Physics Notes

BY

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Class:10+1

Unit: VII-*C,D,E*

Topic: **Properties of Bulk Matter**

<u>*SYLLABUS*</u>: UNIT-VII

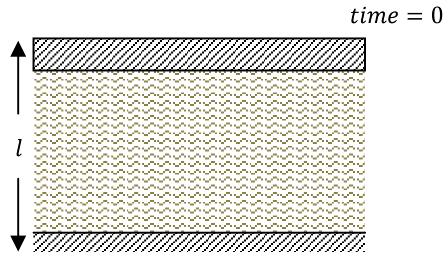
Elastic behavior, Stress-stain relationship, Hooke's law, Young's modulus, bulk modulus, shear, modulus of rigidity.	*7A*
Pressure due to a fluid column; Pascal's law and its applications (hydraulic lift and hydraulic brakes). Effect of gravity on fluid pressure. Surface energy and surface tension, angle of contact, application of surface tension ideas to drops, bubbles and capillary rise.	*7B*
Viscosity, Stokes law, terminal velocity, Reynolds's number, streamline and turbulent flow, Bernoulli's theorem and its applications.	*7C*
Heat, temperatures, thermal expansion; specific heat-calorimetry; change of state- latent heat.	*7D*
Heat transfer-conduction, convection and radiation, thermal conductivity, Newton's law of cooling.	*7E*

Q.1. Viscosity? Co eff. of viscosity? Units? Dimensions?

Ans. <u>**Viscosity**</u>:-

Internal friction of moving fluid is called Viscosity of liquid.

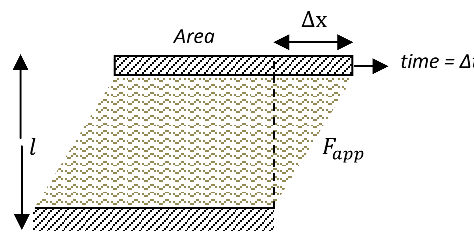
<u>Ex</u>:- Honey is more viscous than water



<u>**Co-eff of viscosity**</u>:- η

Stress ∝ Rate of change of strain

= η (Rate of change of strain)



$$\eta = \frac{\text{Stress}}{\text{Rate of Change of Strain}}$$

$$= \frac{F/A}{\left[\frac{\Delta x/l}{\text{time}}\right]}$$

$$= \frac{F/A}{\frac{\Delta \eta}{L} \times \frac{1}{\Delta t}}$$

$$= \frac{F/A}{v/L}$$

$$F = \eta .\ A. \frac{v}{l}$$

$$F = -\ \eta\ .A. \frac{dv}{dy}$$

<u>**Units**</u>:- S.I units = Pl

1 Pl $= 1\ Nm^{-2}$ sec

$= 10$ dyne cm^{-2} sec

<u>**Dimensions**</u> $\eta = \frac{F/A}{\Delta x/l} = \frac{\left[\frac{M^1\ L^1\ T^{-2}}{L^2}\right]}{\left[\frac{L\ T^{-1}}{L}\right]}$

$$= \left[\frac{M^1\ L^{-1}\ T^{-2}}{T^{-1}}\right]$$

$$= [M^1\ L^{-1}\ T^{-1}]$$

Q.2. Compare Solid friction and viscosity?

Ans. **Similarities**:

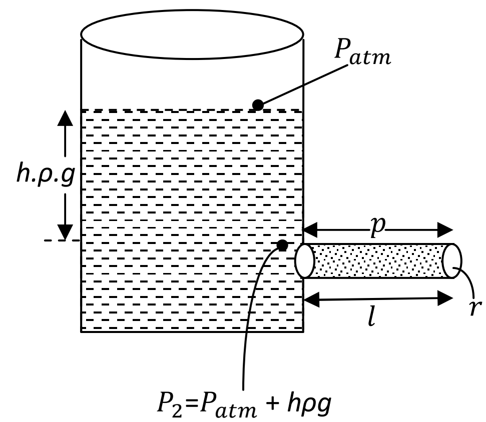
1. Both come into play whenever there is a relative motion.
2. Both oppose relative motion.
3. Both are due to molecular forces.
4. Both are tangentially in a direction opposite to that of motion (Parallel to surface).

