Problems of chapter One

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:

$$w = m\,g \qquad \text{(Newton second law, } F = ma)$$

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

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

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

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

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:

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

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

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

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

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

Problem 1.3 /

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:

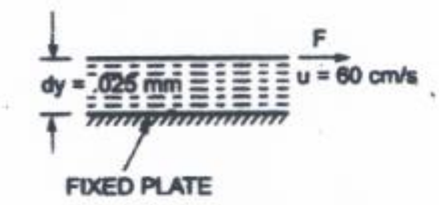


Fig. 1.3

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

du = 0.6 m /s

dy = 0.025 mm = 0.025 × 10^{-3} m

τ = 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

μ = 0.1 N.s / m^2

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

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

F = τ A = 266.66 × 1.5 = 400 N

P = F u (P is power)

P = 400 × 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:

D = 10 cm = 0.1 m

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

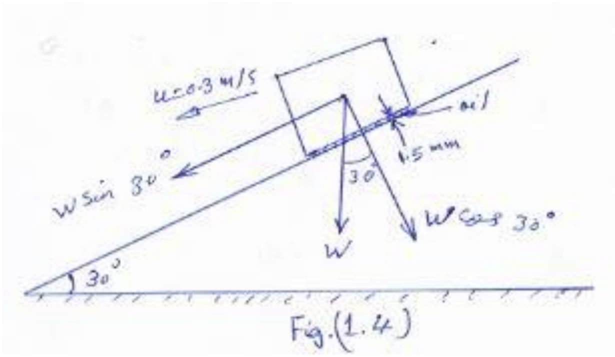
$$\omega \text{ – angular velocity} = \frac{2\pi N}{60} \quad \text{rad/ s}$$

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

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:



Area(A) = 0.8 × 0.8 = 0.64 m²

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

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

= 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 /

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 / m²

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

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

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

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

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

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

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

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

$$= 14.3 \text{ cm}^2 \text{ /s} = 14.3 \text{ stokes}$$

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:

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

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

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

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:

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

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

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

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

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:

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

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

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

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

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.