ICSE
Living Science
Physics

Class 9

Chapter 5 Pressure in Fluids; Atmospheric Pressure

On Board! BOOKS

As per the guidelines of NEP 2020

On Board! BOOKS

Revised and Updated

Living Science Physics

Based on the latest ICSE syllabus

Dhiren M Doshi

9

SCAN QR CODE
for ICSE updates and more study material
onboardbooks.in

LEARNING OBJECTIVES

Thrust and Pressure of the Liquid

- ❖ Pressure exerted by liquid
- ❖ Factors affecting the pressure exerted by a liquid
- ❖ Laws of liquid pressure
- ❖ Consequences of liquid pressure
- ❖ Transmission of pressure in liquids: Pascal's law
- ❖ Applications of Pascal's law
- ❖ Principle of a hydraulic machine
- ❖ Hydraulic press
- ❖ Hydraulic jack
- ❖ Hydraulic brakes

Atmospheric Pressure

- ❖ Existence of atmospheric pressure
- ❖ Consequences of atmospheric pressure

Measurement of Atmospheric pressure

- ❖ Simple barometer
- ❖ Mercury as a barometric liquid
- ❖ Defects of barometer
- ❖ Fortin's barometer
- ❖ Aneroid barometer
- ❖ Uses of barometer

Thrust and Pressure of the Liquid

The total force exerted by a liquid normally on a surface is called **thrust** of the liquid. The thrust exerted by a liquid per unit area of the surface is called the **pressure** of the liquid or hydrostatic pressure.

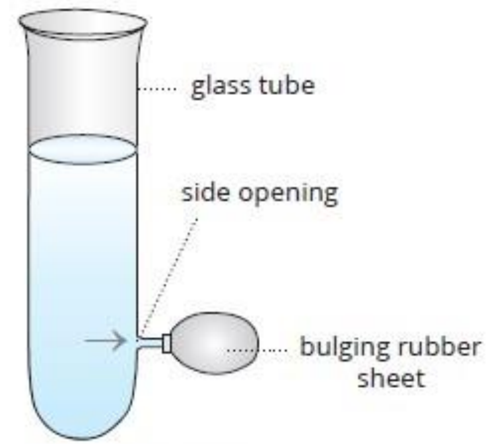
If a thrust (*F*) is acting on a surface area (*A*) in contact with a liquid, then the pressure exerted by the liquid on the surface is Pressure = Thrust/ Area

or $P = F/A$

The SI unit of pressure is N m^{-2} or pascal (denoted by Pa).

Pressure exerted by liquids

Pressure exerted by a standing liquid due to its weight is called **hydrostatic pressure**. Liquids exert pressure not only at the bottom but also on the sides of the vessel containing them. The sideways pressure exerted by a liquid is called its **lateral pressure.**

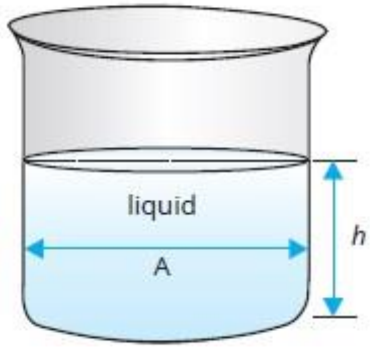


Liquid exerts lateral pressure

The liquid exerts pressure on the walls of the container and lateral pressure increases with depth.

Pressure exerted by the liquid column (*P*= *hρg*)

a cylinder of cross-sectional area *A is* filled with a liquid of uniform density ρ to a height *h.* Pressure *P* exerted by the liquid on the bottom of the cylinder is:



P = Force/ Area of bottom = *F/A*

If m is the mass of the liquid in the cylinder then

F = mg and P = mg/A

But mass m = Volume x Density = (A x h) x ρ

Therefore, P = (A x h x ρ x g)/ A = hρg

Pressure = depth x density of the liquid x acceleration due to gravity

Total pressure exerted by a liquid at depth *h* = Pressure due to liquid column (*h*ρ*g*) + Atmospheric pressure (P_a) = *h*ρ*g* + P_a

Laws of liquid pressure

The five laws of liquid pressure are as follows:

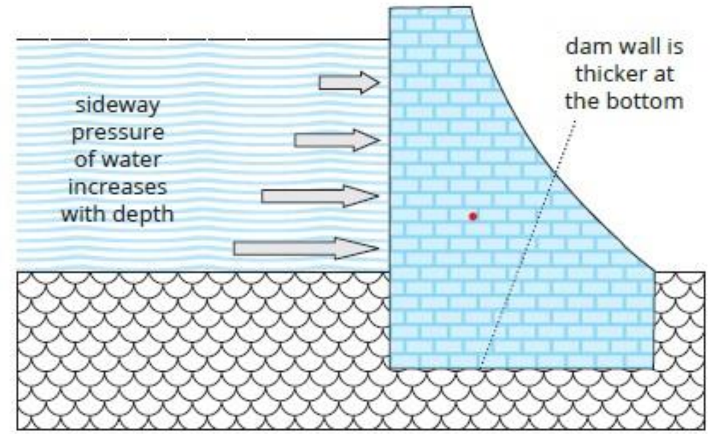
1. Pressure at a point inside the liquid at a given depth increases with the increase in the density of the liquid.

