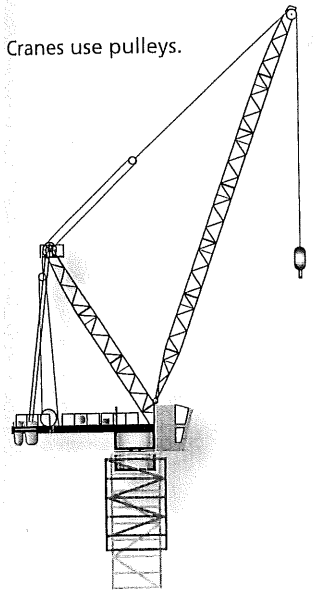
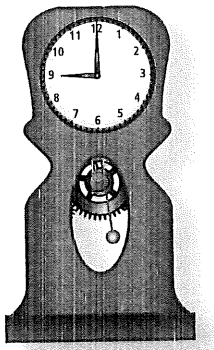
7.1 What is a machine?

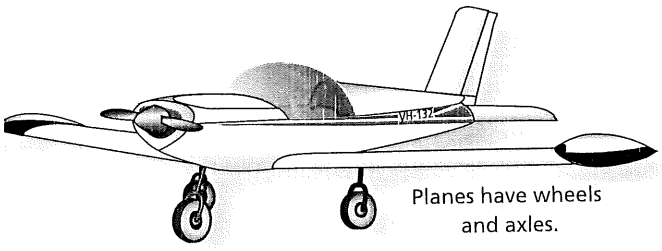
A machine is anything that helps you do things more easily. The most common **simple machines** are levers, pulleys, inclined planes (ramps), screws and gears. Complex machines such as cranes, winches, clocks and bicycles contain many simple machines.



Cranes use pulleys.



Clocks have gear wheels inside.

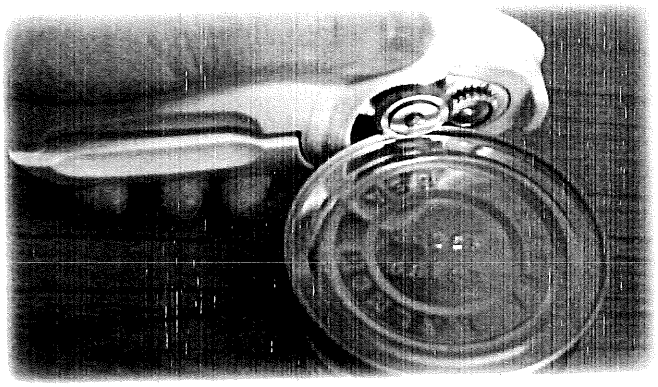


Planes have wheels and axles.

There are four ways simple machines help us do things more easily.

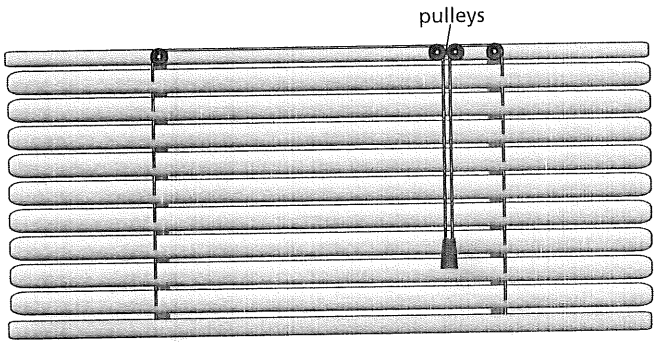
1 Machines can magnify the force you use

Think of a can-opener where you usually turn a big knob, handle or wheel. The effort you put into turning the handle or wheel moves a smaller wheel which in turn moves a circular blade that pierces and slices open the can as it moves. You are turning a large wheel or knob and this requires much less effort than turning the little wheel by itself. In this way the can opener has magnified the force you use. In other words, you have a greater force for less effort. When a machine does this it gives the user a *force advantage*.



