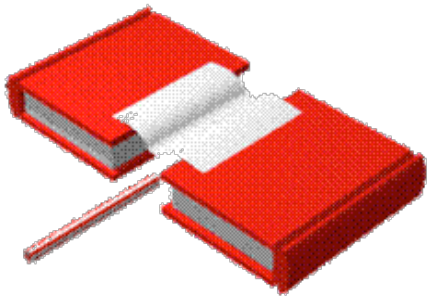
Name_____
Class_____

PLAYING WITH AIR PRESSURE

EXPERIMENT 1:

Equipment:

· 2 thick books or binders
· 1 sheet of notebook paper
· 1 straw



- Place two books or binders parallel to each other on a table and approximately 3" apart.
- Place the sheet of paper over the gap between the books, with the edges of the paper resting on the inside edges of the books.
- Using the straw, blow underneath the paper as hard as possible.

What happened? Describe what you observed and explain why it happened in terms of air pressure._____

_____

_____

_____

_____

EXPERIMENT 2

Equipment:
2 empty soft drink cans
30 or more straws

- Lay about 30 drinking straws parallel to each other on a tabletop
- Place two empty soft drink cans on top of the straws as shown in the picture.
- Using one of the straws, blow as much air as you can between the two cans and watch what happens.
- Get a partner with a second straw, and this time each blow along the outside surface of each can. Can you explain why the cans move the way they do?

Describe what's going on. Explain why this is happening in terms of air pressure.

_____

_____

_____

_____

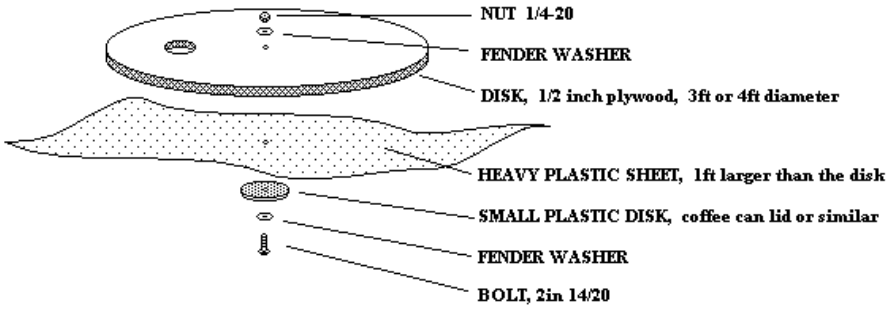
Take the strip of paper out of the book. Grasp one end of the paper and set it against your chin, just below your mouth. Hold it in place with your thumb and blow over the top of the strip as hard as you can. What do you think should happen?. _____

_____

_____

EXPERIMENT 8.3

Science Fair Project
ULTRA-SIMPLE HOVERCRAFT
can lift several adults!
1997 William J. Beaty



NEEDED:

- BATTERY POWERED LEAF BLOWER (or gas powered), or use the type of cannister vacuum cleaner which has a blower outlet, such as older "Shopvac".
- PLYWOOD, 3ft or 4ft square, 3/8in or 1/2in thick
  (or buy a 48in precut round tabletop).
- PLASTIC SHEET, 1ft larger than the above wood
  (Avoid using 1mil thickness garbage bags, instead use a heavy 4mil or 6mil plastic dropcloth from a paint store, or 'Visqueen' sheet, or an old plastic shower curtain)
- SMALL PLASTIC DISK, coffee can lid, or 6" disk 1/8in thick plastic or thin wood.
  - BOLT, 2in, 1/4-20, NUT, 1/4-20, FENDER WASHERS (TWO)
  - or instead use four small self-tapping wood screws
- SMOOTH FLOOR (linoleum, ball court, or smooth concrete)
- electric saber saw, drill, razor knife, staplegun, duct tape
- Optional: lawn chair and clamps/screws to hold it down.
- Optional: some sort of rubber bumper for the edge. Nail on some old bike tires? Just cover it with duct tape?

