

" Chapter 10 "

10-1] There are three common phases of matter &

i) Solid & fixed shape and fixed volume .

ii) Liquid & variable shape and fixed volume .

iii) Gas & variable shape and variable volume .

* Gases and Liquids don't maintain their shape (no fixed shape) \Rightarrow can flow and collectively referred to as " Fluids " .

* A fourth less common type of matter is " Plasma " . It is a collection of positive ions and free electrons . This requires very high temperatures .

10-2] Density and Specific Gravity &

$$\rho = \text{Density} = \frac{\text{mass}}{\text{Volume}} = \frac{M}{V} \left\{ \begin{array}{l} \text{has units of } \text{kg/m}^3 \text{ (SI)} \\ \text{or } \text{g/cm}^3 \end{array} \right.$$

eg \rightarrow $\rho_{\text{water}} = 1000 \text{ kg/m}^3 = 1 \text{ g/cm}^3$

Example 10-1] what is the mass of a solid wrecking ball of iron of radius 18cm?

$$\rho_{\text{iron}} = 7800 \text{ kg/m}^3 \quad / \quad \rho_{\text{iron}} = \frac{m}{V}$$

$$\Rightarrow m = \rho_{\text{iron}} \times V = 7800 \times \frac{4}{3} \pi (r)^3 \\ = 7800 \times \frac{4}{3} \pi (18 \times 10^{-2})^3$$

$$m = 190 \text{ kg}$$

Specific Gravity (SG) :-

$$SG = \frac{\text{density of material}}{\text{density of water at } 4^\circ \text{C}}$$

$$\Rightarrow \text{At } 4^\circ \text{C} \Rightarrow \rho_w = 1000 \text{ kg/m}^3$$

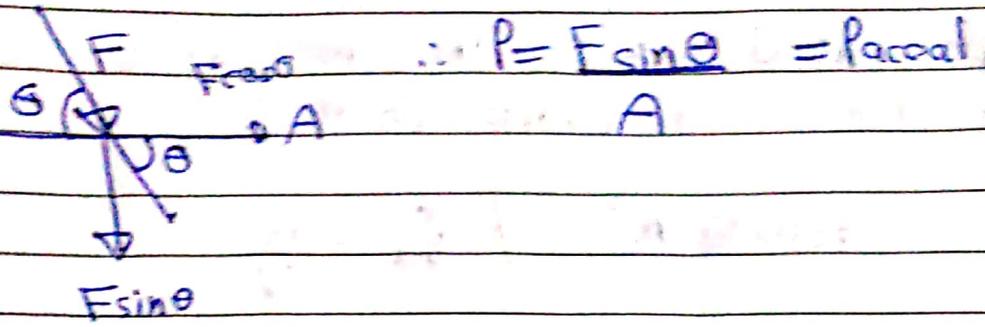
10-3] Pressure in fluids :-

Pressure :- magnitude of the force per unit area where the force is perpendicular to the area.

* Pressure is a scalar quantity.

units of pressure :- $P = \frac{F}{A}$ $\Rightarrow [P] = \frac{N}{m^2} = \text{Pascal}$

$\rightarrow F$ is perpendicular to the area



Example 10-2] Calculating pressure. A 60-kg person's feet cover an area of 500 cm^2

(a) Determine the pressure exerted by the two feet on the ground

(b) If the person stands on only one foot, what will be the pressure under that foot?

$$a) P = \frac{F}{A} = \frac{mg}{500 \times 10^{-4}} = \frac{60 \times 9.8}{500 \times 10^{-4}} = 12 \times 10^3 \frac{\text{N}}{\text{m}^2} = 12 \times 10^3 \text{ Pa}$$

$$b) P' = \frac{F}{(A/2)} = \frac{2F}{A} = 2mg = 24 \times 10^3 \text{ Pa}$$

Static Fluids (fluids at rest) :-

1) At a point inside the liquid, the pressure is the same in all directions.