2 Machines can change the direction of the force

When you pull the cord on a venetian blind at a window, the cord is attached to a pulley wheel. From the pulley, the cord then threads through the slats of the blind. You pull the cord down and the slats of the blind go up. The pulley has changed the direction of the force. It is much easier to pull something down than to push and hold something up. So the pulley helps you move the blind.



3 Machines can speed things up

When you ride a bicycle and push down on the pedals, the pedals don't turn as fast as the back wheel does. A few turns of the pedals can make you go very fast. A machine like the bicycle that does this is said to have a *speed advantage* or a *distance advantage*. The higher the gear you use, the faster you go and the more distance you cover.

To go up a hill you put a bicycle into low gear, so that less effort is needed to move the load (you and the bike) up the hill. The bicycle in this case gives you a *force advantage*.

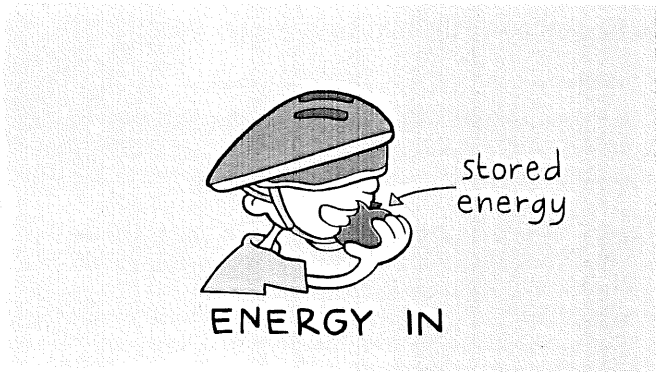
A machine like a bicycle can give you a speed–distance advantage or a force advantage, but not both. You can't have the bicycle in low and high gear at the same time.

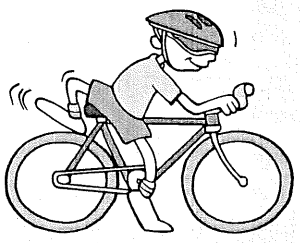
4 Machines can transform energy

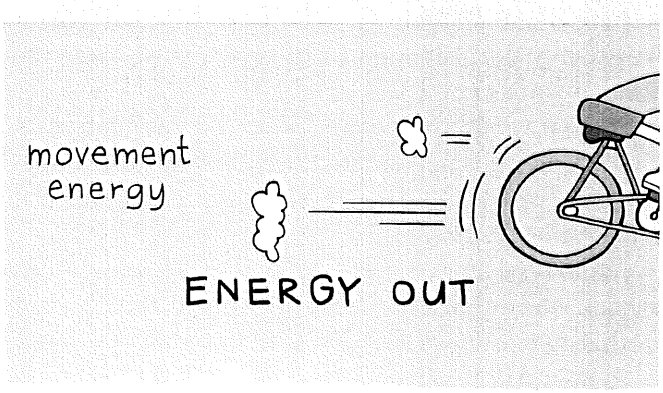
You do work when you use a force to move something. Energy is the ability to do work. In most simple machines, like a can opener, you are applying a force to move the machine. So you are doing work or providing the energy to get the machine working. Machines reduce the amount of work or effort required to get a job done.

Machines are energy transformers. They take the initial or starting energy and transform or change it into a different form. Let's look at a television set. The starting energy is electrical energy. This is transformed to light and sound in the television set, and also heat.

If you are playing hockey, your body is the energy transformer. The stored energy in the food you eat is transferred to your muscles, where respiration occurs and energy is made. This energy is then changed to kinetic energy in your legs and arms when you move. This energy is also changed to heat that makes your body warm because your muscles are working.



