ACTIVITY 8

Take two identical glass tubes A and B open at both ends. Hold them vertical and tie a balloon at the lower end of each tube. Pour some water in the tube A. Now pour mustard oil in the tube B such that its height in the tube B is same as the height of water in the tube A as shown in Fig. 3.26. You will notice that the balloon attached with the tube B bulges more than that attached with the tube A. This shows that the same height of mustard oil exerts more pressure than water. Since the density of mustard oil is more than that of water, therefore we conclude that liquid pressure increases with the increase in density of the liquid.

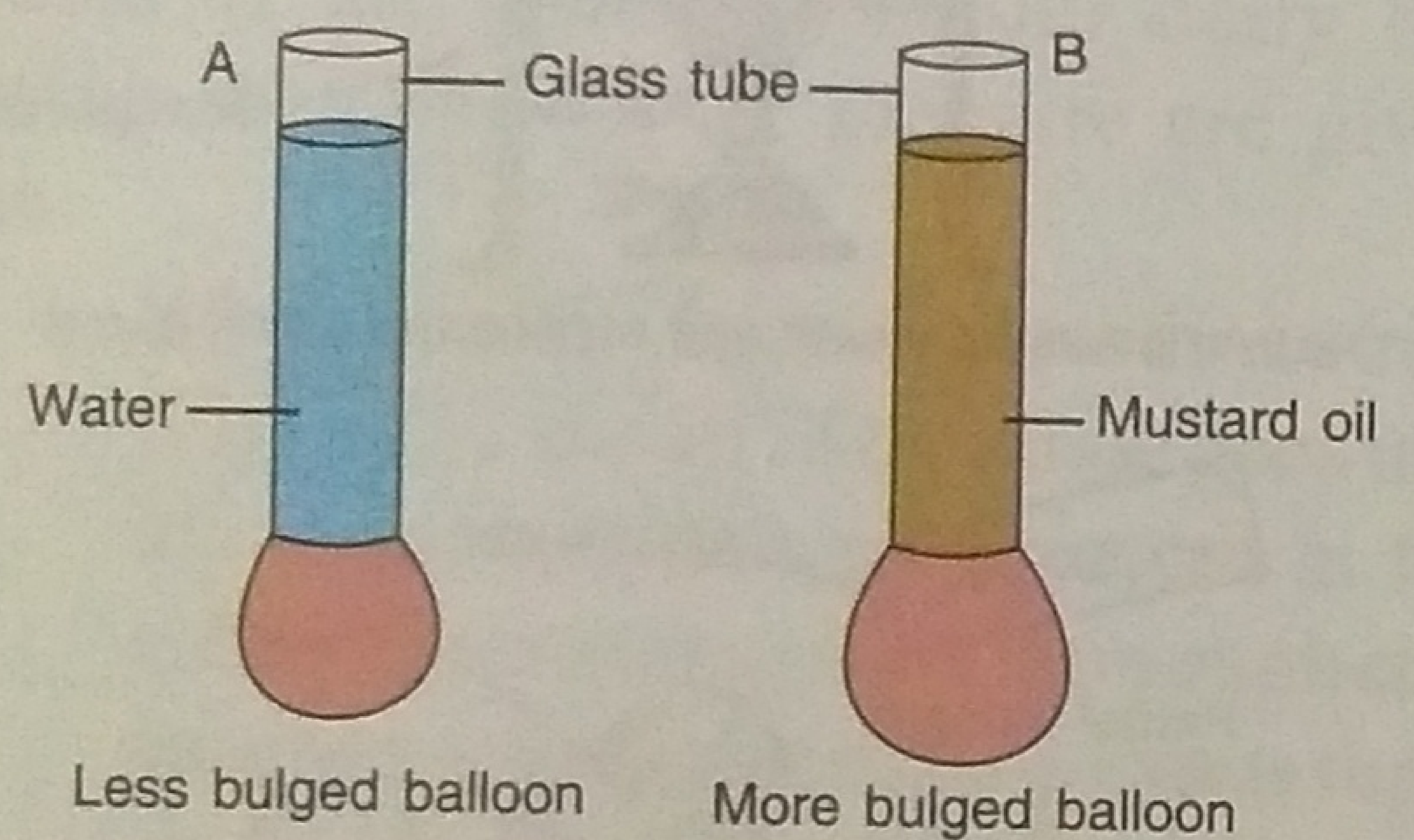


Fig. 3.26 Liquid pressure increases with increase in density of liquid

CONSEQUENCES OF LIQUID PRESSURE

Thickness of walls of a dam is increased towards the bottom : The reason is that the pressure at a point due to a liquid increases with the increase in height of the liquid column above it, so thickness of the walls of a dam is increased towards the bottom so as to withstand the increasing pressure of water (Fig. 3.27). The arrows in the figure show the increasing pressure towards the bottom of the dam.

