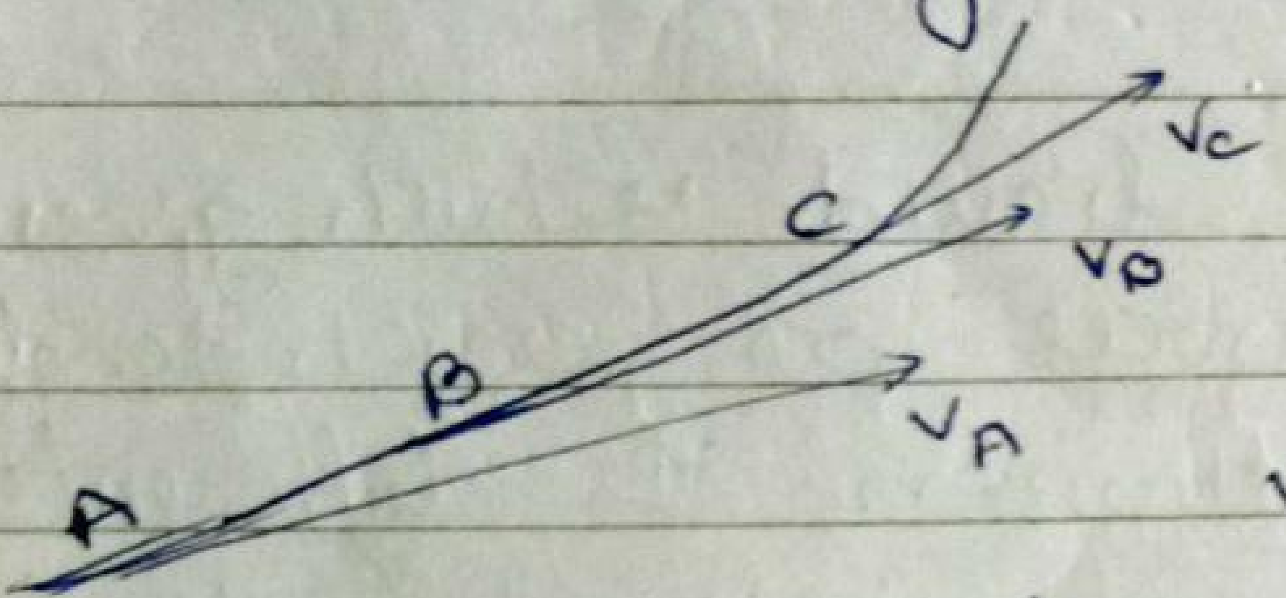
Que What is difference between stream lined and turbulent motion.

Steady OR streamline flow (Lines and tubes of flow)

The flow of ~~liquid~~ fluid is said to be steady, orderly, streamline or laminar, if the velocity at every point in the fluid remains constant (in magnitude as well as direction). The energy needed to drive the fluid being used up in overcoming the "viscous drag" between its layer or each infinitesimally small volume element of the fluid called a particle of the fluid which follows exactly the same path and has exactly the same velocity as its predecessor. ie velocity does not change with time.



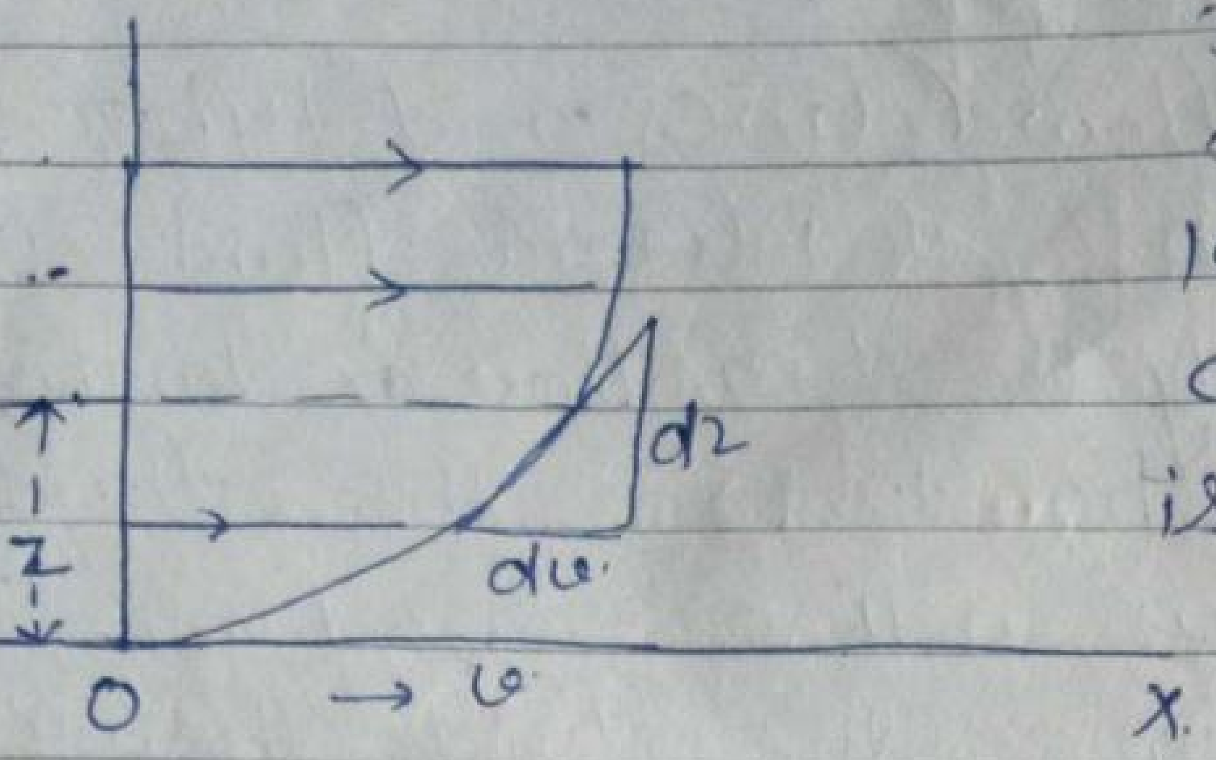
This line ABC along which the particles of the fluid move, one after the other, with their velocities constant at the various points on it and directed along the tangents to these points, is called a steam line.

