# 6
# Simple Machines

**SYLLABUS**

1. **Simple machines :** The lever - identifying load, effort and fulcrum in the three classes of levers; the inclined plane and the screw; the pulley, wheel and axle, wedge, efficiency of a machine, care of machines.
2. Students may be asked to identify simple levers in a variety of common objects and locate the fulcrum, the load and the effort in each case (E).

## MACHINES

In our daily life, though we come across a number of machines, but we do not identify them as machines. This is due to the fact that most of us think that a machine is a complicated device with a number of moving parts and powered by some type of engine or electricity. But, to say in the real sense, even such simple tools such as a hammer, a bottle opener, a spanner or a screw driver are also called machines. In the language of a physicist, ***a machine is a device that allows us to do work with less effort than if you do the same job yourself without taking outside help of any kind***. You might have to apply a large force in lifting a heavy weight by hand, but you can push the same weight up an inclined plane, such as a ramp, very easily. The amount of work done in both the cases is equal, but the inclined plane allows you to put less effort. Hence, **the inclined plane works as a machine**.

We need a lot of energy to perform any work. But what is energy ? In simple terms, energy is the ability or capacity to do work. A simple machine has no energy of its own and at the same time, it cannot do work by itself. It is only when we perform work upon it that it will perform work in turn, upon some other object. In other words we can say that, a machine can do work only after work has been done on it. Thus we derive at a basic law of machines that **the work output of a machine is equal to the work input**.

Truly speaking, in practice, the work output of a machine is never equal to the work input. The reason is that, the work done (input) on a machine *i.e.*, energy given to machine is partly utilised in overcoming the force of friction between its different moving parts. Therefore, in practice, the work output of a machine is less than the work input.

The main utilisation of a machine is to lift a greater load by applying lesser force (effort) on the machine.

The ultimate description of a machine is that it is a device which makes work easier to do. Machines have made our lives comfortable and faster. They have changed the quality of our life style. We just cannot think of our existence without machines.

## Simple Machines

There are actually, six types of simple machines which we use in our daily life. They are (1) lever, (2) inclined plane, (3) wedge, (4) screw, (5) wheel and axle and (6) pulley.

Suppose you want to open the lid of a container filled with oil. You will not be able to open it with bare hands. So, take a spoon and insert it between the lid and the edge of the tin and then press the other end of the spoon. The lid gets opened. Hence, the spoon is used as a machine to open the lid.

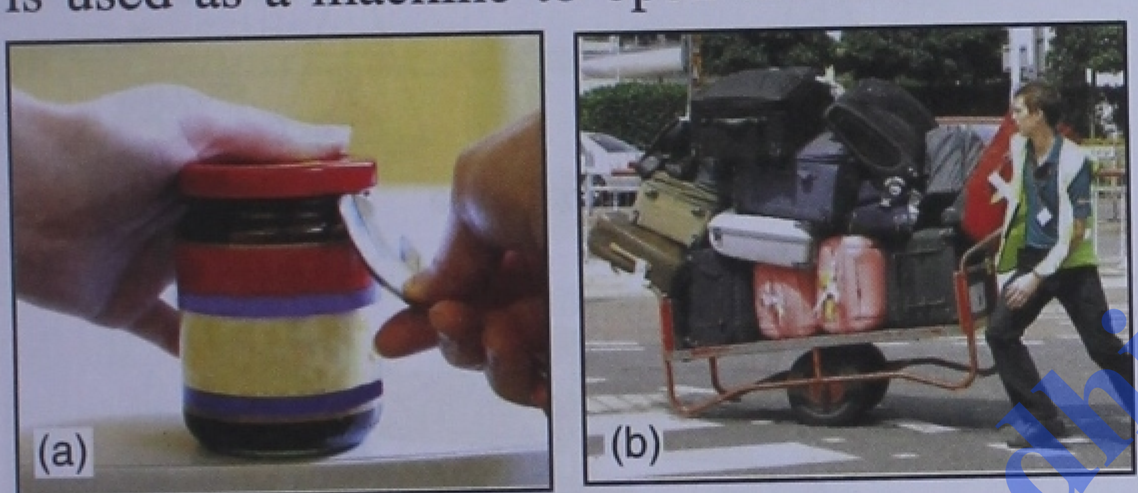



*Fig. 6.1 (a) Spoon can be used as a simple machine to open the lid (b) Luggage on a trolley*

Suppose you wish to move a heavy load from one place to another. You may not find it easy to lift or push this heavy load. But if it is placed on a trolley with wheels, it becomes easier to push. You must have observed at railway platform or an airport that people carry their heavy luggage on trollies.

Sometimes, a machine like a pulley is used for changing the direction of the force applied. By doing so the effort can be applied conveniently. *For example*, while drawing water from a well, a pulley is used so that the effort is applied in the direction of our convenience.

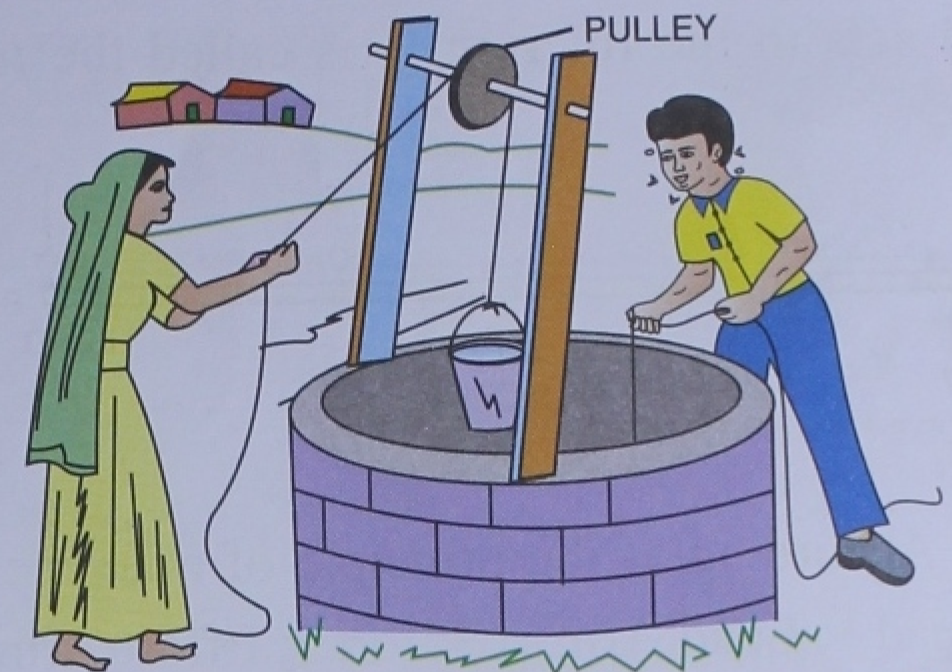



*Fig. 6.2 Examples of a pulley being used as a simple machine*

**Lever :** A lever is called the simplest machine. It is a rigid rod which is free to move about a point on which it rests. This point of rest is called **fulcrum**. The object which has to be moved is called **load** or **resistance**. The force applied on the lever to overcome load is called **effort**. In Fig. 6.3, F shows the position of the fulcrum, E is the effort and L is the load or resistance.



