Pressure in Fluids and Atmospheric Pressure

Thrust and Pressure

- Thrust is the force acting perpendicularly on an object.
- It is a vector quantity. Its SI unit is newton (N).
- Pressure is the force or thrust acting perpendicularly on a unit area of the object.

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}} = \frac{F}{A}$$

- The same force acting on a smaller area exerts a larger pressure and on a larger area exerts a smaller pressure.
- The SI unit of pressure is N/m^2. This unit is named as pascal (Pa).
- One pascal is the pressure exerted on a surface of area 1 m^2 by a force of 1 N acting normally on it.

Pressure in fluids

- A substance which flows is called a **fluid**.
- Fluids exert pressure on the base and walls of the container in which they are enclosed.
- Pressure exerted in any confined mass of fluid is transmitted uniformly in all directions.

Pressure Exerted by a Liquid Column

- The pressure on a surface at a depth 'h' is

$$P = \frac{\text{Thrust on surface}}{\text{Area of surface}} = \frac{Ah\rho g}{A} = h\rho g$$

- The total pressure inside a liquid column at a depth is the sum of the atmospheric pressure on the liquid surface and the pressure due to the liquid column.

$$\text{Total pressure} = P_0 + h\rho g$$

Laws of Liquid Pressure

- Pressure is the same in all directions about a point in the liquid.
- In a stationary liquid, the pressure is the same at all points on a horizontal plane.
- Pressure at a point inside the liquid increases with depth from the free surface.
- Pressure at the same depth is different in different liquids. It increases with increase in density.
- A liquid seeks its own level.

Some Consequences of Liquid Pressure

A) The wall of a dam is made thicker at the bottom.
B) To supply water to a town (or a colony), the water supply tank is placed at a sufficient height.
C) Deep sea divers need to wear a special protective suit. In the deep sea, the total pressure exerted on the diver's body is much more than his blood pressure.

Pascal's law

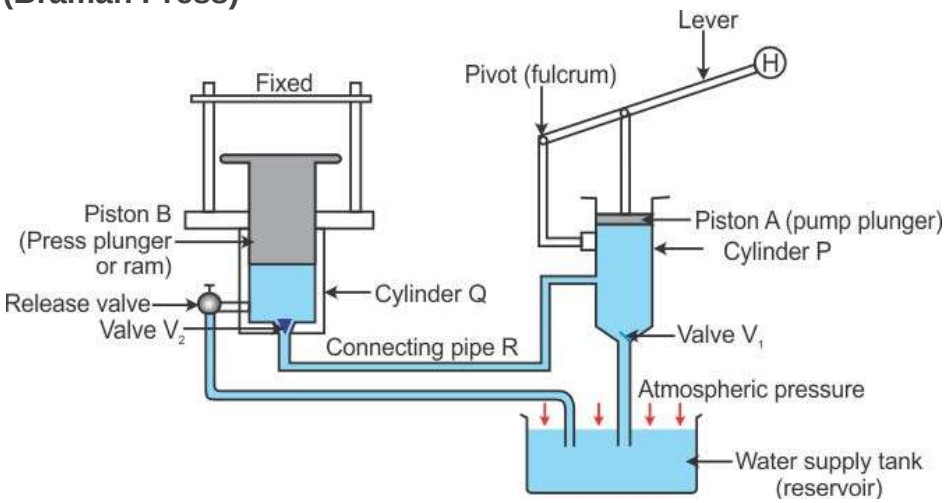
- **Pascal's law:** The pressure exerted anywhere in a confined liquid is transmitted equally and undiminished in all directions throughout the liquid.

Application of Pascal's law

- The hydraulic press, hydraulic jack and hydraulic brakes work on Pascal's law of transmission of pressure.