If a steam line as a curve, the tangent ~~to~~ which at any ~~poin~~ point gives the direction of ~~flow~~ fluid-flow at that point.

The fluid-flow remains steady or streamline if its velocity does not exceed a limiting value, called its critical velocity.

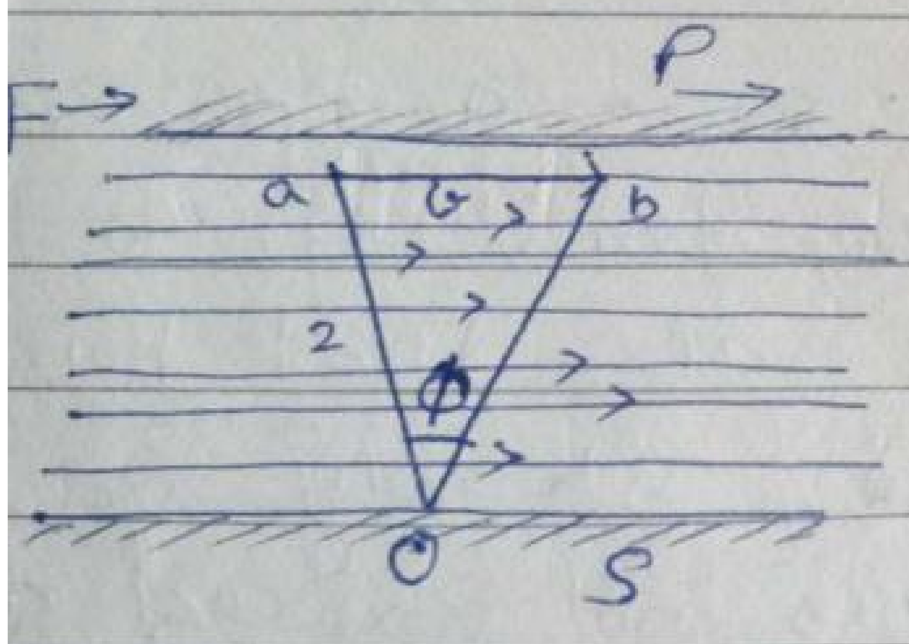
Turbulent flow → when the flow of a liquid is unsteady and the liquid does not flow in a regular manner but follow a zig-zag or sinuous path from side to side, the external energy is chiefly dissipated in causing the eddy currents such ~~type~~ type of motion is called turbulent motion.

