5 Pressure Exerted by Solid

5.1 Pressure

You may have experienced that, when the strap of your school bag is narrow, it is uncomfortable to the shoulder. When it is broad it is not that uncomfortable.

(a) A child bearing a bag with a narrow strap uncomfortably

(b) A child bearing a bag with a broad strap easily

Figure 5.1

There are two school bags of equal weight. The shoulder strap of one of them is narrow and that of the other one is broad. Though, the strap is narrow or broad, the force exerted by the weight of school bag is the same. But, when the strap of it is narrow, the contact area is less, and when it is broad that area is more.

Thus it is clear that, though the force is the same, the pressure against the shoulder differs with the area of contact of the strap.

Consider two bags having the straps of the same breadth and different weights of books. The bag with more weight gives more press against the shoulder.

(a) A child bearing a light-weight bag easily

(b) A child bearing a heavy bag uneasily

Figure 5.2

The force exerted by the weight of the school bag, is distributed through out the area of contact. It is the distributed force, that is felt by the shoulder.

When the strap of the bag is broad, the force is distributed over a large area. Hence, the pressure felt by the shoulder is less. In these instances, it is useful to know the force exerted over a unit area.

The force exerted over a unit area is known as the pressure.

5.2 Factors affecting the pressure

Let us do activity 5.1 to study the factors affecting the pressure.

Activity 5.1

You will need :- Several cakes of soap, thin metal wire, several bags of sand with the weight of 10 N each, a piece of plank which is longer than the length of the cake of soap and similar in breadth of the same, a stop watch

Method :-

- Place the cake of soap on the plank which is kept on two tables as shown in the figure 5.3.
- Hang one sand bag on the wire which is sent round the cake of soap. Observe what happens.

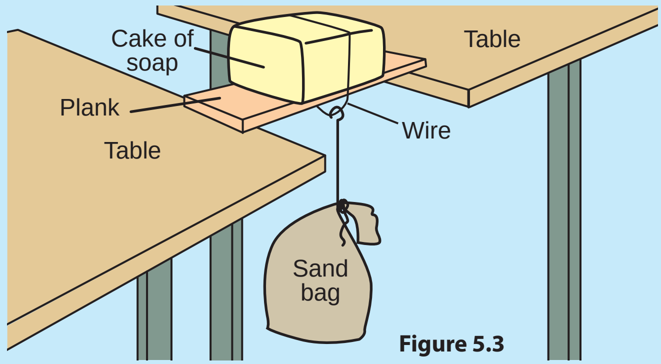


Figure 5.3

- Increase the number of sand bags one by one using a new cake of soap in each instance. Measure the time taken to pass the metal wire through each cake of soap.
- Tabulate your readings as shown below.

Table 5.1

Instance	No. of sand bags hung	Weight of sand bags (N)	Time taken to cut through the cake of soap (s)
01	01	10	-
02	02	20	
03			
04			

In the activity 5.1, sometimes one sand bag will not be enough for the wire to cut through the cake of soap. If it is so, the reason is that the force exerted by the weight of one sand bag is not enough to cut the cake of soap. When the number of sand bags are being increased, time taken for the wire to cut through the cake of soap becomes less.

Two facts are revealed by this activity. They are;

- Force affects the pressure exerted on a solid object.
- Pressure increases with the increase of force.

These facts are confirmed by the activity 5.2.

Activity 5.2

You will need :-

A piece of plank with the size of 15 cm × 10 cm × 1 cm, a piece of plank with the size of 20 cm × 15 cm × 1 cm, a wooden block with the size of 15 cm × 10 cm × 5 cm, a piece of sponge with the size of 15 cm × 10 cm × 5 cm, four 1” nails, a ruler of 15cm or scale, weight of 2 kg, weight of 5 kg, a hammer, a Newton spring balance

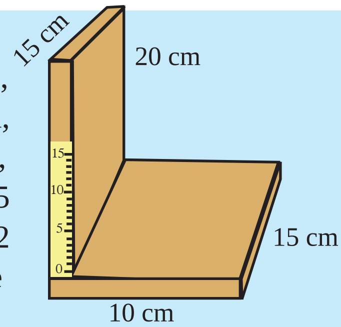


Figure 5.4 a

Method :-

- Fix the planks of the sizes 20 cm × 15 cm × 1 cm and 15 cm × 10 cm × 1 cm as shown in the figure 5.4 a, with nails. Paste the scale of 15 cm along 20 cm long vertical side of the plank.
- Place the piece of sponge on the horizontal plank as shown in the figure 5.4 b.
- Note down the reading of the scale, which is relevant to the upper horizontal edge of the piece of sponge.