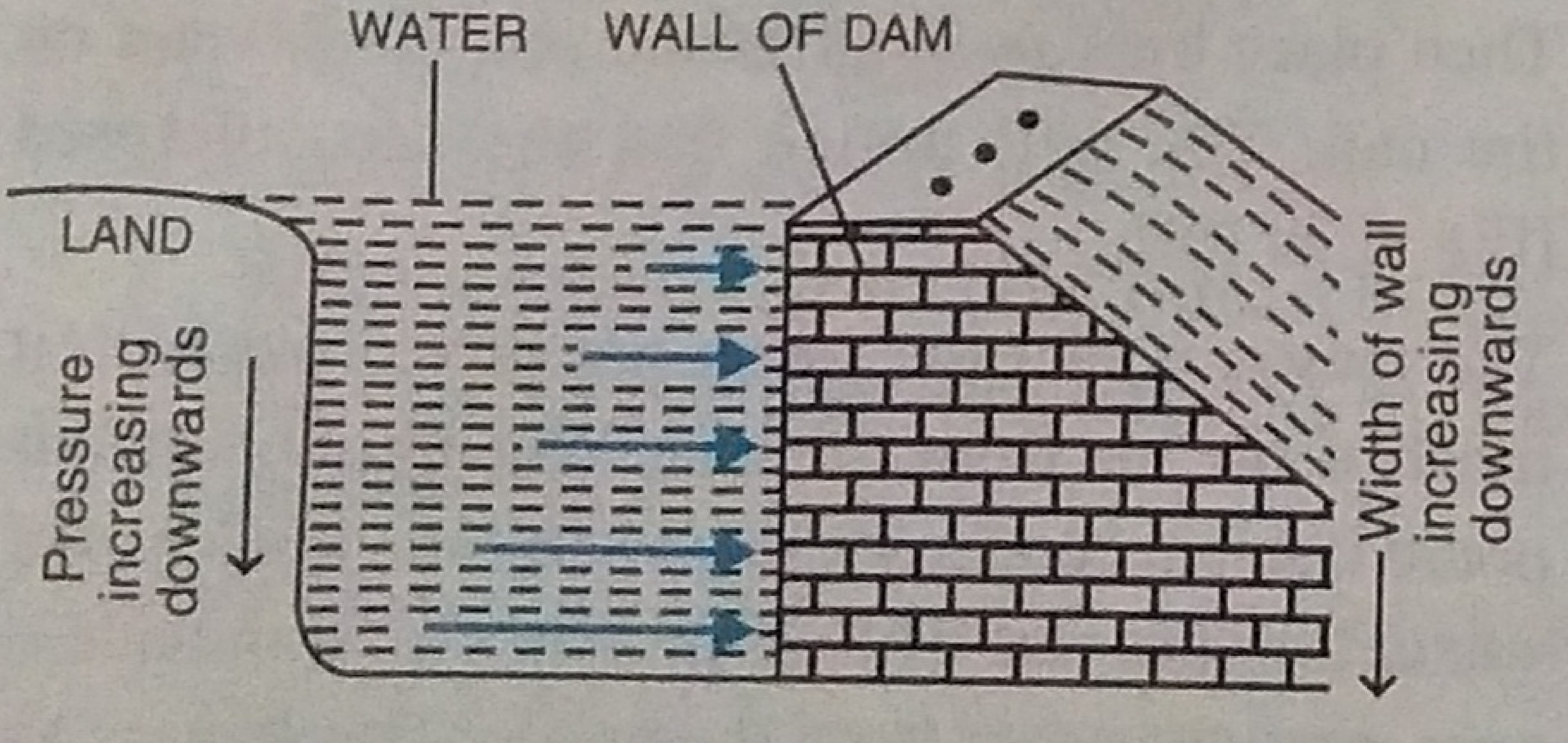


Fig. 3.27 Wall of a dam with its thickness increased towards the bottom

Do You Know ?

1. A liquid seeks its own level. The height of level of liquid in tubes of different areas of cross section always remains same, although volume of liquid is different in different tubes as shown in Fig 3.28. This is called hydrostatic paradox.

