Gravitation - Lesson 16
Thrust vs Pressure

Consider this scenario. You are trying to fix a nail on your wall with a hammer. You hit the nail with some amount of force, let's say, and the nail is fixed. What if you tried to hit the nail and missed and directly hit the wall with the hammer with the same force? What would happen in that case? Will the hammer also go inside the wall as the nail went in? No, it will not. But why? The force applied is the same, then what is the difference?

The above scenario shows us that we cannot describe every physical event happening around us just by knowing the amount of force. This is what physics is; we try to explain the physical events around us. Apart from the force, we need to know that on how much area the force is acting. If the force is acting on a teeny-tiny bit of area, like in the case of the nail, it will impact that part of the wall. Suppose the area is larger, as, in the case of a hammer directly hitting the wall, the force is spread across a region. This will allow the wall to withstand the force, and the hammer does not go inside the wall. This happens due to something called pressure. But before we define pressure formally, we need to understand another bit of data that we overlooked.

What if you hit the nail at an angle? What would happen? The nail would bend and go inside the wall in a crooked manner. But will it pierce the wall as quickly as in the case when you were

hitting it head-on? No, it will not. Something's changed in the second case. Not only does the area matter, but we also need to know the component of force hitting directly perpendicular to the wall. This component (perpendicular) of force will push the nail in, and the rest is used to bend the nail. This perpendicular component is called the thrust, and the thrust acting per unit area is known as the pressure. Thrust is a component of force; thus it has units of force, i.e., Newtons, but the pressure is thrust divided by area,

$$Pressure = \frac{Thrust}{Area}$$

this will have units of $N\,m^{-2}$, which is also called PaPa (Pascal), in honour of the 17th century French Scientist Blaise Pascal.

$$g_{relative} = \frac{g_{moon}}{g_{earth}}$$
$$g_{relative} = \frac{1.621}{9.8}$$
$$g_{relative} = \frac{1}{6}$$

This concept can also explain why we have a hard time standing for long hours but can sleep for the same time without any problem. This is because when we are standing, the weight is concentrated on the legs and bones inside our legs are under enormous pressure, so after some time, the bones and muscle in our legs get tired and exhausted. While sleeping, our weight is distributed about the whole back of our body, making it easier to sleep for long hours. This is why we are comfortable sitting or sleeping rather than standing.

Let us look at a few examples:

1. **Example 1:** How much is the thrust applied by a person having a mass of 40 kg, considering the person is standing perpendicular to the surface?

   Answer
   Thrust is the force which is perpendicular to the surface, in this case the weight is that force. Hence,

   $$Thrust = weight = m \times g = 40 \times 9.8 = 382\ N$$

2. **Example 2:** We have about $51,615\ kg$ of air per $5\ m^2$ above our heads due to the atmosphere. What is the pressure exerted?

Answer

$$\begin{aligned} Thrust = F &= m \times g \\ &= 51,615\ kg \times 9.8\ m\ s^{-2} \\ &= 5,05,827\ N \end{aligned}$$

$$\begin{aligned} Pressure &= \frac{Thrust}{Area} \\ &= \frac{5,05,827\ N}{5\ m^2} \\ &= 101165.4\ N\ m^{-2}, or \\ &= 1.01 \times 10^5\ Pa \end{aligned}$$

This value is also known as the atmospheric pressure at sea level.

3. **NCERT Example:** A block of wood is kept on a tabletop. The mass of wooden block is 5 kg and its dimensions are 40 $cm \times 20\ cm \times 10\ cm$. Find the pressure exerted by the wooden block on the table top if it is made to lie on the table top with its sides of dimensions (a) 20 $cm \times 10\ cm$ and (b) 40 $cm \times 20\ cm$.

Answer

The mass of the wooden block = 5 kg

The dimensions = 40 $cm \times 20\ cm \times 10\ cm$

Here, the weight of the wooden block applies a thrust on the table top. That is,

$$\begin{aligned} Thrust = F &= m \times g \\ &= 5\ kg \times 9.8\ m\ s^{-2} \\ &= 49\ N \\ \text{Area of a side} &= \text{length} \times \text{breadth} \\ &= 20\ cm \times 10\ cm \\ &= 200\ cm^2 = 0.02\ m^2 \\ \text{Pressure} &= \frac{49\ N}{0.02\ m^2} \\ &= 2450\ N\ m^{-2} \end{aligned}$$

When the block lies on its side of dimensions 40 $cm \times 20\ cm$, it exerts the same thrust.

$$\begin{aligned} \text{Area} &= \text{length} \times \text{breadth} \\ &= 40\ cm \times 20\ cm \\ &= 800\ cm^2 = 0.08\ m^2 \\ \text{Pressure} &= \frac{49\ N}{0.08\ m^2} \\ &= 612.5\ N\ m^{-2} \end{aligned}$$

The pressure exerted by the side 20 $cm \times 10\ cm$ is 2450 $N\ m^{-2}$ and by the side 40 $cm \times 20\ cm$ is 612.5 $N\ m^{-2}$.

You should, now, be able to answer the following questions:

1. What is the difference between Force, Thrust and Pressure? Also, mention their respective SI units.
2. Why it is advised to lay flat when stuck in wet sand?
3. In which case the pressure is maximum?
   (a) Standing up
   (b) Lying flat

Conclusion

Thrust is the perpendicular component of the force applied on a surface and Pressure is the thrust acting per unit area.

Note to Teacher

The purpose of the text is describe Force, thrust and pressure in comparitive but distinctive manner. Eventhough, they all seem to be similiar and relative, they are quite different. These are not independet concepts, they are introduced to address different situations in real-life. For some scenarios Force might be an apt description, for other thrust or pressure. The text also illustrates the importance of these concepts through different examples.

Student Worksheet

1. What are the SI units of thrust?
2. What are the SI units of pressure?

3. How much is the thrust applied by a person weighing 40 *Kg*, assuming standing upright?
4. If the thrust applied by a person is 500 *N*, what is the person's mass? Assume that the person is standing upright.
5. A person is pushing a block of wood weighing 20 *kg* with 100 *N* of force along the surface. What is the thrust applied by the block on the floor?
6. Why are concrete slabs laid down beneath the railway tracks?

Answers

1. **Force is a push or pull.** It acts in the direction it is applied. It's SI units is Newtons or *N*.

   Thrust is the force acting perpendicular to a surface. It is also measured in *N*.

   Pressure is thrust acting per unit area. It is measured in $N\,m^{-2}$ or *Pa*.

2. Laying flat will increase the surface area of the body and hence distribute the force, which will stop the person from drowning further.

3. (a) Standing up

Student Worksheet Answers

1. *Newtons* or *N*

2. $N\,m^{-2}$ or *Pa*

3. Thrust is the perpendicular component of the force. As the person is standing upright, all the weight is perpendicular to the surface. Hence,

$$\begin{aligned} Thrust = weight &= m \times g \\ &= 40 \times 9.8 \\ &= 392\ N \end{aligned}$$

4. As the person is standing upright, thrust = weight. Hence,

$$\begin{aligned} Thrust = weight &= m \times g \\ &= 500\ N \\ \implies m &= \frac{500}{9.8} \\ &= 51.02\ kg \end{aligned}$$

5. Thrust is the force perpendicular to the surface. Therefore net thrust is only the box's weight = $m \times g = 20 \times 9.8 = 196\ N$

6. To distribute the force of the passing train evenly