10. FORCES AND SIMPLE MACHINES

10.1 INTRODUCTION

This chapter is about forces and simple machines. Whenever you push, or pull or turn anything you use force. Look at the illustrations below. (i) An elephant uses force to push down a tree. Elephants often do this so that they can eat the tender leaves at the top. (ii) Two teams use force to pull on a rope in a 'tug of war' contest. (iii) We use force to turn a water tap. If you think about turning anything, you will see that you push one side and pull the other, so really we only need to talk about forces that push and forces that pull.

Force and movement go together. A force always tries to move something, or to stop it from moving. A 'tug of war' is a good example. Each team is trying hard to move the other team. They are also trying hard to stop the other team from moving them! When an elephant pushes against a tree, the tree resists being moved - it pushes back at the elephant. If the tree is big enough, and has good roots, the elephant may not be able to push it over. In this chapter we will not have time to study the relationship between force and movement; we will do that in Chapter 17. However, after seeing how force is measured, we will study a very important force that resists movement - a force called friction.

Friction is the force that resists motion between any two surfaces in contact with each other. Friction makes it hard to drag a load along the ground. Strangely enough, although friction resists motion, life without friction would be very difficult. For example, we would be unable to walk! Most vehicles would be unable to move too, and a 'tug of war' would be completely impossible. Can you see why?

After friction, this chapter looks at forces that do not involve contact - forces that act at a distance. You already know about magnetic attraction and repulsion, but in this chapter we will concentrate on gravity. A familiar example of gravity is the force that attracts all objects to the Earth. It is gravity that makes things feel heavy and that makes objects fall to the ground if nothing holds them up. It is also gravity that keeps the Earth in place around the sun, and the moon in place around the Earth. While we are looking at the force of gravity, we will also study stability - why some things, like a stool or a stepladder, are easily knocked over but others, like a table, are not.

To finish the chapter, we look at pressure and simple machines. Pressure is the force on a particular area. What difference do you think it makes if a force is spread over a large area or concentrated in one spot? The answer is in Module 10.8 but the diagram may give you a clue! Finally, a machine is anything that changes the size, direction, or place of a force. Three simple machines that we look at are levers, pulleys and ramps. We will also study water pumps and the hydraulic jack (used in repair yards to lift trucks).
10.2 MEASURING FORCES

Force is usually measured with a spring balance. The force stretches or compresses a spring. The amount of stretch or compression tells us how strong the force is. Spring balances are often used for weighing things, so many spring balances have scales that read in grams or kilograms. However, the unit of force used by scientists is the newton (N).

A force of 1 N is almost the same as the weight of a 100 g mass - that is, the weight of a small mango or any similar fruit. In Module 10.4 we will discuss how scientists use the words mass, weight and force, but to give you an idea, a 1 litre plastic bottle of coke (mass 1 kg) weighs about 10 N and a student (mass 40 kg) weighs about 400 N.

Measure as many different forces as you can. Use any available spring balances including bathroom scales. Bathroom scales are a kind of spring balance because they work by compressing a spring. There are some suggestions in the boxes below. For accuracy, make sure your line of sight is always at right angles to the scale. Convert g or kg to N if necessary.

### Converting forces/weights

- 1 g = 0.01 N
- 1 kg = 10 N
- 1 N = 100 g = 0.1 kg

### Using bathroom scales to measure how strong your muscles are.
First, stand on the bathroom scales and measure your weight in newtons. (Most bathroom scales measure kilograms - just multiply by 10 to convert to newtons). Now measure the strength of your grip (Fig 1), the strength of your biceps (Fig 2), the strength of your triceps (Fig 3) and the strength of your chest muscles (Fig 4). Make a table and record your results in newtons.

### Using spring balances to measure everyday forces.
Use spring balances, like the one illustrated, to measure as many everyday forces as you can. Make a table and record your results in newtons. Here is a list of some of the forces you might measure. Add some of your own ideas too: opening a drawer, stretching a rubber band, lifting different objects, dragging objects along the floor, switching on a light.

- 1. Give the name of a force that, (i) resists motion between two surfaces, (ii) acts at a distance.
- 2. What force (in newtons) is shown on each of the spring balances illustrated at the top of this page?
- 3. How do you convert weights in kg to forces in N?
10.3 THE FORCE OF FRICTION

Friction is a force that resists motion between two surfaces that are sliding against one another. Friction makes it hard to drag a load along the ground. In the picture, a student is trying to pull a box along the classroom floor. At first the force he uses is not enough. The force of friction between the box and the floor prevents motion. However, when the force he uses is greater than the force of friction, the box starts to slide.