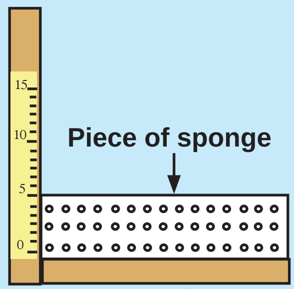


Figure 5.4 b

- Weigh the wooden block of 15 cm × 10 cm × 5 cm using the Newton spring balance.
- Now, place this wooden block on the piece of sponge, as shown in figure 5.4 c. Note down the new reading of scale at the upper edge of the piece of sponge.

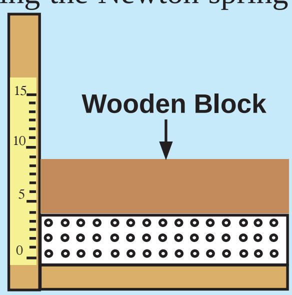


Figure 5.4 c

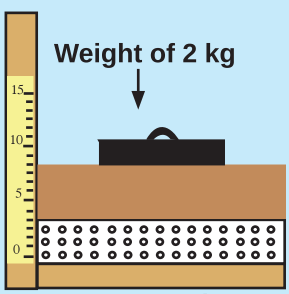


Figure 5.4 d

- Then place the weight of 2 kg on the wooden block as shown in figure 5.4 d and take the reading of the upper edge of the piece of sponge as before.
- Next, remove the weight of 2 kg and place the weight of 5 kg on the wooden block and take the reading.
- Tabulate the readings, you obtained as below in the table 5.2.

Table 5.2

Instance	Force exerted on the piece of sponge (N)	Reading at the upper edge of the piece of sponge (cm)	Reduction of the height of sponge (cm)
Sponge only			
Wooden block on the sponge			
Wooden block and weight of 2 kg on the sponge			
Wooden block and weight of 5 kg on the sponge			

In every instance of the above activity, the area of the wooden block, in contact with the piece of sponge is the same. The force exerted on the piece of sponge is increased gradually. Accordingly, the contraction of the sponge is also increased. Thus, it is clear that the pressure on the piece of sponge is increased gradually. Therefore, it can be concluded that the pressure increases with the increase of force.

Activity 5.3

You will need :- A cake of soap, a piece of thin wire with the diameter of 0.2 mm, a piece of thick wire with the diameter of 1.5 mm, a sand bag of the weight of 20N, a piece of plank which is similar in breadth the cake of soap

Method :-

- Place the piece of plank between two table-tops and keep the cake of soap on the plank as shown in figure 5.5.
- Send the thick wire round the cake of soap and hang the sand bag of 20 N weight. Observe what happens.

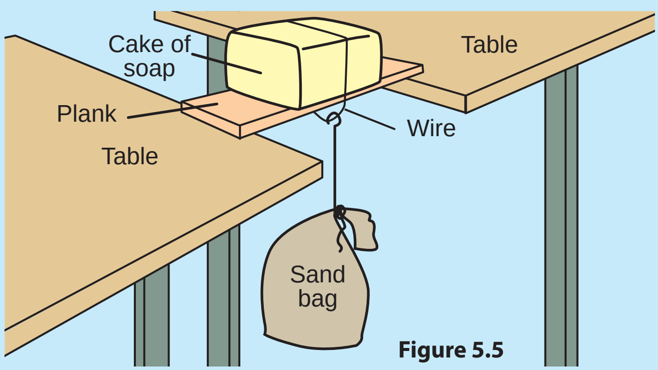


Figure 5.5

- Remove the thick wire and repeat the above step using the thin wire. Observe what happens again.
- What can be concluded according to the observations you made?

In the activity 5.3 above, same weight is used in both instances; with the thick wire as well as with the thin wire. Hence, the force exerted on the cake of soap is the same in both instances. But, the cake of soap is cut through easily when the thin wire is used. The reason for this is that the force acted on unit area of the cake of soap is greater when the thin wire is used. That means, the pressure is greater when thin wire is used, than when the thick wire is used. Cutting through the cake of soap is easier when more pressure is exerted.

The manner the pressure changes according to the area on which force is acted, can be understood further by doing the activity 5.4.

Activity 5.4

You will need :-

A piece of plank with the size of 15 cm × 10 cm × 1 cm,
a piece of plank with the size of 20 cm × 15 cm × 1 cm,
a wooden block (A) with the size of 15 cm × 10 cm × 5 cm,
a piece of sponge (B) with the size of 15 cm × 10 cm × 5 cm,
a piece of sponge (C) with the size of 15 cm × 5 cm × 5 cm,
a piece of sponge (D) with the size of 10 cm × 5 cm × 5 cm,
four 1” nails, a scale of 15 cm, a hammer a Newton spring balance