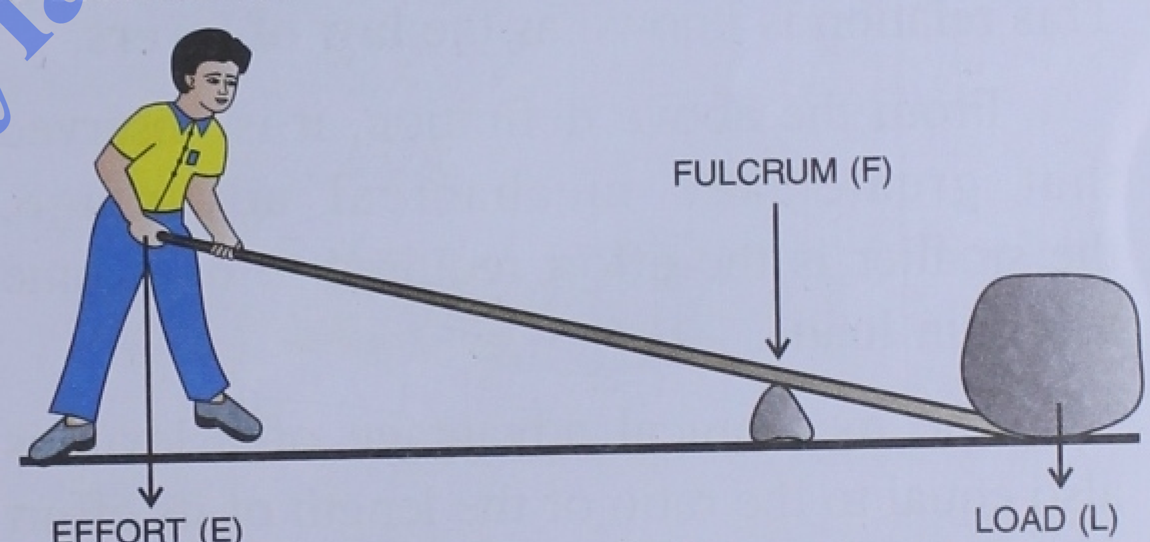
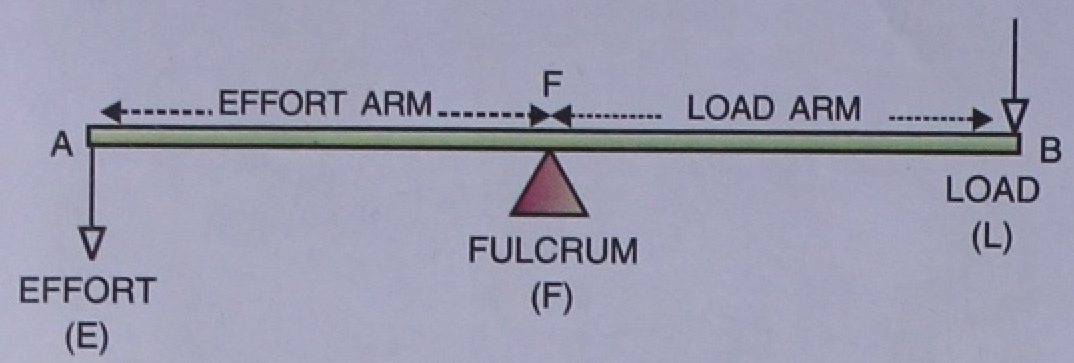



*Fig. 6.3 A man uses a lever to lift a heavy piece of rock*

| |
|---|
| A lever is a simple rigid rod, which is free to rotate about a fixed point called fulcrum. |

**Principle of Lever :** Let us consider a straight rod AB with fulcrum at point F. An effort E, applied at point A of the lever, overcomes a load L at point B. The distance AF, from point A at which the effort is applied to the fulcrum F, is called the *effort arm*. The distance BF, from point B at which the load acts to the fulcrum F, is called the *load arm*.




According to the principle of a lever :

Load × Load Arm = Effort × Effort Arm

$$L \times LA = E \times EA$$

$$\Rightarrow \quad \frac{L}{E} = \frac{EA}{LA} = \text{M.A.}$$

M.A. = Mechanical advantage of a machine.

The mechanical advantage of a machine is the ratio between the load (to be overcome by the machine) and the effort (applied to it).

$$\text{Mechanical Advantage (M.A.)} = \frac{\text{Load (L)}}{\text{Effort (E)}}.$$

This relation is known as the **law of levers.**

From the above definition, it is observed that greater the mechanical advantage, the smaller is the effort required to overcome a certain load.

The mechanical advantage of a lever is also equal to the ratio of the length of its effort arm to the length of its load arm.

**Types of Levers :** Depending upon the relative positions of the fulcrum, load and effort levers are classified into *three* different types.

1. Class I Levers
2. Class II Levers
3. Class III Levers

**Class I Levers :** The lever in which fulcrum is in between load and effort is called *Class I lever* or *lever of the first order.*

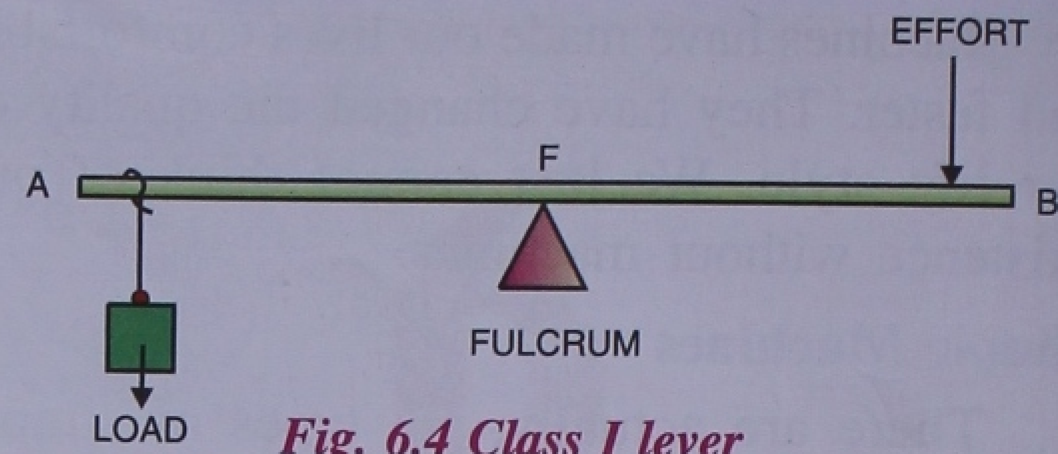



*Fig. 6.4 Class I lever (Fulcrum is between load and effort)*

**Examples :** A beam balance, a see-saw, a pair of pliers, a pair of scissors, claw hammer *etc*. are some common examples of Class I levers. In all these cases, the load is on one side while the effort is on the other side of the fulcrum.

