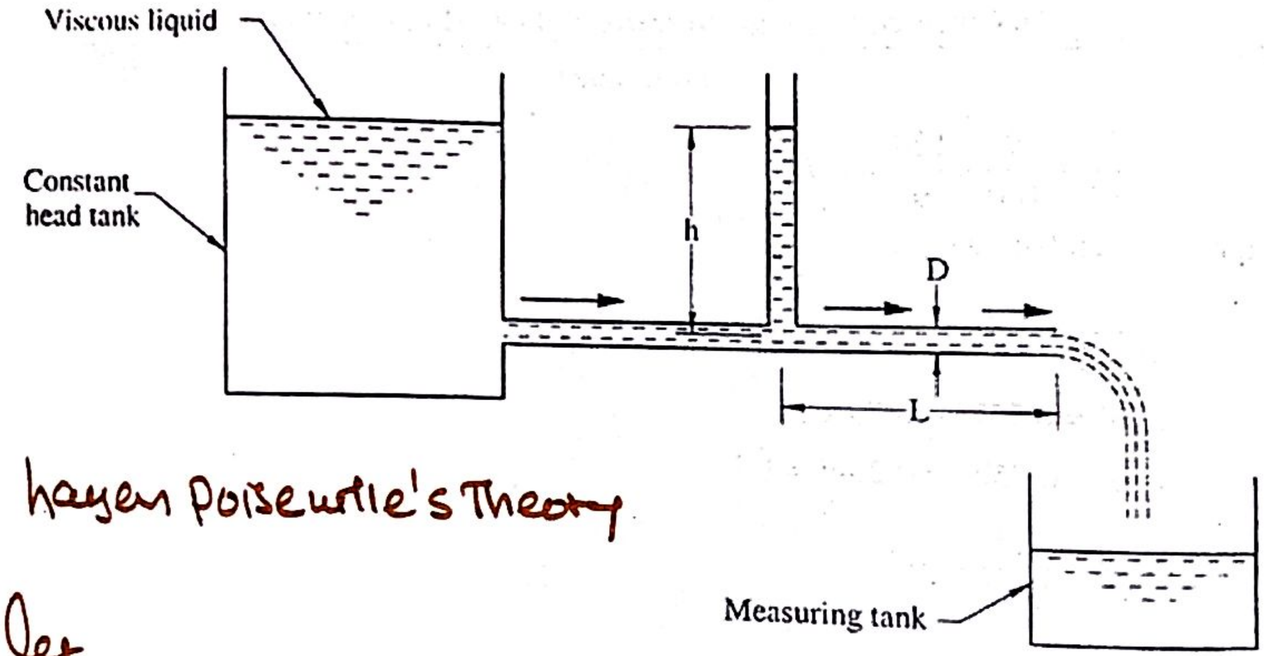
Viscosity Measurement - Capillary Tube Method