Solid friction	**Viscosity**
F = μ.R	F = n.A- $\frac{dv}{dy}$
Different:-	
1) Does not depend on *A*	1)Depends on *A*
2) Does not depend on *dv*	2)Depends on *dv* i.e relative velocity.
3) Does not depends on distance between two layers *dy*	3)Depends upon distance between two layers *dy*
4) Depends on *R*	4)Does not depend on *R*

Q.3. a) Write POISEUILLE's Formula?
b) Derive POISEUILLE's Formula using dimensions?

Ans.a) $\frac{Volume}{Sec} = \frac{\pi.P.r^4}{8.\eta.l} = \frac{\pi(h.p.g).r^4}{8.\eta.l}$

- If r is large, water flowing per second is more
- If l is more, water flowing per second is less
- If P is more, volume per second is more



b) To prove:

$\frac{vol}{sec} = \frac{\pi.P.r^4}{8.\eta.l}$

$\frac{vol}{sec} \propto \left(\frac{p}{l}\right)^a (r)^b (\eta)^c$

$\left[\frac{L^3}{T}\right] \equiv \left[\frac{F}{A-l}\right]^a [r]^b [\eta]^c$

$[L^3\ T^{-1}] = \left[\frac{M^1\ L^1\ T^{-2}}{L^3}\right]^a [L]^b [M^1\ L^1\ T^{-1}]^c$

$[M^0\ L^3\ T^{-1}] = [M^1\ L^1\ T^{-2}]^a\ [L]^b [M^1\ L^{-1}\ t^{-1}]^c$

Comparing powers of M, L, T

$[M^0\ L^3\ T^{-1}] = M^{a+c}\ L^{-2a+b-c}\ T^{-2a-c}$

a+c = 0, -2a+b-c = 3, -2a-c = -1

a = -c, -2(-c)+b-c = 3, 2a+c = 1

a = -c, 2c+b-c = 3 -2c+c = 1

a = -c, 2c+b-c = 3 -c = 1

b+c = 3

b-1 = 3

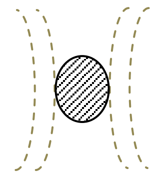
| a = 1 | | b = 4 | | c = -1 |

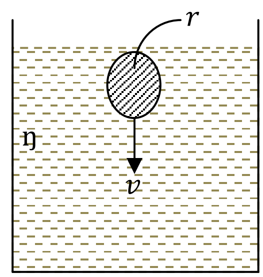
$\frac{Vol}{Sec} \propto \left(\frac{p}{l}\right)^1 (r)^4 (\eta)^{-1}$

$\frac{Vol}{Sec} \propto \left(\frac{p}{l}\right) (r)^4 \left(\frac{1}{\eta}\right)$

$\frac{Vol}{Sec} = (Const)\ \frac{pr^4}{l\ \eta}$ Here constant = $\frac{\pi}{8}$

Q.4. Derive Stoke's Law using dimension?





Ans. $F_{vis} \propto \eta^a \, r^b \, v^c$

$[M^1 \, L^1 \, T^{-2}] \equiv [M^1 \, L^{-1} \, T^{-1}]^a \, [L]^b [M^0 \, L^1 \, T^{-1}]^c$

$[M^1 \, L^1 \, T^{-2}] = M^{a+0.c} \, L^{-a+b+c} \, T^{-a-c}$

Comparing powers of M, L, T

$a = 1$	$-a+b+c = 1,$	$-a-c = -2$
	$-1+b+a = 1$	$a+c = 2$
	$b = 1$	$1+c = 2$
		$c = 1$

$F_{vis} \propto (\eta)^1 \, (r)^1 \, (v)^1$

$F_{vis} = (\text{const})\eta . r . v$

$F_{vis} = 6\pi . \eta . r . v$

Q.5. Derive an expression for terminal velocity of a body moving in a fluid?