LINKS

INSTRUCTIONS:

MAKE THE WOOD DISK
Cut out your plywood disk. You can leave it square, or experiment with other shapes instead of round, but the sharp corners can hurt people. Round is best for safety.

Drill a 5/16in hole in the exact center, and make sure that the 2in bolt easily passes through it.

NOTE: people tell me that you can avoid using a big bolt. Instead, fasten down the small plastic disk with several short wood screws. This is a big improvement! Kids sitting on the hovercraft won't get poked in the butt anymore by that big bolt sticking up.

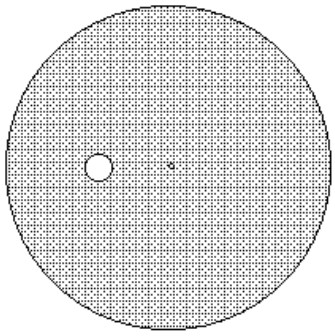
Make a hole in the plywood which exactly fits the end of your leaf blower or vacuum cleaner blower hose. This hole must be placed half way between the center of the disk and the edge, as shown below. It's a good idea to trace the

other shapes instead of round, but the sharp corners can hurt people. Round is best for safety.

Drill a 5/16in hole in the exact center, and make sure that the 2in bolt easily passes through it.

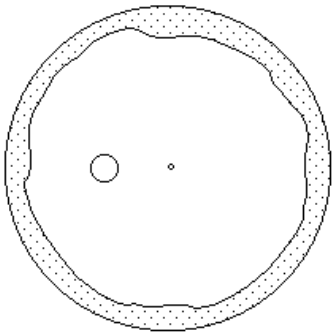
NOTE: people tell me that you can avoid using a big bolt. Instead, fasten down the small plastic disk with several short wood screws. This is a big improvement! Kids sitting on the hovercraft won't get poked in the butt anymore by that big bolt sticking up.

Make a hole in the plywood which exactly fits the end of your leaf blower or vacuum cleaner blower hose. This hole must be placed half way between the center of the disk and the edge, as shown below. It's a good idea to trace the hole in pencil on the wood (place the mouth of the vacuum cleaner on the wood and trace around it.) It DOES NOT have to fit perfectly. Later you can seal any leaks with duct tape. Or just let it leak. The hose should be flush with the bottom surface (don't let it stick out or the floor will block the air flow.)



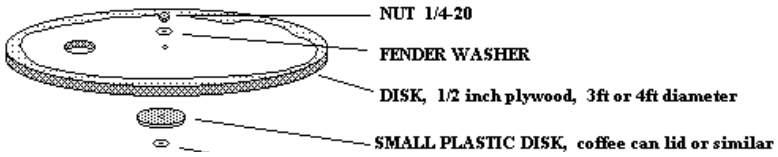
MAKE THE PLASTIC SHEET

Next, lay your plywood disk on the center of your large plastic sheet. Fold the edges of the sheet up over the plywood, then use the staplegun to staple it to the top of the plywood disk. Put a staple about every 4 inches. The plastic should be tight against the wood, but don't pull it TOO tight or the plastic will tear loose when inflated. When finished, you can cut off the excess plastic. If you wish, used duct tape to tape the edge of the plastic down to make it look nice. From above, it should look like this:



ADD THE "SKIRT LIFTER"

Poke a hole in the center of the coffee can lid. Attach it to the bottom of the hovercraft as shown below. It goes over the plastic sheet. It pins the plastic sheet firmly against the plywood. (The coffee can lid forms the "donut hole" when the vacuum cleaner slightly inflates the plastic into a "donut" shape.)