Friction is caused by the roughness of the two surfaces rubbing together. The roughness of one surface catches against the roughness of the other surface and resists movement. When both the surfaces are very rough, for example the surfaces of stone or concrete, the force needed to overcome friction is large. When both the surfaces are smoother, for example surfaces of polished wood, the force needed to overcome friction is much less. However, even a surface that looks very smooth may still have some roughness. The illustration on the left shows the surface of a smooth sheet of paper as seen through a microscope. As you can see, it is really quite rough. Of course there is no friction when there is no force trying to move something - friction only operates when a force is applied.

The importance of friction. Have you ever tried to pick up something very slippery with wet, soapy hands - for example ice, or wet soap, or a wet fish? It is very difficult to hold. When you pick up any object, you need a bit of roughness to provide friction between your hands and the object. Without friction you cannot keep a grip on anything! Imagine trying to have a tug of war with a slippery rope, and with your feet slipping on the ground too!

We need good friction when we walk or drive a truck. When you walk, one foot pushes backwards against the ground while the other foot steps forward. If there is not enough friction between your foot and the ground, your foot slips and you may fall. This is what happens when you step on something slippery like a banana skin! For the same reason, a car or truck uses rubber tyres to give good friction between the wheels and the road. When the wheels try to turn, they push backwards against the road. If there is not enough friction between the wheel and the road, the wheel just spins round and the truck does not move. This is what happens on a soft muddy surface! However, when there is good friction between a rubber tyre and a hard road, the wheel cannot slip so the truck moves forward.

Reducing friction. Although friction is often useful, there are many times when we want to reduce it - for example when we drag a heavy load over the ground or when the wheels in a machine must turn easily and smoothly. Two common ways of reducing friction are the use of rollers and lubricants.
The illustration shows fishermen pulling their boat up the beach. They are using logs as rollers. Without rollers, more men would be needed. However, with rollers to reduce the friction, only a few men are needed.

A lubricant is a substance that reduces friction between two moving surfaces. In machines, moving parts that are made of metal are always lubricated with oil. For example, in a truck oil is added to the engine regularly. The oil circulates to all moving parts. Lubrication means that less force is needed to move the parts of a machine. Lubrication also reduces wear so that the moving parts last longer.

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10.4 GRAVITY, WEIGHT AND MASS

The Earth pulls all objects towards itself with a force called gravity. Because of gravity, any mass that is not supported falls towards the Earth. The sun, the moon and all the planets have gravity too. Because the moon is much smaller than the Earth, the force of gravity on the moon is much less than it is on the Earth.

The weight of an object is the force of gravity pulling it down. Weight is a force so it is measured in newtons. The diagram and the table show the weights (measured in newtons) of a number of different masses (measured in grams or kilograms).

<table>
<thead>
<tr>
<th>Mass</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 g</td>
<td>0.98 N</td>
</tr>
<tr>
<td>200 g</td>
<td>1.96 N</td>
</tr>
<tr>
<td>500 g</td>
<td>4.9 N</td>
</tr>
<tr>
<td>1 kg</td>
<td>9.8 N</td>
</tr>
<tr>
<td>10 kg</td>
<td>98 N</td>
</tr>
</tbody>
</table>

Study the table carefully. Notice that 100 g is actually a tiny bit less than 1 N. Notice also that, when the mass increases so does the weight. When you double the mass, you double the weight; ten times the mass has ten times the weight and so on. You also know that things you buy in shops or markets are weighed in grams or kilograms, not in newtons! So what is really the difference between mass and weight?

**Difference between mass and weight.** The mass of anything is the amount of matter it contains. It is measured in g or kg. The mass of an object doesn't change. The weight of anything is the force of gravity pulling it down. It is measured in newtons. The weight of an object changes if gravity changes!

A student with a mass of 60 kg weighs almost 600 N on Earth. If she travelled to the moon, her mass would still be 60 kg. However, gravity is much less on the moon and she would only weigh about 100 N. She could jump really high! Of course on Earth gravity does not change much, so nor does weight. That is why shops and markets do not bother about the difference between weight and mass.

Mass and weight are measured differently. Mass is measured with a **beam balance** where an object is compared with standard masses. Weight is measured with a **spring balance**.