2. Pressure is same in all directions, about a given point within the liquid.

3. Pressure is the same at all points in a horizontal plane at a given depth in a stationary liquid.

4. Pressure at a point inside the liquid increases with the depth from the free surface of the liquid.
5. A liquid seeks its own level.

Consequences of liquid pressure



1. The wall of a dam is made thicker at the bottom: Since water pressure increases with depth, the wall of a dam is made thicker at the bottom . A thicker wall can withstand a greater pressure exerted by the water at greater depth.

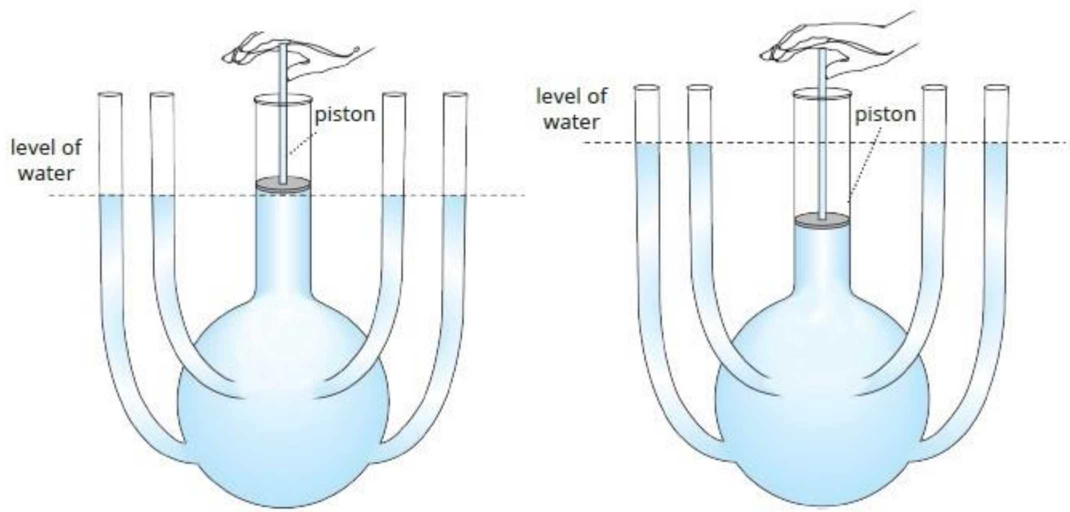
2.Water supply tank is placed at the highest place in a building or a house: This is because as the tanks are placed at a greater height, the pressure of water will be large enough to force the water to rise up the multi-storey buildings and reach the taps of the houses.

3. Diver's suit: We know water pressure increase with depth; the deeper an object is in the water, the greater the pressure acting on the object. Deep sea-divers feel the increasing water pressure on their body while swimming deeper under water. This may cause bursting of some blood vessels resulting in bleeding. A deep sea diver has to wear a suit to counter the high pressure of great depths in the sea.

Transmission of pressure in liquids: Pascal's law

According to Pascal's law, whenever any pressure is applied anywhere in a confined fluid (liquid or gas), it is transmitted equally and undiminished in all directions throughout the volume of the fluid and to the walls of the container.

When the piston is pushed down, a force is applied at a point in the water.



The level of water rises through the same height in each side-tube.

This shows that if pressure is applied at one place in an enclosed liquid, it is transmitted equally in all directions throughout the volume of the liquid.

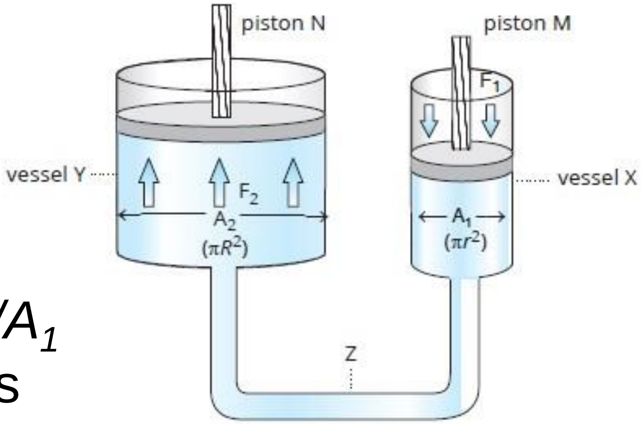
Applications of Pascal's law

Hydraulic machines like hydraulic press, hydraulic jack and hydraulic brakes are based on the application of Pascal's law of transmission of pressure in liquids.

Principle of a hydraulic machine

The pressure applied on piston M in the downward direction = F_1/A_1

According to Pascal's law, the pressure exerted on the piston M is transmitted by the liquid to the piston N.