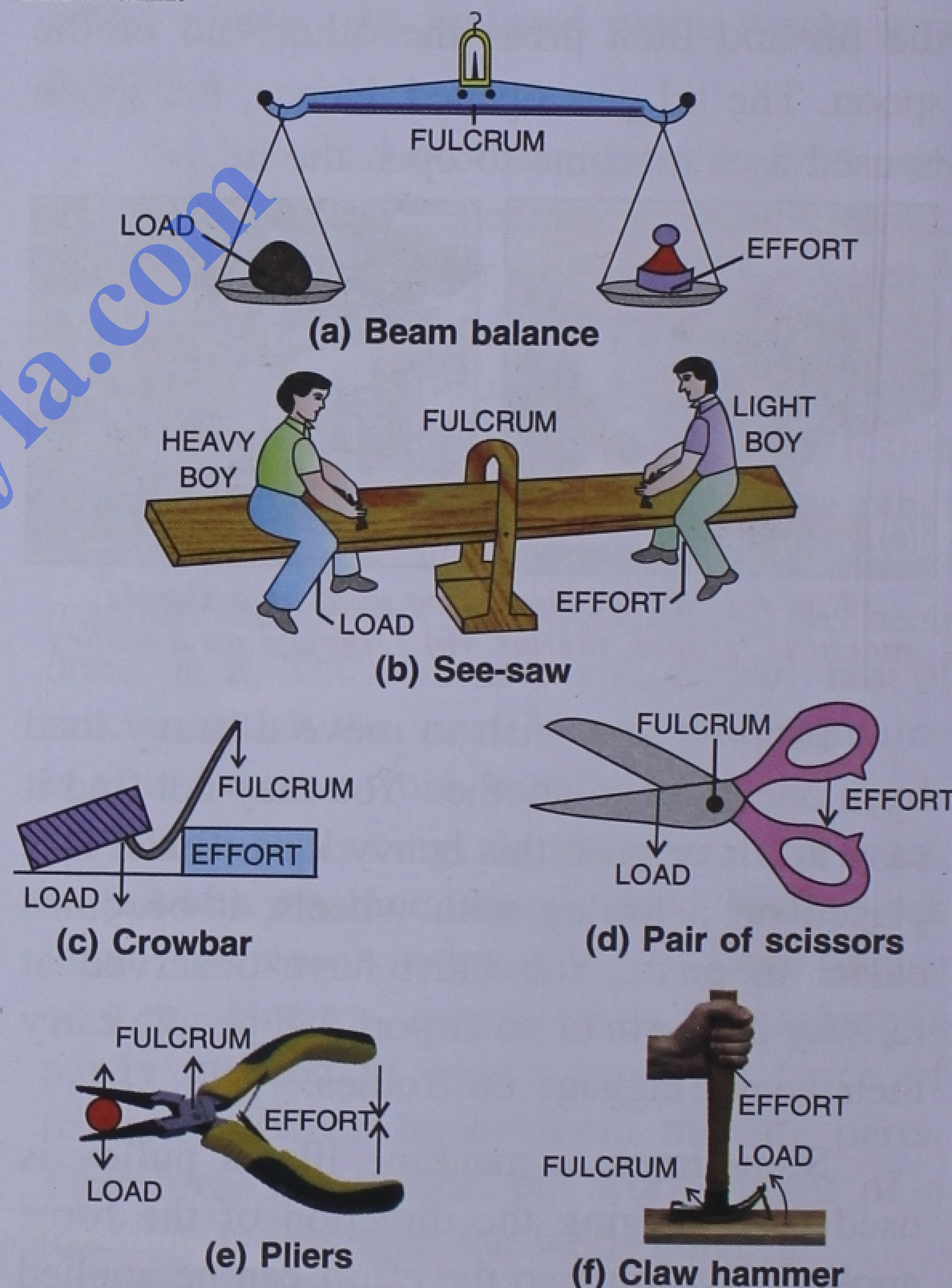



*Fig. 6.5 (a) to (f) Examples of Class I levers*

When you use a spoon to open the lid of a can, you use it as a first class lever.

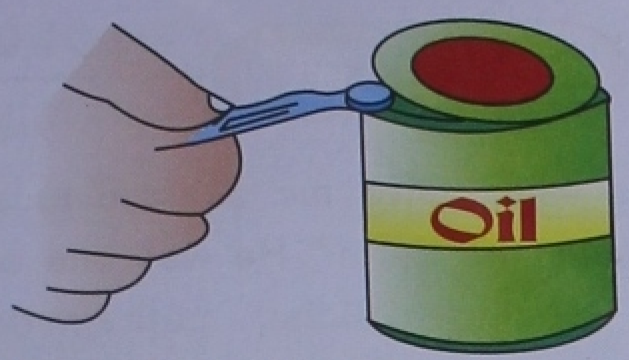



*Fig. 6.6 Opening the lid of a can with the help of a spoon*

Can you mark the position of load, effort and fulcrum in Fig. 6.6 above ?

**Class II Levers :** The lever in which **load** is in between fulcrum and effort is called *Class II lever* or *lever of the second order*. This type of lever is used where lesser effort has to be applied to do the work conveniently.

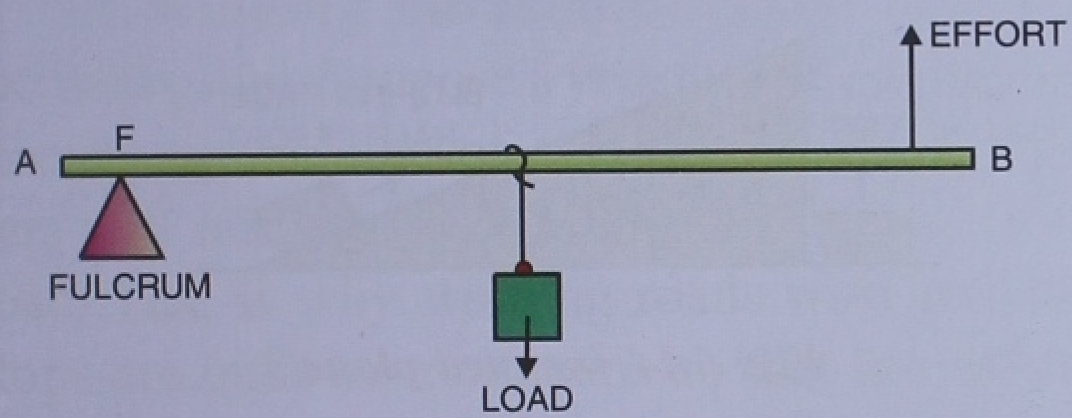



*Fig. 6.7 Class II lever*
*(Load is in-between fulcrum and effort)*

**Examples :** A nut cracker, a bottle opener, a wheel barrow, a mango cutter, *etc.* are few examples of Class II levers.