Ans. Weight downward, mg

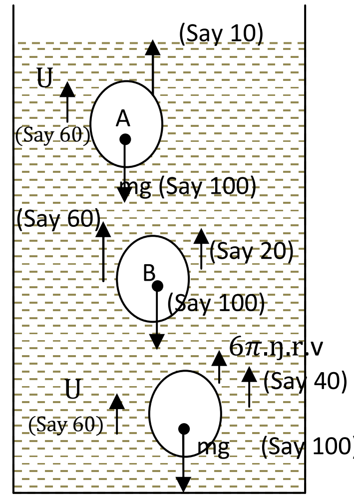
upward Up thrust, $V.\rho_{liq}.g$

upward viscous force. $6\pi.\eta.r.v$

As body moves downwards mg and U are constant.

As body moves downwards $6\pi.\eta.r.v$ keeps on increasing

At some stage, in equilibrium



$F_{net} = 0$

$mg = U + F_{vis}$

$mg = V.\rho_{liq}.g + 6\pi.\eta.r.V_T$

$$V_T = \frac{mg - V.\rho_{liq}.g}{6\pi.\eta.r}$$

$$V_T = \frac{V.\rho_{mat}.g - V.\rho_{liq}.g}{6\pi.\eta.r}$$

$$V_T = \frac{V}{6\pi.\eta.r}(\rho_{mat} - V.\rho_{liq}).g$$

$$V_T = \frac{4/3\,\pi\, r^3}{6\pi\,\eta\, r}(\rho_{mat} - \rho_{liq}).g$$

$$\boxed{V_T = \frac{2r^2}{9\eta}(\rho_{mat} - \rho_{liq}).g}$$

Q.6. **Explain**

i) **a)** **Stream line flow**

b) **Streamline**

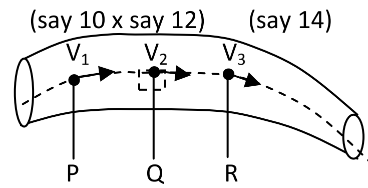
c) **Laminar flow**

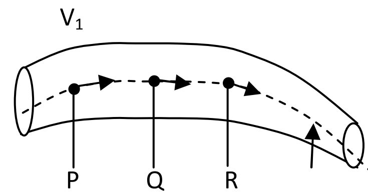
d) **Turbulent flow**

ii) **Reynold no. and its significance**

Ans.i) Streamline flow:-

Streamline flow is flow in which every particle of the liquid follows exactly the path of its proceeding particle and has the same velocity as that of its proceeding particle while crossing through that point.



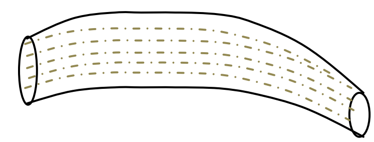


Streamline:-

Streamline is the actual path followed by procession of particle in a steady flow. Streamline may be straight or curved.

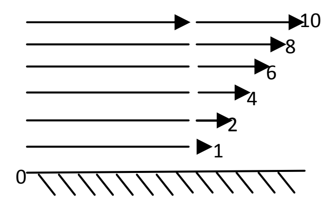
Properties of Streamline

1. No two streamlines can cross each other
2. More crowding of streamlines means high speed.



Laminar flow:-

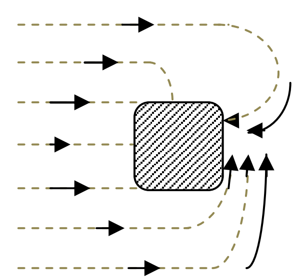
Thus a flow in which liquid moves in layers, is called Laminar flow.



Turbulent flow:-

Turbulent flow is flow in which motion of particles becomes irregular.