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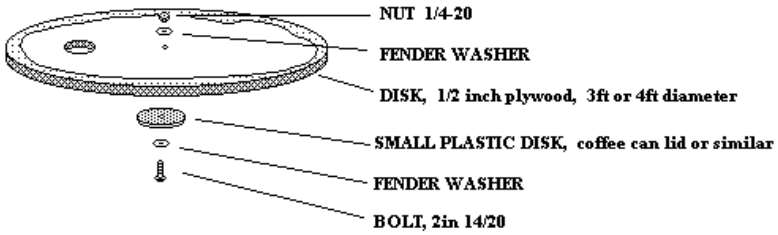
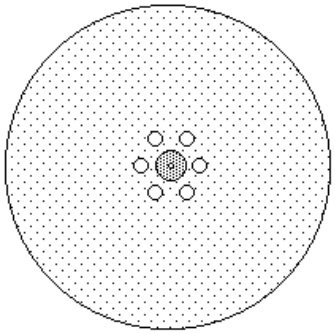


CUT THE CENTER HOLES

Use your razor knife to cut six vent holes in the plastic as shown below. They should be about 2in diameter. They must be placed within a few inches of the coffee can lid. Space them out so that there is plenty of plastic between each of them. But if they are too far away from the center, they will become plugged when the plastic sheet lays flat against the floor. If the plastic between the holes is too narrow, it will tear. If you wish, reinforce the thin necks of plastic between the holes using a couple of layers of duct tape.



DONE!

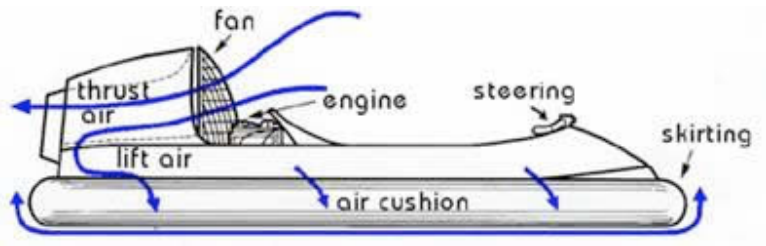
Flip your hovercraft over so the plastic sheet is on the bottom. Place it on a smooth floor. Stick the vacuum cleaner hose into the hole and turn it on. The plastic on the bottom should inflate. **If it does not, lift the plywood up a bit to let the air get in and inflate the "skirt."** The hovercraft will lift up slightly and start gliding around.

-

WHAT IS A HOVERCRAFT AND HOW DOES IT WORK?

NAME DATE

Sometimes called an air-cushion vehicle or ACV, a hovercraft rides on a cushion of air instead of wheels to go over many surfaces. A multi-blade fan forces air under the hull of the hovercraft, creating a high-pressure region called the lift air cushion and making the craft float. The hovercraft lifts off the surface it's resting on when the lift air pressure is greater than the total weight of the hovercraft divided by the area of the lift air cushion. It then hovers just above the surface. Because most surfaces are uneven, additional height is needed so the craft can travel without getting the bottom of the hull caught on anything.

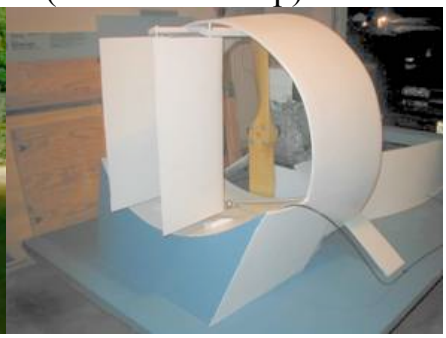


To increase the clearance between the bottom of the hovercraft and any uneven surfaces, a flexible fabric skirt is attached to the bottom outside edge of the hull. This creates a wall that traps the lift air, forcing the hovercraft to rise higher above the surface, 6-9 inches [15.24 – 22.86 cm] in most cases, giving the hovercraft a smooth ride and allowing it to clear obstacles.