→ hagen poiseuille's Theory

let

D = Diameter of capillary tube

h = Pressure head for length L

μ = coefficient of viscosity

ρ = Density of fluid

using hagen poiseuille's equation

$$h = \frac{32 \mu \bar{u} L}{\rho g D^2}$$

$\bar{u}$ = average velocity

$$\bar{u} = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} D^2}$$

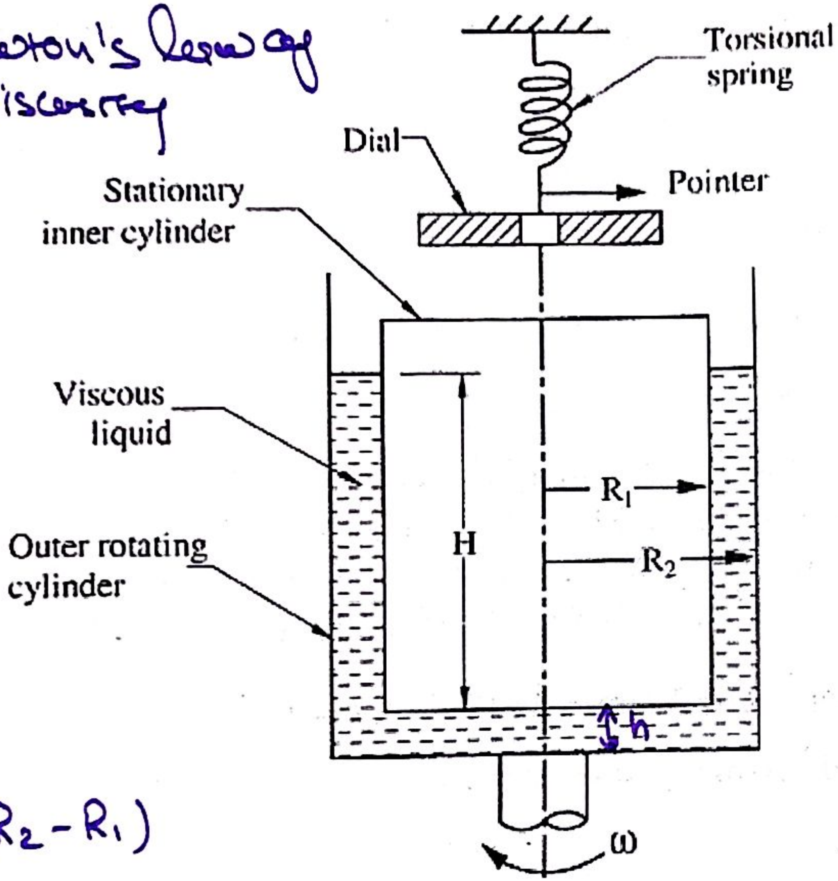
$$h = \frac{32 \mu \frac{Q}{\frac{\pi}{4} D^2} \times L}{\rho g D^2}$$

$$h = \frac{128 \mu Q L}{\pi \rho g D^4}$$

$$\mu = \frac{\pi \rho g D^4}{128 Q L}$$

Viscosity Measurement - Rotating Cylinder Method

Newton's law of viscosity



$(R_2 - R_1)$

let

ω = angular speed of outer cylinder

h = clearance at bottom

H = height of liquid in annular space

μ = coefficient of viscosity

T = Torque

Velocity of outer cylinder

$$V = R_2 \times \omega$$

inner cylinder $= 0$

velocity gradient over the $(R_2 - R_1)$

$$\frac{du}{dy} = \frac{R_2\omega - 0}{R_2 - R_1} = \frac{R_2\omega}{R_2 - R_1}$$