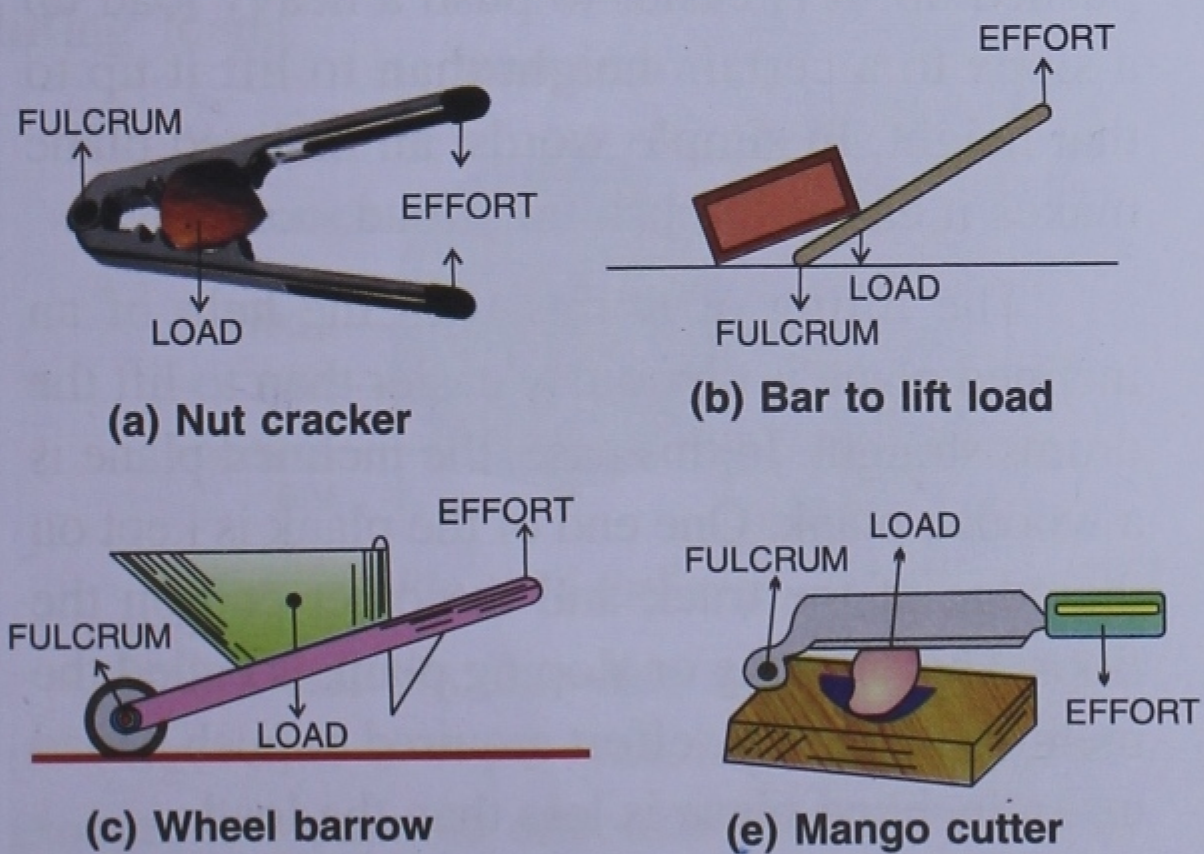



*Fig. 6.8 (a) to (d) Examples of Class II levers*

Can you mark the position of load, effort and fulcrum in Fig. 6.9 below ?

*Fig. 6.9 Bottle opener*

**Class III Levers :** The lever in which effort is in between fulcrum and load is called *Class III lever* or *lever of the third order.*

