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Where Minds Pollinate

Class 11
Physics

Chapter 6

Handwritten Notes

Chapter # 06

Fluid Mechanism

Fluid :- A fluid is a substance that has the capacity to flow. It has no permanent shape of containning vessels. It consists of atoms and molecules in random motion.

Viscosity Viscosity is the resistance to flow of fluid cause of viscosity are intermolecular forces.

Co- efficient of viscosity :- The numeric value of resistance to flow of fluid is called co-efficient of viscosity. SI unit of viscosity is Pascal second (Pa.S).

Most common unit is dyne second per square centimeter called **poise**

$$1 \text{ poise} = \text{dyne} \cdot s / cm^2$$

Viscosity of Methanol = 0.001 Pas

Effect of Temperature :-

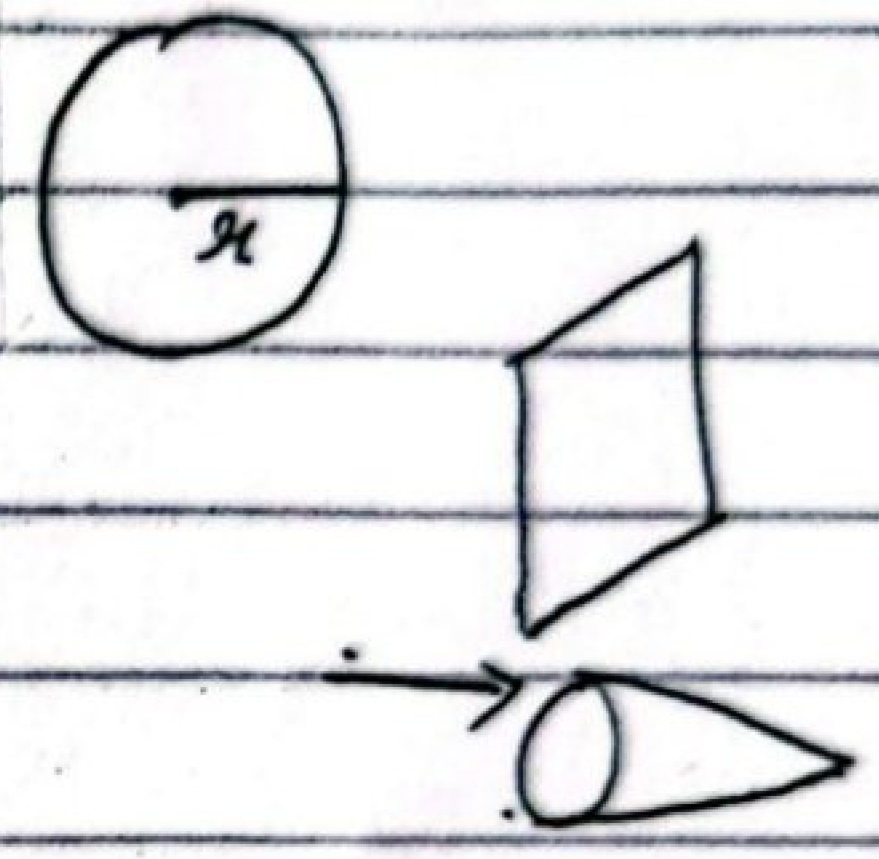
- Increase in temperature of liquid will decrease its velocity
- Increase in temperature of gas will increase its velocity.

Fluid Friction:- A friction that occurs when a solid object moves through a fluid is called fluid friction.

Strokes Law:- The viscous force acting on a spherical body moving through a fluid is directly propotional to co-efficient of viscosity "η", radius "r" and velocity "v"

Drag force:- When an object moves through a fluid, the retarding force experienced by the object moving through it is called drag force. It depends upon size, velocity viscosity and acceleration

$$F_D \propto \eta$$
$$F_D \propto v$$
$$F_D \propto r$$
$$F_D \propto \eta r v$$
$$F_D = A\eta r v$$
$$F_D = 6\pi\eta r v$$



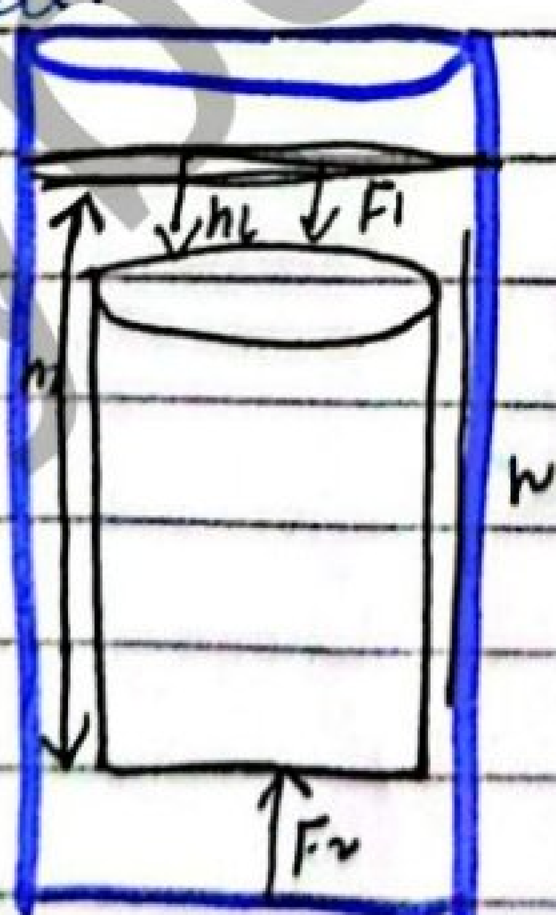
$\therefore A = 6\pi$

Upthrust / Boyant Force:- When an object is partially or wholly embeded / submerged in a fluid (liquid or gas) an upward force acts on the object is called upthrust or boyant force. and this phenomenon is called upthrust or boyancy.

Archimedius Principle

Definition:- When an object is completely or partially immeresed / submerged in a fluid, an upthrust or boyant force acts on the submerged object which is equal in magnitude to the weight of fluid displaced by object. This statement is called "Archimedius principle"

Explanation:- Consider a cylindrical object of Area "A" and height "h" submerged in fluid of density "ρ". Now, we want to calculate the upthrust acting on cylindrical object.



