Viscosity

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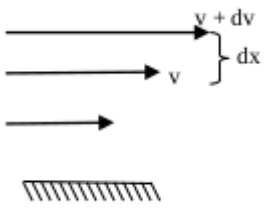
The property of fluid which oppose the relative motion between two layers of fluid is called viscosity, is due to intermolecular force of attraction between two layers of liquid. The viscous force of liquid decreases on increasing temperature while viscous force of gas increases on increasing temperature.

Newton's formula for viscous force

Liquid is flowing then the two layers of area A having velocity difference dv at a distance dx then

Viscous force (F) = $-\eta A \frac{dv}{dx}$



Where -ve sign indicates the viscous force act in opposite direction of motion.

η is constant and is called coefficient of viscosity with unit Nsm^{-2} (decapoise)

Stokes formula

When a sphere of radius 'r' is falling with velocity v in a liquid of coefficient of viscosity η then the viscous force is

$$F = 6\pi\eta r v$$

Poseuille's formula

Liquid flowing through a uniform tube of radius r whose two ends are at a pressure difference P then the volume of liquid flowing per sec is

$$\frac{volume}{sec} = \frac{\pi p r^4}{8\eta l}$$

Terminal velocity (V_t)

When a spherical body whose density is greater than liquid is released in liquid then if accelerate at first so the viscous force increases. A condition come at which apparent wt. of body become equal to the viscous force then body move with constant velocity is called terminal velocity

$$v_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$$

$\rightarrow$ If n drops of liquid falling with velocity v, coalesce to form a single drop of velocity v_2 then

$V_t \propto r^2$

$$\therefore \frac{v_2}{v_1} = \left(\frac{R}{r}\right)^2 = n^2$$

Continuity Principle

When non viscous and incompressible liquid is flowing through a pipe of non uniform cross section then

$A_1 v_1 = A_2 v_2$

Hence volume of liquid flowing per second at any cross section is constant.

Bernoulli's theorem

When non-viscous, incompressible liquid is flowing then sum of PE, KE and pressure energy per unit volume is constant ie

$\rho gh + 1/2\rho v^2 + P$ = constant

Torricelli's theorem (velocity of efflux)

The velocity of liquid through hole at a depth h is

$$v = \sqrt{2gh}$$

Stream line and turbulent flow

When liquid is flowing then each particle follow the path of motion of preceding particle is called stream line flow. The flow of liquid in which each particle has different velocity is called turbulent flow

Certain velocity of liquid in tube below which flow is stream line or laminar is called critical velocity. Above this velocity flow of liquid is turbulent.

Reynolds number

Critical velocity of liquid depends of

$$V_c = \frac{k\eta}{\rho D}$$

η = coefficient of viscosity

ρ = density

D = diameter of tube

K is constant called Raymond's number

The value of Reynolds's number below 2000 represent the flow of liquid laminar where as the number above 3000 represent the flow turbulent. If the number varies from 2000 to 3000 then flow is unstable ie is may change from laminar to turbulent & vice versa.

If a hole of cross sectional area A_o is made at bottom of tank of cross sectional A then time taken to lower the height of liquid from h_1 to h_2 is

$$t = \frac{A}{A_o}\sqrt{\frac{2}{g}}(\sqrt{h_1} - \sqrt{h_2})$$

$\therefore$ So time taken to empty the tank is

$$t = \frac{A}{A_o}\sqrt{\frac{2h}{g}}$$