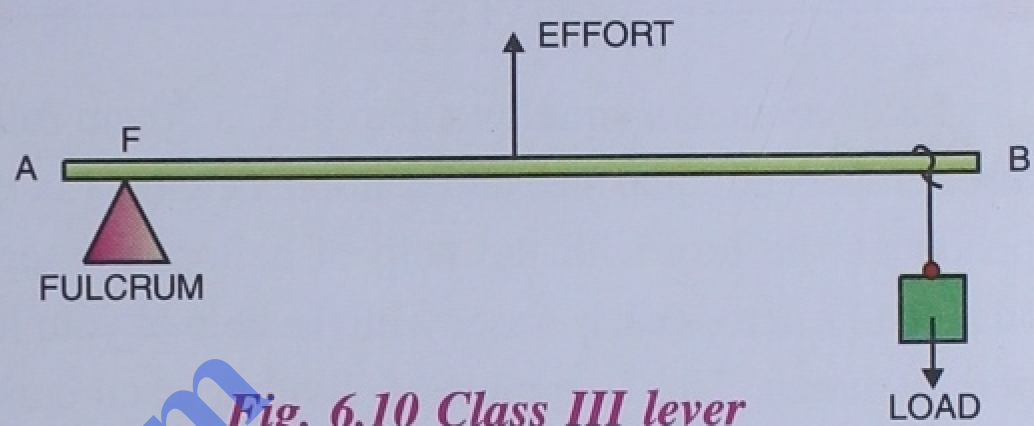



*Fig. 6.10 Class III lever*
*(Effort is in-between fulcrum and load)*

**Examples :** Forceps, sugar tongs, fire tongs, knife and human forearm are some of the examples of *Class III Levers.*

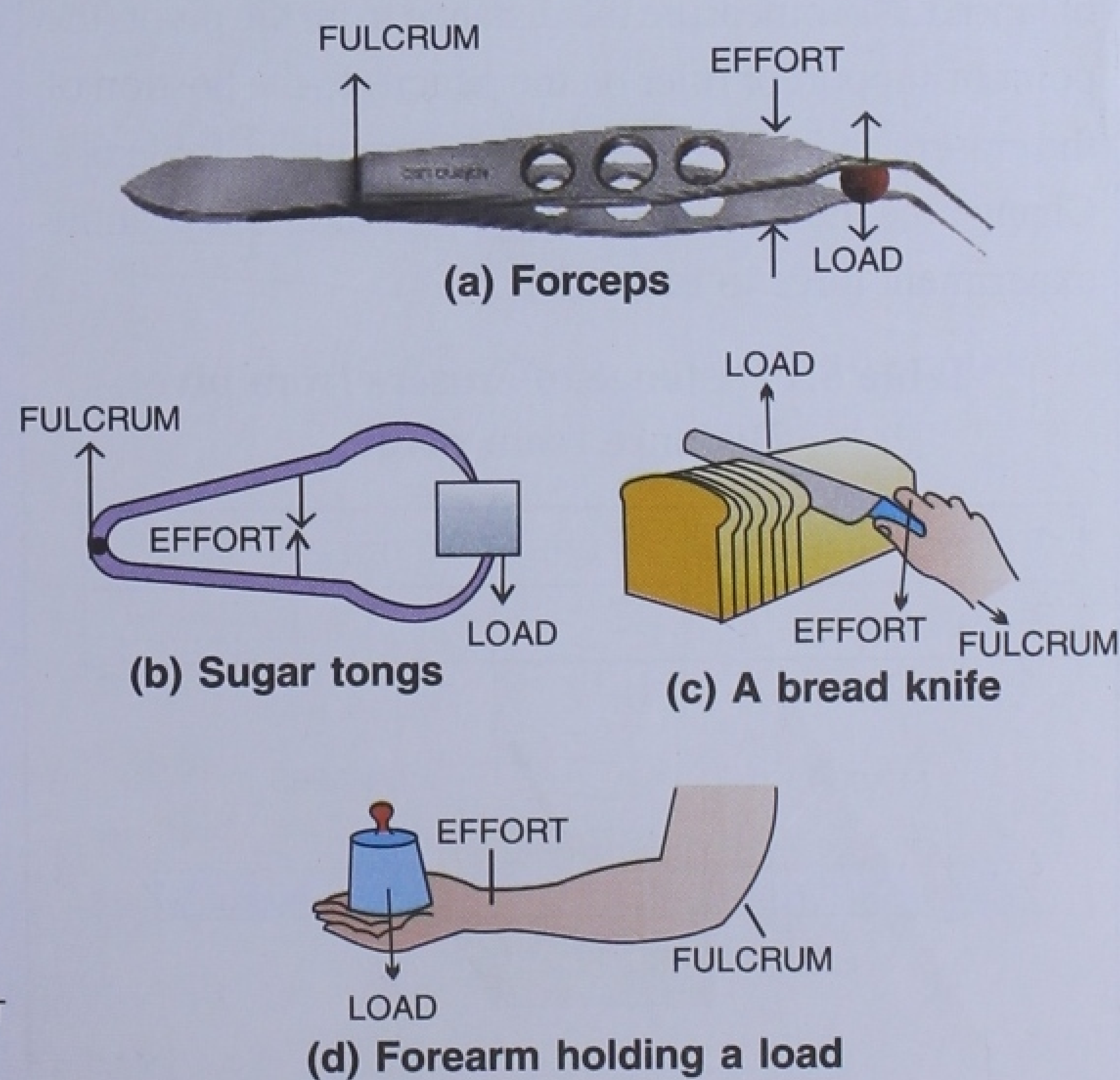



*Fig. 6.11 (a) to (d) Examples of Class III levers*

Can you mark the position of load, effort and fulcrum in Fig. 6.12 below ?

*Fig. 6.12 Fishing rod*

## ACTIVITY 1

Take a pencil, a small wooden box, a 50 cm ruler, three erasers of equal size and cellophane tape. Fix the pencil on the box with the help of cellophane tape. Mark a line across each eraser with the help of your ink pen as shown. This line must be dividing each eraser into two equal parts. We can call it a central line. Then balance the ruler across the pencil (Fig. 6.13). Now place one eraser near one end of the ruler and two erasers (one on top of the other) on the other side. Adujst the position of the two erasers such that the ruler is balanced. Now measure the distance from the pivot (the point of support of ruler on the pencil) to the postion of the erasers and record your measurements in Table 6.1. Change the location of the single eraser and repeat the experiment three to four times.

**Table 6.1 Distance of erasers from pivot**
**Distance from pivot**

| | | | | |
|---|---|---|---|---|
| 1 eraser | 12 cm | 8 cm | 6 cm | .......... |
| 2 erasers | | | | .......... |

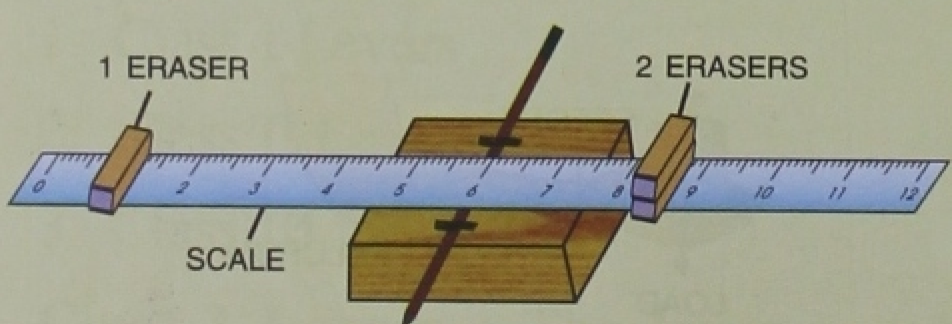



*Fig. 6.13 A simple experiment to show the working of a see-saw*

## Do You Know ?

**Archimedes said, "Give me a place to stand on and I will move the Earth." He was one of the most famous Greak Physicist, mathematician, astronomer and an engineer. He is believed to be the first person to explain lever and was instrumental in designing different machines. He also gave the explanation of displacement method to find volume of solids by immersing them in water and hence find the density. Try to know more about him.**

## Inclined Plane

An inclined plane is a gentle slope that helps us to move a heavy load with less effort. It does not look like a machine at all !


*Fig. 6.14 Inclined plane*

Have you seen people moving barrels or oil drums from the ground on to a lorry ? They don't lift them but they push them up a sloping board called a *ramp* or an *inclined plane*. It is simply a slope over which a load can be pushed up. It is easier to push a heavy load up a slope to a certain height than to lift it up to that height. In simple words, an inclined plane makes it easier to push up a load.

The lifting of drums with the help of an inclined plane is obviously easier than to lift the drums straight. In this case, the inclined plane is a wooden plank. One end of the plank is kept on the edge of the truck and the other end on the floor. This slanting or sloping plank is called the inclined plane. The effort required to push a load up an inclined plane is less than the load.

If the slope is steeper, greater effort will be required to push the load up. A staircase of a building, a road on a hill station, a flyover on a road are some of the examples of an inclined plane.

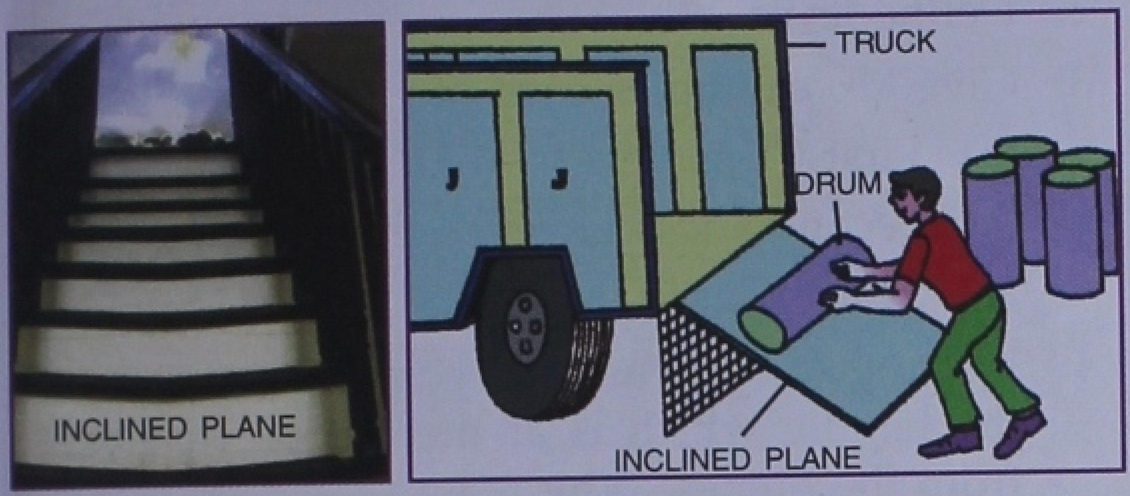



*Fig. 6.15 Examples of inclined plane*

A wheel chair can be easily pushed up an inclined plane in a hospital.