Mathematically:-

Force acting at upper end $= F_1$

$$F_1 = P_1 A$$

$$F_1 = \rho g h_1 A$$

Force acting on upper end $= F_2$

$$F_{net} = F_2 - F_1$$
$$= \rho g h_2 A - \rho g h_1 A$$
$$= \rho g A (h_2 - h_1)$$
$$= \rho g A h$$
$$F_{net} = \rho g V \rightarrow \text{equation } ①$$

This net force is called boyant force or upthrust acting on immersed object
Therefore,

$$F_{net} = F_B = F_{UT}$$
$$F_B = \rho g V$$
$$= g(\rho V) = mg$$

$F_B = mg =$ weight of fluid displaced by object.

Principle of floatation An object will float in any fluid only when weight of object is lesser than or equal to upthrust acting on it.

→ When density of object is equal to the density of fluid, it floats while keeping itself completely inside fluid

→ When density of object is lesser than that of fluid, it floats on the surface of fluid

→ When density of object is greater than fluid it sinks.

Floatation of Ships:- Ships are made up of metals that are denser than water. The design of ships is made such that the apparent density of ships is kept smaller than that of water by making empty spaces inside the ship. To float total weight (weight of body and load on ship) of ship must less than equal to boyant force acting on it.

Floatation of Submarines:- Submarines are made up metals that are denser than water. To make them float on water, they are constructed such that their density is kept smaller than water. This is achived by making empty spaces inside the submarines called water tanks. To float an surface of water, water tanks are kept empty and to float inside the water, water tanks are filled with water

Fluid Flow:-

When particles of fluid start motion, we say that it is a fluid flow

Types:- There are two types of fluid flow:-

i)- Stream line flow
ii)- Laminar flow

Laminar Flow:- A type of fluid flow in which velocity of particles of fluid remains un-changed at each point inside fluid and each particle of fluid follows the path followed by its prodessor.

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Turbulant Flow:- An irregular and random flow of fluid is called Turbulant Flow.

Ideal Flow:- A flow is said to be Ideal if it has following properties:-

1- It is non-viscous
2- It is incompelde
3- It is irrational
4- It has laminar flow

Flow rate:- Volume of a fluid passing through the cross-sectional of a pipe in unit time is called volume flow rate. It is the product of cross-sectional area of pipe and velocity of fluid passing through that area.

Formula:-

$$\text{Flow rate} = \text{Area of pipe} \times \text{velocity}$$
$$= A \times V$$

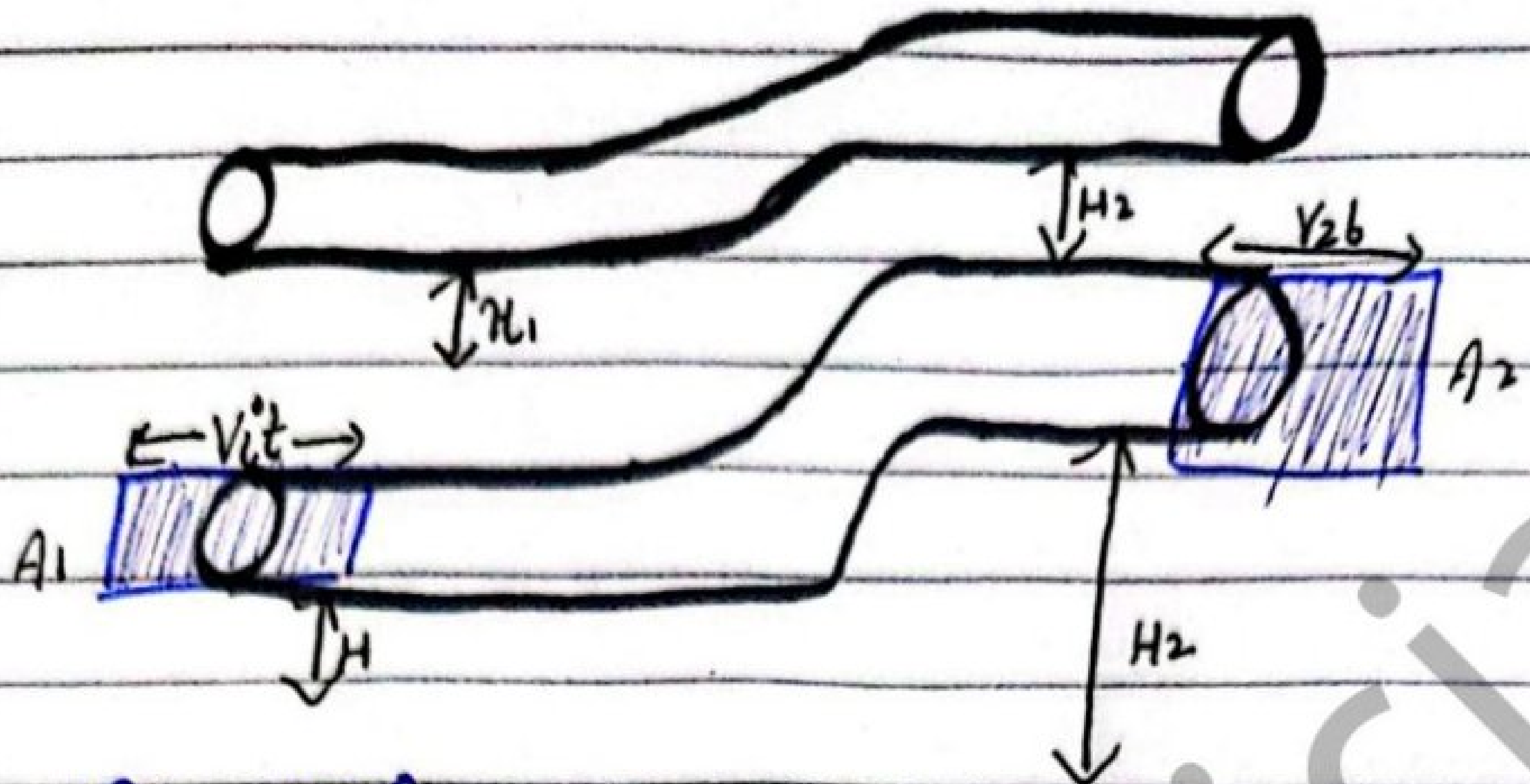
Unit:- $\text{Flow rate} = A \times V$

$$= m^2 \times \frac{m}{s} = \frac{ms}{s} = m^3 s^{-2}$$

Equation of continuity

Volume flow rate passing through the cross-section of pipe remains constant. Amount of fluid passing through the cross-sectional of a liquid remains constant. The product of area of pipe & velocity of fluid passing through that point remains constant.