- 1. Which is greater, a force of 1 N or the weight of a 100g mass?
- 2. What is the difference between mass and weight? How is each one measured?
- 3. A boy can just lift a mass of 40 kg on Earth. What mass can he lift on the moon?
10.5 CENTRE OF GRAVITY

The *centre of gravity* of an object is the point at which the whole weight of the object appears to act. If an object can be supported at its centre of gravity, it will balance.

**Finding the centre of gravity for a flat shape.**

1. Cut any shape from stiff card. Make 3 small holes at different places near the edge of your shape.
2. Use a pin to hang your shape from one of the holes. Hang a key or similar weight on a thread from the same pin. Draw the line of the thread across the shape.
3. Repeat for the other two holes. Where the three lines cross is the centre of gravity of your shape. Check by balancing the shape on the point of a nail.
4. Tape a small coin near one edge of your shape. Find the new centre of gravity.
   - 1. Why has the centre of gravity moved?

**Centre of gravity and stability.** If an object easily falls over we say it is *unstable*. Brick A stands on one end. The whole weight of the brick acts straight down at the centre of gravity. The base that the brick stands on supports the weight. Brick B is tilted to one side. Now the weight is not over the base, so the brick falls on its side. Any object will fall over if its centre of gravity is not vertically above the base it stands on.

Objects are stable when they have a low centre of gravity and a wide support base. Brick C is much more stable than brick A - it cannot fall over. Stability is important in furniture and in vehicles. Tables need to be stable. Although the centre of gravity may be high, the base is very wide. Tall stools easily fall over because the centre of gravity is high and the base is narrow.

**Where is the centre of gravity?**

1. For objects made from a single material, the centre of gravity is at the geometrical centre of the object.
2. For objects that contain different materials, the centre of gravity will be nearer to the heavier (denser) material.

Trucks and buses that carry heavy loads need to be stable. The engine, and the heavy steel framework that supports the engine, are placed as low as possible. The higher parts of the vehicle are made of light materials such as aluminium or wood. This keeps the centre of gravity as low as possible. The wheel base of the vehicle is made as wide as possible. When the vehicle is loaded, the centre of gravity rises. If the vehicle is overloaded, it may become unstable. On a sloping road, the high centre of gravity may fall outside the wheel base. If that happens, the truck will crash over onto its side. In exactly the same way, ships that are overloaded can easily overturn when they are rocked by waves.

- 2. What two things can cause instability?
- 3. Explain why it may be dangerous to load too many passengers onto a ship.
Pressure is the force pushing (pressing) on a fixed area. The SI unit of pressure is the pascal (Pa). One pascal is a force of 1 newton pressing on an area of 1 square metre so we can write 1 Pa = 1 N/m².

To calculate pressure, we need to know the force and the area on which the force is pressing. The pressure in Pa is the force in newtons divided by the area in square metres. Two simple examples for you to try are given in Question 1 at the bottom of the page.

When learning about pressure, it is easier to think about more familiar units. One pascal is roughly the weight of a 100 g mass spread out over an area of 1 m² - so one pascal is a very small pressure! Atmospheric pressure is roughly the weight of a 1 kg mass concentrated on 1 cm² - this is, about 100000 (10⁵) Pa.

Concentrating the force. When a large force is concentrated onto a small area, we get a high pressure. This happens with any sharp object such as a needle or a knife. A needle penetrates heavy cloth because all the force pushing it is concentrated on a tiny area at the point. In the same way, a knife cuts because the force pushing it down is concentrated on the tiny area of the edge of the blade.

Spreading the force. Spreading a force over a larger area reduces the pressure. People in cold climates use special shoes to walk on soft snow. Snow shoes have a large area. This 'spreads the load' so their feet do not sink into the snow.

- 1. Calculate the pressure when a force of 20 N pushes on (i) a door of area 2 m², (ii) the point of a nail with an area of 10⁻⁸ m².
- 2. Explain the shape of a drawing pin (thumb tack) using the word pressure.

Observations: The flat side of the coin makes only a shallow mark in the clay, but the edge of the coin sinks in a long way.

Interpretation: With the flat side of the coin, the 10 N force is spread over a large area. The pressure is low and the coin does not penetrate. When the edge of the coin is used, the same force is concentrated onto a smaller area. The pressure is higher and the coin penetrates the clay.
10.7 MEASURING PRESSURE

A U-tube manometer was used for measuring water pressure in Module 3.9. Go back and read about this. The water manometer measures small pressures as a difference in the height of two water levels in a U-shaped tube. It is easy and cheap to make but not very convenient to use. Mercury is much denser than water so a mercury manometer can measure much higher pressures. Differences in water or mercury levels can be converted to normal pressure units by making a suitable scale. Manometers are not very often used outside laboratories.

