PRESSURE

Definition:

Pressure is the force acting normally per unit area. Pressure is something we have all experienced e.g.

i) We notice water pressure when we try to hold back water from an open tap.

ii) Solid pressure is experienced when we stand in wet sand or when we press a suit or dress.

iii) Gas pressure is felt when we try to stop gas escaping from soda bottle. The standard unit (S.I) for pressure is Nm^{-2}. This unit is also called Pascal (Pa) therefore the pressure.

Formula = $\frac{\text{Normal force}}{\text{Area}}$

$P = {}^{F}/_{A} = Nm^{-2}$ Pascal (Pa)

Where force (thrust) = pressure x area

1Pa is a pressure of 1Newton per square meter where $1Pa = \frac{1N}{1m^2}$

Note that they are many other uses of pressure in everyday use.

E.g. Atmosphere of pressure = Number of times a pressure is greater than atmospheric pressure.

Mm of mercury has pressure read on a mercury barometer.

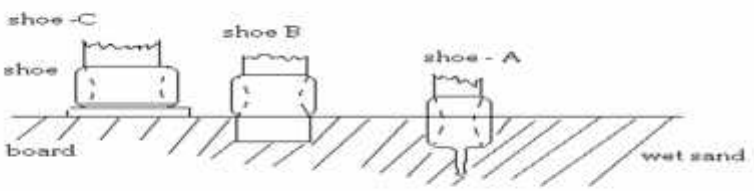
Atmospheric Pressure

This is the pressure due to the weight of all the air pressing down on the earth's surface. It has a value of $100,000Nm^{-2}$. This is a fairly stronger pressure but our bodies are designed to cope with it. Air is taken into our bodies so that the pressure inside is the same as the pressure outside.

Types of Pressure

a) Pressure of solids
b) Liquid or water pressure
c) Gas and air pressure
d) Steam pressure

Pressure Exerted by Solids



The figure above illustrates the effects of pressure exerted by solids namely shoe impressions in soft wet sand; the following is observed;
A sinks; deeply into the sand because the body's weight is supported on a very small area with stiletto shoe.
B sinks; into the soft sand to a lesser extent because the surface area is greater.
C sinks; very little because of the large surface area of the board tied to the shoes. Thus the pressure exerted by the body on the feet depends on the weight of the body and the area of the feet. The greater the surface area of the feet, the less will be the pressure upon them. Therefore pressure is inversely proportional to the area.

Applications of pressure on solids

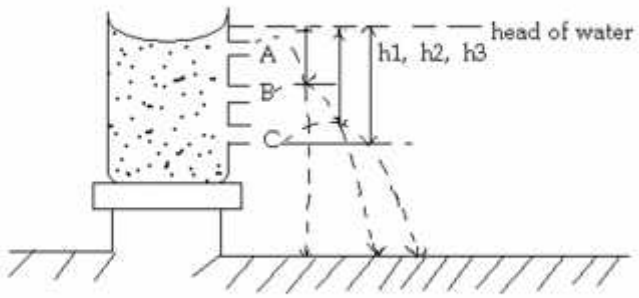
- Stiletto heels can cause damage to floor surfaces by the body weight acting on a small area of the heel. The pressure exerted is of a very high value.
- Large ball castors are preferable for furniture rather than wheel castors, which result in considerable pressure on the floor surface and consequently damage carpets and floor coverings.
- Knives and needles are sharpened to reduce their area at the point of contact so that a small force exerts a big pressure.

Liquid or water Pressure

Investigating the properties of liquid pressure i.e. laws of pressure in liquids.

