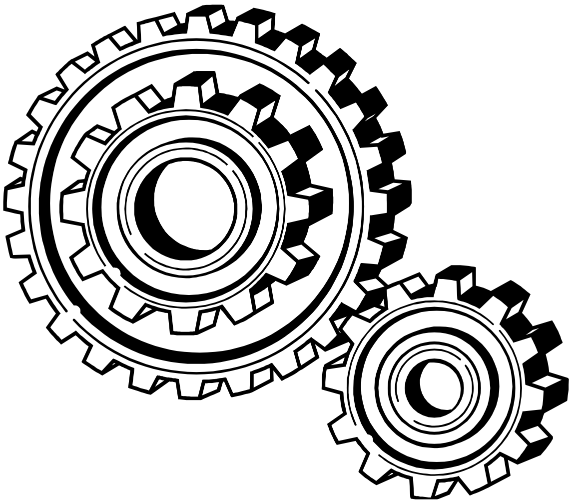
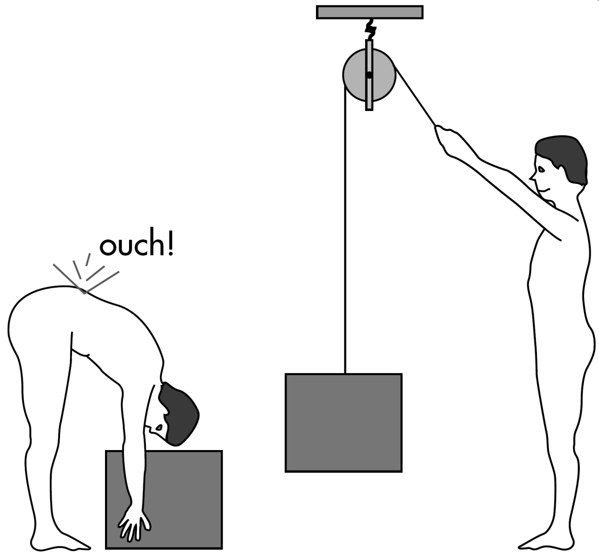
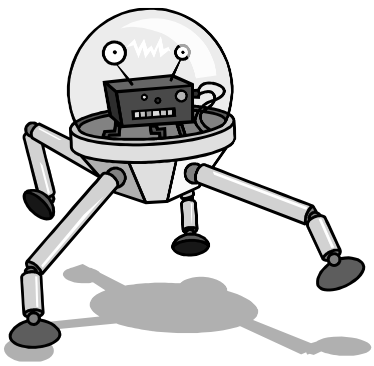
Working





Efficiently

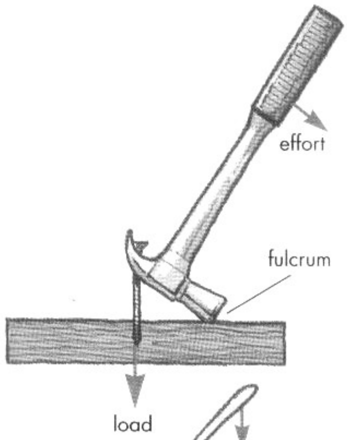


Name: ______________

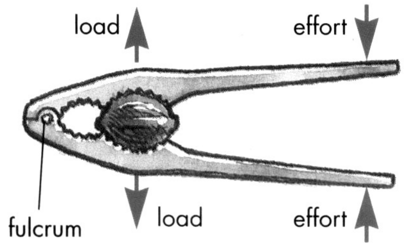
Imagine a Boeing 747 aircraft made of a single, huge diamond—as strong as current materials but only $1/50^{th}$ the weight. Imagine tiny robots that circulate in our bloodstream, seeking out and destroying disease-causing organisms. Imagine computers that are a billion times more powerful than those we have today.
These are all possibilities brought to us by nanotechnology: combining and arranging materials atom-by-atom or molecule-by-molecule. All material is composed of atoms. How these atoms are arranged determines what that the material is. Rearrange the atoms in a lump of coal and you have diamond. Rearranging those in sand produces a computer chip.
To do this, we would need to create very small machines and tools that could use these atoms as building blocks, shifting them around and assembling them in precisely the way we want. These nanomachines or nanobots would be capable of building other nanomachines to help complete tasks quickly and efficiently. A typical nanobot would be about 100 nanometres in length. There are 1 000 000 nanometres in 1 millimetre!
Nanomachines and nanotechnology may sound as if they belong in the far future, but within 30 years nanotechnology is expected to be widely used. Already scientists can move atoms and molecules around to create simple sculptures and they have even created company logos from individual atoms!