The upward pressure exerted on the piston N = F_1/A_1

Hence, the upward force (F_2) exerted on piston N is

F_2 = Pressure on the piston N × Area

[Since force = pressure × area]

$F_2 = (F_1 / A_1) X A_2$

$F_2/F_1 = A_2/A_1$

Since, $A_2 > A_1$, therefore $F_2 > F_1$.

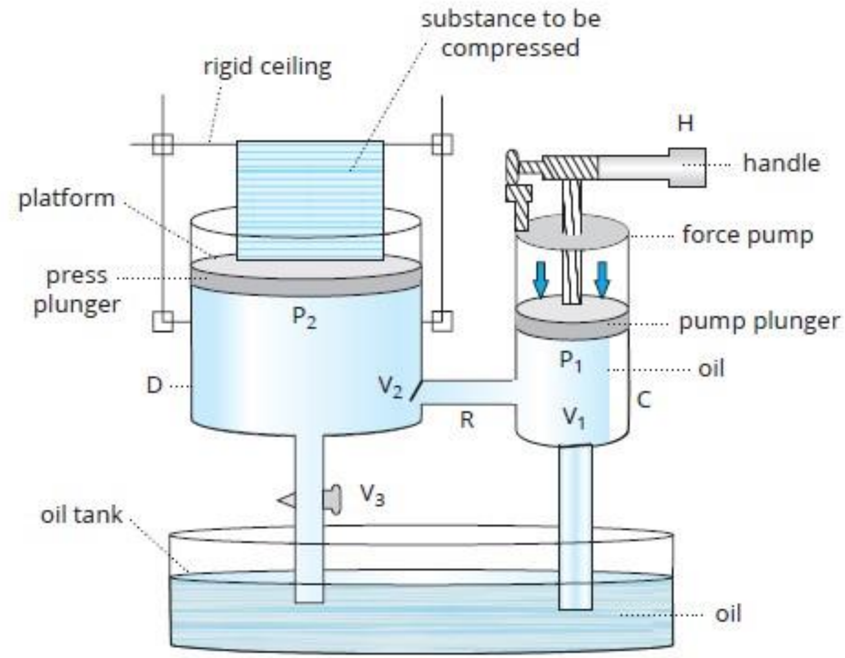
Thus, when a small force F_1 is applied on the smaller piston M it exerts a large force F_2 on the bigger piston N. This explains the principle of a hydraulic machine.

As a result of which a heavy load placed on the larger piston is easily lifted upwards. The smaller force applied gets multiplied.

Examples of Hydraulic machines

Hydraulic press

It works on the principle of Pascal's law.



Note: For Construction and Working of a hydraulic press please refer to the book P-100.

Uses of hydraulic press

1. It is used for compressing the cotton bales and straw.

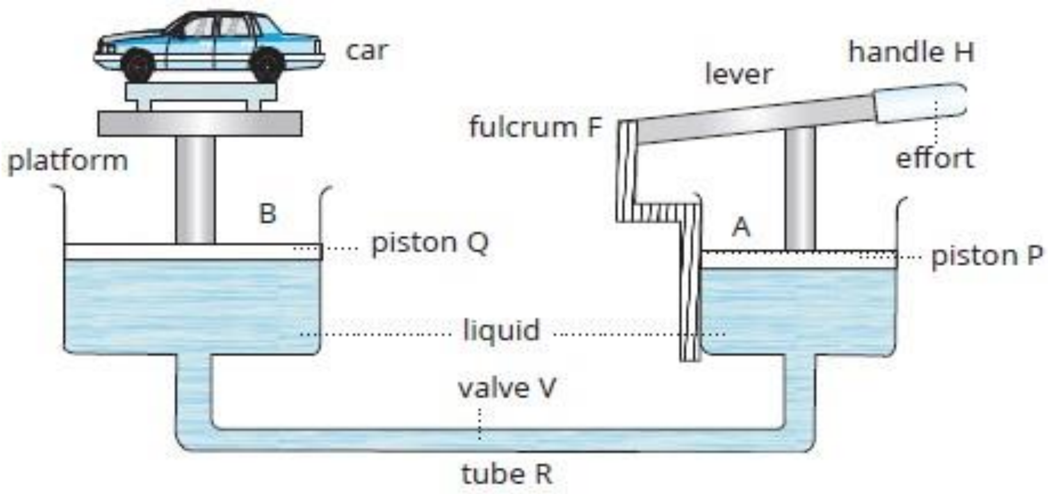
2. It is used for extracting oil from oil seeds like linseed and cotton seeds.

3. It is used for punching holes in metals.

4. It is used for giving specific shapes to metal sheets.

Hydraulic jack

A hydraulic jack works on the principle of Pascal's law. It is used to lift heavy vehicles like trucks, cars and buses during servicing in service centres. It is used to lift elevators in low and medium size buildings.