Shear stress

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

$$= \mu \times \frac{R_2\omega}{R_2 - R_1}$$

Shear force

$$F = \tau \times \text{surface area}$$

$$= \frac{\mu R_2 \omega}{R_2 - R_1} \times 2\pi R_1 H$$

$$F = \frac{\mu \omega R_2}{R_2 - R_1} \times 2\pi R_1 H$$

Viscosity Measurement - Rotating Cylinder Method

T_1 = Torque on inner cylinder due to shear action

T_1 = shear force x Radius

$$= \frac{\mu R_2 \omega}{R_2 - R_1} \times 2\pi R_1 H \times R_1$$

$$T_1 = \frac{2\pi \mu \omega H R_1^2 R_2}{R_2 - R_1}$$

using Theory of footstep bearing

T_2 = Torque applied on inner cylinder

$$T_2 = \frac{\mu}{60t} \times \pi^2 N R^4$$

$$R = R_1 \qquad t = h$$

$$T_2 = \frac{\mu}{60h} \times \pi^2 \times N \times R_1^4$$

T = Total Torque

$$T = T_1 + T_2$$

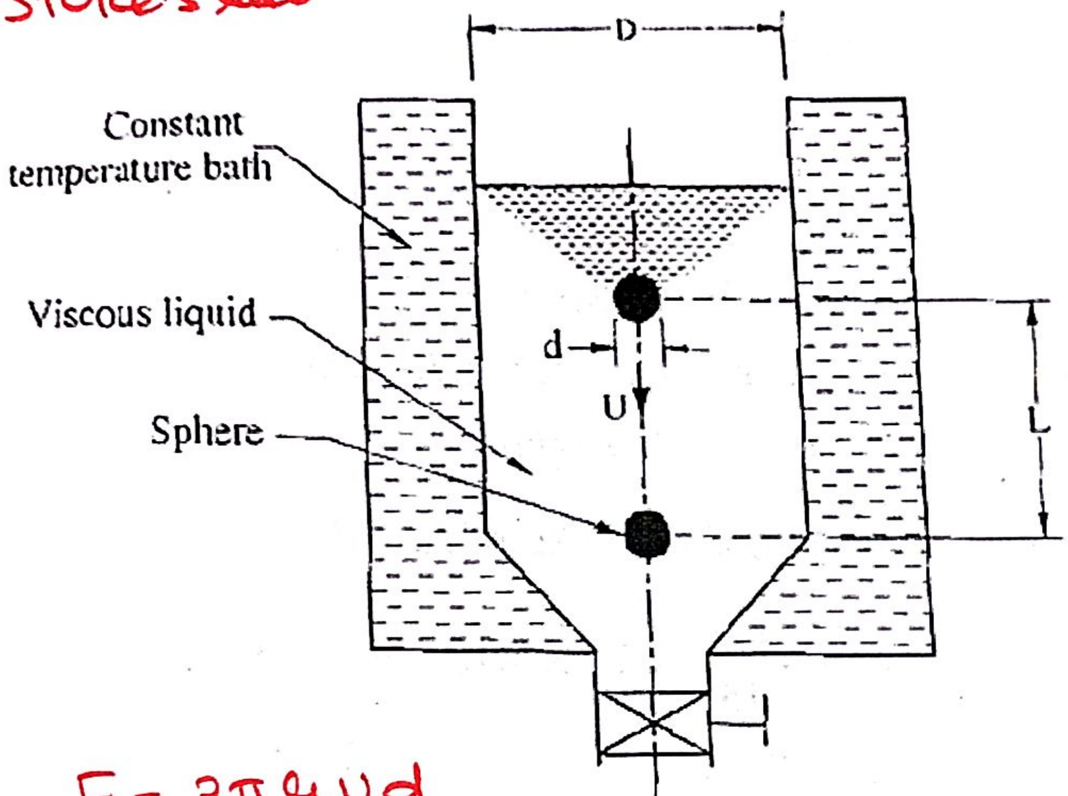
$$T = \frac{2\pi \mu \omega H R_1^2 R_2}{R_2 - R_1} + \frac{\pi \mu \omega}{2h} . R_1^4$$

$$T = 2\pi \mu R_1^2 \omega \left[\frac{R_2 H}{R_2 - R_1} + \frac{R_1^2}{4h} \right]$$

$$\mu = \frac{2(R_2 - R_1) h T}{\pi R_1^2 \omega [4 H h R_2 + R_1^2 (R_2 - R_1)]}$$

Viscosity Measurement - Falling Sphere Method

Stoke's law



$F = 3\pi \mu U d$

d = Dia of sphere

U = velocity of sphere

let = L = Distance Travelled by sphere in viscous liquid

t = time taken by sphere to cover Distance L

ρ_s = Density of sphere

ρ_f = Density of fluid

W = weight of sphere

F_B = buoyant force acting on sphere

$$U = \frac{L}{t}$$

$$W = \rho V \times g$$

$$= \rho_s \times \pi/6 \, d^3 \times g$$

buoyant force

F_B = weight of fluid displaced

$$= \pi/6 \, d^3 \times \rho_f \times g$$

For equilibrium condition

viscous force = weight of sphere - buoyant force

$$3\pi \mu U d = \rho_s \frac{\pi}{6} d^3 \times g - \frac{\pi}{6} d^3 \times \rho_f \times g$$

$$\mu = \frac{\frac{\pi}{6} d^3 g (\rho_s - \rho_f)}{3\pi U d}$$

$$\boxed{\mu = \frac{g d^2}{18 U} (\rho_s - \rho_f)}$$