4

Pressure

SYLLABUS

The concept of pressure and force acting per unit area. Simple calculations based on the formulae : Pressure = $\frac{\text{Force}}{\text{Area}}$ *i.e.*, $P = \frac{F}{A}$. A few examples from daily life.

PRESSURE

Let us try to know how things move and how the moving things come to rest. A door cannot open on its own unless some pull or push is applied to it. Similarly, to move a ball we need to kick it, throw it or hit it. On the other hand, to stop a moving ball coming towards you, you either catch it or stop it by your foot or hand or body. To sum up we say, to make an object move or to bring a moving object to rest, we have to apply force. Thus, force is the push or pull applied to move or stop a moving object.

The effect or magnitude of force applied to an object depends upon the area of the surface on which it acts. For the same force, this effect is less if it acts on a larger area while the effect is more if force acts on a smaller area.

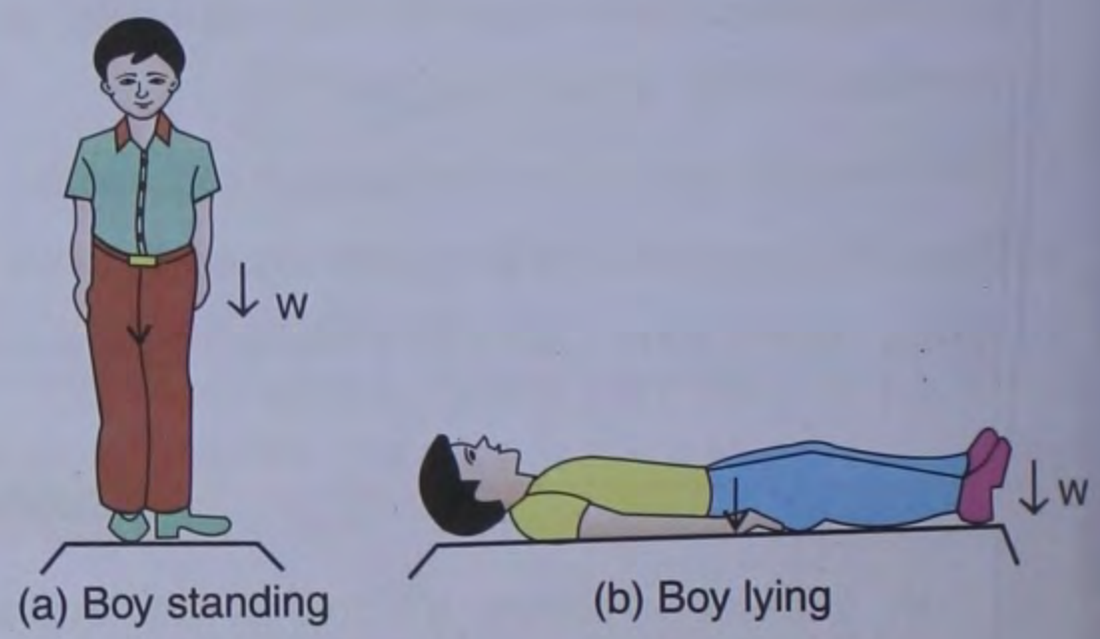


Fig. 4.1 Standing and lying positions exert the same force but different pressures

For example, when a boy stands erect, he exerts a force equal to his own weight. Suppose, he lies down on the ground, he will again exert a force equal to his own weight. But the effect of the force in both the cases will be different because while standing, the area on which the force is acting is small, hence the effect of the force will be more. However, while the boy is lying, the effect of the force will be less as the force will get distributed on a larger area.

The force acting normally on unit area of

a surface is called **pressure** and it is written as,

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}} \quad \text{or} \quad P = \frac{F}{A}$$

Pressure depends on :

(a) *The magnitude of the force applied i.e.,* greater the magnitude of force more is the pressure.