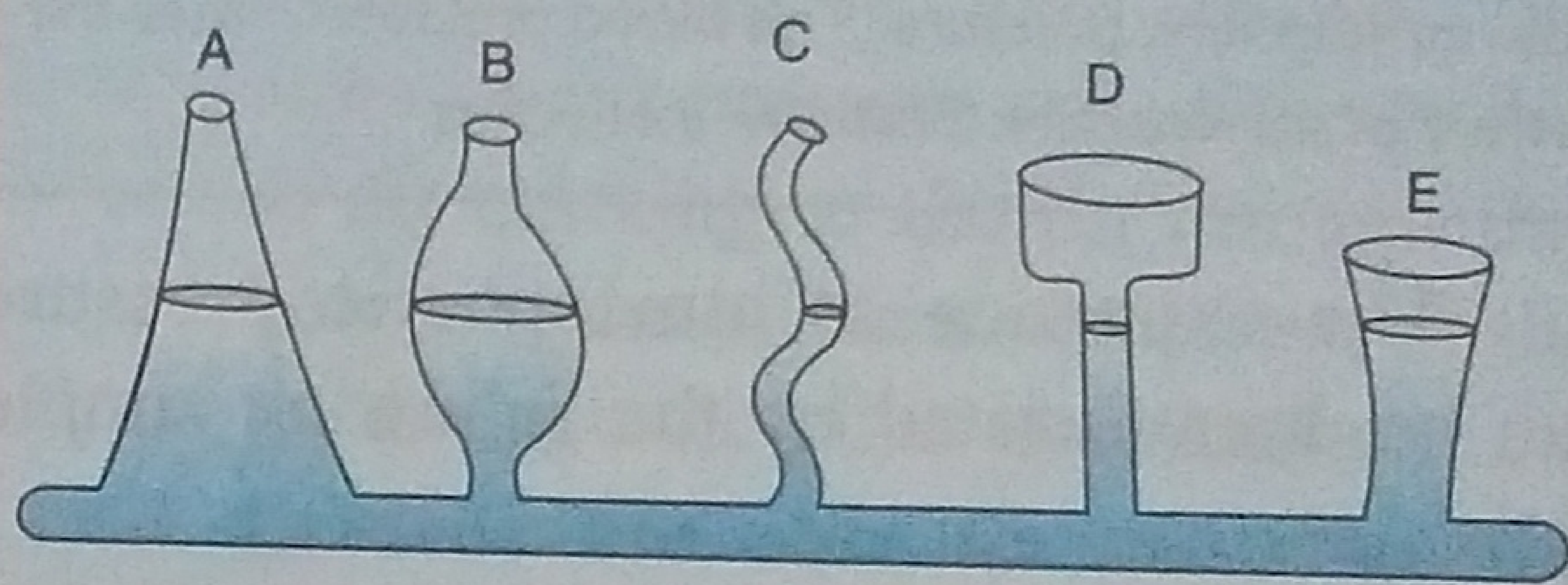


Fig. 3.28 A liquid seeks its own level

2. If a body is immersed in a liquid, the pressure of liquid on the bottom surface of body is more than at its top surface. Due to this difference in pressure, a force acts on the body (force = difference in pressure x area of surface of bottom) in the upward direction which is called the buoyant force or upthrust.

3. Pressure at any point inside the sea/ocean is much greater than that at its surface. The pressure increases with the increase in depth. That is why deep sea-divers wear specially designed swim suits to counter such high pressure.

ATMOSPHERIC PRESSURE

Like liquids, gases also exert pressure. Our earth is surrounded by air to a height of about 200 kilometre. This envelop of air around the earth is called the **atmosphere**.

Air has weight. The weight of air exerts a thrust on earth. The thrust on unit area of the earth surface due to the column of air is called the **atmospheric pressure**. This is about 10^5 N m^{-2}. Thus, a thrust of 100,000 N acts on every 1 m^2 of the surface of objects on earth.

Do You Know ?

We all are under the atmospheric pressure (=100,000 N m^{-2}). The surface area of an average human body is 2 m^2. Therefore, a total thrust of about 200,000 N acts on our body by the atmosphere. However, we are not aware of this enormous thrust since the blood in the veins of our body also exerts a pressure (called the blood pressure) which is slightly more than the atmospheric pressure. This blood pressure makes the effect of atmospheric pressure ineffective.

The existence of atmospheric pressure can be demonstrated by the following simple activities.

ACTIVITY 9

Take a glass filled with water up to its brim and place a post card on top of it as shown in Fig. 3.29. Now press the palm of your one hand on top of the post card, then invert the water filled glass (keeping it tightly closed with the post card placed) upside down. Now gently remove your hand from the post card to release it. You will observe that the post card does not fall down from the glass although the pressure due to water column in the glass acts on it. The reason is that the atmospheric pressure acting upwards on the post card from outside the glass, overcomes the pressure on post card due to water in the glass.