A Bourdon gauge is the most familiar kind of pressure gauge. It is used for measuring the pressure of air in the tyres of motor vehicles and the pressure of gases, such as oxygen, in gas cylinders. The Bourdon gauge works like the party toy that uncurls when you blow into a tube! In the Bourdon gauge the tube is made of metal and it only uncurls a tiny bit. The small movement at the end of the tube is magnified by levers, which turn a pointer on a scale. The units on the scale may be pascals or any pressure unit that is convenient for the user.

A barometer is an instrument for measuring atmospheric pressure. A mercury barometer is made from a strong glass tube, sealed at one end and filled with mercury. The tube is inverted with the open end in a small dish of mercury. A ruler with is fixed beside the tube. The pressure of the atmosphere supports about 76 cm of mercury. Above the mercury is an empty space containing a small amount of mercury vapour. As the pressure of the atmosphere varies, the level of the mercury in the barometer goes up and down.

An aneroid barometer uses a thin metal box with most of the air removed from it. The top of the box is attached to a strong spring. As the pressure of the atmosphere varies, the top of the box moves up and down a tiny bit. The movement is magnified by levers, which turn a pointer on a scale. The scale may be marked in cm of mercury, or millibars (mb), or hectopascals (hPa).

Atmospheric pressure. Atmospheric pressure varies with height. It is greatest at sea level and decreases with height. Even at a fixed height, the pressure of the air varies with the time of day and the weather. The air pressure on an average day at sea level is approximately 1 kg/cm². It is given below in the most commonly used units.

- 760 mm of mercury
- 1 bar (b) or 1000 millibars (mb)
- 100 000 pascals (Pa) or 1000 hectopascals (hPa)

1. What are the following used for (i) a Bourdon gauge, (ii) a barometer?
2. Why are mercury barometers not often used?
3. (i) What do the symbols mb and hPa stand for? (ii) Which is the greater pressure, 1 mb or 1 hPa? (iii) Convert 1040 hPa into mm of mercury.
The bicycle pump (above). When the handle is pushed in, the air pressure inside the barrel increases. The pressure forces the edges of the soft leather washer against the barrel and this traps the air inside. As the washer is pushed further in, the pressure continues to increase. When the pressure in the barrel is greater than the pressure in the tyre, air from the barrel enters the tyre through the valve. A valve is a device that allows a fluid (liquid or gas) to pass through it in one direction only. When the handle is pulled out, the pressure of the air in the barrel falls. The pressure of the air outside the pump forces the edges of the washer away from the barrel and fresh air flows in. The process is repeated until the tyre is full of air.

The syringe (right). Look at the diagram on the right. To fill a syringe, the piston starts at the bottom of the barrel. The end of the syringe is placed under the surface of the liquid and the piston is pulled up. The pressure of the atmosphere on the surface of the liquid pushes the liquid into the barrel of the syringe.

The lift pump (left). Lift pumps are often used to pump water from a well. A handle is pumped up and down and this moves a piston up and down in the barrel of the pump. When the piston moves down, valve A opens and valve B closes. Water flows through valve A into the space above the piston. When the piston moves up, valve A is closed by the pressure of the water above it. The water is lifted by the piston and flows out of the spout. As the piston rises, air pressure, on the surface of water in the well, forces water up the tube through valve B. Atmospheric pressure can hold up a column of water nearly 10 m high. However, because of water vapour and friction in the tubes, a lift pump can only raise water about 7 m. If a well is deeper than 7 m, a force pump must be used.

The force pump (below left). The diagram shows a force pump. Valve A must within 7 m of the surface of the water in the well. The water can be pumped up to any height if the force pushing the piston is great enough. The piston may be moved up and down by a handle (as with the lift pump), or by an engine. When the piston is pulled up, the pressure of the air in the well forces water up the pipe and through valve A. The pressure of the water in the outlet pipe keeps valve B closed. When the piston is pushed down, the pressure of the water in the barrel shuts valve A and opens valve B, so water is forced up the outlet pipe. A diaphragm pump works in exactly the same way, but the piston is replaced by a flexible rubber diaphragm.

