = 8.33 \times 10^{-4} \text{ poise}$$

Problems 1.4 /

A flat plate of area 1.5 m^2 is pulled with a speed of 0.4 m/s relative to another plate located at a distance (dy) of 0.15 mm from it. Find the force (F) and power (P) required to maintain this speed, if the fluid separated them is having dynamic viscosity (μ) is 0.1 N.S/m^2.

Solution:

$A = 1.5$ m^2

$\mu = 0.1$ N.s / m^2

$$\tau = \mu \frac{du}{dy} = 0.1 \times \frac{0.4}{0.15\times10^{-3}} = 266.66 \text{ N / m}^2$$

حفظ

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

$F = \tau A = 266.66 \times 1.5 = 400$ N

حفظ

$P = F\,u$ (P is power)

$P = 400 \times 0.4 = 160$ watt

Problem 1.5 /

Determine the intensity of shear stress (τ) of an oil having dynamic viscosity (μ) is 0.1 N.s/m^2. The oil is used for lubricating the clearance between a shaft of diameter 10 cm and its journal bearing. The clearance (dy) is 1.5 mm and the shaft rotates at (N) is 150 rpm.

Solution:

قانون السرعة

$D = 10$ cm $= 0.1$ m

$$u = \frac{D}{2} \times \omega = \frac{D}{2} \times \frac{2\pi N}{60} = \frac{\pi D N}{60} = \frac{\pi \times 0.1 \times 150}{60} = 0.785 \text{ m/ s}$$

$$\omega - \text{angular velocity} = \frac{2\pi N}{60} \quad \text{rad/ s}$$

$$\tau = \mu \frac{du}{dy} = 0.1 \times \frac{0.785}{1.5 \times 10^{-3}} = 52.33 \text{ N/ m}^2$$

Problem 1.6 /

Determine the dynamic viscosity (μ) of an oil, which is used for lubrication between a square plate of size 0.8 m × 0.8 m and an inclined plane with angle of inclination 30^0 as shown in Fig. (1.4). The weight of the plate is 300 N and it slides down the inclined plane with a uniform velocity of 0.3 m /s. The thickness of oil film is 1.5 mm.

Solution:

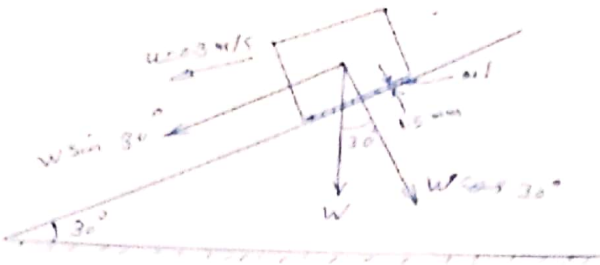


Fig.(1.4)

Area(A) = 0.8 × 0.8 = 0.64 m^2

Thickness of oil film = t = dy = 1.5 mm = 1.5×10^{-3} m

Component of weight W, along the plane = W Sin 30°

= 300 × 0.5 = 150 N

$$\tau = \frac{F}{A} = \frac{150}{0.64} = 234.37 \text{ N/m}^2$$

$$\tau = \mu \frac{du}{dy}$$

$$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{234.37}{\frac{0.3}{1.5 \times 10^{-3}}} = 1.17 \text{ N.s/m}^2 = 1.17 \times 10 = 11.7 \text{ poise}$$

Problem 1.7 / تطبيق مباشر

Two horizontal plate are placed 1.25 cm apart, the space between them being filled with oil of dynamic viscosity (μ) is 1.4 N. s/m². Calculate the shear stress (τ) in oil, if the velocity of the upper plate (du) is 2.5 m/s.

Solution:

t = dy = 1.25 cm = 0.0125 m

μ = 1.4 N.s / m^2

$$\tau = \mu \frac{du}{dy} = 1.4 \times \frac{2.5}{0.0125} = 280 \text{ N/m}^2$$

Problem 1.8 /

The space between two square flat parallel plate is filled with oil. Area of plate is 0.36 m^2. The thickness of the oil film is 12.5 mm. The upper plate, which moves at (du) is 2.5 m/s are requires a force (F) is 98.1 N to maintain the speed. Determine: (1) the dynamic viscosity (μ) of the oil in poise.