Turbulent flow will take place when the velocity of the liquid is more than critical velocity



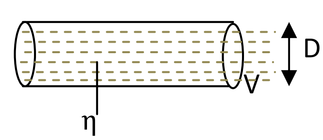
ii) Reynold no:- N_R

$N_R = \frac{\rho . D . v}{\eta}$

ρ -> Density, D -> Diameter, v -> velocity

η -> coeff of viscosity

$N_R = \frac{\rho . D . v}{\eta}$



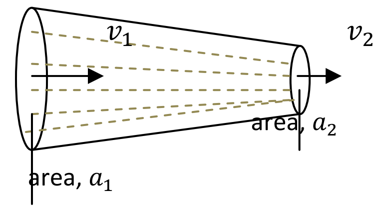
Case I:- $N_R < 2000$ Streamline flow

Case II:- $N_R > 2000$ Turbulent flow

Case III:- $2000 < N_R < 3000$, flow is unstable changing from Streamline to Turbulent flow.

Q.7. Derive Equation of Continuity?

Ans. Under Steady State Conditions



(Mass Entering Per sec)$_1$ = (Mass Leaving Per sec)$_2$

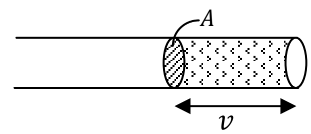
$$\left(\frac{mass}{time}\right)_1 = \left(\frac{mass}{time}\right)_2$$

$$\left(\frac{\rho.vol.}{t}\right)_1 = \left(\frac{\rho.vol.}{t}\right)_2$$

$$\rho_1.\left(\frac{vol}{t}\right)_1 = \rho_2.\left(\frac{vol}{t}\right)_2$$

$$\left(\frac{vol}{t}\right)_1 = \left(\frac{vol}{t}\right)_2 \qquad \{If\ \rho_1 = \rho_2\ same\ liquid\}$$

$$\boxed{\frac{Vol}{Sec} = a_1.v_1 = a_2.v_2}$$

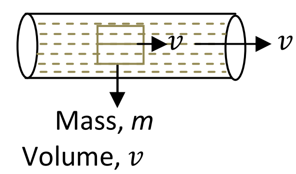


$$\boxed{\frac{Vol}{Sec} = A\ .\ v}$$

Q.8. Explain the following for a liquid
a) Kinetic Energy
b) Potential Energy
c) Pressure Energy

Ans.a) **<u>Kinetic Energy</u>**:-

Kinetic Energy is the energy possessed by a liquid by virtue of its motion or velocity.



K.E = 1/2 m v^2

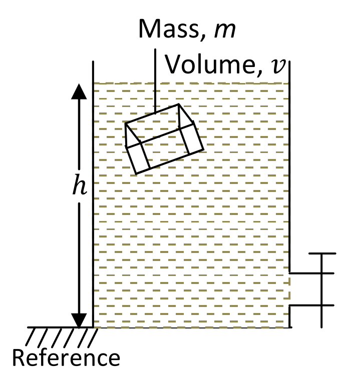
Dividing both sides by volume V

$$\frac{k.E}{vol} = \frac{1}{2}\left(\frac{m}{V}\right).v^2$$

K.E per Unit Volume = $\frac{1}{2}\ .\ \rho.\ v^2$

b) **<u>Potentional Energy</u>**:-

It is the energy possessed by liquid by virtue of its position or height



P.E = m.g.h

Dividing both sides by V

$$\frac{p.\varepsilon}{volume} = \left(\frac{m}{V}\right).g.h$$

$$\boxed{\text{P.E. per Unit Volume} = \rho.g.h}$$

c) **Pressure Energy**:-

Work done by applied force

$= F_{app}.x$

$= (F_{liq}).x$

$= (P.A).x$

Work done gets stored in form of 'Pressure Energy'