Because the hovercraft only puts a very small pressure on the surface it's riding over, it can easily be flown over mud, short grass, sand, water, ice, snow, or pavement. Hovercraft also use air to move forward. Many hovercraft use an engine with an airplane-type propeller or multi-blade axial fan to push air behind the hovercraft, creating forward thrust. Often, a circular enclosure called a thrust duct is built around the propeller. By using a thrust duct built so the tips of the propeller travel within 1/8 inch [0.3175 cm] of the inside face of the duct, the thrust output of the propeller can be increased by 10-15%. (Fowler. Circa: 1993) The thrust

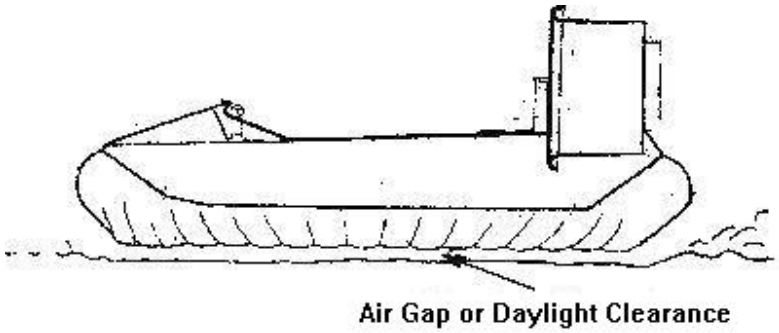
determines how fast the hovercraft can go and how steep a grade (like a boat ramp) it can climb.





Lift air, like other gasses, is considered to be a ***fluid*** because it takes the shape of the container surrounding it. In the case of a hovercraft, the air takes the shape of the bottom of the hovercraft, the inside edges of the skirt, and the surface it's hovering above. The fan that blows air under the bottom of the hovercraft keeps pushing more and more air below the hovercraft, thus increasing the pressure in the air cushion. The pressurized air cushion exerts a force on its container (the bottom of the hovercraft, the skirt, and the surface the hovercraft is resting on). When the force this pressurized air exerts on the surface grows to equal the weight of the hovercraft, it becomes buoyant (like a boat in water) and begins to float on air.

When a hovercraft hovers, it will lift as high as the skirt's designed shape will permit. Lift air begins escaping through the gap between the bottom of the skirt and the surface it's over. The size of this gap will be large enough so that the same amount of air escapes through the gap as is pushed in by the fan, keeping the pressure inside the air cushion constant. Usually, this air gap will be 0 to ½ inches [12.7 mm] between the skirt bottom and the surface and is called daylight clearance.



Sketch by J. Benini

Pressure is defined as the force exerted on a surface per unit area of the surface.

$$\textbf{Pressure} = \textbf{Force} \div \textbf{Area}$$

$$P = F \div A$$

In order to calculate the lift force of a hovercraft, we solve this equation for the force.

$$F = P \cdot A$$

The lift force is therefore the air pressure inside the air cushion multiplied by the area enclosed by the hovercraft skirts.

Example:
A typical pressure inside the air cushion of a Discover Hover One hovercraft is roughly 7 pounds per square foot, or 7 lbs / ft2 [335 N / m^2]. If the hovercraft is 10 ft [3 m] long and 5 ft [1.5 m] wide, what is the total lift force produced by this hovercraft?

Solution:
First we must calculate the area of the hovercraft. This is done by multiplying the length times the width. The solution will be worked out in both Imperial and System International units.

Imperial Units	***S I Units***
Area = Length · Width	**Area = Length · Width**
Area = (10 ft)(5 ft)	**Area = (3 m)(1.5 m)**
Area = 50 ft^2	**Area = 4.5 m^2**

Now we can find the lift force by multiplying the pressure times the area.

Lift force = Pressure · Area	**Lift force = Pressure · Area**
Lift force = (7 lbs / ft^2)(50 ft^2)	**Lift force = (335 N / m^2)(4.5 m^2)**
Lift force = 350 lb	**Lift force = 1508 N**

This hovercraft produces 350 lb [1508 N] of lift force and will therefore be able to support up to 350 lb [1508 N] of total weight and still hover. This means if the actual hovercraft weighed 100 lb [444.8 N], then it could carry 250 lb [1112 N] of people and cargo.