Leavers

A Machine is a device that makes a physical task easier. Can-openers, scissors, tongs, hammers, brooms, racquets and staplers are machines. They are also levers. A lever is a simple machine that uses the turning effect of a force to make a task easier.
The turning point of a lever is called its fulcrum. The resistance to motion that a lever works against is called the load. The force used to cause movement is called the effort.



The levers shown in the illustration are **first-class levers.** The fulcrum lies between the effort and the load. A seesaw is another example of a first-class lever. First-class levers are **force multipliers.** They allow you to move a heavy load with a small force.



The wheelbarrow and nutcracker shown in the diagram are also force-multiplying levers. However, the load is between the fulcrum and the effort. Such levers are' called **second-class levers.** A door (not a sliding one!) is another example of a second-class lever.

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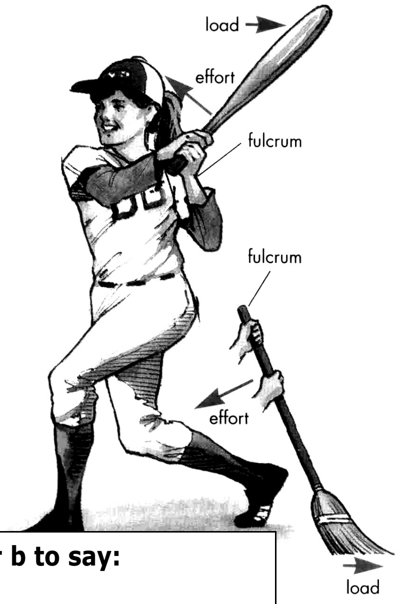
Mass and weight are not the same thing. Mass is the amount of matter in an object or substance and is usually measured in kilograms or grams. Weight is a measure of the force of gravity on an object or substance as it is attracted to the Earth's core, and is measured in newtons

Levers with the effort between the fulcrum and the load are called **third-class levers.** Third-class levers are not force multipliers. They move a load through a larger distance than the effort moves in the same time and are therefore **speed multipliers.** The softball bat and broom shown above right are third-class levers. Golf clubs and tennis racquets are also third-class levers designed to move a small load quickly with a large effort.



A quick way to remember the three classes of lever b to say:
F - L - E equals 1-2-3

F (fulcrum in the centre) = 1 (first-class lever)

L (load in the centre) = 2 (second-class lever)

E (effort in the centre) = 3 (third-class lever)

Experiment GET A LOAD OF THIS

Materials

- ruler at least 30 cm long
- pencil
- 6 x 50 gram masses
- plasticine (to hold pencil in place if it rolls)

Method

1. Use the pencil and ruler to set up a seesaw so that it balances without any masses on it.

2. Place a load of 3 masses 4 cm to the left of the fulcrum. Place the other 3 masses (the effort) to the right of the fulcrum so that the effort balances the load. Record the distance from the effort to the fulcrum in your table.

3. Remove two of the masses from the effort and raise the load of three masses with an effort of only one mass.

4. Experiment with your seesaw to see where various efforts need to be placed to raise loads of 5, 4 or 2 masses. Record your observations in your table.

5. 2. Examine the completed table to see if there is any pattern evident in your data.

6. Do some more testing to confirm your conclusion. Include in your observations the raising of small loads with a small effort.

7. Is there any advantage in using a seesaw-type lever to raise a light load with a large effort?

Results

Load		Effort	
Number of masses	Distance from fulcrum (cm)	Number of masses	Distance from fulcrum (cm)
3	4.0	3	
3	4.0	1	
5		1	
4		2	
4		1	
2		1	