- Pressure increases with depth
- Pressure applied at any point to fluid in a closed vessel is transmitted equally to all points in the fluid (It's the Pascal's principle).
- Pressure in a liquid is independent of cross-sectional area and shape of the vessel containing the liquid.

a) Pressure and depth



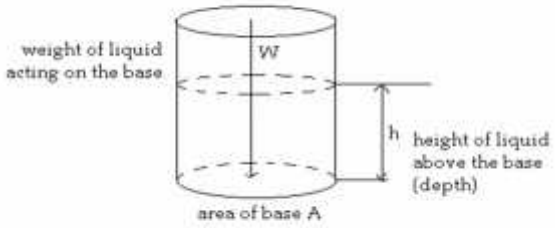
This diagram above shows a simple experiment demonstrating how the pressure in liquid increases with depth.
The water comes out of the lowest tube (C) in the tank fastest due to the increased pressure. The pressure is caused by the weight of the liquid above the level of the tube and the weight of the liquid is proportional to the height of the liquid above that level, hence head of water pressure. Spout A having the least water pressure while spout C has the greatest pressure. The vertical distance between the level of the water in the tank and the level at the open end or spout is called the head of water. It's normally used by water engineers for describing water pressures.
Therefore the pressure of a liquid at a certain level is proportional to the height of a liquid above that level or the pressure in a liquid increases with the depth below the surface.

b) <u>Pressure and Direction</u>
Pressure in a liquid is equal in all directions at the same depth.

c) <u>Pressure and liquid density</u>
If pressure is measured at the same depth below the surface of different liquids you find that;

- Pressure is proportional to the density of the liquid.
- The liquid pressure depends only on a height of a particular liquid and not on the shape/width of the tube.

<u>A formular of liquid pressure</u>



The mass of the liquid of density (ρ) is
Mass = Density x Volume
Mass = ρ x V
M = ρV
Therefore due to the force of gravity acting on the liquid surface.
Weight = Mass x gravity
Of the liquid
W = M x g
W = Mg

Where M = ρv

Hence W = Mg

w = (ρV)g

but V = L x w x h

where (Lxw) = Area (A)

V = A x h

= Ah

W = ρAhg

Hence the pressure of the liquid at a depth (h) is

$$\text{Pressure} = \frac{\text{Normal force on a liquid surface (wt)}}{\text{Area}}$$

$$P = \frac{\rho Ahg}{A}$$

$$P = \rho hg$$

$$\therefore \rho = h\rho g$$

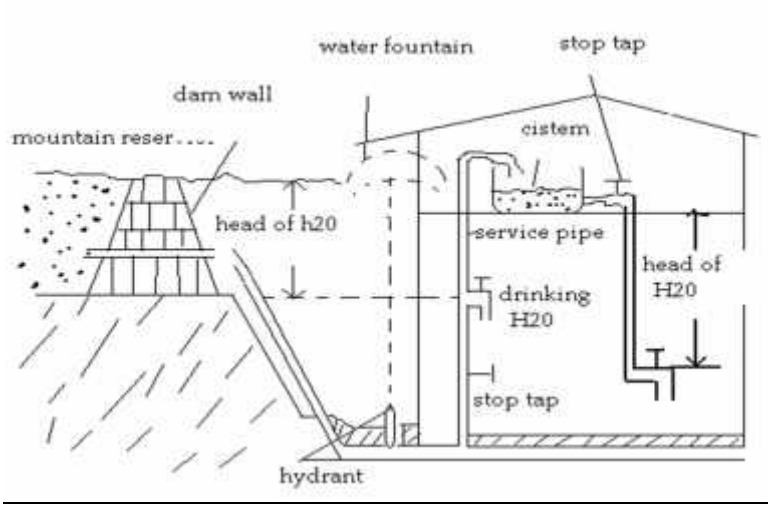
Therefore the pressure of a liquid on a surface is proportional to the height h and hence below the density ρ.

Pressure is independent of the area.

NB: The above formular does not fulfill any air pressure acting on the surface of a liquid at a depth h below its surface.