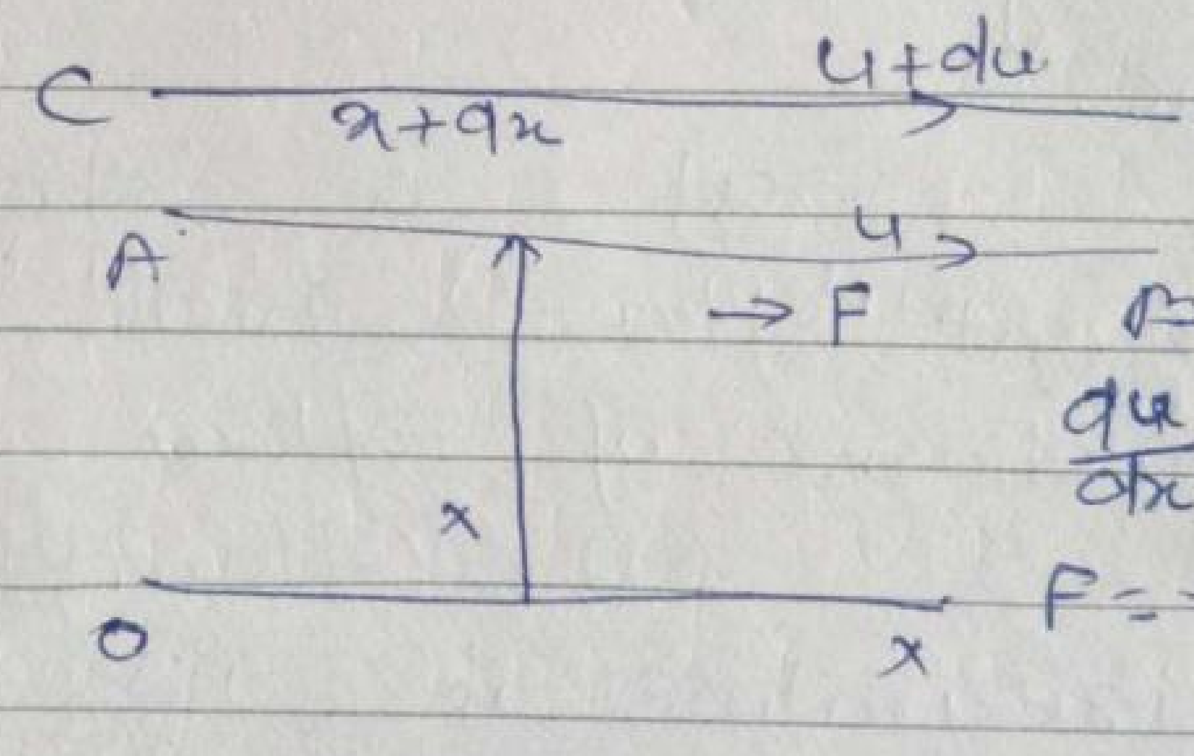
VISCOSITY →



In a steady or laminar flow of a liquid over a fixed horizontal surface. The layer of the liquid in contact with the fixed surface is stationary. The velocity of any layer increases with the distance from the fixed layer. The uppermost layer moves forwards under the shearing stress applied to it. A tangential, backward dragging force, frictional in nature arises between two layers of liquid. This force tends to oppose the relative motion between the two. These force is called viscous force or the viscous drag.

The property of a liquid which gives rise to such viscous forces or which tends to oppose relative motion between its different layers is called viscosity ~~or~~ or internal friction.





$\frac{du}{dx}$ = velocity gradient

$F = -\eta A \frac{du}{dx}$

A liquid is in contact with a fixed horizontal surface at its bottom. F be the external force applied to plate P to maintain a streamline flow of the liquid.

v = The velocity of the uppermost layer at distance z from the lowermost.

Tangential or shearing stress applied = F/A

A = ~~Area~~ Surface area of the layer

In 1 sec a ~~sec~~ on the layer moves through a distance v to the position b

angle of shearing = $\phi = \angle AOb$

coefficient of viscosity of the liquid.

$$\eta = \frac{F/A}{\phi}$$

$$= \frac{F/A}{v/z} = \frac{F/A}{dv/dz}$$

$$\boxed{F = \eta A \, dv/dz}$$

$dv/dz = 1 \quad F = \eta \quad A = 1$

Thus, the coefficient of viscosity of a liquid is equal to the tangential force required per unit area to maintain a unit velocity gradient or The tangential backward force acting on unit area of a liquid layer moving in a region of unit velocity gradient normal to the direction of flow.

units of η = poise.

Dimension $\eta = \frac{[MLT^{-2}]}{[L^2]} \cdot \frac{[L]}{[LT^{-1}]} = ML^{-1}T^{-1}$

The co-efficient of viscosity is also called dynamic viscosity of the liquid.

Viscosity, A Fugitive Rigidity (Fugitive elasticity)

The coefficient of viscosity

$$\eta = \frac{F/A}{dv/dz} = \frac{\text{Tangential stress}}{\text{velocity gradient}}$$

coefficient of Rigidity.

$\theta = dy/dz$

$$\eta = \frac{F/A}{\theta} = \frac{F/A}{dy/dz}$$

$$= \frac{\text{Tangential stress}}{\text{displacement gradient}}$$

Maxwell ~~come to~~ concluded that coefficient of viscosity in liquids ~~analogous to~~ similar to modulus of rigidity in solid when it breaks down under the shearing stress applied.

Therefore, the coefficient of viscosity is called fugitive elasticity.

The rate of breakdown of shear = $\lambda\theta$

where λ is a constant.