Equation of continuity works on the principle of conservation of mass.



Calculations:- Amount of fluid mass that enters in

time "t" = m_1

$m_1 = \rho \times V$

$m_1 = \rho A_1 \times V_1 t$

Amount of fluid that left pipe in time "t" = m_2

$m_2 = \rho \times V$

$m_2 = \rho A_2 V_2 t$

According, to law of conservation of mass, mass of liquid entered into the pipe must be equal to mass of fluid that left the pipe in same interval.

Therefore, $m_1 = m_2$

$\cancel{\rho} A_1 V_1 \cancel{t} = \cancel{\rho} A_2 V_2 \cancel{t}$

$A_1 V_1 = A_2 V_2$

$AV = \text{constant}$

$V = \frac{\text{constant}}{A}$

$V = \frac{1}{A}$

Velocity of fluid is inversely propotional to cross sectional area of pipe & flow rate of fluid always remains constant

This is equation of continuity.

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Bernoulli's equation:-

It states that:

"It states that sum of pressure, Kinetic energy per unit volume and potential energy per unit volume of an ideal fluid flowing in steady state remains constant at each point along a stream line path in a pipe

Derivation

Total work done on fluid will be:-

$W = \Delta K.E + \Delta P.E \rightarrow$ equation (A)

$W = W_1 + W_2 \rightarrow$ equation (B)

Work done on lower end of pipe

$W_1 = F_1 \times \cos\theta \, \Delta x_1$

$= F_1 \, \Delta x_1 \cos(0)$

$= F_1 \Delta x_1$

$W_1 = P_1 A_1 \Delta x_1 \rightarrow$ equation ①

Similarly, work done on upper end of pipe

$W_2 = F_2 \times \cos\theta \, \Delta x_2$

$= F_2 \, \Delta x_2 \cos(180)$

$= - F_2 \Delta x_2$

$W_2 = -P_2 A_2 \Delta x_2 \rightarrow$ eq②

Similarly, work done on upper end of pipe

Put equation (I) and (II) in (B), we get

$W = P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2$

$W =$

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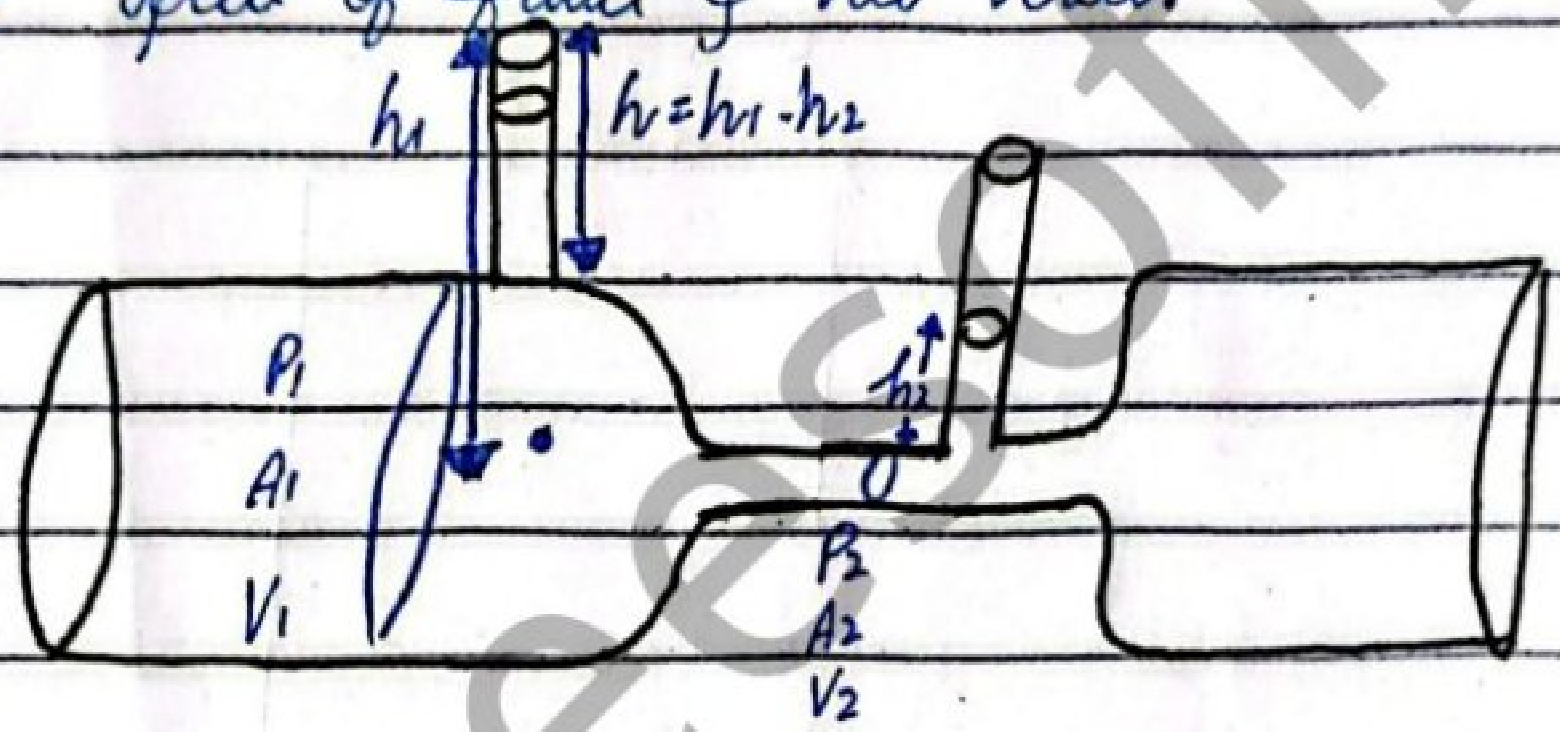
Ventrimeter

Definition:- An instrument which is used to measure the speed of a fluid passing through cross-section of a pipe or the rate of volume flow of a liquid passing through cross-sectional area of a pipe is called **venturimeter**.

Working:- It is based on Bernoulli's equation which states that low pressure of fluid causes high speed of fluid & vice versa.