Discussion

1. Why is this type of lever called a force multiplier?

2. Examine the completed table to see if there is any pattern evident in your data. What is your conclusion?

3. Is there any advantage in using a seesaw-type lever to raise a light load with a large effort?

Activities

1. What is a lever?

2. Why are first-class and second-class levers often called force multipliers?

Extension See Appendix A

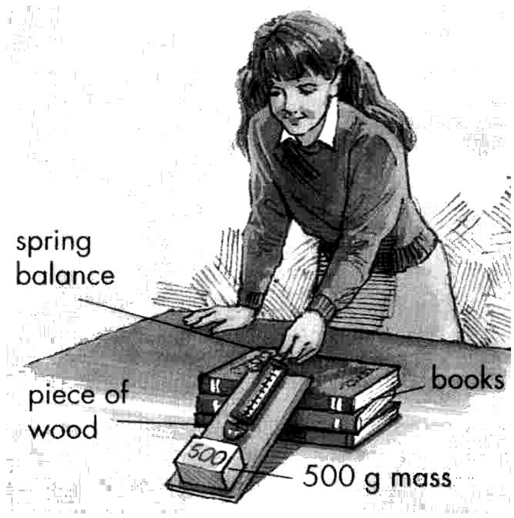
Ramps

A ramp is a machine because it makes the physical task of raising an object easier. A ramp is simply an **inclined plane —** a surface that is set at an angle to the horizontal. It allows objects to be raised with less effort than would be needed to lift them straight up. Ramps are used in shopping centres and other buildings to allow wheelchairs, prams and strollers to be raised with less effort. Although a smaller effort needs to be made, a greater distance must be travelled.

Experiment inclined to make it easier

Materials

- 3 textbooks
- 500 gram mass
- ramp (piece of wood)
- spring balance



Method

1. Place three textbooks on top of each other. Measure and record the height of the textbooks.
2. Place the 500 gram mass next to the pile of books and use the spring balance to slowly lift the mass so that its base is level with the top of the pile. Record the force measured by the spring balance.
3. Lean a ramp against the pile of books as shown in the diagram. Measure and record the distance from the bottom of the ramp to where it meets the top edge of the pile of books.
4. Place the 500 gram mass at the bottom of the ramp and use the spring balance to slowly pull it until its far end reaches the top of the pile.

Results

Discussion Questions

1. Does it take more force to lift the mass straight up or along the ramp?
2. In which case does the mass have to move further — straight up or along the ramp?
3. Which method of raising the mass is better? Why?
4. Look at your measurements of force and distance. Try repeating the experiment with a larger pile of books to see if you can find a pattern. If you do find a pattern, describe it.

Extension See Appendix B

Escalators are moving ramps. The winding mountain road in the photograph is also a ramp. Imagine how much shorter the trip would be if the road went straight up the mountain — but no vehicle would be powerful enough to use the road.

Wedges are inclined planes. They can be used to penetrate or split objects, or to stop them from moving. Axes, knives and your front teeth are examples of wedges. They reduce the force needed to cut through objects. If you have ever tried to cut through a hard piece of food like an apple with a blunt knife you will know the value of a wedge.
The screw is an inclined plane: it is a curved ramp. However, instead of an object being pushed up the ramp, the ramp is pushed clown into the object. The ramp cut into a screw is called the thread; the distance between two turns of the thread is called the pitch. Because the total length of the thread is so great, its force-multiplying effect is very large. Most car jacks use a large screw to lift a huge load with little effort. Similarly, a corkscrew is used to penetrate the tightly fitted cork of a wine bottle with little effort. The cork is then removed by pulling the corkscrew directly out.