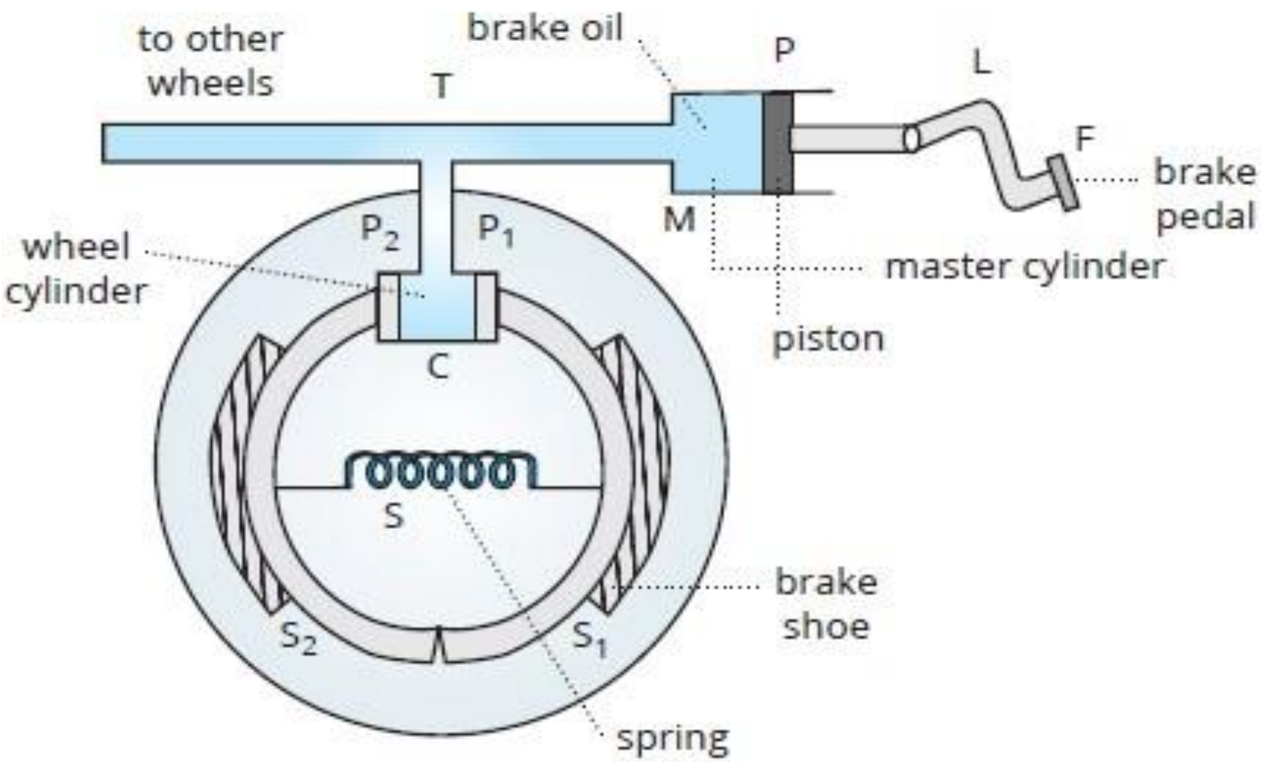
Construction: A hydraulic jack consists of two cylindrical vessels A and B. Both vessels are connected with a tube R having a valve V . Piston Q with a wide platform is connected to vessel B and Piston P attached to a lever is connected to vessel A. Both the vessels are filled with water.

Working: When force is applied on handle H of the lever, the valve opens as the pressure in cylinder A increases. The liquid runs out from cylinder A to B resulting in a rise of platform. When the car reaches the required height, the handle H of the lever is no longer pressed. Then the valve is closed and water does not flow from cylinder B to A. In this way a hydraulic jack works.

Hydraulic brakes

The working of hydraulic brakes used in cars, automobiles, etc. is also based on Pascal's law.

Construction: It consists of a master cylinder M filled with brake oil and provided with an airtight frictionless piston P . The piston is connected to brake pedal F through lever system L.



The master cylinder is connected to wheel cylinder C through a tube T. The wheel cylinder has two pistons P_1 and P_2. These pistons are connected to brake shoes S_1 and S_2 respectively. The spring S holds the brake shoes S_1 and S_2 in position. A similar system is connected to all the wheels of a vehicle.

Working: To apply the brakes, the brake pedal is pressed, and the lever system operates. The piston P of the master cylinder is pushed inwards. There is increased pressure on the liquid at P, which is transmitted equally to pistons P1 and P2 of wheel cylinder in accordance with Pascal's law. Due to this, P1 and P2 move outwards. They force the brake shoes to move away from each other which in turn press against the inner rim of the wheel and hence retard the motion of the wheel, i.e. the brake becomes operative.

When the pressure on the brake pedal is released, the brake shoes return to their normal positions by the action of spring, which in turn forces the brake oil to return from the wheel cylinder to the master cylinder.

Atmospheric Pressure

The weight of air exerts pressure on us. The air above us presses us down with a force equal to that exerted by a mass of 1 kg on an area of 1 cm^2. This is called the **atmospheric pressure**.