Mathematically:-

According to the Bernoulli's equation

$$P_1 + \rho g h_1 + \frac{1}{2}\rho V_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho V_2^2$$

But:-

$$h_1 = h_2 = h$$

Therefore:

$$P_1 + \cancel{\rho g h} + \frac{1}{2}\rho V_1^2 = P_2 + \cancel{\rho g h} + \frac{1}{2}\rho V_2^2$$

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho V_1^2 - \frac{1}{2}\rho V_2^2$$

$$\rho g h_1 - \rho g h_2 = \rho/2\,(V_2^2 - V_1^2)$$

$$\rho g(h_1 - h_2) = \rho/2 (V_2^2 - V_1^2)$$

$$g(h_1 - h_2) = 1/2 (V_2^2 - V_1^2)$$

$$2g(h_1 - h_2) = V_2^2 - V_1^2 \rightarrow \text{equation } ①$$

According to equation of continuity

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{A_1 V_1}{A_2}$$

Putting in equation ①

$$2g(h_2 - h_1) = V_2^2 - V_1^2$$

$$2g(h_1 - h_2) = \left(\frac{A_1 V_1}{A_2}\right)^2 - V_1^2$$

$$2g(h_1 - h_2) = V_1^2 + \left(\frac{A_1 - A_2^2}{A_2^2}\right)$$

$$2gh = V_1^2 \left(\frac{A_1^2}{A_2^2} - 1\right)$$

$$2gh = V_1^2 \left(\frac{A_1^2 - A_2^2}{A_2^2}\right)$$

$$2ghA_2^2 = V_1^2 (A_1^2 - A_2^2)$$

$$V_1^2 = \frac{2ghA_2^2}{A_1^2 - A_2^2}$$

Taking $\sqrt{\ }$ on both sides

$$V_1 = \sqrt{\frac{2ghA_2^2}{A_1^2 - A_2^2}}$$

$$V_1 = A_2 \sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

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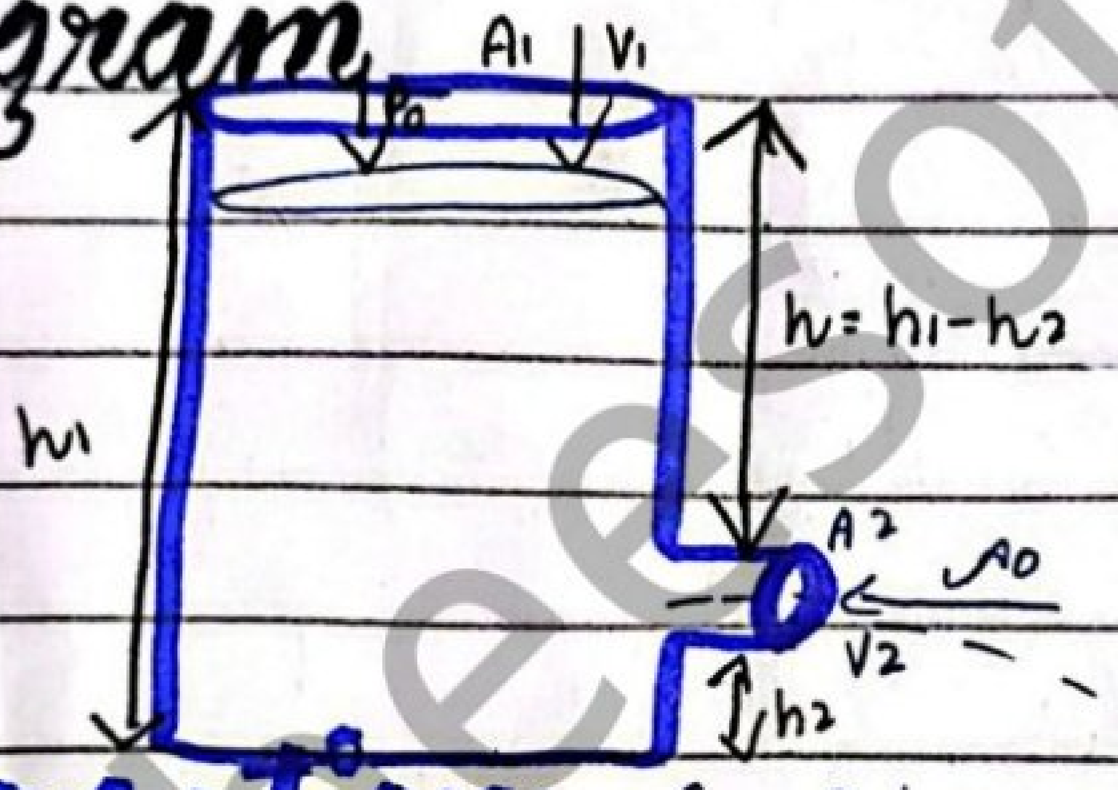
Torcelli's theorem

The speed of flow of fluid through an orifice situated at a depth "h" from surface of fluid is equal to the speed gained by free fall through height "h".

Working Principle

It is an application of Bernoulli's equation.

Diagram



Explanation:

Consider a beaker filled with ideal fluid. Top area of breaker is A_1 and pressure acting at fluid "P_0". An orifice is present at height h from liquid surface. Speed of fluid coming out of orifice is V_2. The area of orifice is really small as compared to Beaker.

Mathematically:

According to Ber-noullis theorem

$$P_1 + \rho g h_1 + \frac{1}{2}\rho V_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho V_2^2$$

$$P_0 + \rho g h + \frac{1}{2}\rho V_1^2 = P_0 + \rho g h_2 + \frac{1}{2}\rho V_2^2$$