In the case of hovercraft, there are two forms of pressure that can be measured: static pressure and dynamic pressure. Static pressure is the pressure of a stationary region of air, while dynamic pressure is the pressure of air that is in motion. Static pressure is what lifts the hovercraft. If you measure the pressure of the lift air cushion by placing a manometer (a device that measures pressure) just under the skirt, you will obtain a different value than if you were to measure the pressure further inside the cushion. This is because the air is moving rapidly out of the bottom of the skirt, so you could be measuring dynamic and static pressure at the same time. At the cushion center, the lift air is more static.

The Discover Hover One hovercraft is an integrated hovercraft. Only one propeller is used to provide both lift and thrust air. Other hovercraft designs have separate lift and thrust systems. The sole purpose of the fan is to maintain the pressure inside the air cushion under the hovercraft. A multi-bladed fan is used for lift because it's better (more efficient) at pumping pressure than a propeller with just two blades. A separate propeller mounted on the back of the hovercraft is responsible for driving the hovercraft forward.

Integrated type systems

Separate lift and thrust

EXPERIMENT 1.1

Equipment:

- 1 old or unwanted cd
- 1 sport water bottle cap (the kind that pull open and push closed)
- 1 balloon
- 1 hot glue gun

In this experiment we will actually build a hovercraft, using only the items listed above! Begin by gluing the bottom of the water bottle cap to the cd, so that the bottle cap covers the center hole in the cd.

While waiting for the glue to dry, blow the balloon up a few times to stretch it out. This will make it easier to inflate once your hovercraft is built. After the glue dries, stretch the open end of the balloon over the top of the water bottle cap.

Now you're ready to go! Inflate the balloon by opening the bottle cap, and blowing into the bottom of the cd hole. Once the balloon is filled, push the bottle cap closed to keep the air in the balloon. Set your craft down on any flat surface (floor, table, desk, etc) and slightly open the bottle cap so that air begins escaping. Give it a push and watch your hovercraft glide! It may take some practice to open the bottle cap just the right amount. If it's opened too much, the balloon runs out of air very quickly. If it's not opened enough, the cd will drag across the surface, slowing it down.

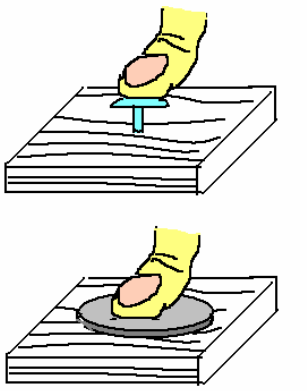
Hovercraft move by floating on a cushion of air. When you open the bottle cap, air travels out of the balloon and under the cd. As this air tries to escape out, it lifts the cd up, allowing it to glide across the surface. Get eye level with your hovercraft as it hovers, and you might be able

to see the small air gap between the surface and the cd. Your hovercraft cd is actually floating on a cushion of air!

Work sheet

Part A

1. What causes the thumbtack to be stuck in the wood but not the coin even though the magnitude of the force used is the same.



_____

2. Why is it easier to walk on the field with sport shoes compared with high-heeled shoes?

_____

Part B

1. Pressure is defined as force per unit area. The formula for pressure is $P = \frac{F}{A}$.

(a) What is the S.I. unit for force?

_____

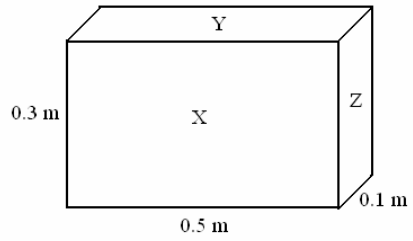
(b) What is the S.I. unit for area?

_____

(c) Deduce the unit for pressure.

_____

2. A block of solid weighs 150 N is placed on the floor. Calculate the pressure exerted by the block on the floor if the surface of the block touching the floor is
(i) X, (ii) Y, (iii) Z.