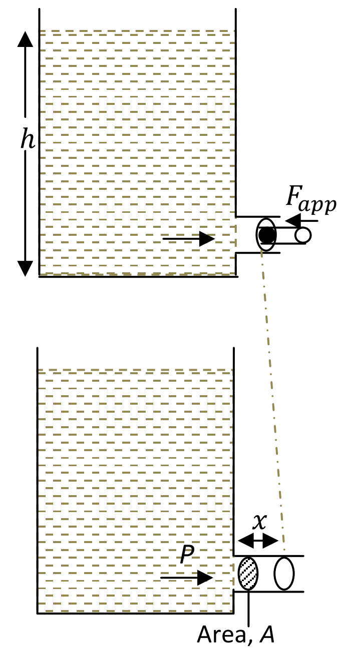
Pressure Energy = Work done

$= P.A.\,x$

Dividing both sides by volume ($A.\,x$)

$$\frac{Pressure\ Energy}{Volume} = \frac{P.A.x}{A.x}$$

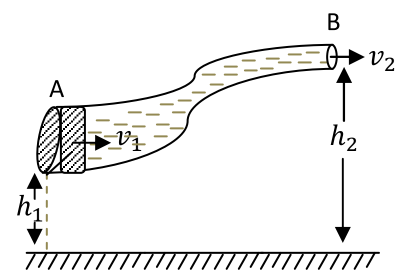
$$\boxed{\frac{Pressure\ Energy}{Volume} = P}$$



Q.9. State, Explain and Prove 'Bernouli's Theorem'?

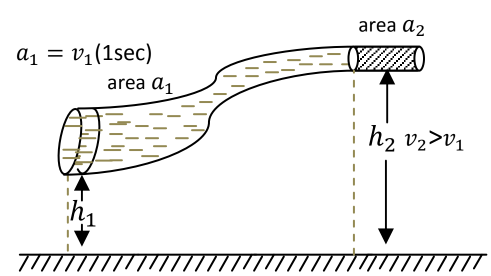
Ans. **Statement**:-

This theorem states that for the streamline flow of an ideal liquid, the total energy (the sum of *Pressure Energy*, *Potentional Energy* and *Kinetic Energy*) per unit mass remains constant at every cross section throughout the flow



Proof:-

Work done per sec =
(by Pressure Energy)
(*Increase in K.E. per sec*) + (*Increase in P.E. per sec*)



$$\frac{P_1\,V_1 - P_2\,V_2}{1\ sec} = \frac{1/2\,m_2\,v_2^2 - 1/2\,m_1\,v_1^2}{1\ sec} + \frac{m_2.g.h_2 - m_1.g.h_1}{1\ sec}$$

1. $P_1V_1 + \frac{1}{2}m_1v_1^2 + m_1.g.h_1 = P_2V_2 + \frac{1}{2}m_2v_2^2 + m_2.g.h_2$

   Total Energy at 1 = Total Energy at 2

2. Dividing both sides by "*Volume*"

$$\frac{P_1V_1}{V_1} + \frac{\frac{1}{2}m_1v_1^2}{V_1} + \frac{m_1.g.h_1}{V_1} = \frac{p_2\,V_2}{V_2} + \frac{\frac{1}{2}m_2\,v_2^2}{V_2} + \frac{m_2.g.h_2}{V_2}$$

$V_1 = V_2$ as $a_1\,V_1 = a_2\,V_2$

Volume flowing per sec remains same

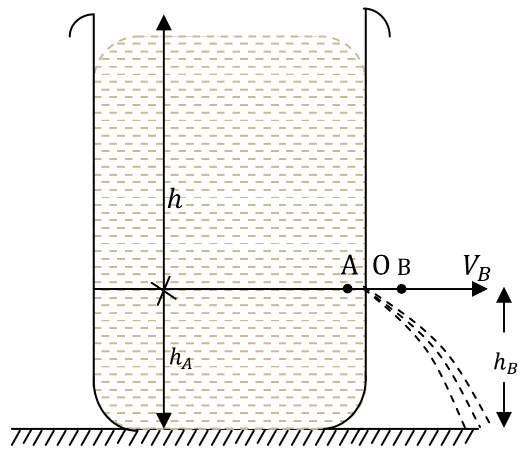
$$\boxed{\mathbf{P_1 + \frac{1}{2}\rho_1.v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho.v_2^2 + \rho.g.h_2}}$$

Q.10. State and Prove Toncelli's Theorem?