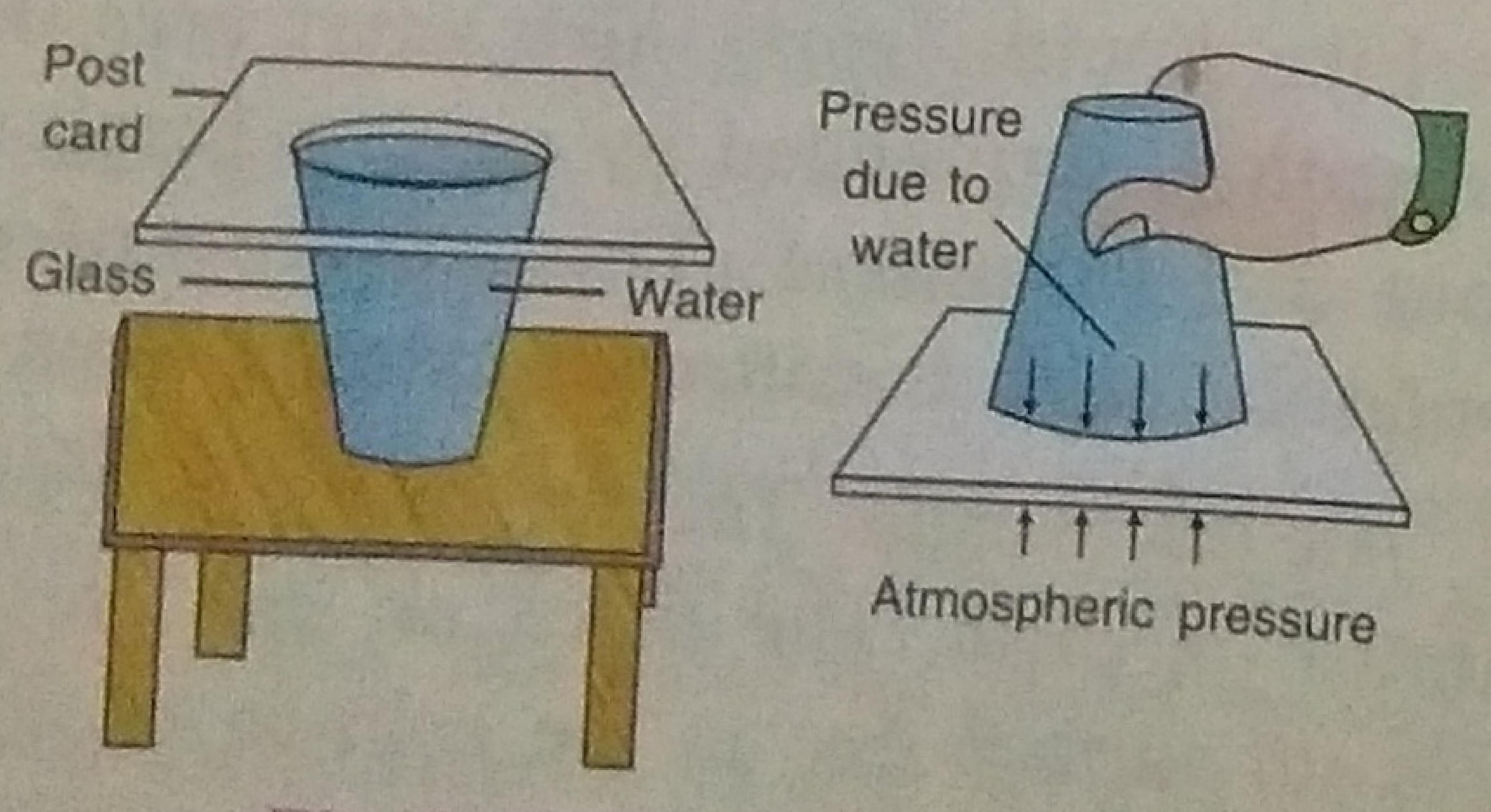