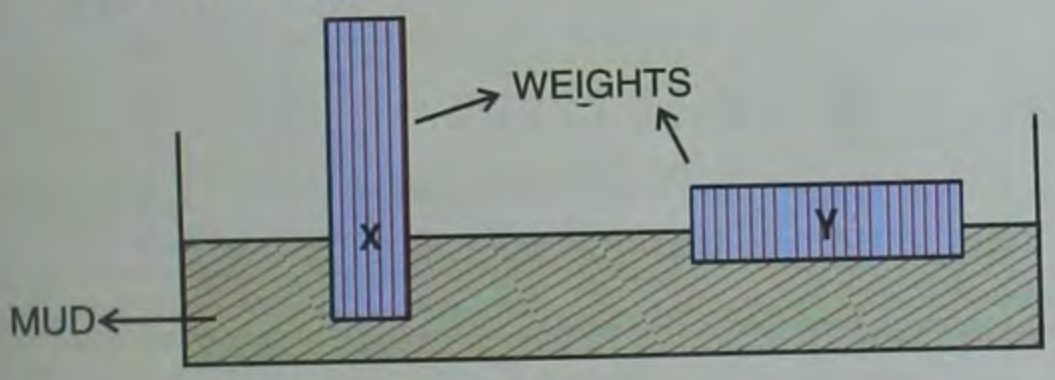
(b) *The area over which the force is applied i.e.,* bigger the area on which the force is applied, lesser will be the pressure (Fig. 4.2).

Thus, for a fixed area of contact, the pressure exerted increases with increase in force.

And for a given force, greater the area of contact, lesser is the pressure exerted by it.

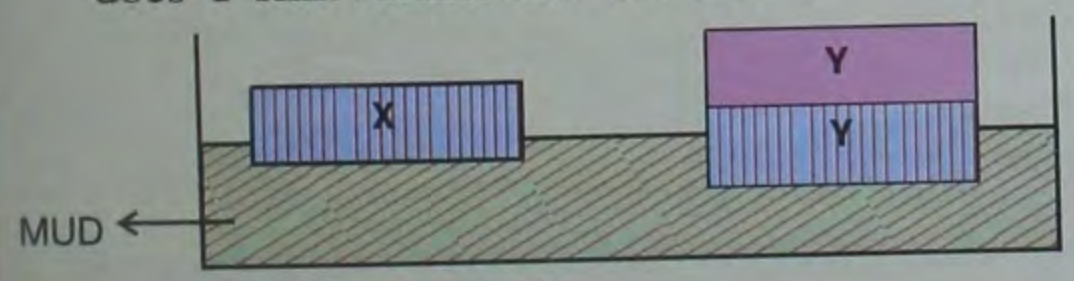
ACTIVITY 1

1. Take two rectangular blocks of iron having the same weight. Place them in mud as shown in Fig. 4.2(*a*). Which block X or Y will sink into the mud deeper ?



(a)

2. Now place both blocks sidewise and keep an additional block of the same size and weight over block Y as shown in Fig. 4.2(*b*). Why does Y sink further into the mud ?



(b)

Fig. 4.2 Pressure depends on force and area

Unit of Pressure

In S.I. units, pressure is measured in newton per square metre or N/m^2. One newton per square metre is called one Pascal and is expressed as Pa. This unit has been derived from the unit of force *i.e.,* Newton (N) and unit of area *i.e.,* square metre (m^2).

$$\text{Unit of Pressure} = \frac{1\,\text{Newton}}{1\,\text{m}^2}$$

$$= 1\ N/m^2 \text{ or } 1\ N\ m^{-2}$$

$$= 1 \text{ Pascal or } 1 \text{ Pa.}$$

The bigger unit of pressure is called kilo Pascal (kPa).

$$1 \text{ kPa} = 1000 \text{ Pascals}$$

Blaise Pascal was a physicist as well as a mathematician. He did a lot in the field of atmospheric pressure, hence the unit of pressure was named after him.

Knowledge bank

Commonly the unit 1 atm is taken as the unit of pressure

1 atm = 76 cm of mercury column
= 760 mm of mercury column

Pressure Depends on Force and Area

Let us conduct the following activity to understand the concept of pressure more precisely.