2) Evidence :- the very small volume of the the fluid is at rest. If the pressures were different \Rightarrow cube of liquid would move.

look fig 10-1
"In book"

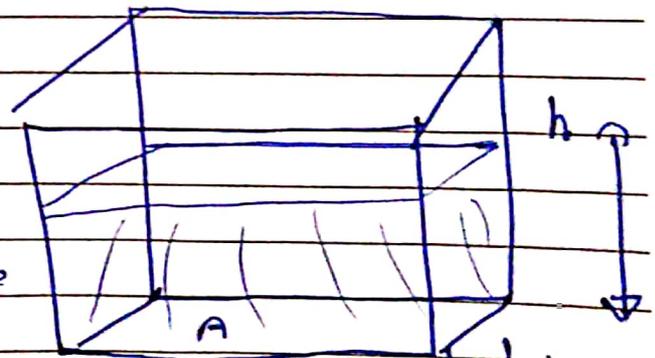
② The pressure of any static fluid is always perpendicular to any surface that is in touch with the fluid.

⇒ If the force of the fluid on the container had a component F_{\parallel} parallel to the bottle's wall ⇒ The wall will act on the fluid with an opposite force downwards, which would move the fluid but since the fluid is at rest ⇒ $\therefore F_{\parallel} = 0$

* Calculating The pressure due to the liquid on a height h below the surface of the liquid.

look figure (10-2) "In book"

The pressure of the liquid on the area A is due to the weight of the liquid &



$$P = \frac{F}{A} = \frac{mg}{A}$$

weight of the liquid.

$$P = \frac{\rho \cdot V \cdot g}{A} = \rho \cdot A \cdot h \cdot g = \rho \cdot h \cdot g$$

(AT)

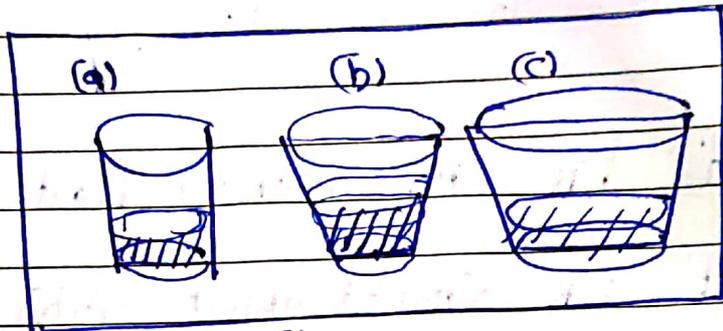
"fig 10-3"

↓ + Pressure increases as we go down

* $P = \rho \cdot g \cdot h$

NOTE :- that the pressure is independent of the Area A.

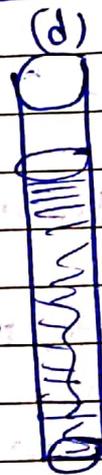
Example :-



which container has the largest pressure at the bottom of the container?

$d > b > c > a$

" we depend on h "



(e) The pressures are equal

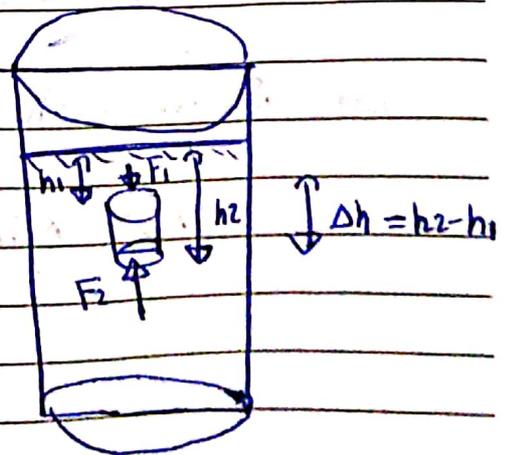
* Pressure on the top surface is

$$P_1 = \rho g h_1$$

Pressure on the bottom surface is

$$P_2 = \rho g h_2$$

Note :- $h_2 > h_1 \Rightarrow P_2 > P_1$

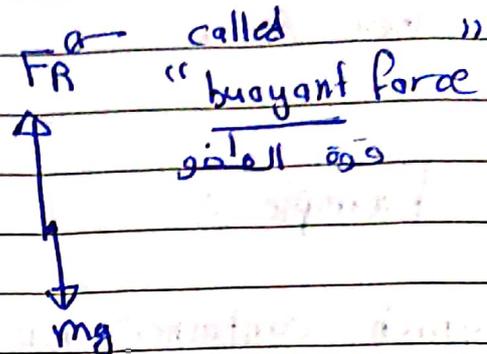


$$\Delta P = P_2 - P_1 = \rho g (h_2 - h_1) \Rightarrow \Delta P = \rho g \Delta h$$