(2) The kinematic viscosity of the oil (ν) in stokes, if the specific gravity(S) of the oil is 0.95.

Solution:

Area (A) = 0.36 m^2

$dy = 12.5 \times 10^{-3}$ m

du = 2.5 m/s

$$\tau = \frac{F}{A} = \frac{98.1}{0.36} = 272.5\ N/m^2$$

$$\tau = \mu \frac{du}{dy}$$

(1) $$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{272.5}{\frac{2.5}{12.5 \times 10^{-3}}} = 1.36\ N.s/m^2 = 13.6\ poise$$

(2) $$\rho_{oil} = S \times \rho_w = 0.95 \times 1000 = 950\ kg/m^3$$

$$\nu = \frac{\mu}{\rho} = \frac{1.36}{950} = 0.00143\ m^2/s$$

$$\nu = 0.00143 \times 10^4\ cm^2/s\ (stokes)$$

$$= 14.3\ cm^2/s = 14.3\ stokes$$

Problem 1.9 /

Find the kinematic viscosity (ν) of an oil having mass density (ρ) is 981 kg/m^3. The shear stress (τ) a point in oil is 0.2452 N/ m^2 and velocity gradient (du / dy) at the point is 0.2 per second.

Solution:

$$\tau = \mu \frac{du}{dy}$$

$$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{0.2452}{0.2} = 1.226 \text{ N.s / m}^2$$

تحويل

$$\nu = \frac{\mu}{\rho} = \frac{1.226}{981} = 0.0012 \text{ m}^2/\text{s} = 0.0012 \times 10^4 \text{ cm}^2/\text{s} = 12 \text{ stokes.}$$

Problem 1.10 /

Determine the specific gravity (S) of a fluid having a dynamic viscosity (μ) is 0.05 poise and kinematic viscosity (ν) is 0.035 stokes?

Solution:

$$\mu = 0.05 \text{ poise} = 0.005 \text{ N. s / m}^2$$

تحويل

$$\nu = 0.035 \text{ stokes} = 0.035 \text{ cm}^2/\text{s} = 0.035 \times 10^{-4} \text{ m}^2/\text{s}$$

$$\nu = \frac{\mu}{\rho}, \quad \rho_f = \frac{\mu}{\nu} = \frac{0.005}{0.035 \times 10^{-4}} = 1428.5 \text{ kg / m}^3$$

$$S_f = \frac{\rho_f}{\rho_w} = \frac{1428.5}{1000} = 1.4285$$

Problem 1.11 /

Determine the dynamic (μ) viscosity of a liquid having kinematic viscosity (ν) 6 stokes and specific gravity (S) is 1.9?

Solution:

تحويل

$$\nu = 6 \text{ stokes} = 6 \text{ cm}^2/\text{s} = 6 \times 10^{-4} \text{ m}^2/\text{s}$$

$$S_f = \frac{\rho_f}{\rho_w}, \quad \rho_f = S_f \times \rho_w = 1.9 \times 1000 = 1900 \text{ kg / m}^3$$

$$\nu = \frac{\mu}{\rho_f}, \quad \mu = \nu \times \rho_f = 6 \times 10^{-4} \times 1900 = 1.14 \text{ N.s / m}^2$$

$$= 11.4 \text{ poise.}$$

Problem 1.12 /

The velocity distribution for flow over a flat plate is given by equation: $u = \frac{3}{4}y - y^2$ in which u is the velocity in m /s at a distance (y) m above the plate. Determine the shear stress at y = 0.15 m. Take dynamic viscosity (μ) of fluid as 0.85 poise.