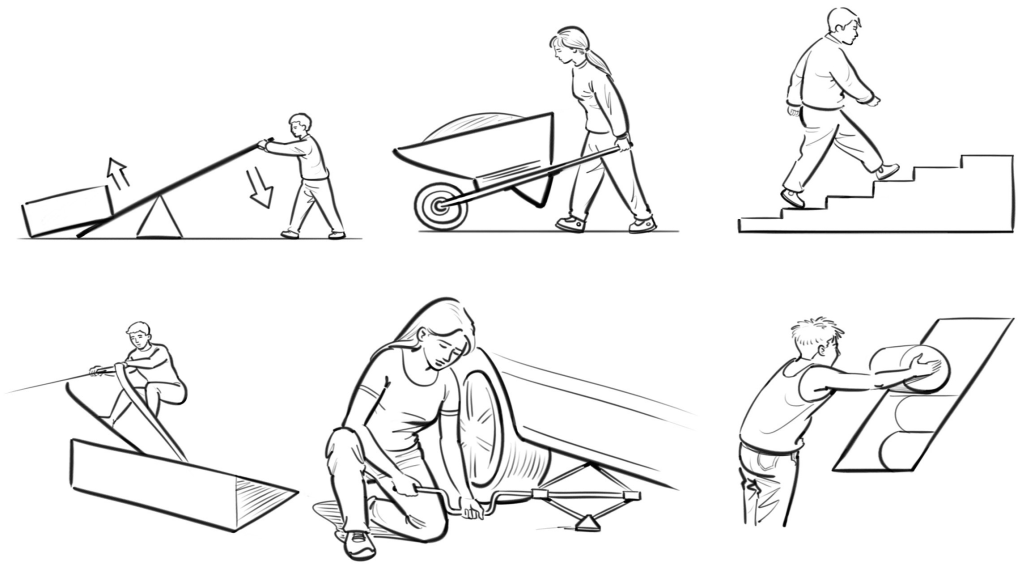
Activities

1. What is a ramp? Why is a ramp a machine?

2. What is the difference between the thread of a screw and the pitch of a screw?

3. A ramp makes it easier to push or pull objects upwards. What is the 'penalty' for making the task easier?

4. Under each of these machines, write whether it is a lever or an inclined plane.



Pulley

A pulley is a simple machine that consists of a single wheel and axle. The wheel has a groove around it so that a rope or cable can be passed over or under it. A single fixed pulley can be used to make it easier to lift a load. It does not decrease the size of the force, or effort, needed to lift the load. It simply changes the direction of the effort.

It is much easier to pull down on a rope to lift a load than it is to push the load. Your own weight can be used to advantage.
When more than one pulley is used, a large load can be lifted with a small effort. A system of two or more pulleys therefore acts as a force multiplier. It magnifies the size of the effort. As with other force multipliers, there is a cost. The rope needs to be pulled through a large distance to move the load through a small distance.
A multiple-pulley system is visually called a block and tackle. The block is the frame around the pulleys. The tackle is the string or cable joining the load to the effort. With a block and tackle it is possible to lift many times your own weight. Of course, you have to pay for it by pulling over a long distance.
A block and tackle system is used in garages to lift engines out of cars. It is also used on cranes, wharves and ships.

Experiment LIFTING THAT LOAD

Materials

- 2 single pulleys
- 2 double pulleys
- 1 metre length of string
- set of slotted 50 gram masses
- 5.0 Newton spring balance
- metre ruler
- hook from which to suspend pulleys

Method

1. Load the slotted masses to a mass of 400 grams and attach them to one end of the string.

2. Use the spring balance to measure the weight, in newtons (N), of the slotted masses. This weight is the load that must be lifted. Record the load in your table.

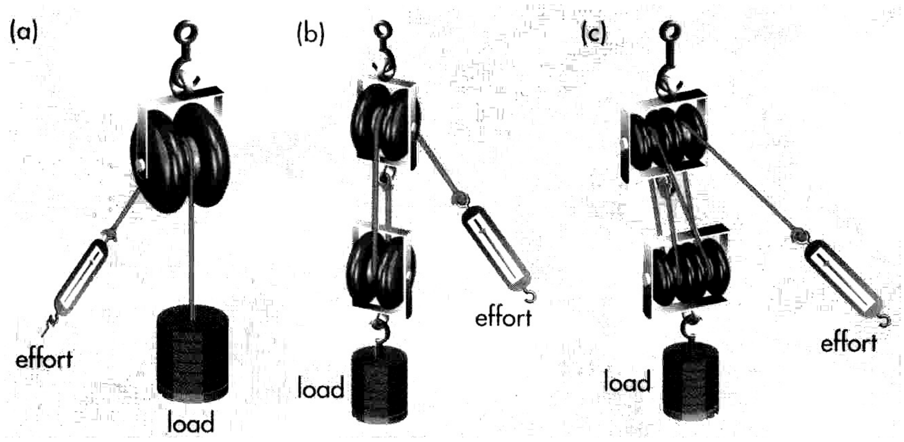
3. Place the other end of the length of string over the wheel of a single pulley and attach it to the spring balance as shown in diagram (a) on.

4. Pull slowly on the spring balance so that the load is lifted slowly and steadily upwards through a distance of 5 cm.

5. Record the force in newtons (N) measured by the spring balance. This force is the effort. Also record the distance through which you had to pull the spring balance to lift the load 5 cm. The distance moved by the effort (your pull on the spring balance) is called the effort distance.

6. Arrange the system with two single pulleys as shown in diagram (b). The pulleys should be about 10 cm apart.
7. Pull slowly on the spring balance to lift the load steadily. In your table, record the force and effort distance needed to lift the load through a distance of 5.0 cm.