ACTIVITY 2

Push a *sharp pin* into a piece of wood as shown in Fig. 4.3. Also, try to push a *nail* with your thumb

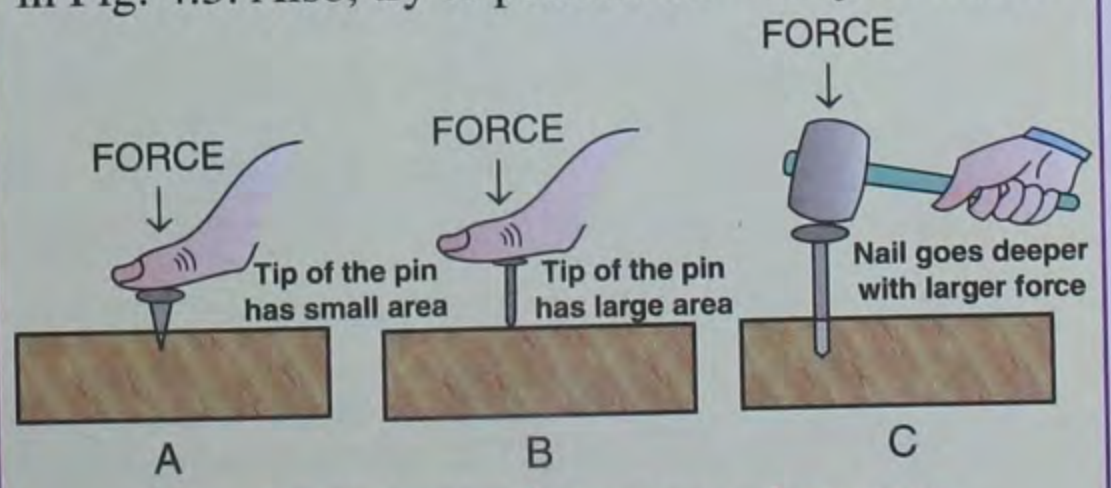


Fig. 4.3 Pressure increases when area decreases and force increases

into the wood. Even when you apply the maximum force by your thumb you cannot push the *nail* into the wood. Why ?

Obviously, the difference has something to do with the area of the tip of the *pin* and the *nail*. Though the force applied is the same, the *tip of the pin* has a smaller area, hence the force acts on a smaller area and puts a larger pressure. However, if you press the *nail* with your thumb, the force is spread over a larger area and therefore, the pressure is less and hence it does not push the *nail* into the wood. Now take another *nail* and push it down with the help of a hammer. The *nail* will go deeper as a larger force is applied on the nail.

The above activity indicates that pressure depends on *two* factors–area and force. Pressure increases if : (*a*) the area decreases or (*b*) the force increases.

Intext Questions

1. Write the formula to calculate pressure.
2. The effect of force depends on which factors ?
3. Give an example of exerting pressure in your daily life.
4. Where is the pressure due to water higher in a dam — near its base or near its top ?

Examples Related to Area and Pressure

To understand the fact that the decrease in area increases the pressure and conversely, the increase in area decreases the pressure, let us consider the following examples :

1. A nail or a board pin has one end pointed and sharp while the other end is blunt and flat. *On applying force, the pointed end will exert greater pressure as the area of contact is small* and hence it will pierce into the given surface.
2. The cutting instruments like a blade, knife, axe, *etc.*, have very sharp edges. *The sharp edges have very small area of contact, so the pressure is more.* Hence, they can easily penetrate through the given surface.

Fig. 4.4 Pressure is more when objects are sharp

3. Heavy trucks have six to eight tyres instead of the conventional four. *More number of tyres are used to increase the area of contact and thereby reduce the pressure on the ground.*
4. A camel can move more conveniently on sand as compared to a horse, due to the fact that the camel has broader feet than a horse. *The broader feet of the camel provide lesser pressure on the sand* and it becomes easier for the camel to walk. In the case of a horse, the area of the feet is less, due to which the pressure increases and hence the feet show a tendency to sink inside the sand, making it difficult to walk.
5. Skiers use long flat skis to slide over the snow. *The larger the area of contact, the lesser is the pressure on the snow*. This helps the skier to slide comfortably without sinking in the snow.
6. Army tanks are usually very heavy and they exert large amount of pressure on the ground, if move on wheels. Hence, they are made to move over broad steel tracks called caterpillar wheels of tanks rather than an ordinary wheels. The steel tracks are used to increase the surface area which reduces the pressure on the ground and hence avoid sinking of the wheels in the ground.
7. Foundation of buildings are kept wide so that the weight of the building may act on larger area. As a result it will exert less