Examples of Hydraulic Machines

Hydraulic Press (Bramah Press)



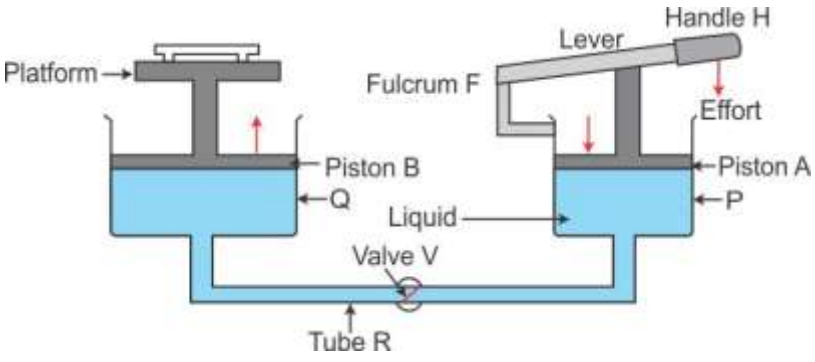
Uses

1) For engraving monograms on books.

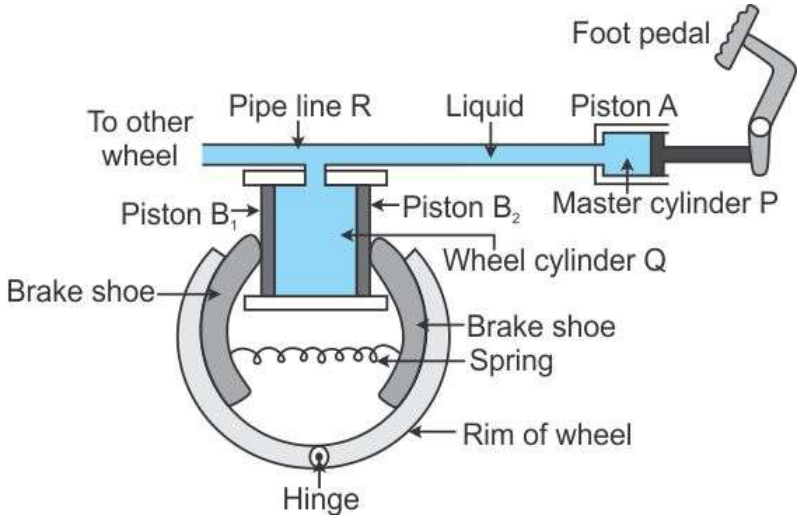
2) For extracting juice from sugarcane.
3) For squeezing oil from linseed and cotton seeds.
4) For pressing cotton bales and goods, quilts, books etc.

Hydraulic jack

A hydraulic jack is used to lift heavy vehicles at service stations for repair works.



Hydraulic brakes



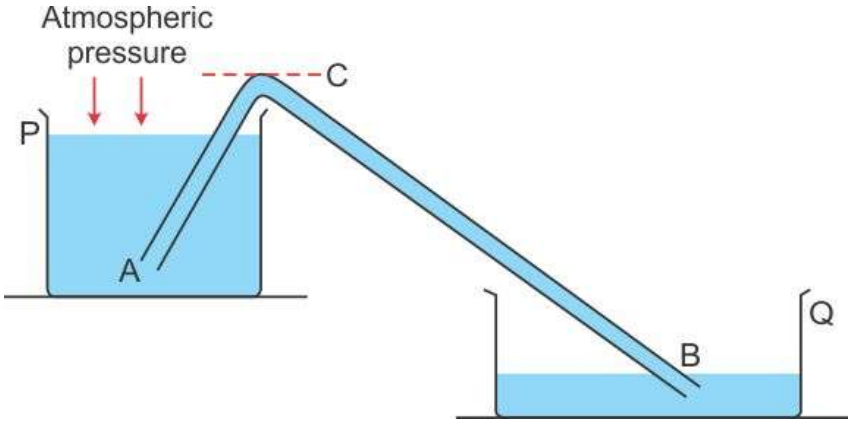
Atmospheric Pressure

- The envelope of air surrounding the Earth is called the **atmosphere**.
- The thrust exerted per unit area of the Earth's surface due to a column of air is called the atmospheric pressure on the Earth's surface.
- Its value is about $1\,\text{kgf/cm}^2 = 10^5\ \text{N m}^{-2} = 10^5\ \text{Pa}$.
- We do not feel this large amount of thrust as our blood pressure balances this thrust.