Ans. **Statement**:-

According to this theorem, velocity of efflux i.e. the velocity with which the liquid flows out of an orifice is equal to that freely falling body would acquire in falling through a vertical distance equal to the depth of orifice below the free surface of liquid.

1. *A* and *B* are at same level, so grave *P.E.* is same
2. As per Bernoulli's Theorem



$$T.E_A/Vol = T.E_B/Vol$$

$$\frac{P_A}{\rho} + \frac{1}{2} V_A^2 + g.h_A = \frac{P_B}{\rho} + \frac{1}{2}.V_B^2 + g.h_B$$

Velocity inside container $\simeq 0$

$$\frac{P_A - P_B}{\rho} = \frac{1}{2} V_B^2$$

$$\frac{1atm + h.\rho.g - 1atm}{\rho} = \frac{1}{2} V_B^2$$

$$\frac{h.\rho.g}{\rho} = \frac{1}{2} V_B^2$$

$$\boxed{V_B = \sqrt{2gh}}$$

Q.11. What is Venturi meter?
Explain construction and working of a Venturi meter?

Ans. **<u>Venturi meter</u>**:-

It is a device used for measuring the speed of incompressible liquid and rate of flow of liquid through pipes. It's working based on Bernoulli's theorem.

<u>Construction</u>:-

It consists of two identical tubes *A* and *C* connected by a narrow coaxial tube B.A monometer in the form of *V* tube is attached to it, with one arm at the wider neck point at the tube A and the other arm at the narrow middle point of tube *B*

<u>Working</u>:-

This Venturi meter is horizontally connected to the pipe through which the liquid is flowing with steady flow. Note down the difference of liquid column in two arms of U tube, Let it be *h*

Let ρ= density of liquid flowing through pipe

. ρ_m = density of liquid in U tube

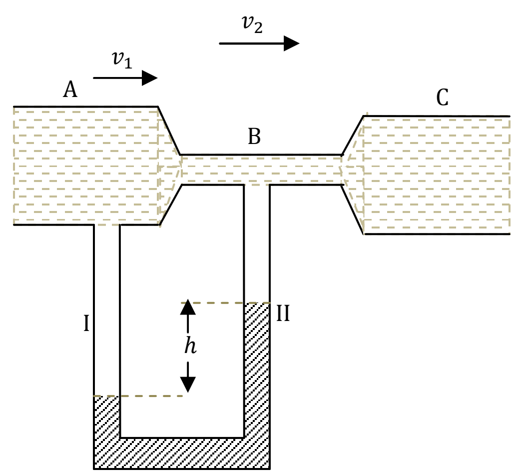
a_1, a_2 = area of cross – section of tubes *A* and *B*

v_1, v_2 = Velocity of liquid flow through tube *A* and *B*

$P_1 P_2$ = Pressure at *A* and *B*

$V = a_1 v_1 = a_2 . v_2$. (V→ Volume flowing/sec)

$\therefore \frac{a_1}{a_2} = \frac{v_2}{v_1}$ and $v_1 = \frac{V}{a_1}$, $v_2 = \frac{V}{a_2}$



<u>Using Bernoulli's Theorem</u>

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$= \frac{1}{2}\rho . v_1^2\left[\frac{v_2^2}{v_1^2} - 1\right]$$

$$= \frac{1}{2}\rho . v_1^2\left[\frac{a_1^2}{a_2^2} - 1\right] \quad \text{—— (1)}$$

$$P_1 - P_2 = h . \rho_m . g \quad \text{—— (2)}$$

From (1) & (2)