From the previous page :-

$$\vec{F}_R = \vec{F}_2 - \vec{F}_1$$

↑ upwards Since $F_2 > F_1$



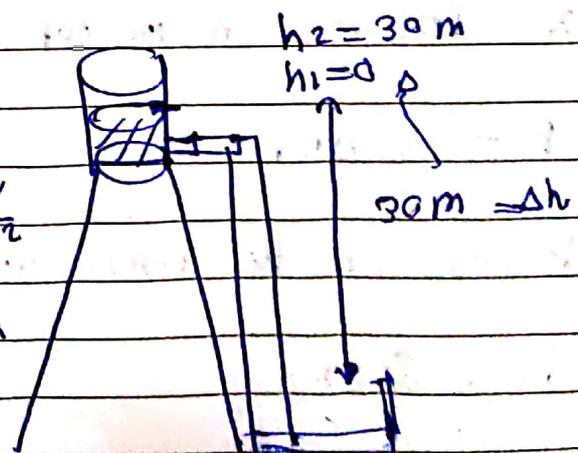
- If $F_R > mg \Rightarrow$ object floats.
- If $F_R < mg \Rightarrow$ object sinks.

Example 10-3] Pressure at a Faucet.

The surface of the water in a storage tank is 30 meters above a water faucet in the kitchen of a house. Calculate the difference in water pressure between the faucet and the surface of the water in the tank.

$$\Delta P = \rho_{\text{water}} g \Delta h$$

$$= 30 \times 1000 \times 9.8 = 2.9 \times 10^5 \frac{\text{N}}{\text{m}^2}$$
$$= 2.9 \times 10^5 \text{ Pa}$$

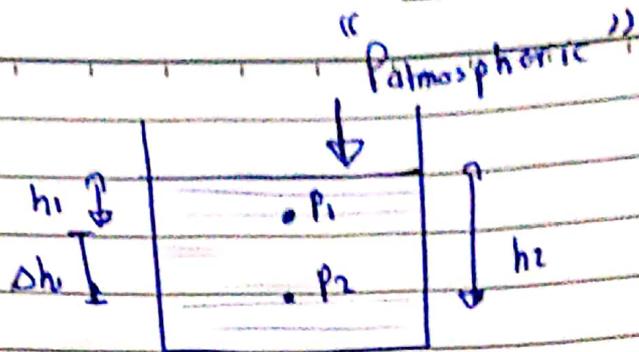


$$\Delta P = P_2 - P_1 = \rho g (h_2 - h_1)$$

$$P_2 - P_1 = \rho g \Delta H$$

$$P_2 = P_1 + \rho g \Delta H$$

$$P_2 = P_1 + \rho g h$$



$$P_1 = \rho g h_1$$

Pressure due to The liquid only

* due to liquid and air $P_1^{tot} = P_1 + P_{atm}$

$$P_2^{tot} = P_2 + P_{atm}$$

$$P_2^{tot} - P_1^{tot} = (P_2 + P_{atm}) - (P_1 + P_{atm})$$

$$= P_2 - P_1 = \rho g \Delta H$$

10-4] Atmospheric pressure law :- P_{atm}

The air around us has mass \Rightarrow it has weight.
The weight of the air leads to what we define

:- "atmospheric pressure P_{atm} ".

* Atmospheric pressure varies with altitude.

\Rightarrow At sea level, the average atmospheric pressure is

$$P_{atm} = 1.013 \times 10^5 \text{ Pa} \quad 1 \text{ bar} = 1 \times 10^5 \text{ Pa}$$

$$\Leftrightarrow \boxed{1 \text{ Patm} = 1.013 \text{ Bar}} \cdot$$

This means a force $1.013 \times 10^5 \text{ N/m}^2$ due to the weight of the column of air above the ground.

* How could our bodies withstand such high pressure?

\Rightarrow Our body cells maintain an internal pressure close to that of P_{atm} inside the cells.

* A balloon maintains an internal pressure $\sim P_{atm}$.

The tire of a car maintains an internal pressure much ~~more~~ higher than P_{atm} .