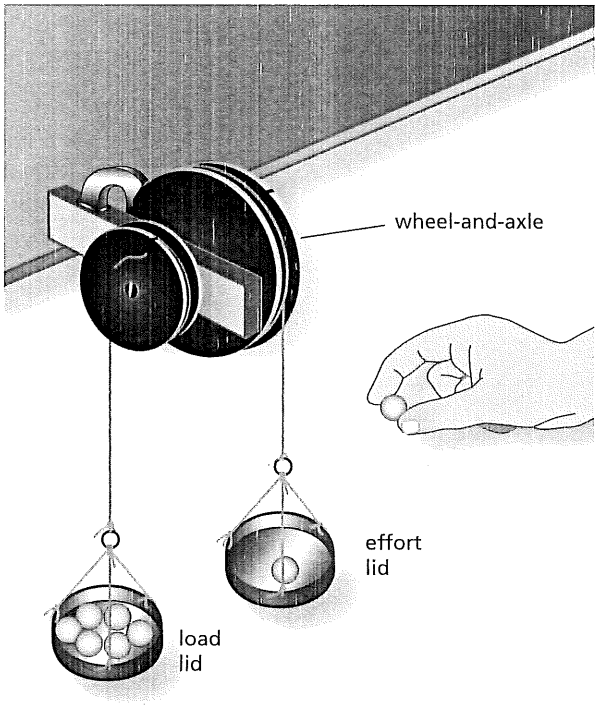




INQUIRY 1 Load and effort

You will need: apparatus pictured

1 Set up the wheel and axle with lids attached as pictured here. (Your teacher may have this set up already as a demonstration.)



2 Add marbles to the load lid until it moves downwards and the effort lid is as high as it can go.

3 Now slowly add marbles to the effort lid until it starts to move downwards, needing no further marbles.

Questions

1 How many marbles did you need in the effort lid compared to the load lid?

2 Is there a force or distance advantage in this machine? Explain.

3 Did this machine change the direction of the force? Explain.

4 Using the same equipment, how could you show that:

a the two lids do not travel the same distance?

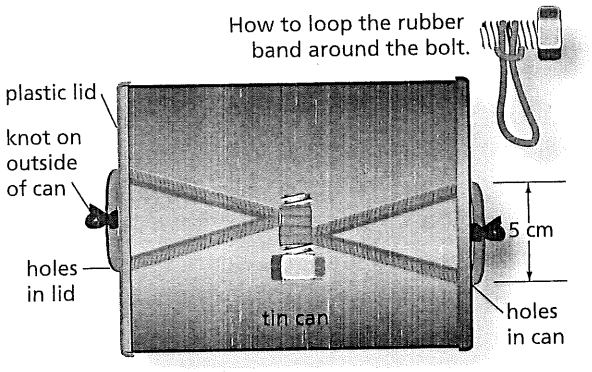
b the two lids do not travel at the same speed? (Hint: If both lids move at the same time, the lid that covers more distance moves faster.)

INQUIRY 2 An energy transformer

Machines can be energy transformers. They can take the initial energy and transform it into a different form.

You will need: a container or can at least 10 cm in diameter with a lid (e.g. 1 L paint tin or a baby's formula tin), nail, hammer, scissors, 1 or 2 large rubber bands, medium-sized bolt

1 Make sure your can has no rough edges and that you can get your hand inside it.



2 Punch two holes in the bottom of the can about 5 cm apart. Do the same with the lid.

3 Loop one of the rubber bands around the bolt as shown. Cut the rubber band and thread it through the holes in the bottom of the can. Then tie the two ends together on the outside of the can.

4 Loop the second rubber band around the bolt and attach this one through the lid of the can. Then put the lid on the can and tie the two ends together on the outside of the lid.

5 Roll the can and observe what happens.

6 Make an inference to explain your observations.

7 How did your can store energy?

8 How did your can transform the stored energy?

9 Consider the design of your can. What variables could you change to make it store more energy and transform this energy more efficiently?

You may want to have a competition to see whose machine can roll back the furthest.

Over to you

1 Copy and complete the following sentences.

a The _____ is the force you put into a simple machine.

b Some machines help you by changing the _____ of the force.

c Some machines _____ the force you use.

2 The following statements are false. Rewrite them to make them true.

a A simple machine can give you a bigger force and make things go faster as well.

b When the effort is larger than the load, the machine has a force advantage.

c The effort is what the machine has to work against to move.

d A high gear on a bicycle will provide a force advantage.

e Another name for the crank on a bicycle is a gear wheel.

3 Give your own examples (different from those in the text) of how a machine:

a magnifies the force used

b changes the direction of a force

c makes things go faster

d transforms energy.