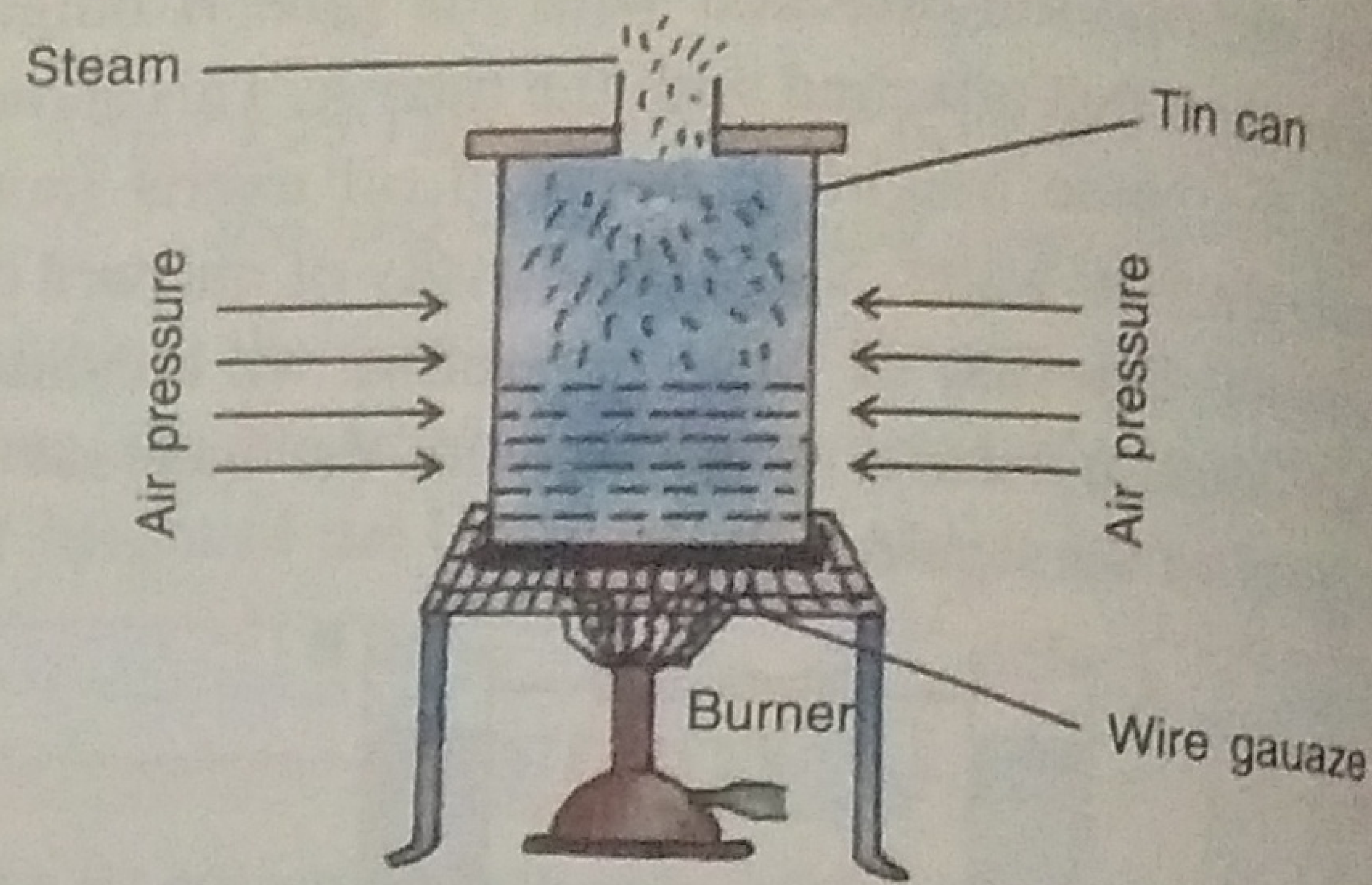