Example 10-4] Holding water in a straw.

The portion of water inside the straw is in static equilibrium.

$$\Rightarrow \sum F_y = 0$$

$$\uparrow F_b - F_t - mg = 0$$

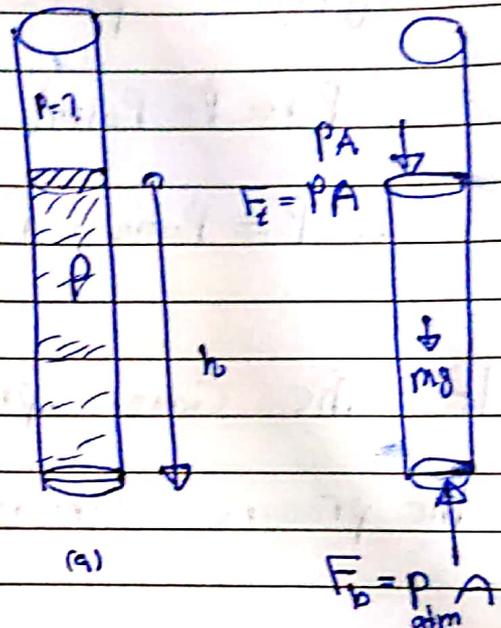
$$P_{atm}A - PA - mg = 0$$

$$P_{atm}A - PA - \rho_f Vg = 0$$

$$\text{but } V = Ah \Rightarrow$$

$$P_{atm}A - PA - \rho_f Ah = 0$$

$$P_{atm} = P + \rho_f gh$$

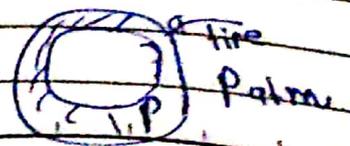


P is pressure of the air which is entrapped between the water and finger.

* Gauge Pressure :- Tire gauges measure the pressure inside the tire with respect to the atmospheric pressure (i.e. relative to the atmospheric pressure).

P :- actual pressure inside tire called absolute pressure.

P_{atm} :- atmospheric pressure.



Five Apple

* What does the pressure gauge in the picture measure?

⇒ It ~~measures~~ measures " $P - P_{atm}$ " which is called gauge pressure P_G ⇒

$$P_G = P - P_{atm}$$

$$\therefore P = P_{atm} + P_G$$

* If The Gauge pressure reads 220 kPa ⇒ then

The pressure inside the tire is $P = 220 \text{ kPa} + 101.3 \text{ kPa}$

$$= 3.213 \times 10^5$$

$$\approx 3.17 \text{ atm}$$

$$\therefore 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

10-5] Pascals Principle :-

Pascal's principle states that if an external is applied to a confined fluid, the pressure at every point within the fluid increases by that amount.

$$P_1 = \rho fgh \quad \text{or} \quad P_2 = \rho fgh$$

P_1 and P_2 are pressures due to the fluid Only.



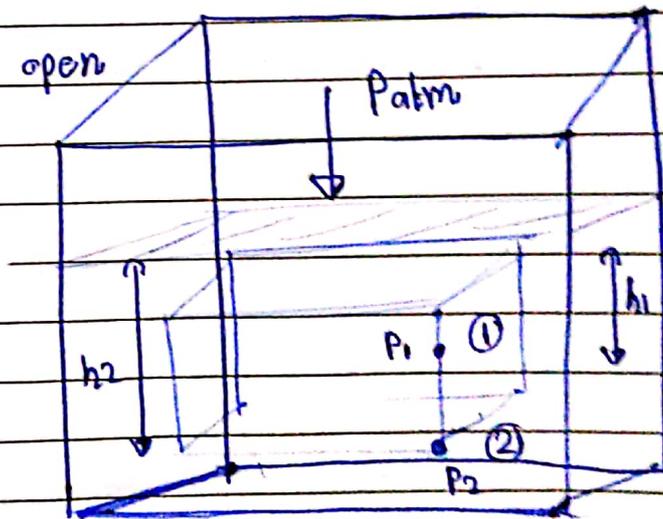
$$P_a = P_b = P_c$$

* The water container is open

to the atmosphere.

Therefore we have the atmospheric pressure

P_{atm} acting at the water surface.