4 Describe in your own words the difference between effort and load.

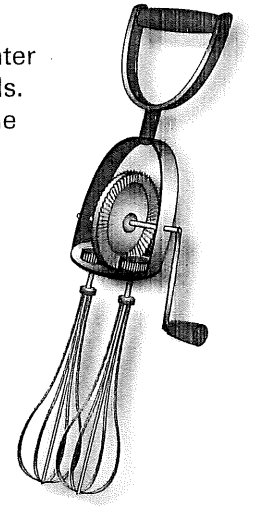
5 Explain what the following examples show about machines.

a John pulled up the sails on his boat. The pulley at the top of the mast made it easier. As he pulled the rope down the sail went up.

b Allison's car had a flat tyre. Using a jack, she was able to lift the car and change the wheel using very little effort.

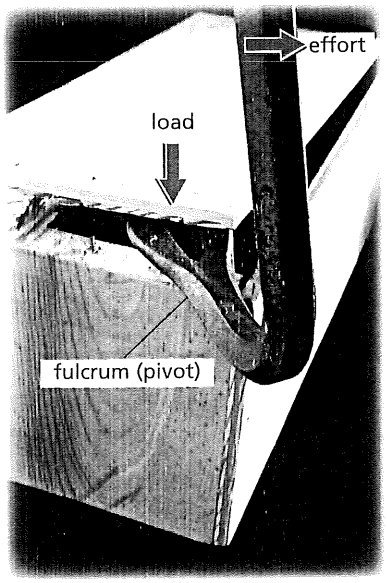
c A car battery has the energy in it to start the engine moving. The engine gets hot as the parts in it move.

d A hand-held egg-beater has three gear wheels. These gears make the beaters turn faster than the handle used to turn them.



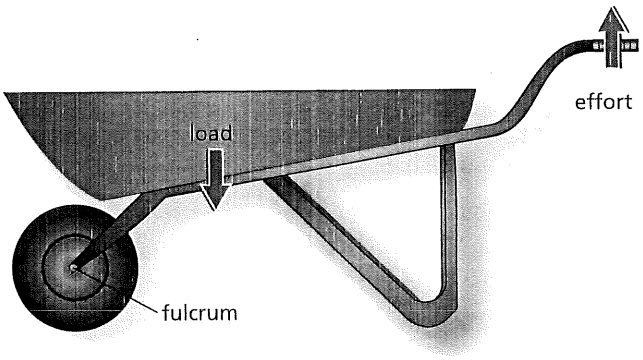
7.2 Levers

It is difficult to get the lid off a wooden packing case, but you can do it easily with the right tool—a pinch-bar. You simply work the claw end of the bar under the lid and pull back on the other end of the bar, as in the photo. A pinch-bar is a common simple machine called a **lever**.



A lever is made up of a long bar or handle that moves around a fixed point called the **fulcrum** or pivot. For example with a wheelbarrow, the fulcrum is the wheel axle. This connects to a tray and then the handles extend from the tray.

Whatever you want to move in the tray is the load, and the force you apply to the handles to do this is the effort. It takes far less effort to move the load with a wheelbarrow than if you tried to lift the load yourself. So in this particular case the wheelbarrow gives you a force advantage.