8. Repeat the previous two steps, using the system with the two double pulleys shown in diagram (c).



Results

Pulley arrangement	Load (N)	Load distance (cm)	Effort (N)	Effort distance (cm)
Single pulley		**5.0**		
Two single pulleys		**5.0**		
Two double pulleys		**5.0**		

Discussion

1. How does the effort needed to lift the load using two single pulleys compare with that needed to lift it with one single pulley?

____

____

2. How does the effort needed to lift the load with two double pulleys compare with that needed to lift it with one single pulley?

____

____

3. Would it be true to say that the system with two double pulleys has the same advantage as one with four single pulleys? Why?

____

____

4. Looking at your tabulated results, how would you say the effort needed changes as the number of pulleys increases?

5. How does the effort distance change as the effort itself decreases?

6. Predict how much effort would be needed to lift the same load by 5 cm if you used two triple pulleys instead of two double pulleys. How far would you need to pull on a string to lift the load 5 cm?

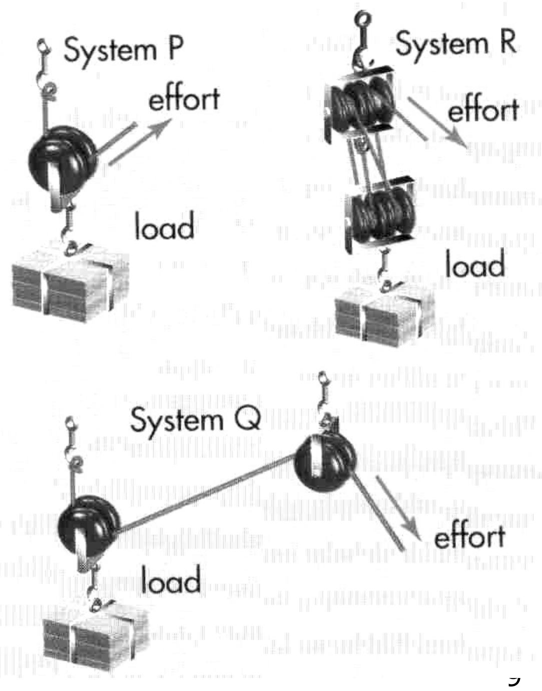
Activities

1. How is a single fixed pulley useful even though it does not decrease the size of the force needed to lift a load?

2. Why is a system of two single pulleys better than one single pulley for lifting very heavy loads?

3. What is a block and tackle? What is it used for?

4. In the diagram below, which of the systems P, Q and R would you need to:
   (a) Apply the least effort
   (b) Apply the most effort
   (c) Pull the string through the greatest distance
   (d) Apply an effort equal to the load
   (e) Apply an effort equal to half of the load?



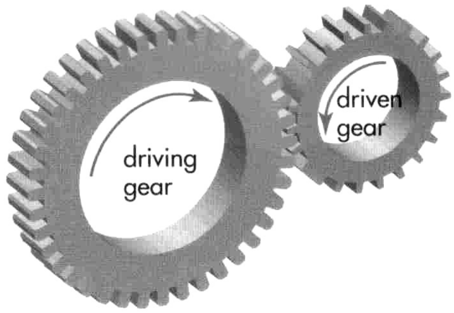
Archimedes (287-212 BC), a Greek mathematician, invented the multiple pulley system. It is believed that he boasted to King Hiero II of Syracuse, 'Give me a place to stand on, and I shall move the whole Earth'. The king challenged Archimedes to prove it. Archimedes responded by using a system of pulleys to single-handedly drag a ship, fully loaded with cargo and passengers, out of the water and onto the land

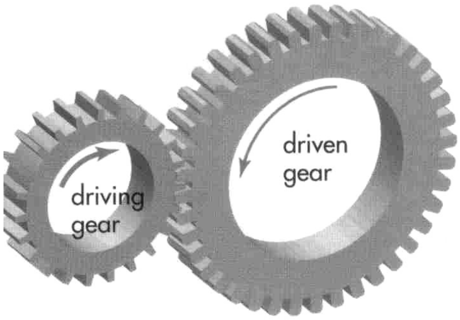
Extension See Appendix C

Gears

Different sizes and arrangements of gears are used to make wheels turn faster, slower or in different directions.