The value of atmospheric pressure on the surface of earth at the sea-level is nearly 1.013×10^5 N m^{-2} or 1.013×10^5 Pascal in SI units and 1.013×10^6 dyne/ cm^2 in CGS system.

This means that **weight of air on 1 m^2 surface of earth is about 10^5 N**.

Various units for atmospheric pressure

1. The SI unit of atmospheric pressure is N^{-2} or pascal (denoted by Pa) and CGS unit is dyne/cm^2 (1 Pascal = 1 N/m^2).

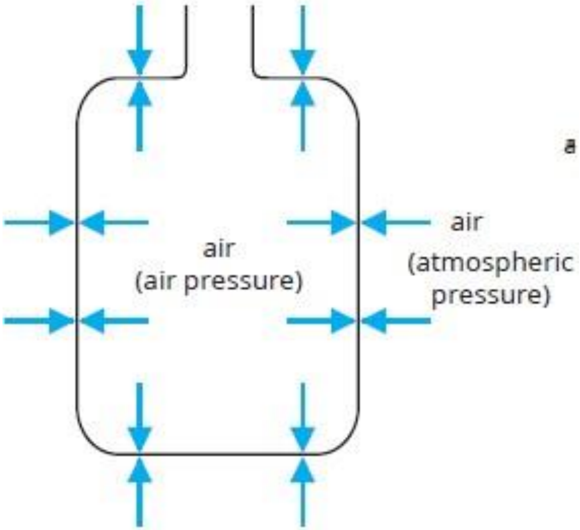
2. Atmospheric pressure is also measured in **mm** or in **cm**, in terms of the height of the mercury column.

3. Atmospheric pressure is also measured in **Torr** where 1 torr = 1 mm of mercury column.

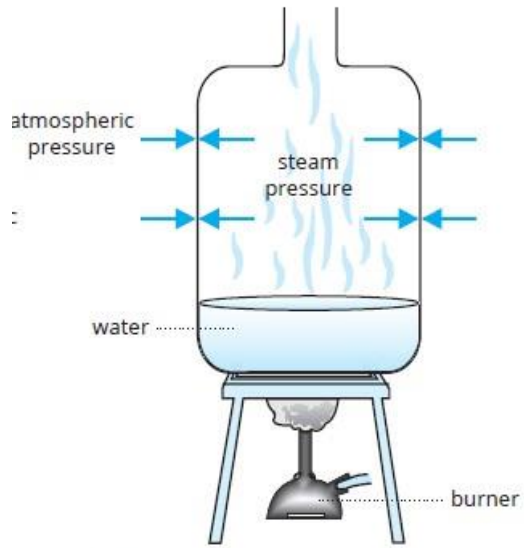
4. The unit of atmospheric pressure used for meteorological purposes is called **bar** where 1 bar = 10^5 Pa and 1 millibar = 10^{-3} bar = $10^{-3} \times 10^5$ Pa = 100 Pa.

Experiment to demonstrate the existence of atmospheric pressure

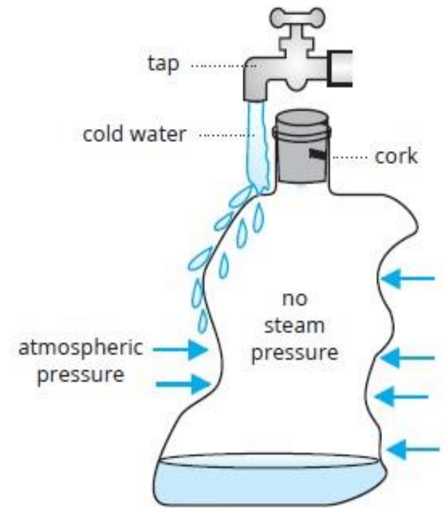
Crushing tin can experiment



a. An empty tin can does not get crushed by atmospheric pressure.



b. The outside atmospheric pressure is balanced by steam pressure (from inside the tin can).

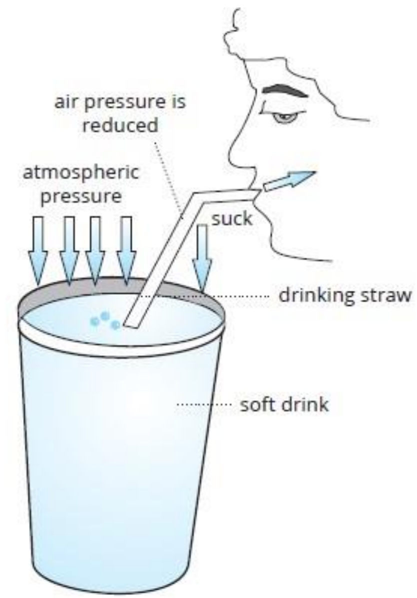


c. Atmospheric pressure crushes the tin can because there is no steam pressure inside the tin can to balance it.