The rate of formation of shear $d\theta/dt \neq \lambda\theta$

$$\frac{d\theta}{dt} = \frac{d}{dt}(dy/dx) = \frac{d}{dx}\left(\frac{dy}{dt}\right) = dv/dx = \phi$$

where v is the velocity in the same plane.

For the liquid-motion to be steady, the rates of breakdown and formation of the shear must be the same.

$$\lambda\theta = dv/dz$$

$$\theta/dv/dz = \frac{1}{\lambda} =$$

$$\frac{\eta}{n} = \theta/dv/dz = \frac{1}{\lambda}$$

$$\boxed{\eta = n/\lambda}$$

where $1/\lambda$ is called the time of relaxation. ie the time taken by the shear to vanish. The time t taken by the shear to fall to half its value is given by the relation $\lambda t = \log 2$

Critical velocity → The flow of liquid remains steady or orderly only when its velocity does not exceed a certain limiting value for it is called critical velocity. Beyond the critical velocity, the flow loses all its steadiness. ~~and orderliness~~ The paths and velocities of the liquid particles ~~char~~ are changing continuously and haphazardly. This flow is called turbulent flow. Due to this most of the energy needed to drive the liquid is now dissipated in setting up eddies and whirlpools in it.

~~Reynolds~~ According to Reynolds formula.

$$v_c = K\eta/\rho r$$ η, ρ = coefficient of viscosity, Density of the liquid

r = radius of the tube

K = Reynolds number

Deduction dimensionally →

$v_c \propto \eta^a \rho^b r^c$

$v_c = k\eta^a \rho^b r^c$ k = Dimensional constant

$[M^0LT^{-1}] = k[ML^{-1}T^{-1}]^a [ML^{-3}]^b [L]^c$

$[M^0LT^{-1}] = k[M^{a+b} L^{-a-3b+c} T^{-a}]$

equating dimension both side.

$a+b=0$ $-a-3b+c = 1$ $-a = -1$

$a = -b$ $+b-3b+c = 1$ $a = 1$

$-2b+c = 1$

$b = -1$ $-2\times -1 + c = 1$

$2+c = 1$

$c = -2+1 = -1$

$v_c = k\eta \rho^{-1} r^{-1} = \frac{k\eta}{\rho r}$

$\boxed{v_c \propto 1/r}$

For a perfectly mobile or inviscid liquid. $\eta = 0$, its critical velocity v_c too is zero. Its flow will be disorderly or turbulent.

Significance of Reynold's number →

Reynold's number $K = v_c(\rho r)/\eta$ is pure number, no dimensions.

Smaller value of Reynold's number indicate that force of viscosity predominates.
larger value of Reynold's number indicate that viscous forces are of little consequence.

(a) Variation of viscosity of liquids with temperature or Effect of temperature on viscosity of liquids.

The viscosity of liquids decreases rapidly with ~~the~~ increase in temp. Slotte gave the empirical formula

$$\eta_t = \frac{\eta_0}{1+at+bt^2} \qquad \eta_0 = \text{coefficient of viscosity at } 0^\circ C$$

At modified relation

$$\eta_t = \frac{A}{(1+Bt)^c} \quad \text{where } \eta_t = \text{coefficient of viscosity at temp } t.$$

According to Andrade's theory A & B & c are const

$\eta = Ae^{C/T}$ applies as a first approximation.

A & C are constants.

The empirical criteria pointed out by Porters That

if T & T_0 are two temperatures at which two liquids have the same ~~veloci~~ viscosity, then the graph T/T_0 against T is a straight line.

Andrade's theory gives the more complex viscosity - temperature relation.

$$\eta v^{1/2} = Ae^{c/vT} \quad \text{where } v = \text{specific volume}$$

This formula agrees closely with the results for many liquids.

(b) Effects of pressure on the viscosity of liquids →

The effect of pressure on viscosity is small. For mobile liquids (ie liquids with low viscosity). The viscosity of water decreases with increase of pressure up to a few hundred atmospheres.

In the case of liquids with high viscosity like mineral oils, the change in viscosity with pressure is very much greater

By Bridgman

$$\frac{\eta_P}{\eta_1} = \left(\frac{v_1}{v_P}\right)^{1/6} \sqrt{K_P/K_1} \cdot e^{c/T\left(\frac{1}{v_P} - \frac{1}{v_1}\right)}$$

where v is the specific volume
k - Adiabatic Bulk modulus.

At high pressures it would be unreasonable to anticipate any good agreement since, in these circumstances the molecules undergo deformation barring the case of water (an exceptional liquid in many other ways) whose viscosity decreases with pressure, the viscosity of all other liquids increases with pressure and the higher the pressure to which they are subjected the higher the rate of increase of viscosity with pressure.