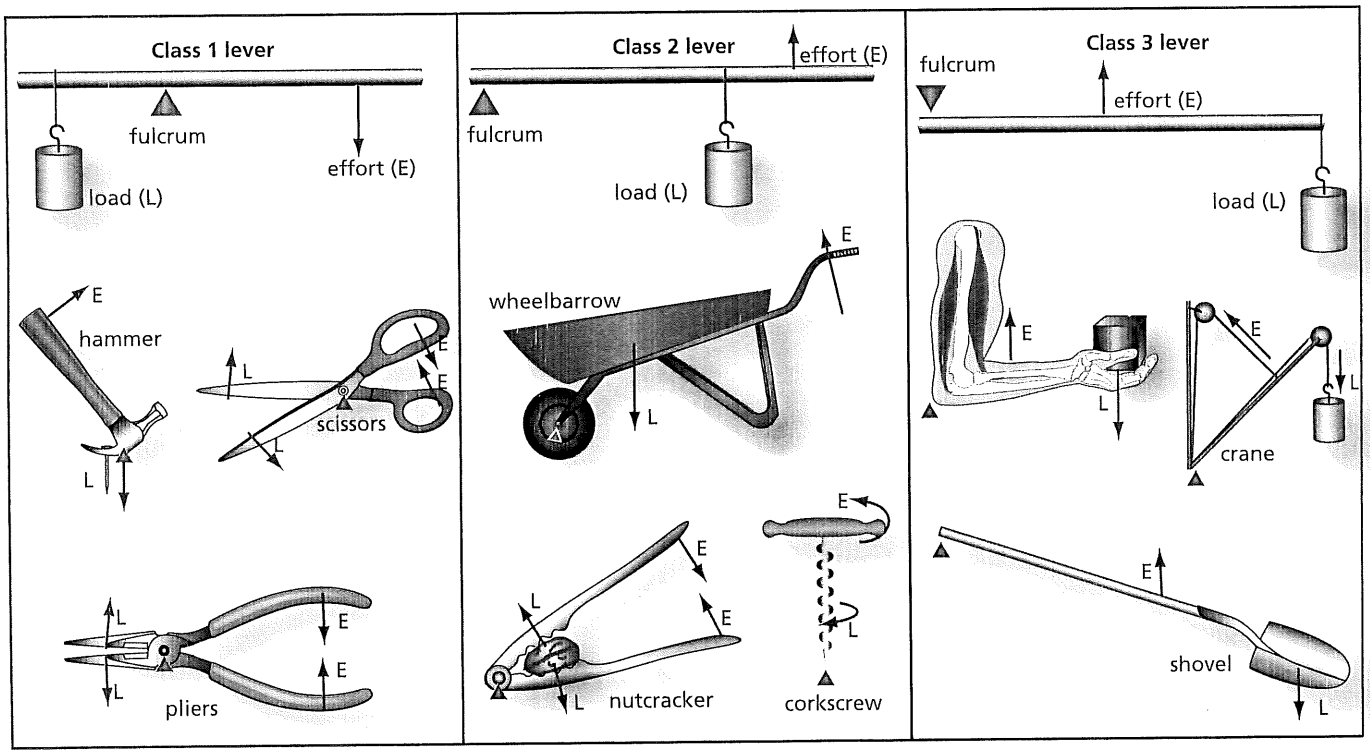
There are times when a lever can provide a distance advantage. For example you can use a slingshot, which is a lever, to catapult a piece of paper across a room. The effort you need to move the paper with the slingshot is much more than if you moved the paper yourself, but the distance the paper moves is much greater than the distance you pull back the elastic.

There are three different classes or types of levers.

Class 1: The fulcrum is between the effort and the load.

Class 2: The load is between the fulcrum and the effort.

Class 3: The effort is between the fulcrum and the load.