Fig. 3.29 Air exerts pressure

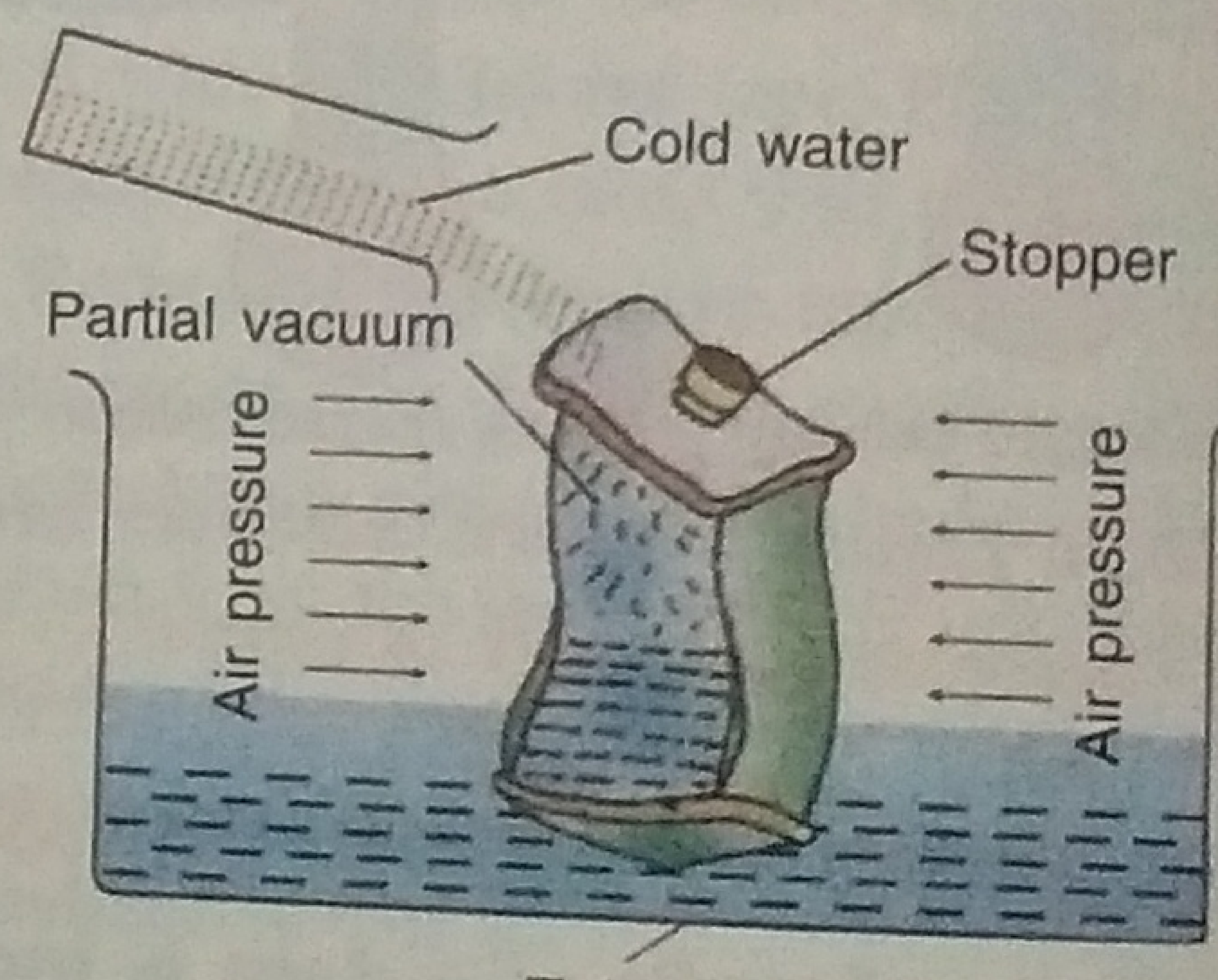
ACTIVITY 10

Crushing can experiment

Take a thin walled tin can provided with an airtight stopper. Remove the stopper. Fill the can partially with water. Heat the can over the flame of a burner till water begins to boil [Fig 3.30(a)]. Now the air pressure inside and outside the can is the same.



(a) Air pressure inside and outside the can is same



(b) Air pressure outside the can is more than that inside

Fig. 3.30 Crushing can experiment

When the steam starts coming out of the opening, put the stopper and remove the can from the burner. Then place the can in a tub and pour cold water on the can. You will notice that the can collapses [Fig. 3.30 (b)].

The reason is that the steam has driven out with it most of the air from the can. When cold water is poured, steam condenses into water, leaving a partial vacuum in the can. The air pressure from outside is now more than that from the inside. This excess air pressure from the outside exerts force due to which the can collapses.

STANDARD VALUE OF ATMOSPHERIC PRESSURE

At sea level on earth surface, the atmospheric pressure is 76 cm or 760 mm of mercury column which is equal to 1 atm or $1{\cdot}013 \times 10^5$ Pa.

Note : The atmospheric pressure decreases with increasing altitude *i.e.* as we go higher above the earth surface, the air pressure decreases.

SOME EXAMPLES IN DAILY LIFE TO SHOW THE EXISTENCE OF ATMOSPHERIC PRESSURE

Some of the examples in our daily life showing the effect of air pressure are given below:

1. When a drink is sucked with a straw (Fig. 3.21), the air of the straw goes into the lungs and thus air pressure in the straw decreases. The atmospheric pressure acting on the drink exerts force on the drink to move up into the straw and then into the mouth.