Solution:

$u = \frac{3}{4}y - y2$, $\frac{du}{dy} = \frac{3}{4} - 2y$

At $y = 0.15$ m , $\frac{du}{dy} = \frac{3}{4} - 2 \times 0.15 = 0.45$

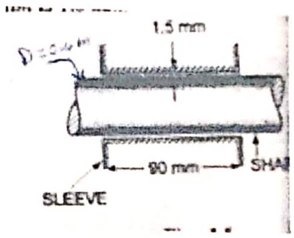
If $\mu = 8.5$ poise $= 0.85$ N .s / m^2

$$\tau = \mu \frac{du}{dy} = 0.85 \times 0.45 = 0.3825 \text{ N / m}^2$$

Problem 1.13 /

The dynamic viscosity (μ) of an oil, used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates (N) at 190 rpm. Calculate the power lost in a bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.

Solution:



$\mu = 6$ poise $= 0.6$ N.s / m^2

$$u = r\,\omega = \frac{D}{2} \times \frac{2\pi N}{60} = \frac{\pi D N}{60} = \frac{\pi \times 0.4 \times 190}{60} = 3.98 \text{ m/s}$$

$$\tau = \mu \frac{du}{dy} = 0.6 \frac{3.98}{1.5 \times 10^{-3}} = 1592 \text{ N / m}^2$$

$\tau = \frac{F}{A}$ (A is surface area)

$$F = \tau A = \tau \times \pi D L = 1592 \times \pi \times 0.4 \times 90 \times 10^{-3} = 180.05 \text{ N}$$

$T = F \times \frac{D}{2}$ (T is Torque N.m)

$$= 180.05 \times \frac{0.4}{2} = 36.01 \text{ N.m}$$

Power (lost) $= T\,\omega = 36.01 \times \frac{2\pi N}{60} = 716\ 48$ watt.

Problem 1.14 /

The weight density (γ) of gas is 16 N/m^3 at 25°c and at an absolute pressure of 25×10^4 N/m^2. Determine the mass density (ρ) of gas and gas constant (R)?

Solution:

$T_{abs.} = 25 + 273 = 298^o$ K

$P = 0.25 \times 10^6 = 25 \times 10^4$ N/m^2

$\gamma = \rho\, g$

$\rho = \frac{\gamma}{g} = \frac{16}{9.81} = 1.63$ kg/ m^3 , $\quad \frac{P}{\rho} = R\,T, \quad R = \frac{P}{\rho T} = \frac{25\times10^4}{1.63\times298}$

= 532.5 N.m/kg.k

Problem 1.15 /

A cylinder of 0.6 m^3 in volume contains air at 50°c and P_1 is 30×10^4 N/m^2 absolute pressure. The air is compressed to 0.3 m^3. Find (1) pressure inside the cylinder, assuming isothermal process and (2) pressure and temperature, assuming adiabatic process. (Take 1.4).

Solution:

$V_1 = 0.6$ m^3 , $T_1 = 50 + 273 = 323^o$ k, $P_1 = 30\times 10^4$ N/m^2

$V_2 = 0.3$ m^3 , $k = 1.4$

(1) Isothermal process:

$P\,V$ = constant

$P_1 V_1 = P_2 V_2 \quad , \quad P_2 = \frac{P_1 V_1}{V_2} = \frac{30\times10^4 \times0.6}{0.3} = 0.6 \times 10^6$ N/m^2

(2) Adiabatic process:

$P\,V^k$ = constant

$P_1 V_1^k = P_2 V_2^k$

$P_2 = P1\frac{V_1^k}{V_2^k} = 30\times10^4 \times \left(\frac{0.6}{0.3}\right)^{1,4} = 30 \times10^4 \times 2^{1.4}$

$$= 0.791 \times 10^6 \ N/m^2$$

$$R\,T\,V^{k-1} = \text{constant}$$

$$T\,V^{k-1} = \text{constant} \qquad (\text{R is constant})$$

$$T_1 V_1^{k-1} = T_2 V_2^{k-1} \quad , \quad T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{1.4-1}$$

$$T_2 = 323 \left(\frac{0.6}{0.3}\right)^{0.4} = 323 \times 10^{0.4} = 426.2^{\circ}\ k$$

$$T_2 = 426.2 - 273 = 153.2^{\circ}c$$

Problem 1.16 /

Determine the Bulk modulus of elasticity (K) of a liquid. If the pressure of the liquid increased from 70 N/cm² to 130 N/cm². The volume of the liquid decreases by 0.15 per cent (15%) .