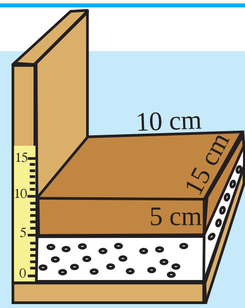


Figure 5.6 a

Method :-

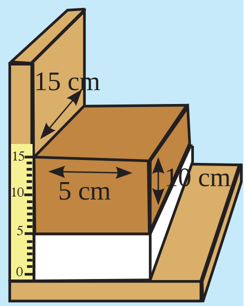


Figure 5.6 b

- Weigh the wooden block using the spring balance.
- Paste the scale of 15 cm on to the L shaped frame made as in the activity 5.2.
- Now place the sponge B on the plank. Note down the reading of the scale relevant to the upper horizontal edge of the sponge.
- Then place the 15 cm × 10 cm surface of the wooden block on the sponge as shown in figure 5.6 a.
- Note down the new reading of the scale relevant to the upper horizontal edge of the sponge.
- Now remove the sponge B and place the sponge C on the plank as shown in figure 5.6 b (place the 15 cm × 5 cm surface horizontally). Note down the reading of the scale relevant to the upper horizontal edge of the sponge.
- Then place the 15 cm × 5 cm surface of the wooden block on the sponge. Note down the reading of the scale relevant to the upper horizontal edge of the sponge.

- Now remove the sponge C and place the sponge D on the plank (place the 10 cm × 5 cm surface horizontally). Note down the reading relevant to the upper horizontal edge.
- Then place the 10 cm × 5 cm surface of the wooden block on the 10 cm × 5 cm surface of the sponge. Now take the reading of the upper edge of the sponge.
- Tabulate your readings as below.

Table 5.3

Instance	Force exerted on the surface (N)	Contact surface area (cm^2)	Height of the sponge (cm)	Reduction of the height of sponge (cm)
Sponge B only				
When wooden block contacts its 15 cm × 10 cm surface				
Sponge C only				
When wooden block contacts its 15 cm × 5 cm surface				
Sponge D only				
When wooden block contacts its 10 cm × 5 cm surface				

- What is the conclusion that can be made according to the observations?

During this activity, same wooden block is kept on all sponges. Therefore, the force exerted on all different sponges is the same. But, the contact area of the wooden block on each piece of sponge is changed.

When the contact area is large, the contraction of the sponge is less and when that area is less, the contraction of sponge is higher.

Therefore, it is clear that the pressure is less, when the contact area is high and vice-versa.

Accordingly, it can be concluded as follows.

- The pressure exerted by a solid object on a solid surface depends on the surface area on which the force is acting.
- Higher the surface area on which the force is acting pressure become low.
- Lower the surface area on which the force is acting pressure become high.

According to the above activities it is confirmed that the pressure exerted by a solid object on a solid surface depends on two factors. They are;

1. Perpendicular force acting on the surface
2. Surface area on which the force is acting

Pressure is defined as the perpendicular force acting normally on an unit area. Pressure exerted by a solid object on a solid surface can be calculated according to the following formula.

$$\text{Pressure } (P) = \frac{\text{Perpendicular force } (F)}{\text{Surface area on which the force is acting } (A)}$$

5.3 Units of pressure

Units of pressure can be deduced by using the above relationship of pressure. The standard unit of measuring force is N (Newton) and the standard unit of measuring surface area is m^2 (square metre).

$$\text{Pressure} = \frac{\text{Perpendicular force}}{\text{Surface area on which the force is acting}}$$

$$\text{Pressure} = \frac{N}{m^2}$$

$$= Nm^{-2} \text{ (Newtons per square meter)}$$

The standard unit of measuring pressure is Nm^{-2}. It is also known as Pascal (Pa). In honour of the French mathematician Blaise Pascal unit of pressure was named after him.

$$1\ Nm^{-2} = 1\ Pa.$$

Let us pay our attention to the solved problems on pressure.

Solved example 1: What is the pressure exerted on a surface of 2 m^2, when a normal force of 300 N is acting on it?

$$\text{Pressure} = \frac{\text{Perpendicular force}}{\text{Surface area on which the force is acting}}$$

$$= \frac{300\ N}{2\ m^2}$$

$$= 150\ Nm^{-2} \text{ or } 150\ Pa$$

Solved example 2: Weight of a cubic box is 400 N. It is kept on a horizontal plane surface. Pressure exerted by the box on the surface is 200 Pa. What is the contact area of the surface of the box?

$$\text{Pressure} = \frac{\text{Perpendicular force}}{\text{Surface area}}$$

$$\text{Surface area} = \frac{\text{Perpendicular force}}{\text{Pressure}}$$

$$\text{Surface area} = \frac{400\ N}{200\ Nm^{-2}}$$

$$\text{Surface area} = 2\ m^2$$

5.4 Changing the factors affecting pressure as needed

When cutting something it is easier if the knife is well sharpened. When sharpening, the knife-edge becomes very thin. It can exert a high pressure on the object. So, the object can be cut thinner and easier (figure 5.7).