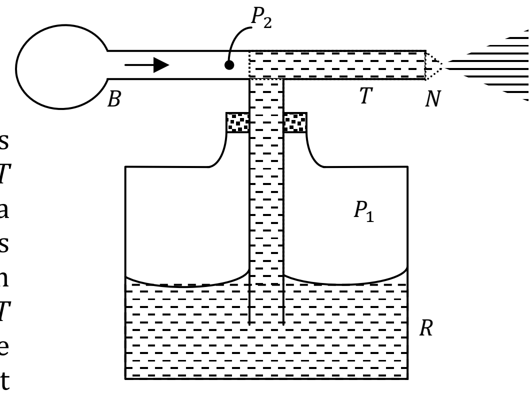
$$h . \rho_m . g = \frac{1}{2} . \rho . v_1^2\left(\frac{a_1^2}{a_2^2} - 1\right)$$

$$V = a_1 . \sqrt{\frac{2h.\rho_m.g}{\rho}} . \left(\frac{a_1^2}{a_2^2} - 1\right)^{-1/2}$$

$$= a_1 a_2 . \sqrt{\frac{2h.\rho_m.g}{\rho.(a_1^2 - a_2^2)}}$$

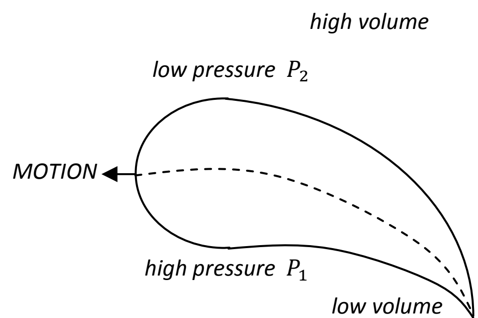
Q.12. Discuss any four applications or examples of Bernoulli's Theorem?

Ans.(1) **Atomiser or Sprayer**:-



The common form of Atomiser when its rubber bulb *B* is squeezed, the air blows in the tube *T* with high speed. According to Bernoulli's Theorem, a low pressure P_2 is created inside which is much less than atmospheric pressure P_1 on the liquid surface in vessel *R*. Due to it, the liquid rises up in the tube *T* and is pushed out with air through nozzle *N* in the form of a spray. This principle is used in a paint sprayer, oil scent and nazal sprayer.

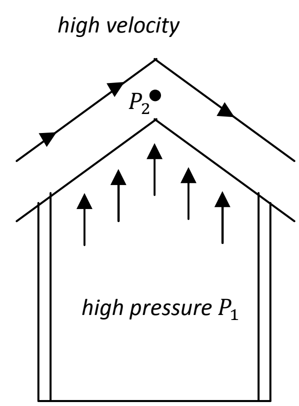
(2) **Lift on an aero plane wing**:-



The shape of the aero plane wing is peculiar. Its upper surface is more curved than its lower surface and its leading edge is more thick than its trailing edge. As the aero plane moves forward, the air blown in the form of stream lines over the wings of aero plane.

$$F_{upward} = (\Delta P)\ (\text{Area}) = (P_1 - P_2)\ (\text{Area})$$

(3) **Blowing off the roots during storm**:-



During storms or cyclones, the roofs of the huts are generally blown off without causing any damage to the house. This is because during the storms the wind blows with very high speed over the top side of the roof. Due to it the pressure p_2 of air over the roof become low. Below the roof i.e. inside the room, wind is not blowing. So, pressure P_1 is high. $(P_1 - P_2)$ pushes the roof upward.

(4) **Motion of two parallel boats**:-

If two boats, small distance apart are rowing parallel to each other in the same direction the velocity of water between the two boats becomes very large as compared to the velocity of water on other sides of the boats. Due to this the pressure is reduced in between the boats according to Bernoulli's Theorem. Two boats may hit each other.