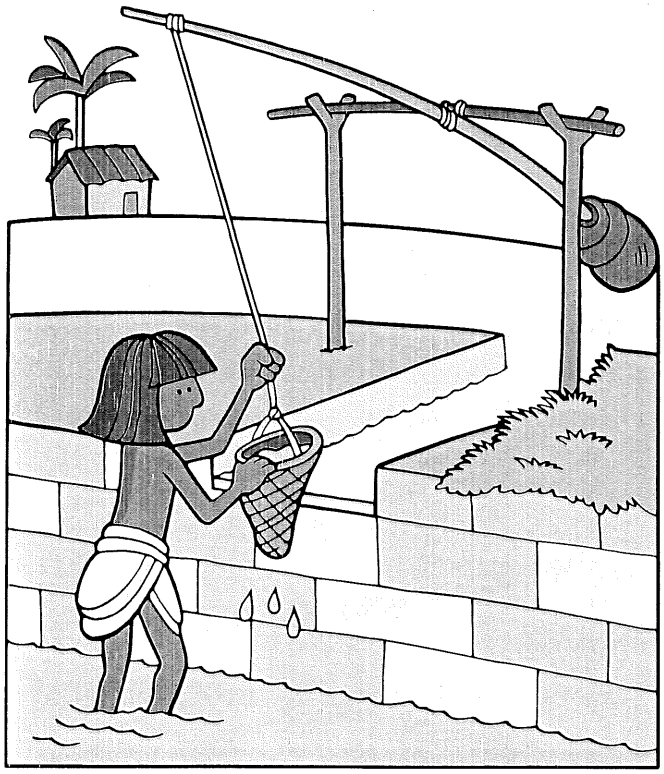


Mechanical advantage

You can see how useful a simple machine is by working out its **mechanical advantage**. To do this, you divide the load moved by the effort you put in. For example, if you were using a car jack to lift a car weighing 1200 N and applied a force of 100 N, the mechanical advantage would be:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$
$$= \frac{1200\,\text{N}}{100\,\text{N}}$$
$$= 12$$

Levers are not modern inventions. The ancient Egyptians used them to help them with their daily tasks. A machine known as a *shadoof* was used to help irrigate farms. When the Nile River was too low for water to reach the irrigation channels, the shadoof was used to lift water to the crops. It was a simple lever as shown.



A shadoof is a lever.

The Romans used a lever to make a wine press. They put grapes under a lever with a hinge at one end. When they pulled the lever down, the grapes were crushed and the wine ran out. Even today farmers, workers and gardeners use levers such as crowbars to make difficult jobs easier.

INQUIRY

3 Classes of levers

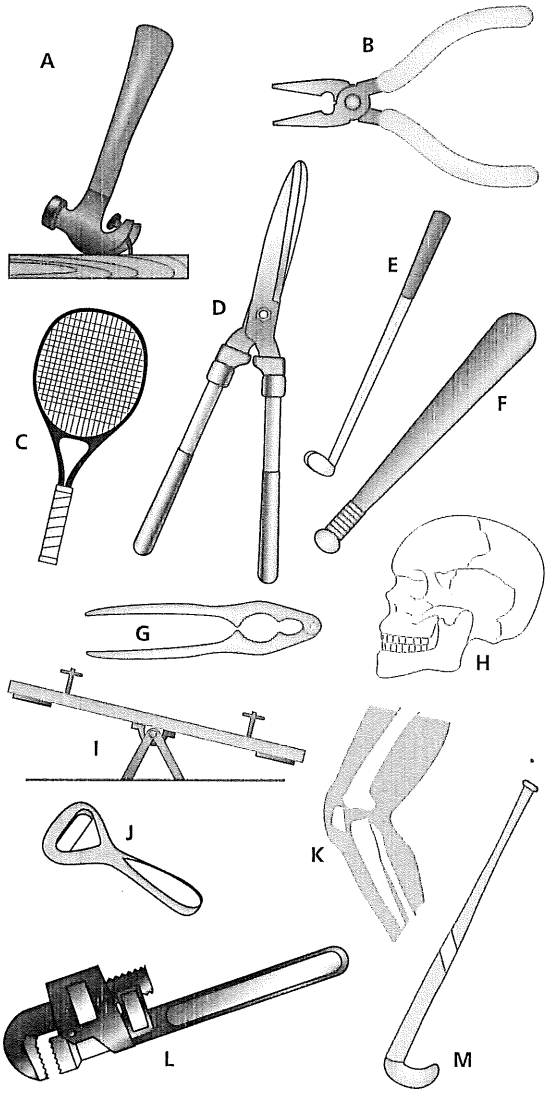
You will need: collection of different classes of levers, e.g. pliers, nutcracker, claw hammer, scissors, spanner, bottle-opener, can-opener, stapler, egg-beater

1 Explain in your own words how the three different classes of levers work. Where is the fulcrum, effort and load in each?