A winding mountain road is also an inclined plane. Suppose a very steep road is built directly up the side of a mountain. Buses and cars will not be able to go up on such a steep road. That is why winding roads with gradual slope are built on mountains so that less effort is needed to go up the mountain though the distance to be covered becomes greater.

## Pulley

Pulley is another simple machine which is very commonly used in our daily life for lifting loads.

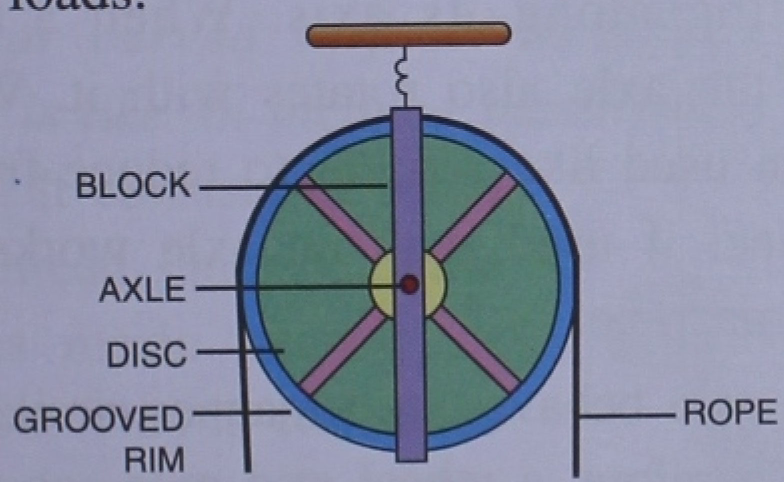



*Fig. 6.16 Pulley*

It is a flat circular disc with a groove in its edge and a rope passing through the groove. It is capable of rotating around a fixed point passing through its central axis called *axle*. Though it is mostly made of some metal, wooden pulleys are still in use. Pulleys are generally used in workshops and factories to lift heavy load. In villages, we see people drawing water from a well with the help of a pulley. We find that mechanics lift heavy engines using a grooved wheel with a long rope. It consists of a wheel with a groove to hold a rope. The wheel moves around an axle fixed to a support called *block*. While using a pulley, the load is attached to one end of the rope and the effort is applied at the other end as shown in Fig. 6.16.

Several pulleys can be used together to reduce the force needed to lift a load. Such as arrangement is called a **block and tackle**. The greater the number of pulleys, the smaller is the force needed to lift the load. Such pulleys are used whenever we need to lift heavy loads such as in factories, farms, garages and godowns.

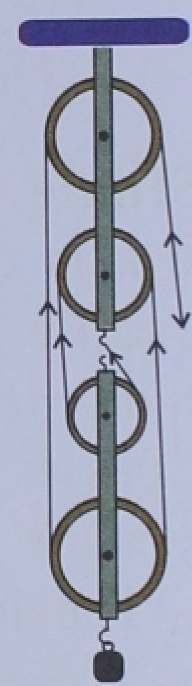


*Fig. 6.17 Block and tackle*

## Types of Pulleys

**Single Fixed Pulley :** The simplest form of pulley is called the *"single fixed pulley"*. A pulley which has its axis of rotation fixed, is called a fixed pulley. Figure 6.18 shows a *single fixed pulley* in which a string passes around the grooved rim of the pulley. Such a pulley makes our work easier by changing the direction of force. A downword effort is used to lift the load up.

However, a simple pulley does not reduce the effort required to lift a heavy load. Such a pulley is used to lift water from a well, hoist a flag and to lift bricks and cement by workers at a construction site.

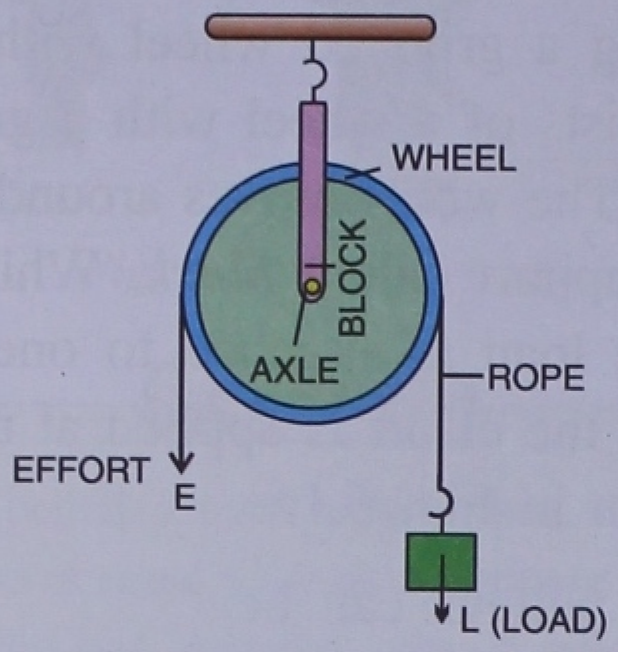



*Fig. 6.18 Single fixed pulley*

**Single Movable Pulley :** A pulley whose axis of rotation is not fixed is called a **movable pulley**. Figure 6.19 shows a single *movable pulley* attached to a load. A string passes through the grooved rim of the pulley. One end of the string is tied to a hook. Tension acts on both sides of the pulley. The effort balances the tension at the free end.

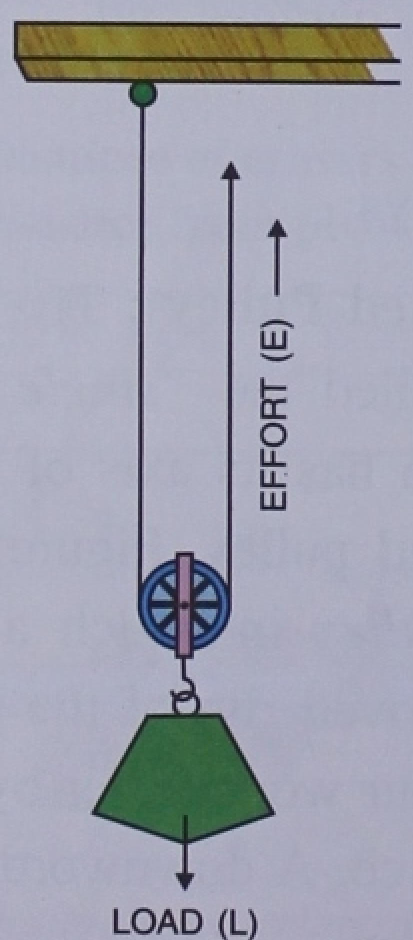



*Fig. 6.19 Single movable pulley*

## Intext Questions

1. Name some simple machines used in everyday life.
2. Define lever.
3. Give *two* examples each of :
   (a) First Class Lever
   (b) Second Class Lever
   (c) Third Class Lever
4. When you open a door, you apply force on the handle which is at the largest distance from the hinges. Why ?
   Where is its fulcrum ?
   Where is its load ?