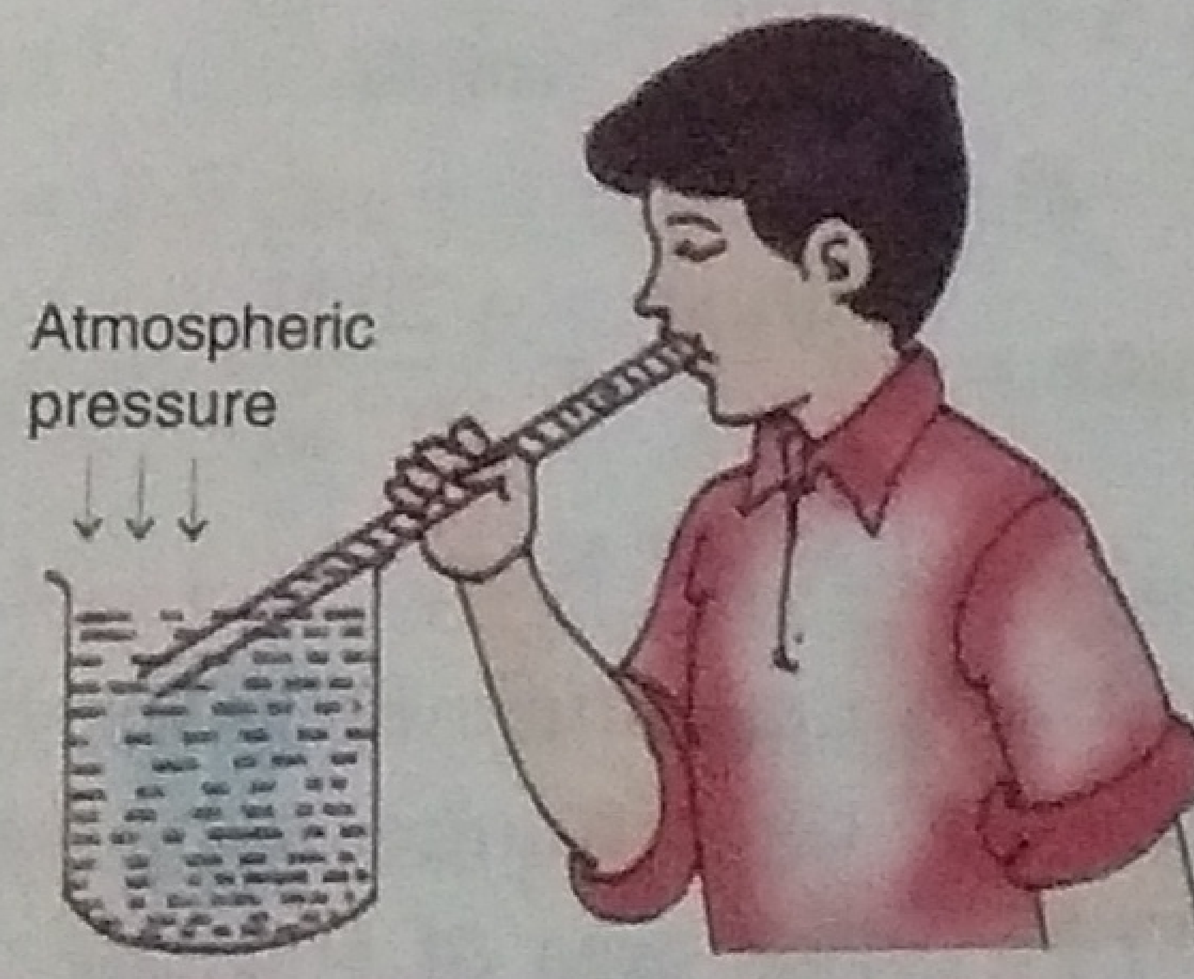


Fig. 3.31 Sucking a drink with a straw

2. When we blow air in a balloon, it bulges because of the pressure exerted by the air filled in it.
3. It is due to atmospheric pressure that ink gets filled into a fountain pen.
4. Water is drawn up from a well by a water pump because of the atmospheric pressure acting on water in the well.
5. The syringe gets filled with the liquid when its plunger is pulled up due to the atmospheric pressure acting on the liquid.
6. Rubber suckers are used as hooks in the kitchen and bathroom. They remain pressed against the wall due to the atmospheric pressure from outside.
7. It is difficult to take out oil from a sealed tin if only one hole is made in it. But if another hole is also made, the atmospheric pressure acts on the oil due to air entering in the tin through this hole and the oil then comes out of the tin through the other hole easily.
8. Lizards are able to move on the wall and stay wherever they desire. This is because their feet behave like suction pads, so they remain pressed against the wall due to the atmospheric pressure.
9. The astronauts and mountaineers have to wear special type of suits to protect themselves from adverse effects of low pressure prevailing at the great heights.
10. Nose bleeding often occurs at high altitudes. The reason is that the atmospheric pressure is low at high altitudes, but the pressure inside the human body does not change. Thus, the excess pressure inside the body compared to the atmospheric pressure, causes nose bleeding.

SOLVED EXAMPLES

1. Calculate the moment of force of 5 N applied on a body at a distance of 20 cm from a pivoted point.

RECAPITULATION

- A force when acts on a rigid body which is free to move, can produce only the change in state of rest or motion.
- A force when acts on a non-rigid body which is free to move, can produce change in state of rest or motion as well as change in size or shape of the body.
- A force requires both its magnitude and direction to represent it.
- Force is represented by an arrow. The length of arrow is a measure of its magnitude and the arrow gives its direction.
- The S.I. unit of force is newton (symbol N) and its gravitational unit is kilogram force (kgf) where

  1 kgf = 10 N (nearly).
- If a force is applied on a body which is pivoted at a point, the force can turn the body about that point. This is called the turning effect of force.
- The turning effect of a force depends on two factors : (i) the magnitude of force, and (ii) the perpendicular distance of force from the pivoted point. Greater the magnitude of force, more is the turning effect. Similarly greater the perpendicular distance of force from the pivoted point, more is the turning effect.
- The product of magnitude of force and the perpendicular distance of force from the pivoted point is called moment of force about the pivoted point, *i.e.*