(i)

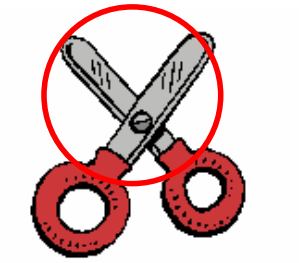
_____

(ii)

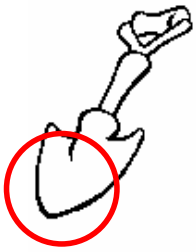
_____

(iii)

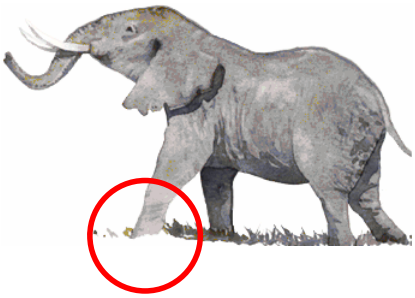
Part C (Group discussion)



The blades of a pair of scissors.

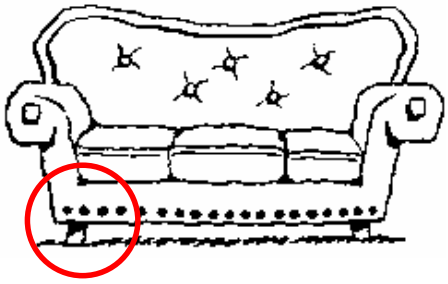


The tip of a spade.



The soles of an elephant.

The soles of the shoes of an Eskimo.



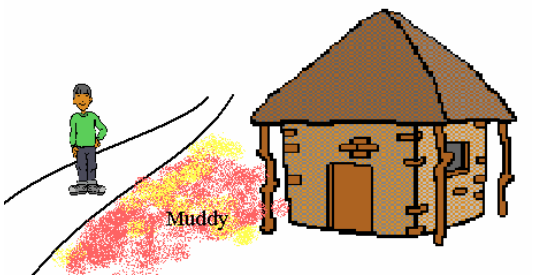
The base of a sofa.

1. The diagram shows some applications of pressure.

(a) Group them according to:
(i) Decreased surface area to increase the pressure;
(ii) Increased surface area to decrease the pressure.

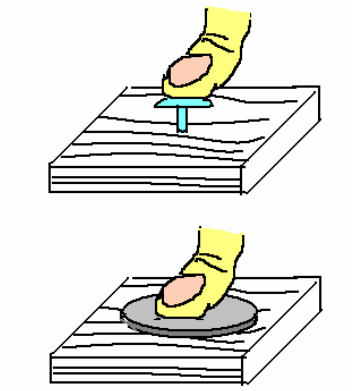
(b) Give reason to each of your answers.

2. Mat wants to enter a hut. If he walks on the muddy ground, his new shoes will sink into it. Using the concept of pressure, discuss and suggest how Mat can walk without sinking into the ground.



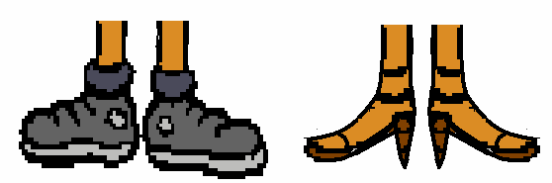
Work sheet

Part A



1. What causes the thumbtack to be stuck in the wood but not the coin even though the magnitude of the force used is the same?

The surface area of the thumb tack in contact with the wood is much smaller than that of the coin.



2. Why is it easier to walk on the field with sport shoes compared with high-heeled shoes?

The soles of the sports shoes have bigger surface area than that of the high-heeled shoes.

Part B

1. Pressure is defined as force per unit area. The formula for pressure is $P = \frac{F}{A}$.

(a) What is the S.I. unit for force?

N

(b) What is the S.I. unit for area?

m^2

(c) Deduce the unit for pressure.

$P = \frac{F}{A}$, Its unit = $\frac{\mathrm{N}}{\mathrm{m}^2}$ or N m^{-2}.

---

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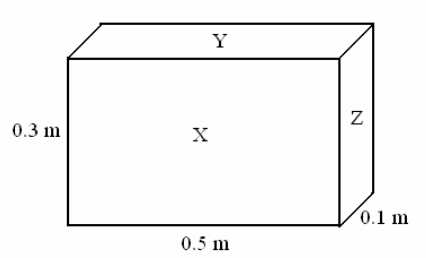
(i) X, (ii) Y, (iii) Z.