Solution:

Increase of pressure (dP) = 130 - 70 = 60 N/cm²

Decrease of Volume (dV) = 15 %

$$K = \frac{dp}{\frac{dV}{V}} = \frac{60}{\frac{15}{100}} = 4 \times 10^4 \ N/cm^2$$

Problem 1.17 /

What is the Bulk modulus of elasticity of a liquid (K) which is compressed in a cylinder from a volume of 0.0125 m³ at 80 × 10⁴ N/m² pressure to a volume of 0.0124 m³ at 150 × 10⁴ N/m² pressure?

Solution:

$$dV = 0.0125 - 0.0124 = 0.0001 \ m^3$$

$$dP = 150 \times 10^4 - 80 \times 10^4 = 70 \times 10^4 \ N/m^2$$

$$K = \frac{dP}{\frac{-dV}{V}} = \frac{70\times10^4}{\frac{0.0001}{0.0125}} = 70 \times 125 \times 10^4 \ N/m^2$$

Problem 1.18 /

A surface tension of water in contact with air (σ) is 0.0725 N/m. The pressure inside a droplet of water is to be 0.02×10^4 N/m² greater than the outside pressure. Calculate the diameter of the droplet of water.

Solution:

$$P = 0.02 \times 10^4 \quad N/m^2$$

$$P = \frac{4\sigma}{d} \quad , \quad d = \frac{4\sigma}{P} = \frac{4 \times 0.0725}{0.02 \times 10^4} = 0.00145 \text{ m} = 1.45 \text{ mm.}$$

Problem 1.19 /

Find the surface tension in a soap bubble (σ) of a 40 mm diameter, when the inside pressure is 2.5 N/m² above atmospheric pressure.

Solution:

$$P = \frac{8\sigma}{d} \quad , \quad \sigma = \frac{P\,d}{8} = \frac{2.5 \times 40 \times 10^{-3}}{8} = 0.0125 \text{ N/m}$$

Problem 1.20 /

The pressure outside the droplet of water of diameter 0.04 mm is 10.32 N/cm² (atmospheric pressure). Calculate the pressure within the droplet, if surface tension is given as 0.0725 N/m of water.

Solution:

$$P_{inside} = \frac{4\sigma}{d} = \frac{4 \times 0.0725}{0.04 \times 10^{-3}} = 7250 \text{ N/ m}^2 = 0.725 \text{ N / cm}^2$$

$$P_{outside} = P_{inside} + P_{atm.} = 0.725 + 10.32 = 11.045 \text{ N / cm}^2$$

Problem 1.21 /

Calculate the capillary effect in millimeter in a glass tube of 4 mm diameter, when immersed in (1) water, and (2) mercury. The values of the surface tension of water and mercury are 0.073575 N/m and 0.51 N/m respectively. The angle of contact for mercury 1.30°.

Solution:

$$h = \frac{4\,\sigma\cos\theta}{\rho\,g\,d}$$

(1) For water rise, $h = \frac{4 \times 0.073575}{1000 \times 9.81 \times 4 \times 10^{-3}}$ (Θ is zero)

$h = 7.51 \times 10^{-3}$ m = 7.51 mm

(2) For mercury depression, $h = \frac{-4 \times 0.51 \times \cos 1.30^{o}}{13600 \times 9.81 \times 4 \times 10^{-3}}$

$h = -2.46 \times 10^{-3}$ m = - 2.46 mm

Problem 1.22 /

Find the diameter of glass tube (capillary tube) that can be used to measure surface tension of water in contact with air as 0.073575 N/m.

Solution:

$$h = \frac{4\,\sigma}{\rho\,g\,d} \quad , \quad d = \frac{4\,\sigma}{\rho\,g\,h} = \frac{4 \times 0.073575}{1000 \times 9.81 \times 2 \times 10^{-3}}$$

= 0.015 m = 1.5 cm.