Figure 5.7

The bottom of the skates used by skiers is made sharp like a knife-edge. Because of this, a high pressure is exerted on ice, when the skier is skating. That high pressure makes the ice liquify and form a slippery surface.

Figure 5.8

Roads can be easily damaged because of the high pressure exerted by heavily loaded trucks and container carriers. To avoid this, such vehicles are made with a large number of wheels. Then, the contact area with the road is increased and the pressure is decreased. Hence, the damages to the roads are minimized.

Figure 5.9

Assignment 5.1

In our day-to-day activities, we have to increase or decrease pressure. One way of doing this is the change of surface area. List such instances and explain them scientifically.

Summary

- Pressure is defined as the perpendicular force acting on an unit area.
- The pressure exerted by a solid object on a solid surface depends on two factors. They are,
    - Perpendicular force acting on the surface
    - Surface area on which the force is acting
- $$\text{Pressure } (P) = \frac{\text{Perpendicular force } (F)}{\text{Surface area } (A)}$$
- The unit of measuring pressure is Nm^{-2} / N/m^2 or Pascal (Pa).
- Pressure can be increased or decreased by manipulating the factors which are affect on pressure.

Exercise

01) Select the correct or most suitable answer.

1. What is the unit of measuring pressure?

    1. Nm^2 2. Nm 3. Nm^{-1} 4. Nm^{-2}

2. What is the unit of measuring pressure, that indicates specific name.

    1.Newton 2. Joule 3. Pascal 4. Watt

3. Consider the following statements of pressure.

    a. Pressure is equal to the ratio, $\frac{\text{Perpendicular force}}{\text{Surface area}}$

    b. Pressure increases when perpendicular force is increased.

    c. Pressure increases when surface area is increased.

    Which of the above statements are true?

    1. a and b only 2. a and c only
    3. b and c only 4. a, b and c

4. A perpendicular force of 60 N was applied on an area of 3 m^2. What is the pressure exerted on the surface?

    1. $\frac{1}{60\text{ N} \times 3\text{ m}^2}$ 2. $\frac{3\text{ m}^2}{60\text{ N}}$ 3. $\frac{60\text{ N}}{3\text{ m}^2}$ 4. $60\text{ N} \times 3\text{ m}^2$

5. The pressure was 50 Pa, when a perpendicular force was applied on a surface area of 2.5 m^2. The force applied was;

    1. $\frac{1}{25}$ N 2. $\frac{1}{20}$ N 3. 20 N 4. 125 N

06. In which of these instances, the devices are applied to decrease pressure?


1


2


3


4

02) Answer the following questions.

1. (a) What are the units of pressure?

   (b) Mention the factors affecting pressure.

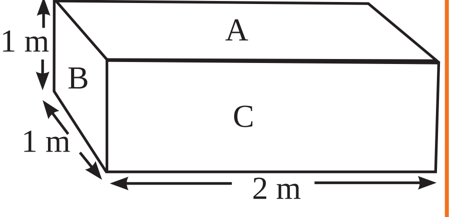
   (c) Write down a relationship for pressure in terms of those factors.

2. (a) Write two examples where the factor, area is practically used to increase pressure.

   (b) Mention two examples where the factor, area is practically used to decrease pressure.

   (c) State two examples where the factor, perpendicular force is practically used to increase pressure.

03) The length, breadth and height of the cuboid shown in the figure are 2 m, 1 m and 1 m respectively. Its weight is 400 N.



(a) The cuboid is kept on a horizontal surface as shown in the figure. How much is the pressure acting on the surface?

(b) While the cuboid is in the position as in part (a), an object weighing 150 N is kept on it. Then, what is the pressure acting on the horizontal surface.

(c) The object weighing 150 N is removed and the cuboid is kept to contact its surface B with the horizontal surface. Then, what is the pressure exerted on the horizontal surface?

04) (a) The figure shows a machinery used in the construction of roads. Clarify how the factors affecting pressure are changed, to change the pressure exerted by this machine on the road.

(b) Factors affecting pressure are used to increase pressure in the life activities in nature. Give two examples for applications in day-to-day life which are adopted by natural adaptations of living beings.

(c) Factors affecting pressure are used to decrease pressure in the life activities in nature. Give two examples for applications in day-to-day life which are adopted by natural adaptations of living beings.

Technical Terms

Pressure	- පීඩනය	- அமுக்கம்
Perpendicular force	- අභිලම්බ බලය	- செங்குத்து விசை
Surface area	- පෘෂ්ඨ වර්ගඵලය	- மேற்பரப்பின் பரப்பளவு
Pascal	- පැස්කල්	- பஸ்கால்