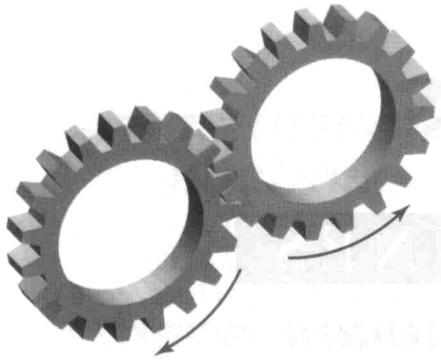
A large driving gear makes a small driven gear move faster, but in the opposite direction. Hand-operated eggbeaters and drills use this combination of gears to make them spin quickly.

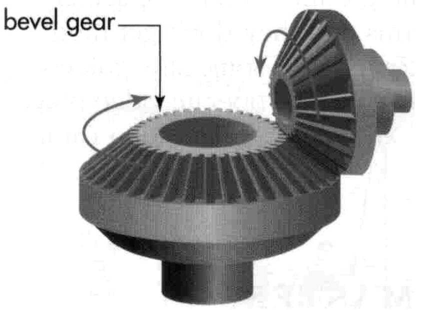




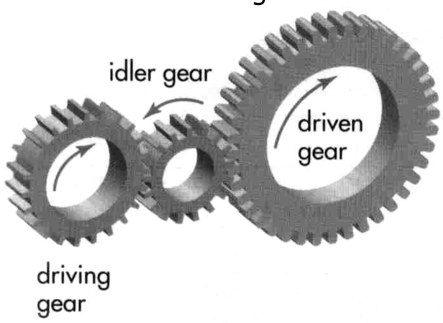
A small driving gear makes a large driven gear move slower but in the opposite direction. This arrangement acts as a force multiplier. It is used to move large loads with a small effort. This arrangement is used in cars to allow them to climb hills or gather speed quickly. It is also used in rotating shopwindow displays to make them turn slowly.

Pairs of gears the same size change the direction of turning without changing the speed.

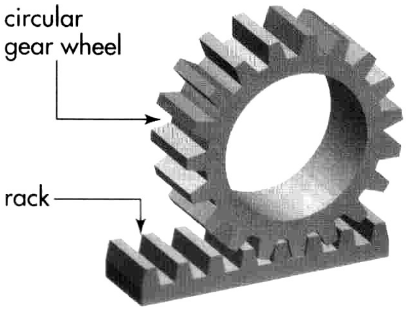




Gear wheels at right angles to each other can change vertical motion into horizontal motion. Hand-operated eggbeaters and drills use this arrangement

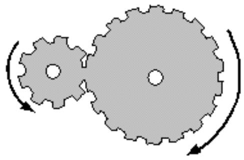


An idler gear can be used between the driving and driven gears to make them turn in the r direction. Why do you think it is called an idler gear?



Rack and pinion gears consist of a flat row of teeth called a rack and a circular gear wheel. A corkscrew changes the circular movement of the driving gears into the upward straight line movement that pulls the cork out.

Wheels with teeth (gears) can be used to change the speed and direction of a force. They are also classed as a type of continuous rotating lever. By using different sized wheels and different numbers of teeth it is possible to multiply either the force or the distance.



In the diagram above, wheel A has nine teeth and wheel B has 18 teeth. As wheel A (the driving wheel) turns, energy is transferred to wheel B (the driven wheel). Because wheel B does not turn as far as wheel A, the force it exerts is larger. **The large wheel multiplies the force exerted by the smaller wheel.**
It is possible to calculate by how much the large wheel multiplies the force:

$$\frac{\text{number of teeth on driven wheel}}{\text{number of teeth on driving wheel}}$$

For the example above, this gear ratio = $\frac{18}{9}$ = 2

The force exerted by the larger wheel is twice that exerted by the smaller wheel.
The ratio can be expressed as a fraction, a decimal or a ratio (18:9).

EXERCISE 1

For the example above, calculate the gear ratio if wheel B is the driving wheel.

EXERCISE 2

Number of teeth on driven wheel	Number of teeth on driving wheel	Gear ratio
50	25	
45	15	
24	48	
60	24	
18	81	

Calculate the gear ratios for the pairs of gears in the table. In which examples is the force exerted by the driving wheel greater than that exerted by the driven wheel? In which examples is the force exerted by the driving wheel less than that exerted by the driven wheel?

EXERCISE 3

Complete the table below.