  Moment of force = force (F) × perpendicular distance (d).
- The S.I. unit of moment of force is newton × metre (symbol N m).
- If a body turns towards the right, the moment of force is clockwise and negative but if the body turns towards the left, the moment of force is anticlockwise and positive.
- Thrust is a force that acts normally on a surface.
- Thrust exerted by a body on a surface is same howsoever it is placed.
- The effect of thrust depends on the area of the surface on which it acts.
- The units of thrust are kgf, gf and newton (N). They are related as :

  1 kgf = 1000 gf, 1 kgf = 10 N (nearly) and 1 N = 100 gf (nearly)
- Pressure is defined as the thrust per unit area *i.e.* Pressure $P = \frac{\text{Thrust F}}{\text{Area A}}$.
- Pressure on a surface depends on :

  (a) the area of the surface on which the thrust acts, (b) the magnitude of thrust acting on the surface.
- Smaller the surface area, more is the pressure exerted by the thrust.
- More the thrust on an area, more is the pressure.
- The pressure on a surface is increased by reducing the area of the surface and is reduced by increasing the area of the surface.
- The S.I. unit of pressure is newton per metre^2 (symbol N/m^2 or N m^{-2}) which is also called pascal (symbol Pa).
- Liquids and gases exert pressure in all directions. They exert pressure not only at the bottom, but also on the sides of the container in which they are kept.
- Pascal's law states that the pressure exerted by a liquid at a depth is same in all directions.

9. A normal force of 100 N can produce a pressure of 100000 Pa. Calculate the area in cm^2 on which the force shall act to exert the pressure.

Solution : Given, Thrust F = 100 N

pressure P = 100,000 Pa

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

$\therefore\ A = \frac{F}{P} = \frac{100}{100000}\ m^2 = \frac{1}{1000}\ m^2$

$= \frac{1}{1000} \times 10000\ cm^2 = 10\ cm^2$

10. A force of 10 N acts normally on a surface of area $0{\cdot}2\ m^2$. Find the pressure exerted on the surface.

Solution : Given, F = 10 N, A = $0{\cdot}2\ m^2$

Pressure $P = \frac{F}{A} = \frac{10\ N}{0{\cdot}2\ m^2} = 50\ N\ m^{-2}$

11. The dimensions of heel of shoes of a girl weighing 45 kgf are 1·5 cm × 1 cm. Find the pressure exerted on the ground when she is standing on one heel.

Solution : Given, F = 45 kgf,

$A = 1{\cdot}5\ cm \times 1\ cm = 1{\cdot}5\ cm^2$

Pressure $P = \frac{F}{A} = \frac{45\ kgf}{1{\cdot}5\ cm^2} = 30\ kgf\ cm^{-2}$

12. A block of weight 5 kgf and dimensions 5 cm × 2 cm × 1 cm rests on a table in three different positions with its base as (i) 5 cm × 2 cm, (ii) 2 cm × 1 cm, (iii) 1 cm × 5 cm. Calculate the pressure exerted on the table in each case.

Solution : Given, In each case, F = 5 kgf

(i) In the first case,

$A = 5\ cm \times 2\ cm = 10\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{10\ cm^2} = 0{\cdot}5\ kgf\ cm^{-2}$

(ii) In the second case,

$A = 2\ cm \times 1\ cm = 2\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{2\ cm^2} = 2{\cdot}5\ kgf\ cm^{-2}$

(iii) In the third case,

$A = 1\ cm \times 5\ cm = 5\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{5\ cm^2} = 1\ kgf\ cm^{-2}$

13. A girl weighing 50 kgf wears sandals of pencil heel of area of cross section 1 cm^2, stands on a floor. An elephant weighing 2000 kgf stands on foot each of area of cross section 250 cm^2, on the floor. Compare the pressure exerted by them.

Solution : Given, for girl: Weight or force F_1 = 50 kgf

Area of both heels

$A_1 = 2 \times 1\ cm^2 = 2\ cm^2$

Pressure $P_1 = \frac{F_1}{A_1} = \frac{50\ kgf}{2\ cm^2} = 25\ kgf\ cm^{-2}$

For elephant, Weight = force F_2 = 2000 kgf

Area of four feet

$A_2 = 4 \times 250\ cm^2 = 1000\ cm^2$

Pressure $P_2 = \frac{F_2}{A_2} = \frac{2000\ kgf}{1000\ cm^2} = 2\ kgf\ cm^{-2}$

now, $\frac{\text{Pressure exerted by girl}}{\text{Pressure exerted by elephant}} = \frac{P_1}{P_2}$

$= \frac{25\ kgf\ cm^{-2}}{2\ kgf\ cm^{-2}} = 12{\cdot}5 : 1$

Thus, the girl's pointed heel sandals exert 12·5 times more pressure than the pressure exerted by the elephant.