$$\rho g h_1 + \frac{1}{2}\rho V_2^2 = \rho g h_2 + \frac{1}{2}\rho V_2^2$$

$$\rho g h_2 + \frac{1}{2}\rho V_2^2 = \rho g h_1 + \frac{1}{2}\rho V_2^2$$

$$\frac{\rho V_2^2}{2} - \frac{\rho V_1^2}{2} = \rho g h_1 - \rho g h_2$$

$$\frac{\rho}{2}(V_2^2 - V_1^2) = \rho g (h_1 - h_2)$$

According to equation of continuity

$$A_1 V_1 = A_2 V_2$$

$$V_1 = \frac{A_2 V_2}{A_1}$$

$$V_1 = \left(\frac{A_2}{A_1}\right) V_2$$

According to equation of continuity

$$A_1 V_1 = A_2 V_2$$

$$V_1 = \frac{A_2 V_2}{A_1}$$

$$V_1 = \left(\frac{A_2}{A_1}\right) V_2.$$

As

$$A_2 <<< A_1$$

$$\frac{A_2}{A_1} <<< 1 \approx 0$$

Therefore. $V_1 \approx 0$

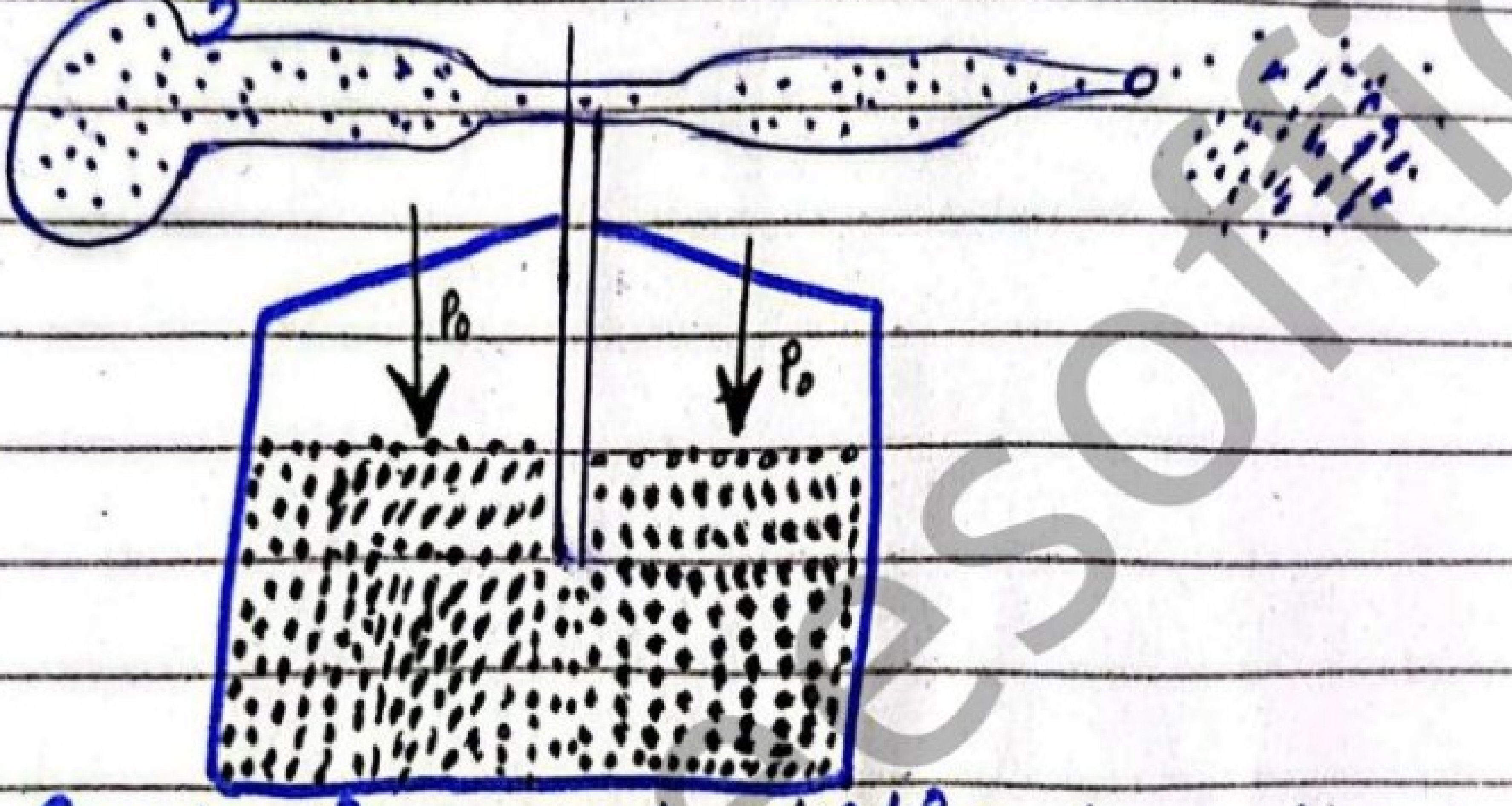
Putting in

Atomizer

An atomizer is an instrument which gives fine spray of water, perfume & other liquids.