∴

According to Pascal's principle,

the pressure at each point in the liquid must increase by an amount of P_{atm} .

∴ pressure at (1) due to liquid only

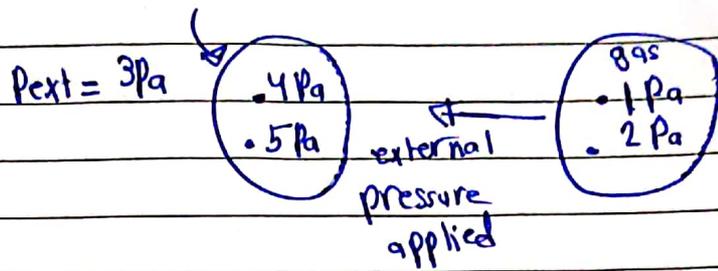
$$P_1 = P_{atm} + P_1 = P_{atm} + \rho_{fluid} g h_1$$

↑ pressure at point (1) due to the liquid and air

Similarly :-

$$P_2 = P_{atm} + P_2 = P_{atm} + \rho g h_2$$

Note that :- $P_2 - P_1 = \rho g h_2 - (\rho g h_1)$
 $= \rho g (h_2 - h_1) = \rho g \Delta h$



* Hydraulic Lift :-

A device that uses and lifts a car with a small force.

It makes use of Pascal's principle.

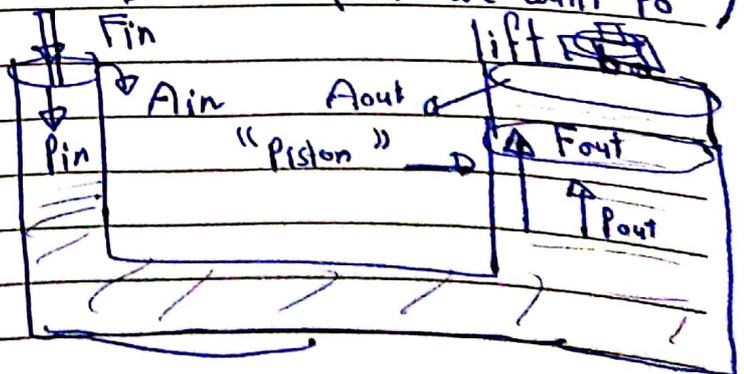
Assume the levels of the fluid in both out and in pistons to be the same



$\therefore P_{in} = P_{out}$

applied force
 "we apply it to lift the car"
 $\rightarrow F_{in} = F_{out}$
 $\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$

The load force (Weight of the car we want to lift)



$\frac{F_{in}}{F_{out}} = \frac{A_{in}}{A_{out}}$

$\Rightarrow \frac{F_{out}}{F_{in}} = \frac{A_{out}}{A_{in}}$

Note :- $A_{out} \gg A_{in}$
 $\therefore F_{out} \gg F_{in}$

⇒ We can lift a heavy car by applying a small force.

Example 8- The weight of the car $W = 10000 \text{ N}$
 $A_{\text{out}} = 20 A_{\text{in}}$. Find how much force we need to apply to lift the car and keep it in equilibrium?

$$\Rightarrow \frac{F_{\text{out}}}{F_{\text{in}}} = \frac{A_{\text{out}}}{A_{\text{in}}} = 20$$