Rotary pumps (right) are usually driven by engines. The engine rotates a paddle wheel (impellor), which sucks in water at the centre and throws it outwards. The inlet must be within 7m of the surface of the water being pumped. Rotary pumps can pump water to any height if they are strong enough.

- 1. (i) What is a valve? (ii) In the lift pump, what does the valve B do?
- 2. (i) In a rotary pump, why must the inlet be no more than 7 m from the surface of the water? (ii) In a force pump, how is the piston moved and, (iii) how high can the water be pumped?
Carpenters and mechanics do not try to push in nails or turn bolts with their bare hands! They use tools such as a hammer or a spanner to make the job easier. In a similar way a cook uses a spoon to mix the ingredients of a cake and a seamstress uses a sewing machine to make clothes. A tool is any device that makes a job easier. Machines are tools, but the word machine has a technical definition. A machine changes the magnitude, or direction, or point of action of a force. The force we apply to the machine is called the effort, and the force that the machine pushes or pulls against is called the load.

One of the simplest kinds of machine is the lever. A lever is any rigid object that pivots at some point when a force (effort) is applied. A good example is a crowbar. In the diagram, one end of a strong iron crowbar is pushed under a rock that someone wants to move. Close to the rock is a small stone to act as a pivot (or fulcrum). When a downward force (effort) is applied to the end of the crowbar, it pivots on the stone. The end under the rock pushes upwards against the weight of the rock (load) with a force that is much greater than the effort.

Type 1 levers are like the crowbar. Type 1 levers have the pivot in the middle, between the load and the effort. Other examples of type 1 levers are shown below.

Type 2 levers have the load in the middle, between the effort and the pivot. Type 2 levers always magnify the effort so a small effort can lift a larger load. A good example is using a pole to roll a tree trunk as illustrated. Other examples of type 2 levers are illustrated below.

Type 3 levers have the effort in the middle, between the load and the pivot. For type 3 levers the effort is always larger than the load. Type 3 levers are useful because they magnify the distance moved. A smaller movement of the effort causes a greater movement of the load. Study the diagram below, which shows the action of the biceps muscle in your arm. Your biceps have to be very strong because they must exert a force much greater than the load you are lifting. The advantage of the biceps is that a small movement of the muscle can move your hand a long way.

1. (i) Why is a lever called a machine? (ii) Demonstrate or draw two examples of each type of lever - one example from this page and one new example. For each lever, label load, effort and pivot; also state if the effort is greater or less than the load.

2. Which type of lever is a spanner turning a nut?
10.10 MACHINES 2 - PULLEYS

In the last section you learnt that a machine changes the magnitude, or direction, or point of action of a force.

A pulley is a simple machine in which a rope passes through one or more blocks containing wheels that are free to turn. A pulley with one fixed block is illustrated on the right. In the illustration, a downward pull (effort) is used to lift a mass (load). Providing no effort is wasted overcoming friction, the effort is equal to the load. Notice also that the distance moved by the load (upwards) is the same as the distance moved by the effort (downwards). The main advantage of this pulley is that most people find it easier to pull downwards than to lift upwards, because they can use their weight to help.

When a single block is attached to a load, the force of the effort is magnified. Study diagram A below. The man is pulling up on the rope, but the load feels the force of two ropes pulling upwards. If no effort is wasted overcoming friction, the effort needed is only half the load! System A has two disadvantages. (i) The man has to pull upwards so he cannot use his weight. (ii) The effort has to move twice as far as the load. The man must pull 2 m of rope to raise the load only 1 m. In diagram B, an extra block has been added so the man can use his weight to pull downwards. The extra block does not change the force (effort), it only changes the direction of the pull. In any pulley system, only the blocks that move magnify the effort.

\* Friction is often a problem in pulleys. Friction prevents the wheels in the blocks from turning easily. When this happens, a lot of extra effort is needed just to turn the wheels.

Pulleys are much more effective when the wheels are well lubricated with oil so they turn very easily.

A block and tackle is a common pulley system that uses two double blocks. One of the blocks is fixed and the other is attached to the load and moves. A block and tackle usually multiplies the effort by four. The illustration below shows a block and tackle lifting an engine out of a truck. Blocks and tackles with wire ropes are used in cranes for lifting heavy loads and in lifts that carry people up and down in tall buildings.