Working principle:- Atomizer works on Bernaulli's principle

Diagrams-

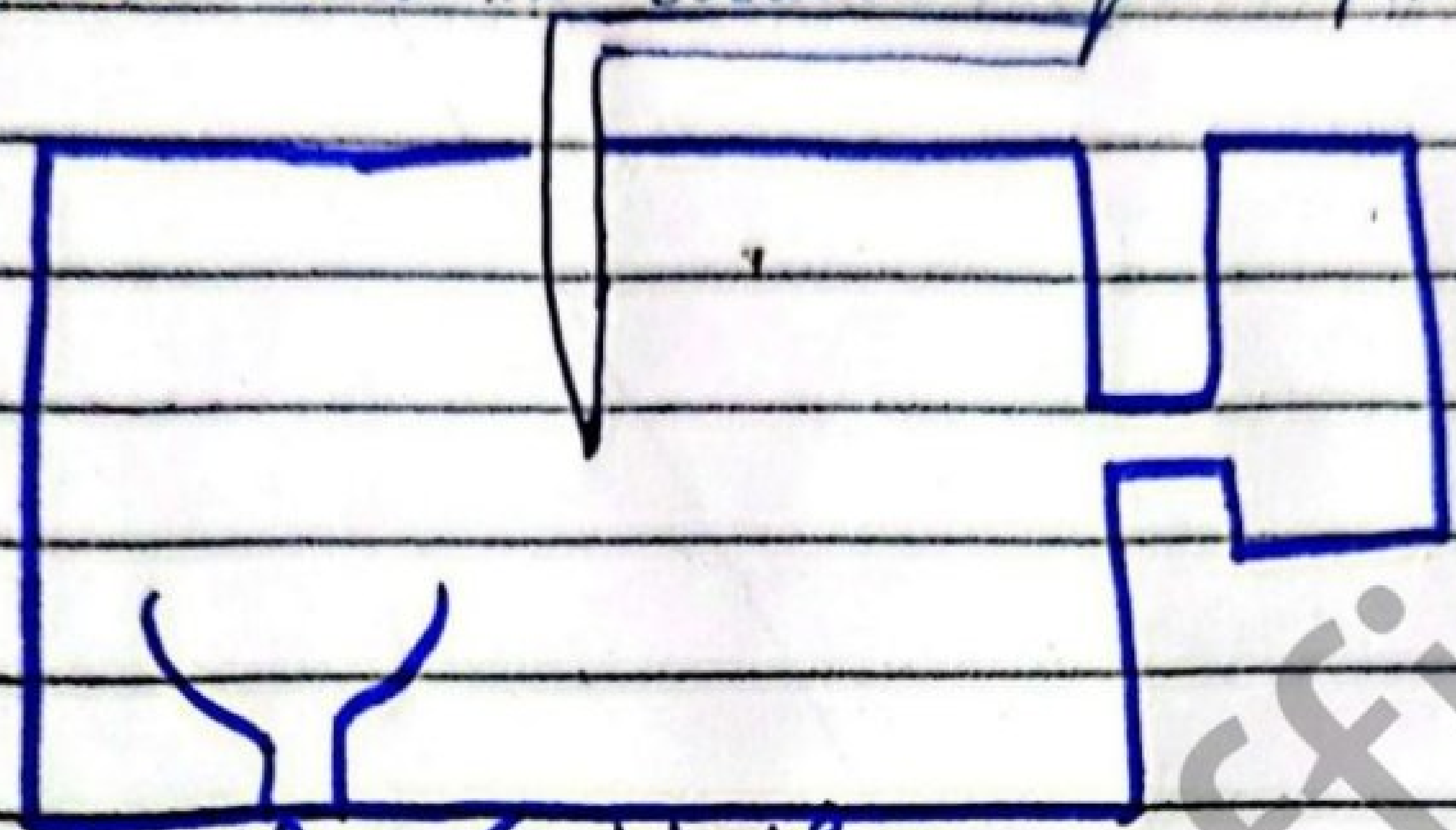


Construction and Working It consits of a Tank filled with liquid, a vertical tube horizontal tube containning bulb, jet and nozzle, when bulb is squeezed, it pushes the air at a very speed and high speed air passes through the jet reducing the pressure at jet. Hence, liquid flows from high pressure to low pressure inside vertical tube and come out of nozzle mixed with air

Filter pumps

Definitions- Filter pump is a device which is used to remove impurities such as dust particles from the water.

Working Principle:- Working of filter pump is based on the Bernaulli's equation/ Principle



Construction & Workings:- When water passes through the nozzle its speed increases causing the pressure of water and surrounding air to decrease
Hence, air from right moves towards left with high speed and mixes with the water. This combination comes out of pump from exit at bottom.

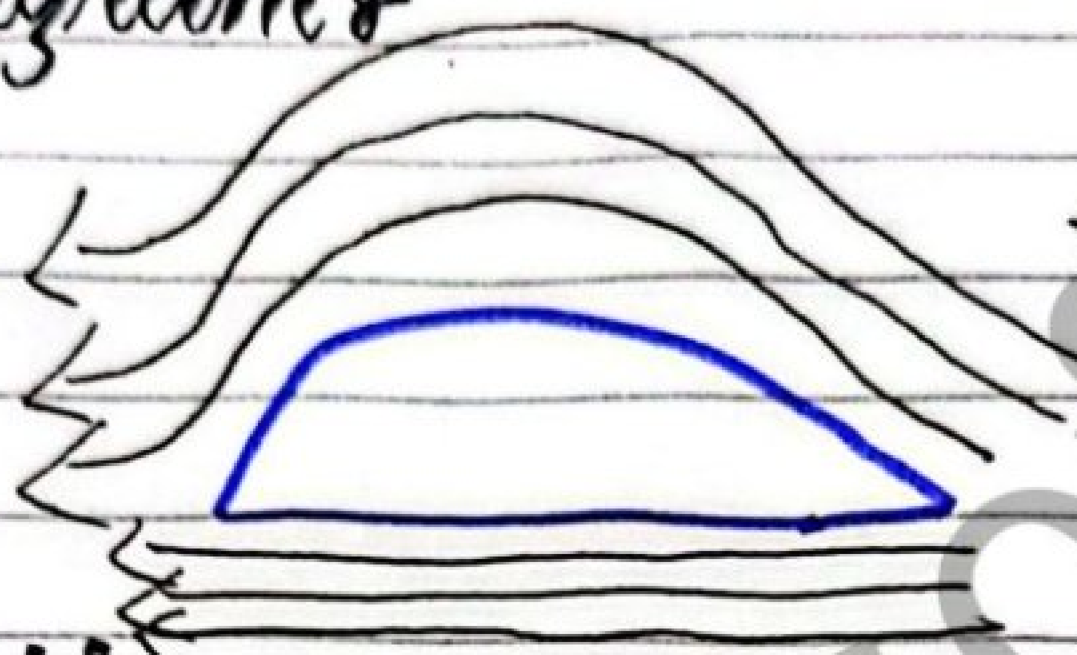
Aerofoil:

A device which is designed such as it experiences force (lift) perpendicular to its motion while passing through fluid is called Aero-foil.

Principle:

It works on Bernoulli's principle.

Diagram:



Working: At upper region of aerofoil, speed of fluid is greater, creating low pressure region. Thus, a force is created due to this pressure difference on aerofoil in direction perpendicular to motion of aerofoil or fluid. This force is called lift which helps air-plane to take off

Magnus effect

Definition:- The phenomenon in which a spherical rotating object deflects from its straight line path while passing through the fluid is called **magnus effect**.

Principle: Magnus effect is caused because of Bernaulli's theorem

12 November, 2025 Wednes

Super Fluidity

Super fluidity is State of liquid in which viscosity of liquids become zero There is no friction between different layers of liquid. There is no less in kinetic energy of liquids because of fluid friction.

Cause: The cause of super-fluidity is the quantum mechanical phenomenon which comes into existance at very low temperature when motion of indiuiual particles of liquid almost vanishes

Example:- Helium-3 and Helium-4 are examples of super fluids. Helium-4 becomes super-fluids at 2.17K and Helium-3 becomes Superfluid at 0.0026K

Uses: Super fluids are used:
→ In gyroscope to make precise measurment of direction.
→ Trap light and to decrease speed of light.