2 Classify the levers you have been given into either Class 1, Class 2 or Class 3.

3 Ask your teacher whether you have classified the levers correctly.

4 Look at the diagrams of levers provided here. Classify them.

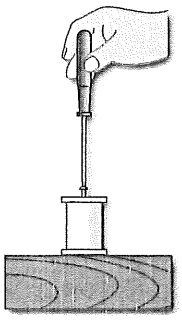


5 Provide your own example of each class of lever, other than those pictured here.

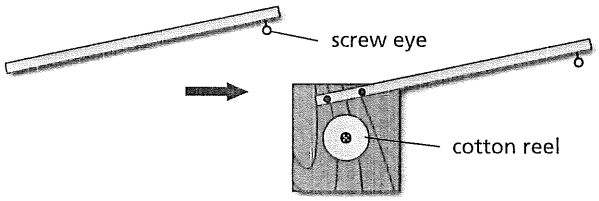
INQUIRY 4 Making your own crane

You will need to collect the equipment pictured.

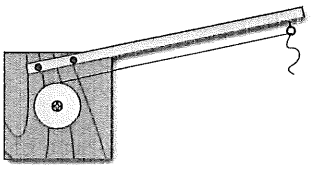
1 Drill a hole in the large block of wood and screw the cotton reel to the wood.



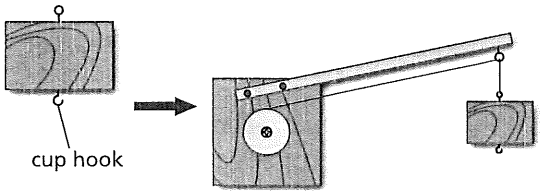
2 Attach a screw-eye to the end of the length of wood and nail it onto the large block as shown.



3 Wind fishing line around the cotton reel and put the end of the line through the screw-eye as shown.



4 Put another screw-eye into the top of the small block of wood and a cup hook into the bottom. Then tie the screw-eye to the fishing line.



5 Try lifting different objects with your crane. Hold the cotton reel to stop it spinning and letting the load fall.

6 Is the crane a simple machine? How does it allow you to do things more easily? (Look at the four ways simple machines help us to do things more easily on pages 135 and 136.)

Over to you

1 Explain in your own words what a lever is and give an example.

2 Explain how a lever can be arranged to have:

a a force advantage

b a distance advantage

3 State whether the following are true or false.

a In a Class 1 lever the fulcrum is between the effort and the load.

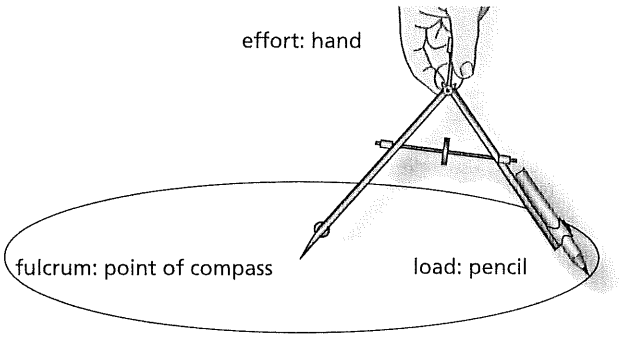
b An example of a Class 1 lever is a wheelbarrow.

c In a Class 2 lever the load is between the fulcrum and the effort.

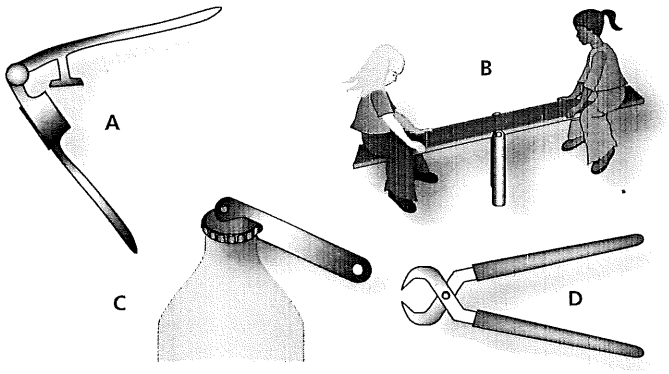
d An example of a Class 2 lever is a pair of pliers.

e In a Class 3 lever the effort is between the fulcrum and the load.

f A drawing compass is an example of a Class 3 lever.



4 State where the fulcrum, effort and load are in the following pictures. Then state what class of lever each one is.



PROBLEM SOLVING

What have you learnt so far that can help you with your task from page 133? Have you decided what sort of gadget you are going to build?