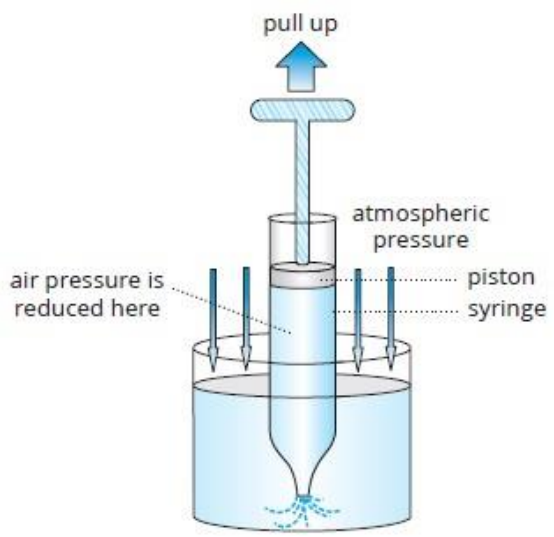
When steam is formed, it pushes most of the air out of the tin can. When the can is cooled by pouring cold water, the steam present inside the can condenses to form water, thereby creating a partial vacuum inside the can. The pressure of air inside the can becomes much less than that outside the can. The large atmospheric pressure crushes the tin can inwards. This shows the existence of a large atmospheric pressure around us.

Common consequences of atmospheric pressure

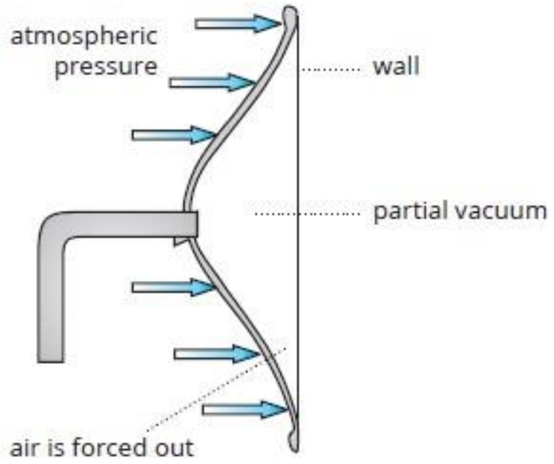
1. Sucking soft drink through a straw: For sucking soft drink through a straw the lower end of the drinking straw is dipped in the soft drink. When we suck at the upper end of the straw with our mouth, the pressure of the air inside the straw is reduced. But, the pressure acting on the surface of the soft drink is equal to the atmospheric pressure. So, the greater atmospheric pressure acting on the surface of the soft drink pushes the soft drink up the straw into our mouth.



2. Working of a syringe: When the nozzle of a syringe is dipped in a liquid and its piston is withdrawn, the pressure inside the syringe is lowered. The greater atmospheric pressure acting on the surface of the liquid pushes the liquid up into the syringe.



3. Working of a rubber suction pad: Rubber suction pads are used on the walls to hang clothes and calendars. When moistened rubber suction pad is pressed against the wall, the air between the suction pad and the wall is forced out, reducing the pressure inside. The outside atmospheric pressure being greater, pushes the suction pad firmly and it adheres to the surface of the wall. Even lizards are able to adhere to the wall because their feet function like suction pads.



4. Nose starts bleeding at high altitudes: Mountaineers suffer nose bleeding at high altitudes. The atmospheric pressure is maximum on the surface of the earth. When we go to higher altitudes, then the atmospheric pressure decreases. Since, our blood is at a higher pressure than the outside atmospheric pressure (which is low at high altitudes) some of the blood vessels burst and bleeding takes place through nose.

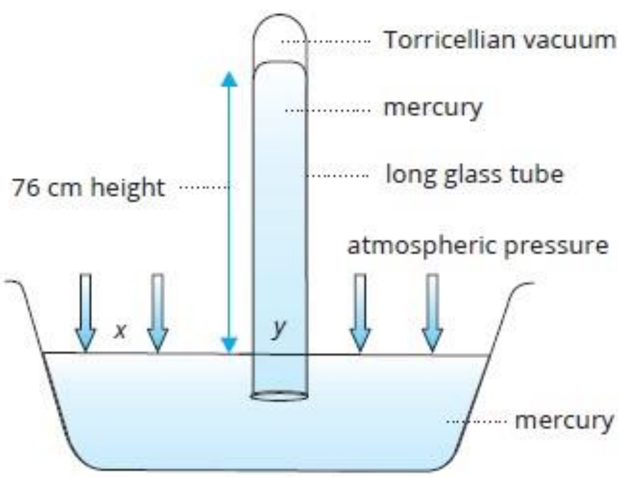
Measurement of Atmospheric Pressure

The atmospheric pressure is measured by an instrument called barometer. Three types of barometer are in common use:

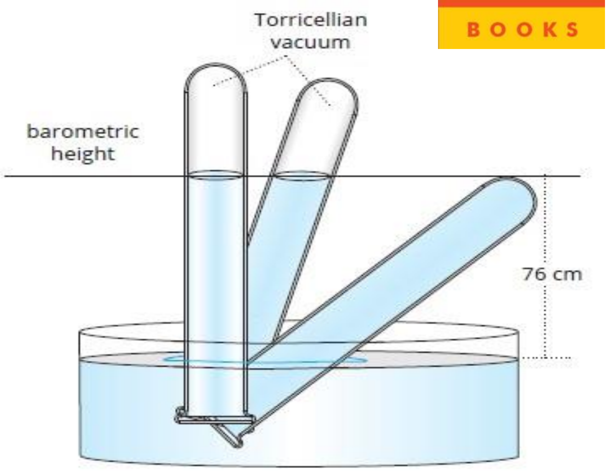
1. Simple barometer
2. Fortin's barometer
3. Aneroid barometer

Simple barometer

In 1643, an Italian mathematician named Torricelli discovered the principle of a barometer by using a long glass tube closed at one end, which he put upside down in an open container holding a liquid. He found that the pressure of the air bearing down on the liquid in the container forced it up the tube, and the measurement of various lengths of the column of liquid was, therefore, a means of expressing the changes in air pressure. In order to have a tube of manageable length, the heaviest of all liquids, mercury, was later used.



the **atmospheric pressure is equal to the weight of the column of mercury having a height of 76 cm**. The barometric height (76 cm) remains the same even when the shape or size o the tube is changed or the tube is tilted from its vertical position.



Advantages of using mercury (and not water) as a barometric liquid

1. Mercury is a shining and an opaque liquid metal, therefore readings can be seen easily.

2. The density of mercury is 13.6 g/cm^3, which is the maximum for any liquid. Therefore, the length of the mercury column needed to balance the atmospheric pressure is 76 cm, which is manageable whereas water needs 10.3 metres of height to balance the atmospheric pressure, which requires a very long tube and is highly inconvenient to manage.

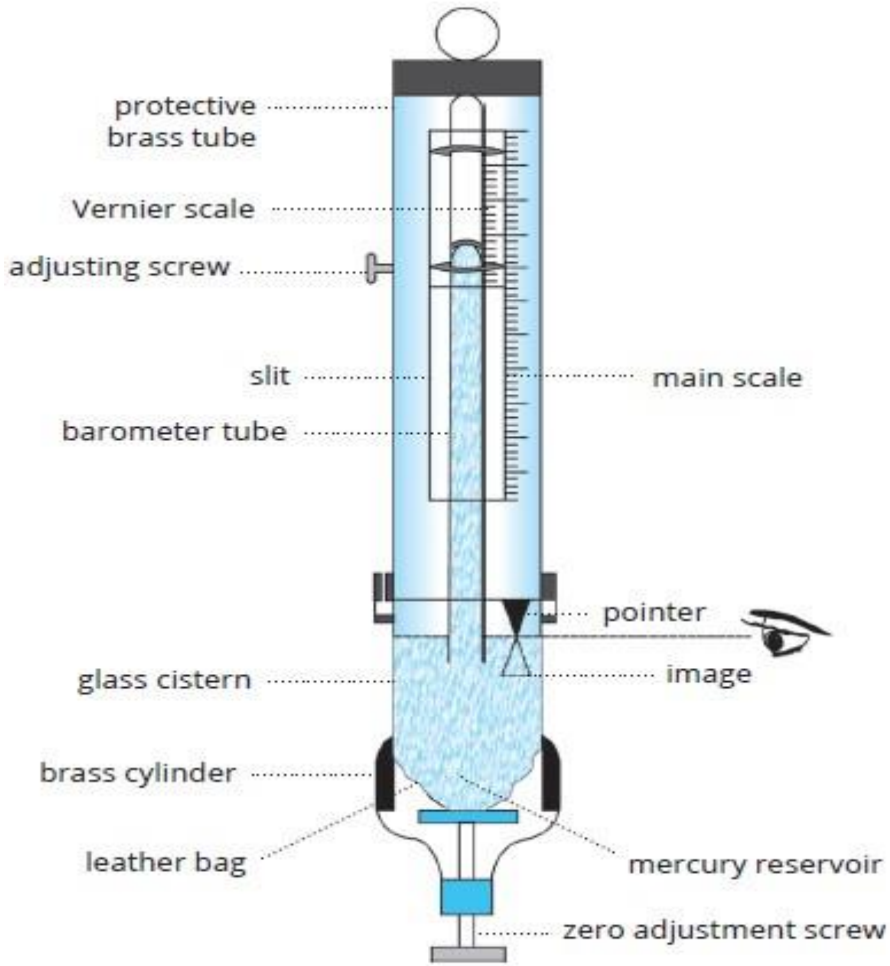
3. The freezing point of mercury is –30 $^\circ$ C, which is much lower than that of water.