Question #02) Short question

(i) A ping pong ball can be suspended in a stream of air blow vertically upward. This is application of Bernaulli's principle. when ping pong ball is placed in stream of air moving upward, speed of air at the bottom of ball decreases creating high pressure region and speed of air at top of ball increases

Numerical

Numerical 01:

① Given Data:

$V = 2.98 \times 10^{-3} m/s$

$r = ?$

$\eta = 1.9 \times 10^{-5} kgm^{-1}s^{-1}$

$\rho = 1000 kgm^{-3}$

Formula: $V_t = \frac{2\rho g r^2}{9\eta}$

$$r^2 = \frac{9\eta V_t}{2\rho g}$$

$$r = \sqrt{\frac{9\eta V_t}{2\rho g}} = m$$

$$r = \sqrt{\frac{9(1.9 \times 10^{-5})(2.98 \times 10^{-3} m/s)}{2(1000)(9.8)}}$$

$$r = 5.1 \times 10^{-6} m$$

Numerical 02:

② Given Data

$V_1 = 2ms^{-1}$

$D_1 = 1.6 \; cm = 0.0016m$

$V_2 = 15ms^{-1}$

To find: $\frac{V}{t} = ?$

$D_2 = ?$

Solutions:-

$$\frac{V}{t} = A_1 V_1$$

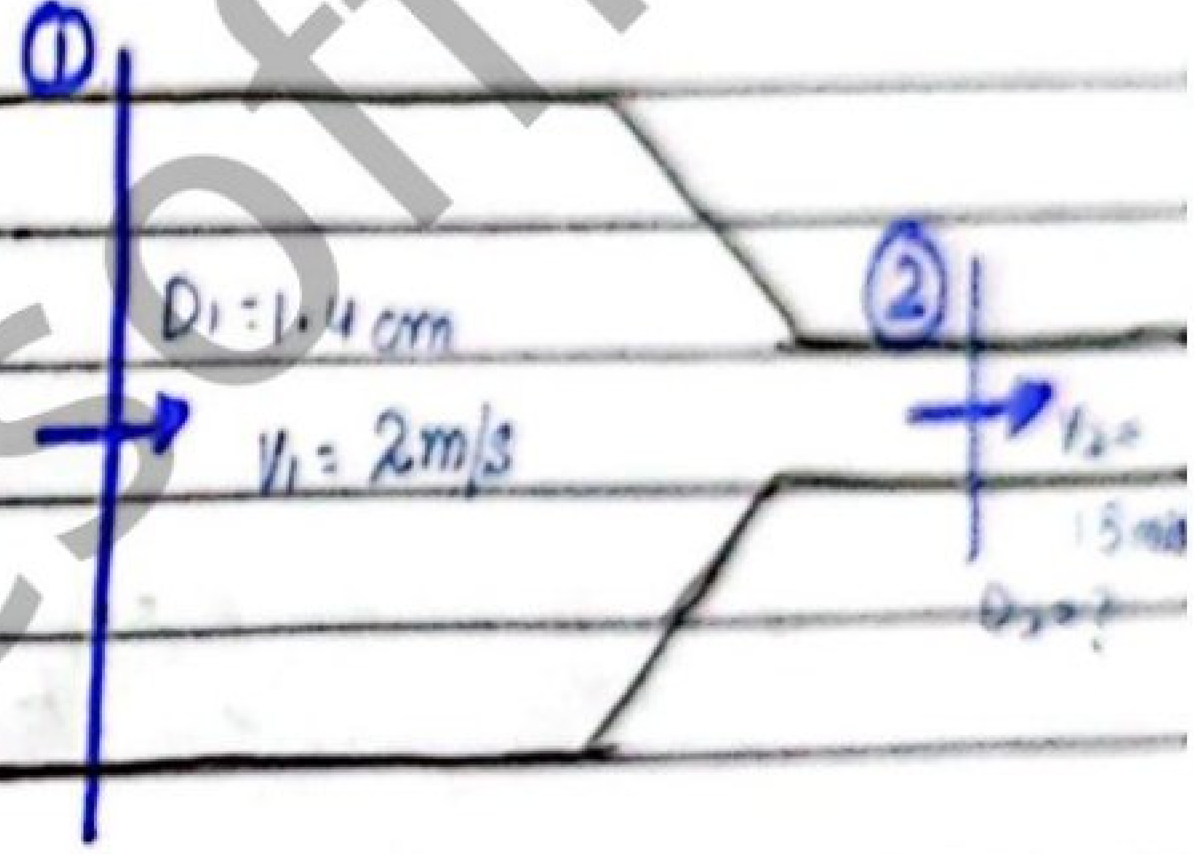
$$= \pi r_1^2 V_1$$

$$\text{Flow rate} = \frac{\pi D_1^2 V_1}{4} = \frac{3.14 \times (0.016)^2 \times 2}{4}$$

$$= 4.02 \times 10^{-4}\ m^3 s^{-1}$$

Putting $1m^3 = 1000$ litre

$$\text{Flow rate} = 4.02 \times 10^{-4} (1000\ \text{litre/s}) = 0.402\ \text{litre/s}$$



By equation of continuity:-

$$A_1 V_1 = A_2 V_2$$

$$\pi r_1^2 V_1 = \pi r_2^2 V_2$$

$$\left(\frac{D_1}{2}\right)^2 V_1 = \left(\frac{D_2}{2}\right)^2 V_2$$

$$D_1^2 V_1 = D_2^2 V_2$$

$$(0.016)^2 \times 2 = D_2^2 (15)$$

$$D_2^2 = (0.016)^2 \times 2$$

Taking square root on both sides:-

$$D_2 = \sqrt{\frac{(0.016)^2 \times 2}{(15)^2}}$$

$$D_2 = 5.84 \times 10^{-3} m$$

$$D_2 = 5.84 \times 10^{-3} (100cm) = 0.584\ cm$$

Numerical 08:

Given Data:

$$\text{Flow rate} = \frac{V}{t} = 5 l\ min^{-1} = \frac{5 \times 0.001 m^3}{60s} =$$

$$= 8.3 \times 10^{-5}\ m^3 s^{-1}$$

Numerical 6.5

Initial Condition:-

Initial condition/speed at ground level: 5.4 m/s

Initial height: 0 m

Final Condition:-

Final height of water: 1.3 m

Final speed of water: $V_2 = ?$

Solution:

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

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2.$$

$$\frac{1}{2}v_1^2 + g h_1 = \frac{1}{2}v_2^2 + g h_2$$

Substitute values:-

$$\frac{1}{2}(5.4)^2 + 0 = \frac{1}{2}V_2^2 + 9.8(1.3)$$

$$\frac{1}{2}(29.16) = \frac{1}{2}V_2^2 + 12.74$$

$$14.58 = \frac{1}{2}V_2^2 + 12.74$$

$$1.84 = \frac{1}{2}V_2^2$$

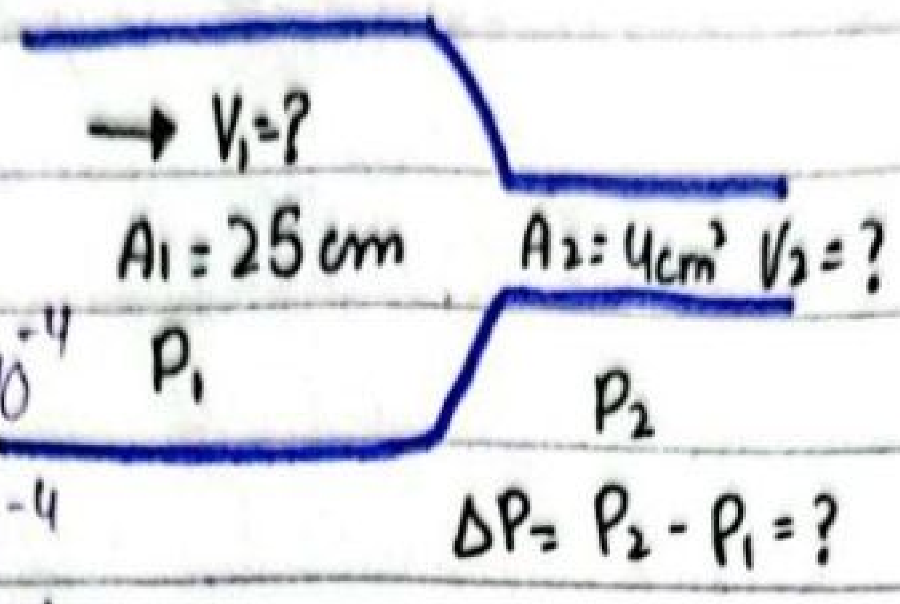
$$V_2^2 = 1.84 \times 2$$

$$V_2^2 = 3.68$$

$$V_2 = \pm\sqrt{3.68}$$

$$V_2 = 1.92\ m/s$$

Example 6.6



Given data:-

$A_1 = 25\,cm^2 = 25 \times 10^{-4}$

$A_2 = 4\,cm = 4 \times 10^{-4}$

Flow rate $= 5 \times 10^{-3}\,m^3/s$

To find:-

Flow rate at $A_1 = ?$

Flow rate at $A_2 = ?$

Solution:

i). Flow rate $= A_1 V_1$

$$V_1 = \frac{\text{Flow rate}}{A_1}$$

$$V_1 = \frac{5 \times 10^{-3}}{25 \times 10^{-4}}$$

$$V_1 = 2\,ms^{-1}$$

ii). Flow rate $= A_2 V_2$.

$$V_2 = \frac{\text{Flow rate}}{A_2}$$

$$V_2 = \frac{5 \times 10^{-3}}{4 \times 10^{-4}}$$

$$V_2 = 12.5\,m/s$$

10:

Given Data:-

$V_1 = 30\,ms^{-1}$

$V_2 = 20\,ms^{-1}$

To find:-

Pressure difference $= \Delta P = ?$

Solutions:

$$P_1+\frac{1}{2}\rho V_1^2+\rho g h=P_2+\frac{1}{2}\rho V_2^2+\rho g h$$
$$(h_1\approx h_2\approx h_3)$$

$$P_1+\frac{1}{2}\rho V_1^2=P_2+\frac{1}{2}\rho V_2^2$$

$$P_2-P_1=\frac{1}{2}\rho V_2^2$$

$$P_2-P_1=\frac{1}{2}\rho(V_1^2-V_2^2)$$

$$P_2-P_1=\frac{1}{2}\times 1.29(30^2-20^2)$$
$$P_2-P_1=322.5\ Pa.$$

Example 6.8:

Given Data:-

Height of water $h_1=h$

Height of orifice $=h_2=0$

To find:- Speed of efflux = ?

Solution:- By Bernoulli's equation:-

$$P_1+\frac{1}{2}\rho V_1^2+\rho g h_1=P_2+\frac{1}{2}\rho V_2^2+\rho g h_2$$

$$\frac{1}{2}\rho V_1^2+\rho g h_1=\frac{1}{2}\rho V_2^2+\frac{1}{2}\rho g h_2$$

$$\frac{1}{2}\rho(0)+\rho g h_1=\frac{1}{2}\rho V_2^2+\rho g h_2$$

$$\frac{1}{2}\rho V^2=\rho g(h_1-h_2)$$

$$V_2=\sqrt{2g(h_1-h_2)}$$

$$V_2=\sqrt{2g(h-0)}$$

$$V_2=\sqrt{2gh}$$

Numericals·11

Given Data:

$W_{EB} = 80\,N$, $V_H = 10\,m^3$, $\rho_H = 0.09\,kg/m^3$

$\rho_H = 1.3\,kg/m^3$

To find:- Content = ?

Solution:-

We know that

upthrust acting on balloon = weight of Balloon + weigh of content

weight of content = (upthrust acting on balloon) + upthrust acting on baloon

weight of content = upthrust acting on balloon − weight of Balloon. → eq ①

Now,

$$Upthrust = \rho_A g V_{balloon}$$

$$Upthrust = (1.3)(9.8)(10)$$

$$\boxed{Upthrust = 127.4\,N} \rightarrow (A)$$

Weight of Balloon = 80N + Weight of H

$= 80N + mg$

$= 80N + \rho_H V_H g$

$= 80 + (0.09)(10)(9.8)$

$\boxed{W_B = 88.8N} \rightarrow$ — — equation ②

Put in eq ①

Weight of content $= 127.4 - 88.8N$

$= 38.58\,N$