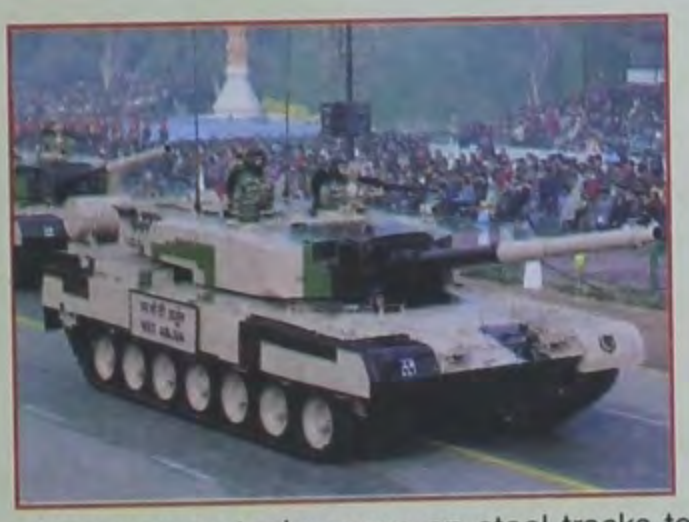
pressure on the ground. This avoids sinking of building into the earth.

8. Porters wear turbans on their heads when they have to carry heavy loads. This helps them in increasing the area of contact. *This increase in the area of contact reduces the pressure of the load on their heads.*
9. School bags and shopping bags have broad straps or belts so that the area of contact increases and thus, the pressure on the hand is reduced.
10. Pointed heels of footwear exert more pressure on the ground than regular flat heels.
11. When a man swims under water, he feels a pressing sensation upon his eardrums. This is due to the weight of the water above him. The deeper he goes, the greater is the pressure. The reason is that as the man goes down deeper in water, the weight of the water above him increases *i.e.*, force on him and his eardrums increases. **Increase in force without any increase in area increases the pressure**. Submarines and underwater tunnels are specially made to withstand such pressure exerted on them.
12. The sledges are not provided with wheels. This is because wheels have lesser area of contact. Hence, it will exert high pressure on the snow and sink deeper into it.
13. Drawing pins, alpins have larger top and highly pointed and sharpened lower end. That is why these can be easily pressed into softwood board.

Thrust

Thrust is defined as the force acting perpendicularly to a surface. The S.I. unit of thrust is Newton.

Larger area of skis reduces pressure on snow



Heavy army tanks move on steel tracks to reduce pressure on the ground

Turbans increase area of contact which reduces pressure on the head

Heavy trucks have more tyres to reduce pressure on the road

Broader feet of camel provide less pressure on sand

Pointed heels exert more pressure on the ground

Fig. 4.5 Examples showing that the decrease in area increases pressure or increase in area reduces pressure

Main differences between thrust and pressure

Pressure	Trust
1. Pressure is thrust acting per unit area.	1. Thrust is the total force acting perpendicularly to a surface.
2. It depends on the area on which the force acts.	2. It is independent of the area over which the force acts.
3. It's S.I. unit is N/m^2 or Pa.	3. It's S.I. unit is newton (N).

Knowledge bank

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 suit to counter such high pressure.

Example 1

A solid weighs 80 N. When placed on a surface, the area of contact is found to be 1·6 m^2. Find the pressure exerted by the solid on the surface.

Solution :

Given Force = Weight = 80 N

Area = 1·6 m^2

P = ?

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{80\ \text{N}}{1{\cdot}6\ \text{m}^2}$$

$$= 50\ \text{N/m}^2 = 50\ \text{Pa}$$

Example 2

If a pressure of 50 N/m^2 acts on an area of 4 m^2, calculate the force applied.

Solution :

Since, $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

$\therefore$ $\text{Force} = \text{Pressure} \times \text{Area}$

$= 50 \times 4 = 200\ \text{N}$

Example 3

A force of 20 N acts on a body of area of cross-section 10 cm^2. Calculate the pressure exerted by the body.