(i) Area = 0.3 x 0.5 = 0.15 m^2.

$$P = \frac{F}{A} = \frac{150}{0.15} = 1000 \text{ N m}^{-2}$$

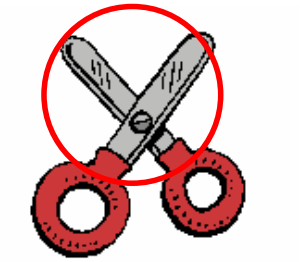
(ii) Area = 0.1 x 0.5 = 0.05 m^2.

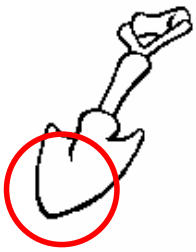
$$P = \frac{F}{A} = \frac{150}{0.05} = 3000 \text{ N m}^{-2}$$

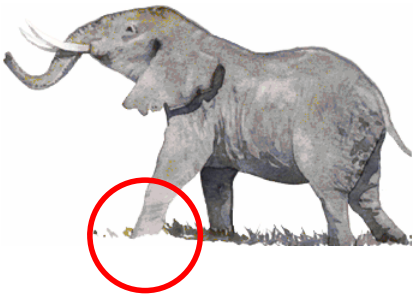
(iii) Area = 0.1 x 0.3 = 0.03 m^2.

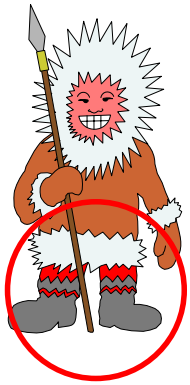
$$P = \frac{F}{A} = \frac{150}{0.03} = 5000 \text{ N m}^{-2}$$

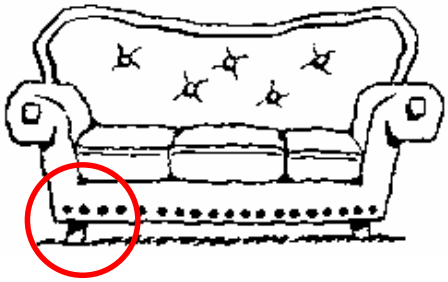
Part C (Group discussion)


The blades of a pair of scissors.


The tip of a spade.


The soles of an elephant.


The soles of the shoes of an Eskimo.


The base of a sofa.

1. The diagram shows some applications of pressure.

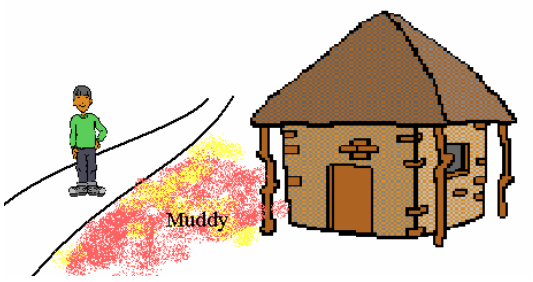
(a) Group them according to:
(i) Decreased surface area to increase the pressure;
(ii) Increased surface area to decrease the pressure.

(b) Give reason to each of your answers.
(a)
(i)Decreased surface area to increase the pressure
The blades of a pair of scissors.
The tip of a spade.

(ii)Increased surface area to decrease the pressure
The soles of an elephant.
The soles of the shoes of an Eskimo.
The base of a sofa.

(b) As for (a)(i), the reason is to increase the pressure and make cutting easier.
As for (a)(ii), the reason is to decrease the pressure to prevent sinking or destroying the surface of the floor.

2. Mat wants to enter a hut. If he walks on the muddy ground, his new shoes will sink into it. Using the concept of pressure, discuss and suggest how Mat can walk without sinking into the ground.



The ground is soft. Therefore it cannot withstand the pressure exerted by Mat while standing with his shoes on.To prevent sinking, Mat has to increase the area of contact between his feet and the ground. One possibility is to place planks on the ground and walk on them.