$1\,\text{atm} = 0.76\ \text{m of Hg} = 76\ \text{cm of Hg} = 1.013 \times 10^5\ \text{Pa}$

Consequences of Atmospheric Pressure

- We can suck a drink with a straw
- We can fill a syringe with the liquid
- We can fill ink into a fountain pen
- Rubber suckers work due to atmospheric pressure
- Action of a siphon system is based on atmospheric pressure

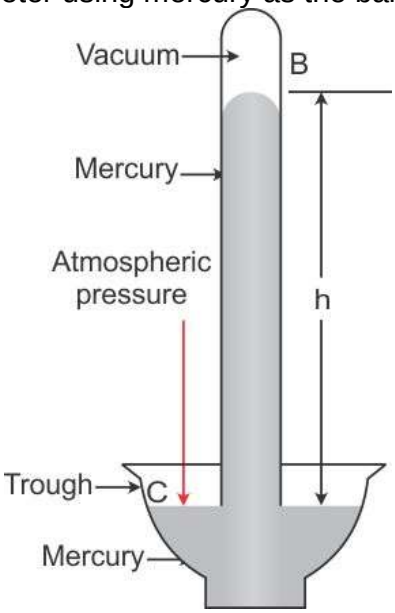


Measurement of Atmospheric Pressure

- Atmospheric pressure is measured using a **barometer**.

Simple barometer

Torricelli first designed a simple barometer using mercury as the barometric liquid.



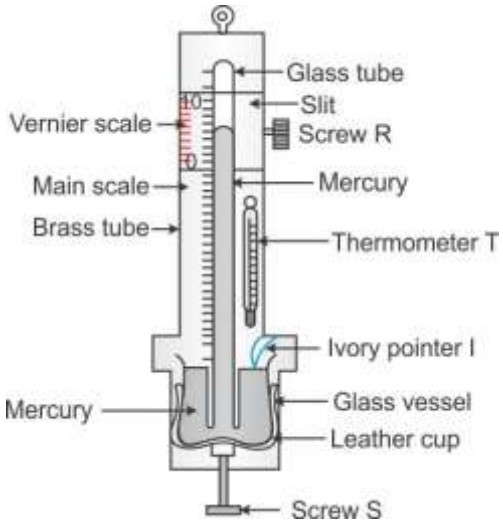
- **Advantages of using mercury as a barometric liquid**
  - The density of mercury is greater than that of all other liquids, so only 0·76 m height of the mercury column is needed to balance the normal atmospheric pressure.
  - The vapour pressure of mercury is negligible, so it does not affect the barometric height.
  - The mercury neither wets nor sticks to the glass tube. Therefore, it gives the correct reading.
  - The surface of mercury is shining and opaque. Therefore, it is easily seen while taking the observation.
  - It can easily be obtained in the pure state.

- **Disadvantages of using water as a barometric liquid**
  - The density of water is low, so nearly 10·4 m height of the water column is needed to balance the normal atmospheric pressure. It will be very inconvenient to use a tube of height 10·4 m for a barometer.
  - The vapour pressure of water is high, so the vapours in the vacuum space will make the reading inaccurate.
  - Water sticks to the glass tube and wets it, so the reading becomes inaccurate.
  - Because water is transparent, its surface is not easily seen while taking the observation.

- **Defects of a simple barometer**
  - There is no protection for the glass tube.
  - The surface of mercury in the trough is open; therefore, there are chances that the impurities may fall in and get mixed with the mercury of the trough.
  - It is inconvenient to move the barometer from one place to another.
  - A scale cannot be fixed with the tube (or it cannot be marked on the tube) to measure the atmospheric pressure.