## ACTIVITY 2

Visit a park or a garden. Sit on a see-saw with your friend. Note the position of Effort, Load and Fulcrum in the see-saw. Can you guess who is heavier, you or your friend ?



## Wheel and Axle

A wheel and axle is another form of simple machine. It is actually a combined structure of a wheel and a rod.

The importance of a wheel is known to everyone. A wheel is a circular object capable of rotating along its axis. When a wheel rotates, the axle also rotates with it. Wheels are often used like a roller to reduce friction. The wheel if used with an axle works as a simple machine.

An axle behaves in a manner similar to a wheel. Therefore, a **wheel and axle** consists of two wheels of different diameters which are attached together. It may also consist of a large wheel attached to an axle. Common examples of wheel and axle are a steering wheel of a motorcar, bicycle pedal, door knobs, *etc.* In every type of a wheel and axle, the effort is applied to the bigger wheel and the load is applied to the smaller wheel (axle).

Let us take an example of a screw driver. Imagine, its round handle to be a wheel (as it rotates) and the rod attached to it as an axle (it rotates when the handle is rotated). When a force is applied to the handle, the axle rotates with a greater turning effect of force. Hence, the screw driver pushes the screw with a greater turning effect of force into the wood.

A tap is also an example of wheel and axle arrangement. When we turn the tap, the axle inside the tap turns.


*Fig. 6.20 Examples of wheel and axle arrangement*

## Screw

*A screw is a simple machine which appears like a nail with grooves made on its circular curved surface. In other words, a screw is like an inclined plane wound around a rod.* It consists of a rod with thread. One end of the rod is made narrow or pointed. This is called the tip of the screw. The other end is made flat which is called the **head of the screw**. A narrow slit is made in the head of the screw so as to turn the screw with the help of a screw driver. The thread acts like an inclined plane. When the screw makes one complete rotation, the rod advances a distance equal to the space between the two consecutive threads.

*Fig. 6.21 A Screw*

It takes less force to insert a screw into wood than to insert a nail into wood. This is because the screw makes it move round and round as it goes in, travelling a longer distance than a nail. Also, because of the grooves a screw holds the wood more firmly than a nail.

A jack also works on the principle of a screw. It is commonly used in lifting automobiles for changing flat tyres.

## Wedge

*A wedge is a simple machine with two inclined planes put together forming a sharpened edge.*

It is used for splitting logs. The thinner the wedge, the easier it is to drive it into a log.

A speed boat has its leading edge shaped like a wedge to cut through water easily.

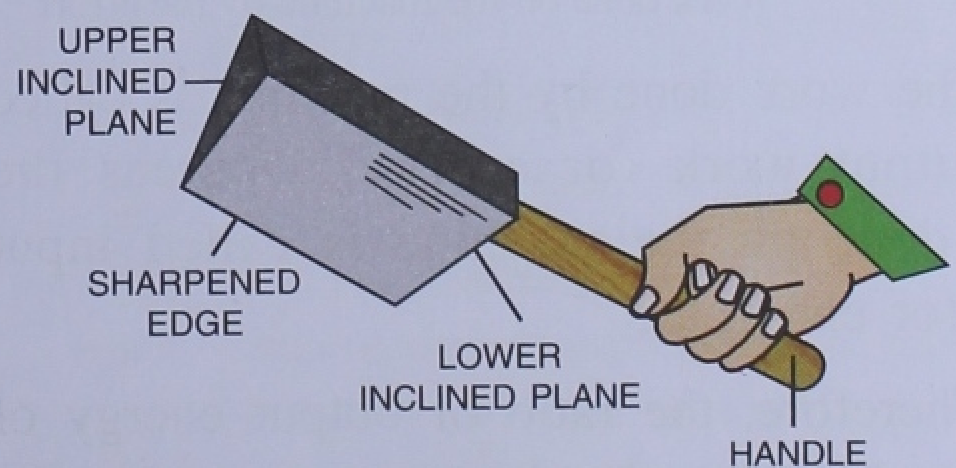



*Fig. 6.22 A wedge*

**Examples :** Knives, axes, ploughs, nails, saw, needles, *etc*.

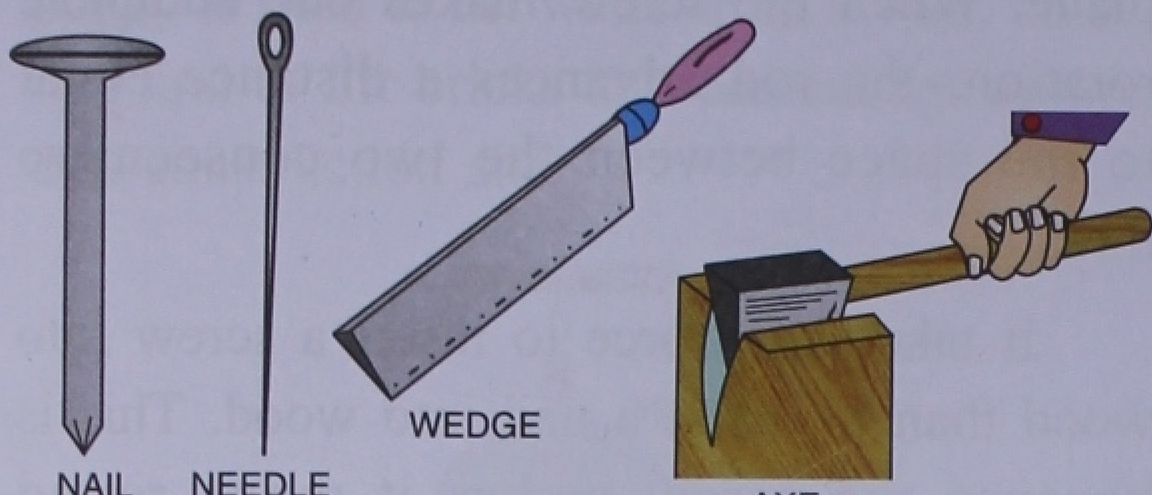



*Fig. 6.23 Examples of wedge*

**ACTIVITY 3**

Visit a nearby flour mill in your neighbourhood market. Try to find out what simple machines are being used there. Write them in your notebook.

## EFFICIENCY OF A MACHINE

Experimentally, it is found that no machine is ideal. Whenever we do some work on a machine, some work is used up in overcoming the friction existing between different parts of the machine. Therefore, the amount of work done by the machine is always less than the work done on the machine. *The ratio of work done by the machine to the work done on the machine is called its efficiency.*

$$\text{Efficiency} = \frac{\text{Work done by the machine on the load}}{\text{Work done on the machine by the effort}}$$

The work done by the machine is called the output work (or energy) whereas the work done on the machine is called input work (or energy).