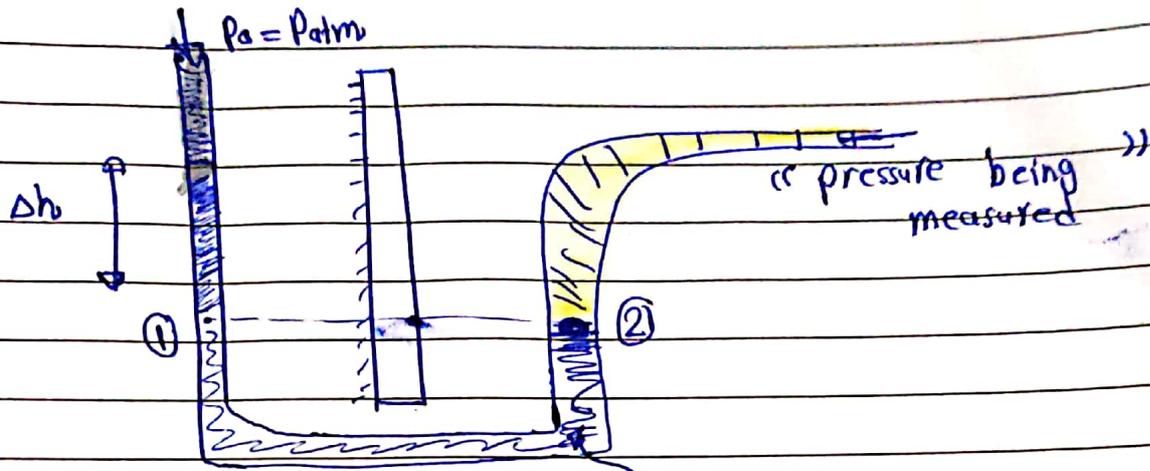
$$F_{\text{out}} = 20 F_{\text{in}} \Leftrightarrow F_{\text{in}} = \frac{F_{\text{out}}}{20} = \frac{500 \text{ N}}{20} = \underline{\underline{500 \text{ N}}}$$

∴ Can lift a weight of 10000 N using a force of 500 N only!

* Hydraulic breaks in a car also use pascal's principle.

Another example is the power steering in a car.

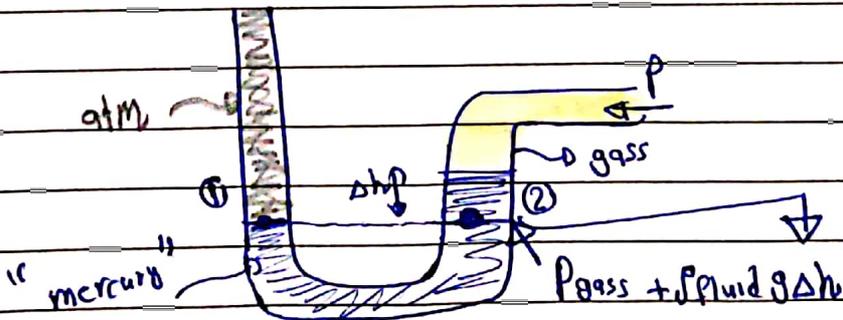
10-6] Measurement of Pressure, Gauges and Parameter.



(a) Open-tube manometer → mercury

$P_1 = P_2$ / The 2 points ① and ② are at the same height.

$$\therefore P_{atm} + \rho_f g \Delta h = P_{gas}$$



8 51 1 11 1 1 *

① - ②
Same level
Same fluid
↓
 $P_1 = P_2$

$$\therefore P_{gas} + \rho_{fluid} g \Delta h = P_{atm}$$

$$\therefore P_{gas} = P_{atm} - \rho_{fluid} g \Delta h$$

Sometimes, instead of having to calculate $\rho g \Delta h$, only the value of Δh is given and the unit of pressure in this case is mmHg.

$$\Rightarrow 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa} = 760 \text{ mmHg}$$

* This means that the pressure of a column of mercury of height 760mm is equivalent to the atmospheric pressure.

Mercury Barometer :-

A column of mercury of height 760mm (76cm) results in a pressure equivalent to that of 1 atm.

Question 8- If water is used instead of mercury, find the height of the water column to balance the P_{atm} (1 atm)

look figure ((10-8))
In book

$$\Rightarrow \rho_w g \Delta h = P_{atm} = 1.013 \times 10^5 \text{ Pa}$$

$$h = \frac{1.013 \times 10^5 \frac{\text{N}}{\text{m}^2}}{(1000 \frac{\text{kg}}{\text{m}^3}) \times 9.8 \frac{\text{m}}{\text{s}^2}} = 10.13 \frac{\text{N s}^2}{\text{kg}}$$

$$\therefore h = 10.13 \frac{(\text{kg m/s}^2) \text{ s}^2}{\text{kg}} = 10.13 \text{ m}$$

For mercury :- $\rho_{Hg} g h = 1.013 \times 10^5$

remember :- $\rho_{Hg} \gg \rho_{water}$ $\leftarrow h_{Hg} \ll h_{water}$

$$h_{Hg} = \frac{1.013 \times 10^5}{\rho_{Hg} \times g}$$