Number of teeth on driven wheel	Number of teeth on driving wheel	Gear ratio
14	56	
49	13	
	32	2
	12	5.25
10		2.5

For each example, state whether the gear set-up is being used to increase or reduce the force exerted by the driving wheel.

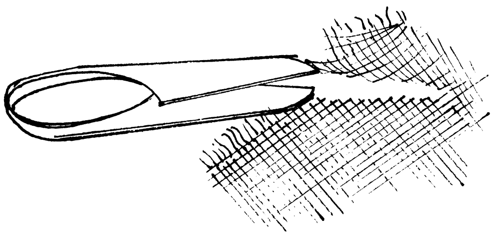
Extension See Appendix D

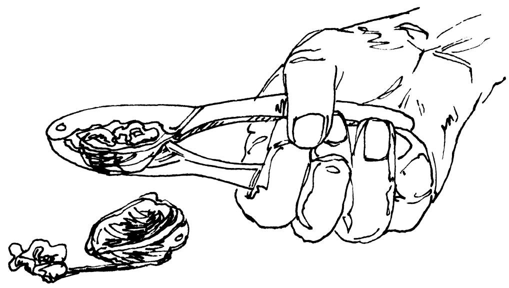
Circle the correct word in each of the following statements.

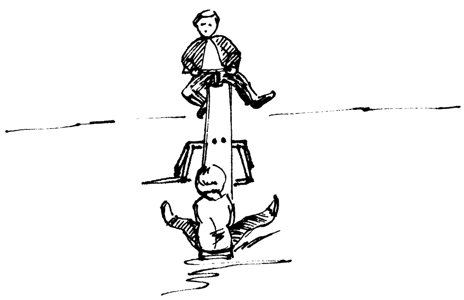
- **a** A machine is any device that makes our lives easier/harder, or does things that we cannot do ourselves.
- **b** A machine needs/does not need energy to perform its functions.
- **c** There are four/six types of machines.
- **d** There are simple machines and engines/complex machines.
- **e** A simple machine is a machine that does/does not do only one thing.
- **f** An inclined plane is the scientific/unscientific name for a ramp.
- **g** A door is an example of a lever/inclined plane.
- **h** A screw with a fine thread is easy/hard to turn.
- **i** A machine has energy when it is able to produce a change/charge through a push, a pull or a twist.
- **j** A lever is usually short/long.
- **k** Gears are teeth cut into wheels to make them work together more/less smoothly.
- **l** A single pulley is a wheel with a rim that acts/doesn't act like a lever.
- **m** Axes and wedges are double inclined planes that can/cannot split wood.

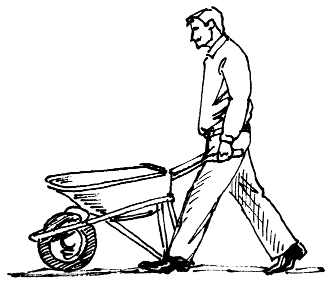
2 Use the three words in the box to label the diagrams below.

load	pivot	effort









A WORLD OF MACHINES

Levers, inclined planes, wheels and axles, pulleys and gears are all simple machines. Most machines, however, consist of two or more simple machines. They are called compound machines. A bicycle is a compound machine consisting of many simple machines. Robots and cars are other examples of compound machines.

Untouched *by human* hands

Robots are compound machines that perform physical tasks without direct human assistance. They can be used to do jobs that are unpleasant, dangerous or boring. Robots can work in hot weather, cold weather, under water, under the ground, in outer space and in noisy places. They don't spread germs and they don't get tired.
Most robots are controlled by computers. Some are guided by remote-control units — similar to those used to operate video players and TV sets. Some robots can 'see' and 'hear' using video cameras and microphones.

Think about this THE CAR — SERVANT OR MASTER?

Cars are compound machines. Most people rely on cars to get around. Think of the advantages of having one; but think also of all of the problems that cars cause — air pollution is just one of them.

- Construct a table like the one below. In a small group, 'brainstorm' the advantages and disadvantages of cars, completing the table as you go.

Advantages of cars	Disadvantages of cars

- After you have completed your table, discuss these questions with your group.

(a) Are cars our essential servants? Could we live without them?
(b) Do cars control our lives so much that they are our masters? Are we slaves to our cars?

Finally, write one or two paragraphs to state your own opinion on whether the car is our servant or our master. Include reasons for your opinion.