Therefore, the ratio of output energy of the machine to the input energy on the machine is also known as *efficiency of the machine*. In terms of percentage, we write it as :

$$\text{Efficiency } \% = \frac{\text{Output energy}}{\text{Input energy}} \times 100\%$$

If a machine is 80% efficient, it means that 80% of the work input to the machine is obtained as the useful work output. The remaining 20% of the work input is lost in overcoming the friction.

A machine with 100% efficiency is called an ideal machine. No machine has efficiency more than 100%. In fact, the efficiency of every practical machine used by us is always less than 100%.

Every machine has friction acting with in its internal parts. Therefore to overcome this friction some amount of energy is utilised and hence the efficiency of practical machines is always below 100%.

### Care of Machines

Machines are a gift of science. They play an important role in our lives. There would have been no economic progress if machines would not have been there. Thus, for their proper functioning and efficiency, we must take proper and timely care for them.

1. Machines should be protected from rust by applying paint or rust-proof coating.
2. Regular oiling of parts increases their efficiency, otherwise they wear out or make too much of noise due to friction.
3. Machines, when not in use, should be kept covered to protect them from dust.

## ACTIVITY 4

- Visit a factory with your parents. Observe how different machines work. Discuss with the factory staff about the care and maintenance of machines.
- You might have heard or seen people talking about car and scooter servicing. Visit a mechanic shop and discuss about servicing of vehicles. What are the benefits of it ? Does it increase the efficiency of the vehicles ?

## Intext Questions

1. Define wheel.
2. Why a screw takes less force to move into wood than a nail ?
3. Where is a simple machine wedge used ?
4. Where is a screw jack used ?
5. Identify the simple machine.
   (a) Grooved wheel with a rope passing through it.
   (b) A wheel with a rod attached in the centre.
   (c) A rod free to rotate about a fixed point
   (d) A sloping surface.
   (e) A nail with a winding edge cut into it.

## TEST YOURSELF

### A. Short Answer Questions

1. Tick the correct answer :

(a) Which of the following is not true for a machine ?
   (i) To make our work convenient.
   (ii) To enable us to lift more load with less force.
   (iii) To enable us to make the measurement correctly.
   (iv) To make our work faster.

(b) A force applied to a machine to do mechanical work is called
   (i) load (ii) effort
   (iii) output (iv) efficiency

(c) A physical balance is an example of
   (i) inclined plane (ii) wedge
   (iii) lever

(d) When you open or close the door of a house by holding its handle, it is an example of
   (i) wedge (ii) lever
   (iii) wheel and axle arrangement

(e) A pair of pliers is an example of
   (i) Class I Lever (ii) Class II Lever
   (iii) Class III Lever

2. Match the following columns :

| *Column A* | *Column B* |
|---|---|
| (a) A wheel barrow | (i) An inclined plane |
| (b) Screw | (ii) Changes the direction of force |
| (c) A pulley | (iii) Lever of Class I |
| (d) Beam balance | (iv) Lever of Class II |
| (e) Sugar tong | (v) Lever of Class III |

3. Fill in the blanks :
   (a) In Class III levers, ................. is in between ................. and ................. .
   (b) The pulley changes the ................. of force.
   (c) ........... is used to lift heavy objects like cars.
   (d) A machine having 100% efficiency is known as an ................... machine.
   (e) An inclined plane is a ................... surface.
   (f) A crow-bar is a lever of ...................

4. Answer the following questions :
   (a) What is a machine? Why do we use a machine?
   (b) State the principle of a machine.
   (c) Name *two* factors by which a machine's ability to do work can be measured.

(d) What is the main advantage of a pulley ?

(e) Name *six* types of simple machines.

(f) Define the following : Pulley, Lever, Inclined plane and Wedge.

(g) Which machine is used to move a big piece of rock ?

(h) Give two examples of an inclined plane.

## B. Long Answer Questions :

1. State four objectives which can be achieved by a machine.
2. (a) What for a single pulley is commonly used ?
   (b) Draw a neat diagram of a single movable pulley and state its one use.
3. Classify the following simple machines :
   (a) A railway signal (b) A door knob
   (c) A screwjack (d) A staircase
   (e) An axe (f) A wheel barrow
4. Give *three* uses of a screw.
5. State the principle of levers.
6. Show with the help of diagrams, the differences between the first, second and third kinds of lever.
7. What is the advantage of using a pulley ?
8. What is an inclined plane. Describe its uses ?
9. Why do we use a wooden plank when we load heavy drums in a truck ?
10. Why do we use wheels in our vehicles ?
11. The load arm of a lever is 3 m long and effort arm is 1·5 m long. What effort is required to lift a load of 40N ? **[80 N]**
12. A rod of length 1·20 m has its fulcrum situated at a distance of 0·2 m from the load placed at one end of the rod. Calculate the mechanical advantage (MA) of rod. **[5]**
13. A load of 400 N can be lifted by a force of 40 N with the help of a lever. Find the mechanical advantage. **[10]**
14. From the data given below, find the unknown quantity :
    (a) Load = 200 N, Effort = 25 N, M.A. = ?
    (b) Load = 100 N, Effort = ?, M.A. = 4
    (c) Load = ?, Effort = 40 N, M.A. = 4
    (d) Load = 180 N, Effort = ?, M.A. = 6
    **[(a) 8 (b) 25 N (c) 160 N (d) 30 N]**

## RECAPITULATION

- Machines are devices which have made our lives convenient, easier and faster.
- Machines can lift greater load with less effort applied.
- There are six types of simple machines : the lever, the inclined plane, the screw, the pulley, the wedge and the wheel and axle.
- Effort is the force exerted on the machine to overcome the load.
- Fulcrum is the point or the support about which the lever rotates.
- Class I Lever : Fulcrum is in-between load and effort.
- Class II Lever : Load is in-between fulcrum and effort.
- Class III Lever : Effort is in-between fulcrum and load.
- Principle of Lever : Load × Load Arm = Effort × Effort Arm.
- Law of Lever : $\text{M.A.} = \dfrac{\text{Effort Arm}}{\text{Load Arm}}$
- $\text{Efficiency} = \dfrac{\text{Work done by the machine}}{\text{Work done on the machine}}$ Also, $\text{Efficiency} = \dfrac{\text{Output energy}}{\text{Input energy}}$
- Machines can change the direction of force.
- A pulley is used to change the direction of applied force.
- An inclined plane is a sloping surface.
- A needle is a wedge-type simple machine.
- The wheel is a circular disc, capable of rotating about an axle.
- Machines require care and maintenance.



## Project Work

1. Make a model of pulley by using the lid of jam bottle, some papers, spring, a thin nail to act as axle.
2. Take a pair of scissors, a pair of tin cutter and think of a see-saw. How are their effort arms different from each other. Write a reform about it, taking help of your teacher.
3. Draw pictures of various appliances you come across to work as levers. Mark the positions of fulcrum, effort point and load point in each. Draw at least 15 to 20 such appliances.