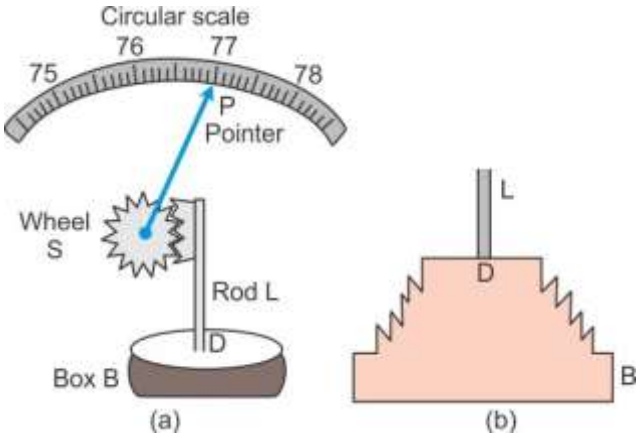
Fortin's barometer

It is a modified form of a simple barometer. It is used in the laboratory to measure the atmospheric pressure. It also uses mercury as barometric liquid.



Aneroid barometer

This barometer does not have a liquid. It is light and portable. Hence, it can easily be carried from one place to another. It is calibrated in such a way that it reads the atmospheric pressure directly.

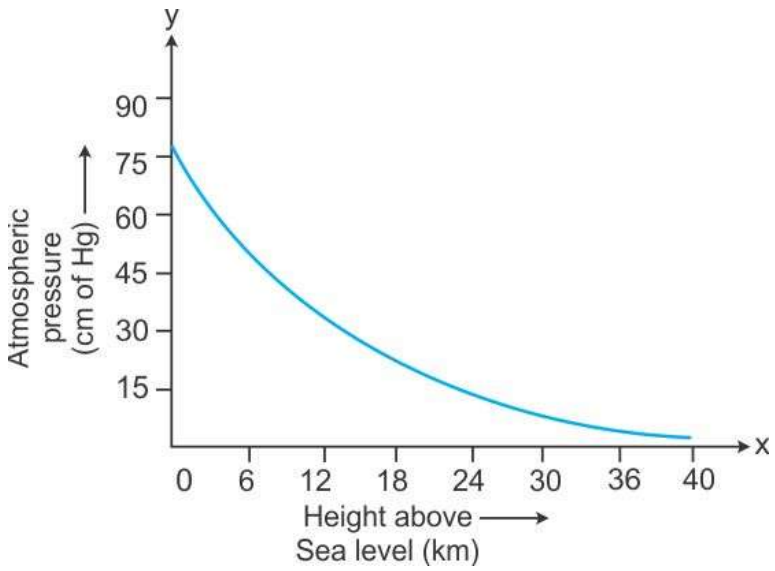


- **Uses of a barometer**
  - To measure the atmospheric pressure at a place
  - For weather forecast
  - As an altimeter

Variation of atmospheric pressure with altitude

- The pressure of air decreases with increase in altitude.
- The decrease in atmospheric pressure is due to
  - Decrease in height of the air column which causes a linear decrease in atmospheric pressure.
  - Decrease in density of air which makes the decrease in atmospheric pressure less rapid with increase in altitude.

- The following graph shows the variation of atmospheric pressure with height above sea level.



- **Consequences of travelling to high altitudes**
  - The air pressure reduces and hence breathing problems occur. Also, the nose may bleed.
  - A fountain pen will start leaking due to the pressure difference at a high altitude compared to the air pressure on the surface.

Weather Forecast by a Barometer

- A weather forecast is done as follows:
  - If the barometric height at a place falls, then it means that the pressure at that place has fallen, indicating the coming of a storm or cyclone.
  - If the barometric height gradually falls, then it indicates that the moisture is increasing, i.e. there is a possibility of rain.
  - A gradual increase in the barometric height means that the moisture in the air is decreasing. This indicates dry weather.
  - A sudden rise in the barometric height means a flow of air from that place to surrounding low pressure areas. This indicates extremely dry weather.
  - If there is no abrupt change in the barometric height, then it indicates that the atmospheric pressure is normal, i.e. the weather is fair.

Altimeter

- An altimeter is a device used in an aircraft to measure its altitude. Because the atmospheric pressure decreases with the increase in height above the sea level, a barometer measuring the atmospheric pressure can be used to determine the altitude of a place above the sea level.
- An aneroid barometer which has the scale calibrated in terms of height of ascent can be used as an altimeter.
- The scale of an altimeter is graduated with height increasing towards the left because the atmospheric pressure decreases with increase of height above the sea level.