- The illustration on the right shows how a pulley might be used to pull a car out of a ditch. (i) How would you minimise the effort wasted by friction? (ii) How much rope must be pulled to move the car 1 m? (iii) How many times is the effort multiplied? (iv) Draw a better set-up using the same pulleys - one that multiplies the effort more.
Scientists and technologists call a slope that is used like this a *ramp*, or an *inclined plane*. An inclined plane is a machine because it changes the direction and magnitude of the force needed to raise a load.

The ancient Egyptians used ramps more than 4500 years ago when they built the world famous pyramids to hold the tombs of their kings. It has been calculated that the Great Pyramid contains more than 2 million blocks of stone. Each block weighs about 2 tonnes. With no cranes or modern machinery, each block had to be dragged up ramps of earth by teams of workers. As you can see, they used rollers to reduce friction too.

A screw, or a nut-and-bolt use an inclined plane to clamp two things tightly together. Look closely at a screw. A groove called the *thread* forms an inclined plane that spirals from one end to the other. Screws are inserted into a hole by turning them clockwise with a screwdriver. The effort is the force used to turn the screw. At first, the inclined plane draws the screw into the hole and the load is just friction. However, when the screw is tightened, the load becomes a force that pulls together the things being joined. Providing there is not too much friction, the force (load) clamping things together is much greater than the effort applied in tightening the screw. The same thing happens when a nut is tightened on a bolt. At first the nut turns easily because the only load is friction. But when the nut is tightened, the objects being joined are clamped together with great force. *Washers* are often used under the head of a bolt, and particularly under a nut, to spread the load and avoid damage to the objects joined.

1. State two ways you might use to minimise the effort needed to drag a heavy load up a ramp.
2. State the main advantage and the main disadvantage of using a ramp to raise a heavy load.
3. Explain why each of the following is a machine. (i) A type 2 lever (ii) An inclined plane.
4. Use the idea of machines to explain what happens when a spanner is used to tighten a nut on a bolt.
Hydraulic machines use the pressure in a liquid to change the magnitude and direction of a force. When a force is applied to a liquid, it is transmitted through the liquid as pressure that acts equally in all directions. Study the diagram on the right. Imagine a force of $F$ Newtons pressing down on piston A. Pressure is force divided by area so we need to know the area of the piston. Piston A has a surface area of 1 cm$^2$ so the pressure will be $F \div 1 = F$ N/cm$^2$. Now look what happens at piston B, which has an area of 10 cm$^2$. The pressure of the liquid is $F$ N/cm$^2$ and there are 10 cm$^2$, so the upward force on piston B is 10F N. The force has been multiplied 10 times!

**Hydraulic fluid.** The liquid used in most hydraulic machines is an oil called **hydraulic fluid**. Hydraulic fluid does not easily evaporate or deteriorate. It can be safely used for a long time, even in harsh conditions.

In a hydraulic machine, the force of the ***effort*** is magnified (or diminished) in proportion to the area of the pistons. At the same time, the distance moved by the ***load*** is diminished (or multiplied) in the same proportion. In the diagram above, an ***effort*** of $F$ N on piston A, can lift a ***load*** of 10F N on piston B. But if the effort moves down 10 cm, the load will move up only 1 cm. Examples of hydraulic machines below are the foot brake on a car or truck and the hydraulic jack used by mechanics to lift vehicles they are working on.

When a foot presses the brake pedal on a car (diagram left), it pushes down a piston in a master cylinder. The cylinder contains hydraulic fluid, which transmits the pressure through sealed tubes to four slave cylinders, one for each wheel. In each slave cylinder, two pistons move outwards, forcing the brake shoes apart.

These press hard against a brake drum attached to the wheel of the car. The wheel is slowed by friction between the drum and the outer lining of the brake shoes.

With a hydraulic jack, anyone can lift a car by hand (diagram below). When piston A is pushed down, valve A closes, valve B opens, and the load on piston B is raised a tiny bit. When piston A is raised, valve B closes so piston B cannot move. Valve A opens and fluid from a reservoir R enters cylinder A. Each time the process is repeated, the load on piston B is raised a little more. To lower the car, a release valve is opened, allowing fluid from cylinder B to return slowly to the reservoir. The release valve must be closed before the jack is used again. Obviously the cylinders and tubes in any hydraulic machine must be very strong and must not leak!

- 1. What type of lever is the handle on the hydraulic jack? Is the force applied to piston A more or less than the effort?
- 2. Brake shoes are lined with a special material. What properties do you think this material needs to have, and why do brake linings need to be replaced regularly?