Solution :

Force (F) = 20 N

$$\text{Area (A)} = 10\ \text{cm}^2 = \frac{10}{10000}\ \text{m}^2$$

$$\therefore \text{Pressure (P)} = \frac{\text{F}}{\text{A}} = 20\ \text{N} \times \frac{10000}{10\ \text{m}^2}$$

$$= 20{,}000\ \text{Pa}$$

or F = 20 N and $A = 10\ cm^2$

$$\Rightarrow \quad P = \frac{F}{A} = \frac{20\ \text{N}}{10\ \text{cm}^2} = 2\ \text{N cm}^{-2}$$

Example 4

A girl weighing 50 kg and wearing pencil heels is standing on a floor, each heal having an area of cross-section 1 cm^2. An elephant weighing 2000 kg and foot area of cross-section of 250 cm^2 is standing on the floor. Which of the two will exert more pressure on the floor ?

Take, weight of a body of mass 1kg = 10 N

i.e., force exerted by a body of mass 1 kg = 10 N

Solution :

Pressure exerted by the girl

Mass of the girl = 50 kg

$\therefore$ Force exerted by the girl = 50 × 10 N

= 500 N

Area of cross-section of both the heels

$= 2 \times 1\ \text{cm}^2$

$$= 2 \times \left(\frac{1}{100}\ \text{m}\right)^2 = \frac{2}{10{,}000}\ \text{m}^2$$

Pressure exerted by the girl

$$= \frac{\text{Force}}{\text{Area}} = 500\ \text{N} \times \frac{10{,}000}{2\ \text{m}^2}$$

$$= 2{,}500{,}000\ \text{Nm}^{-2}$$

Pressure exerted by the elephant

Mass of the elephant = 2000 kg

∴ Force exerted by the elephant

= 2000 × 10 N = 20,000 N

Area of cross-section of all the four feet of elephant

$= 4 \times 250\ cm^2$

$= 1000\ cm^2 = 1000 \times \left(\frac{1}{100}\ m\right)^2$

$= 1000 \times \frac{1}{10,000}\ m^2 = \frac{1}{10}\ m^2$

Pressure exerted by the elephant

$= \frac{\text{Force}}{\text{Area}} = \frac{20,000\ N}{\frac{1}{10}\ m^2} = 20,000 \times 10\ N/m^2$

$= 200,000\ Nm^{-2}$

It is clear that the girl's heels exert more pressure.

Example 5

What is the magnitude of force required in newtons, to produce a pressure of 26500 Pa on an area of 100 cm^2 ?

Solution :

Force (F) = ?

Area (A) = 100 $cm^2 = \frac{100}{10000}\ m^2$

Pressure (P) = 26500 Pa

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

$\therefore$ **F** = P × A = $26500 \times \frac{100}{10000}$ N

= **265 N**

Example 6

A force of 100 N can produce a pressure of 100,000 Pa. Calculate the area in cm^2 on which the force acts.

Solution :

Force (F) = 100 N

Pressure (P) = 100,000 Pa

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

$\therefore$ **A** $= \frac{F}{P} = \frac{100}{100,000}\ m^2 = \frac{1}{1000}\ m^2$

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

Example 7

A solid weighs 200 N. What will be the pressure exerted by the solid when it is kept on a glass surface having an area of contact as 500 cm^2.

Solution :

Given Force = 200 N

Area = 500 $cm^2 = \frac{500}{10000}\ m^2$

$= \frac{5\ m^2}{100} = \frac{1}{20}\ m^2$

$\therefore$ Pressure exerted = $\frac{F}{A}$

$= \frac{200\ N}{\frac{1}{20}\ m^2} =$ **4000 Pa**

Intext Questions

1. (a) An elephant weighs 50,000 N. The area of its feet is 1000 cm^2. What pressure does it exert on the ground if it stands on one foot ?
   (b) A man weighs 1000 N. Suppose he stands on a pointed edge with base area 2 cm^2. What pressure does he exert on the ground ?
   (c) Now compare the man standing on the pointed edge and the elephant on one foot. Find out
      (i) Who exerts greater force on the ground, the man or the elephant ?
      (ii) Who exerts greater pressure on the ground, the man or the elephant ?
      (iii) Who is likely to leave a hole in the ground, the man standing or the elephant's foot and why ?