4. Mercury can be obtained easily in its pure state.

5. Mercury does not evaporate under ordinary conditions.

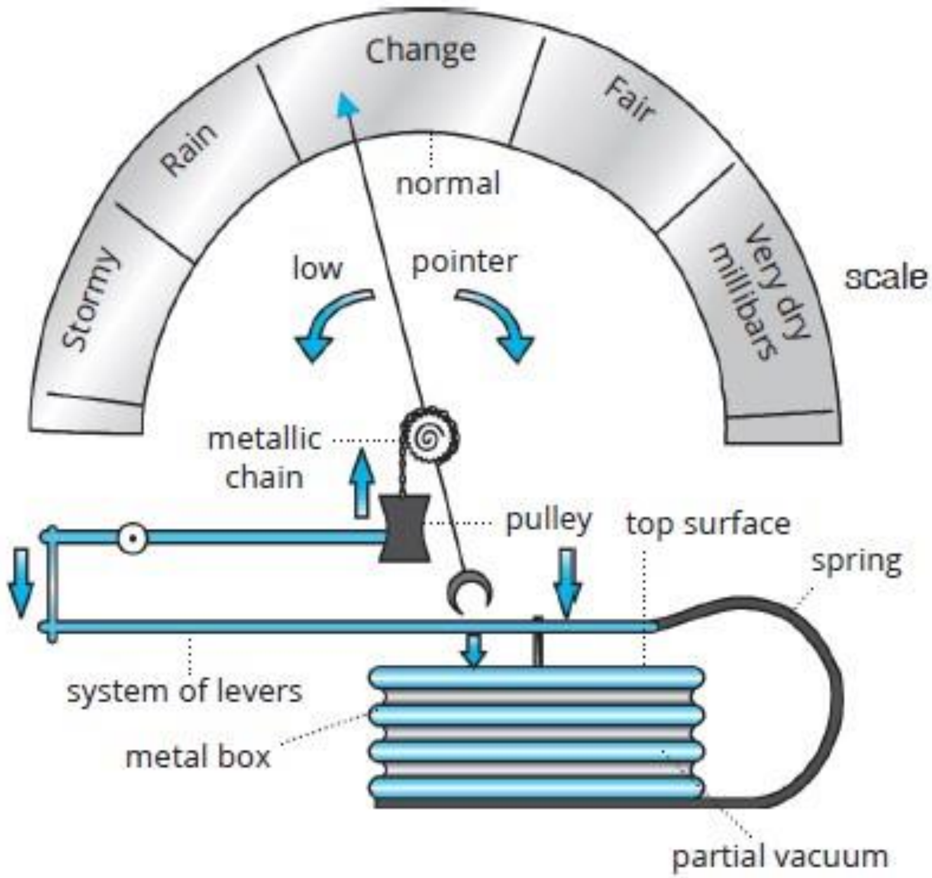
Fortin's barometer

Fortin's barometer consists of a glass cistern, attached with a leather bag. By raising or lowering the bottom of the bag with the help of a zero adjustment screw, the level of mercury in a reservoir is made to touch the tip of the ivory pointer



Aneroid barometer

The French scientist Lucien Vidie invented the aneroid barometer in 1843. The word aneroid means 'without liquid' in Greek. The barometer is so called because it does not contain mercury or any other liquid. It is as compact as a small clock.



Uses of barometer

1. For determining altitudes (barometer as altimeter): We know that atmospheric pressure changes with ltitude. Observations indicate that the pressure decreases by 1 mm Hg with every 12 m ascent (increase in altitude).

2. For forecasting weather (barometer as weather forecaster): Atmospheric pressure at a given place changes from time to time which in turn is related to changes in the weather.

- Rapid fall in the mercury level in a barometer at a place indicates low pressure. This would result in the rushing of air from the surrounding higher pressure regions to that place. This usually results in a storm or cyclone.
- Gradual fall in the mercury level in a barometer, if there is too much moisture in the air, indicates the possibility of rain.
- The absence of any abrupt change in the atmospheric pressure, being normal, indicates fair weather.
- Gradual rise in the mercury level in a barometer, if there is less moisture in the air, indicates dry weather.
- Sudden rise in the atmospheric pressure results in the air from that place to rush to the surrounding low-pressure areas resulting in anti-cyclone. It indicates an extremely dry weather.

SUMMARY

1. Thrust of the Liquid: It is the total force exerted by a liquid normally on the surface.

2. Pressure of the Liquid: The thrust exerted by a liquid per unit area of the surface is called the pressure of the liquid.

3. Laws of Liquid Pressure: a. Pressure at a point inside the liquid at a given depth increases with the increase in the density of the liquid. **b.** Pressure is same in all directions about a given point within the liquid. **c.** Pressure is the same at all points in a horizontal plane at a given depth in a stationary liquid. **d.** Pressure at a point inside the liquid increases with the depth from the free surface of the liquid. **e.** A liquid seeks its own level.

4. Pascal's Law: Whenever any pressure is applied anywhere in a confined fluid, it is transmitted equally and undiminished in all directions throughout the volume of the liquid and to the walls of the container.

5. Atmospheric Pressure: The weight of atmospheric air acting per unit area is known as the atmospheric pressure.

6. Barometer: Atmospheric pressure is measured by an instrument called the barometer. The three types of barometer are **a.** Simple barometer **b.** Fortin's barometer **c.** Aneroid barometer.