TEST YOURSELF

A. Short Answer Questions :

1. Write *true* or *false* for each statement :
   (a) Pressure is inversely proportional to force and directly proportional to the area of contact.
   (b) A horse can run faster and easily in the desert compared to a camel.
   (c) By making a knife sharp, we decrease the area of contact and hence the pressure increases.
   (d) Lesser the area of contact, more will be the pressure.
   (e) Pressure increases when area increases and force decreases.
2. Fill in the blanks :
   (a) The force acting perpendicular on an area is called .....
   (b) The pressure exerted on a surface of area ..... by a force of ..... is called one pascal.
   (c) The standard unit of pressure is .....
3. Match the following columns :

Column A	*Column B*
(a) Camel	(i) Broad and deep foundation
(b) Truck	(ii) Flat and long
(c) Knives	(iii) Broad feet
(d) High buildings	(iv) Six or eight tyres
(e) Skis	(v) Sharp cutting edge

4. Answer the following questions :
   (a) Define the term pressure. Give its S.I. unit.
   (b) Why is it easier to cut vegetables by a sharp knife than a blunt one ?
   (c) Why is it easier to hammer a sharp pointed nail than a blunt one into a wooden piece ?
   (d) It is difficult for persons wearing pencil heel shoes to walk on softer ground. Explain.

B. Long Answer Questions :

1. State the factors on which the pressure depends.
2. Give *two* examples in which pressure is increased by reducing the surface area of contact.
3. When do you apply more pressure, whether on standing on the floor or when you are lying on the floor. Explain.
4. Write any *two* examples of pressure.
5. Explain why army tanks move on caterpillar wheels rather than ordinary round wheels?
6. The foundation of a building has a wider bottom part. Explain.
7. When the force applied on an object is doubled, how does the pressure exerted on the object change ?

C. Numericals :

1. A force of 200 N acts on an area of 0·02 m^2. Find the pressure in pascals. **[10,000 Pa]**
2. What force will exert a pressure of 50000 pascals on an area of 0·05 m^2 ? **[2500 N]**
3. Find out the area of a body which experiences a pressure of 50000 Pa by a force of 100 N ? **[20 cm^2]**
4. Calculate the pressure exerted by a force of 300 N acting on an area of 30 cm^2.
   [10 N cm^{-2} =100,000 Nm^{-2}]
5. What force will be required to exert a pressure of 20000 Pa on an area of 1 cm^2 ? **[2 N]**
6. The base of a container measures 15 cm × 20 cm. It is placed on a table top. If the weight of the container is 60 N, what is the pressure exerted by the container on the table top ? **[2000 Nm^{-2}]**
7. Ritu wears pencil heel shoes. Each heel has an area of contact as 0.001 m^2. If Ritu's weight is 350 N, what is the total amount of pressure when she stands on the floor on both the feet ? **[175000 Pa]**
8. Calculate the pressure exerted at the point of a drawing pin if pushed against a board with a

force of 20 N, assuming the area of the point to be 0.1 mm^2. [2×10^8 Pa]

9. A force of 100 N acts on an area of 0·16 m^2. What is the magnitude of pressure in pascal ? [625 Pa]

10. What is the magnitude of a force which produces a pressure of 3500 Pa while acting on a surface of area of cross-section of 0·25 m^2 ? [875 N]

11. A force of 200 N, while acting on an area A, produces a pressure of 1000 Pa. Calculate the magnitude of A in cm^2. [2000 cm^2]

12. What is the area of cross-section of a body in m^2, when it exerts a force of 50 N and produces a pressure of 4000 Pa ? [0·0125 m^2]

RECAPITULATION

- The force acting per unit area on the surface is called pressure.
- Pressure depends on two factors – the force and the surface area perpendicular to the direction of force.
- The S.I. unit of pressure is newton per square metre ($N/m^2 = Nm^{-2}$) and is expressed as Pa.
- Lesser the area of contact, more will be the pressure exerted by an object.
- The magnitude of pressure decreases with the increase in the area.
- The magnitude of pressure increases with the increase in the magnitude of force.
- When a force of 1 newton acts perpendicularly on an area of cross-section of 1 m^2, then one pascal pressure is produced.
- The pressure exerted by a body increases on decreasing the area of its base.

Project Work

Study the extension in a spring with the increase in mass. Draw a graph between mass and extension. Ask for help from your teacher.