Applications of water Pressure

1. **The domestic of water supply system**



Many towns receive water from a water reservoir situated at a higher level. Water flows from a high level to a low level. The reservoir dam wall is thicker at the bottom to meet the

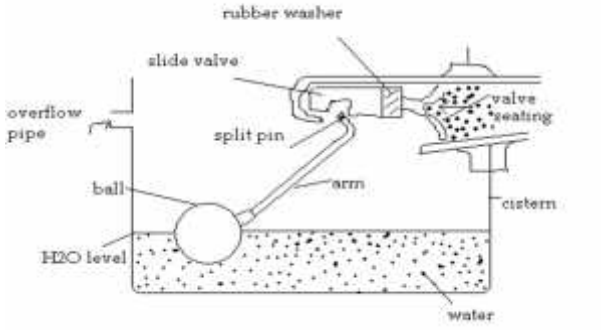
increasing water pressure there. A thick wall pipe brings the water to the consumer in the low lying towns and villages, the water flow being controlled by a hydrant.
If there is a burst in the main water pipe, a great fountain will be produced, due to the greater head of water pressure.

The water enters the residence/home by the service pipe (service main) which can be controlled by the water bolt tap, this is situated immediately outside the residence or near the cold water tap in the kitchen. The service supplies the cold drinking water in the kitchen and the remaining cold water taps to the bathrooms and toilets and finally till the cistern storage tank at the top (in the attic). This method of supplying all the cold water from raising main (service pipe) is called the intermittent system. If the stop tap or the cistern tank. It's usually to turn off the stop tap in the events of the burst pipe or if a tap needs repairing or when a residence is left unattended to.

In some areas, all cold water taps are supplied from service water taps. This is necessary if the water pressure from the cold water tap in the kitchen.

The difference in the tap pressure/the rate of water flow is due to the smaller head of water main water pressure in the drinking water tap. It's therefore important to draw/get drinking water from the main water supply tanks and not from taps supplied by the cistern tank as the tank is liable to be contaminated by dirt and the water is only suitable for toilet purposes.

2. The ball value/water closet/lavatory flush

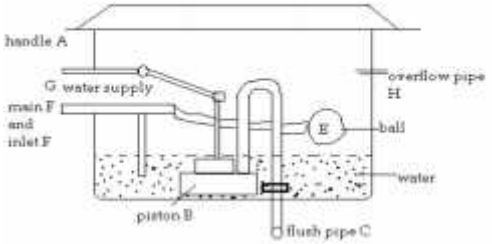


The ball value is used to control water closet flush cisterns and other water storage cisterns which have an automatic control to the water supply e.g. Café set boilers and steam provers for dough.

The working mechanism

The floating ball is made of plastic and is attached to a long arm hinged by a split pin. If the tank is full of water, the ball floats and the arm presses on the sliding value, this in turn stops the water flow by means of the small rubber washer. When the tank is partly empty, the ball is at a lower level, bringing with it the arm which moves the slide value and allows the water to flow into the tank.

The construction and working of a toilet flushing system



The flushing of a water closet is based on the principle of the siphon (Siphonage). It consist of a simple mechanisms which lifts and forces water over a siphon bend whereby displacing the air sufficiently enough to setup siphonage.

When the handle A is turned downwards, the lever attached is lowered to one side (at the outside) and raised on the other (inside). As the lever is raised, it draws up the piston B which action forces water into the siphon and fills it at B.

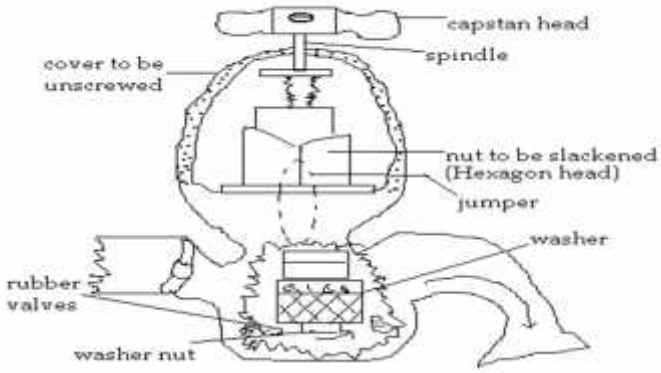
Once the siphon is filled with water, it continues to run through the pipe to the water closet through flush pipe C, until the level of water in the cistern goes below the level of the piston B.

As the level of the water in the cistern falls, the floating ball E sinks with it and on reaching a certain level run on the mains inlet F to fill the cistern.

When the cistern has filled, the floating ball turns off the water supply G and ball floats once the tank is full.

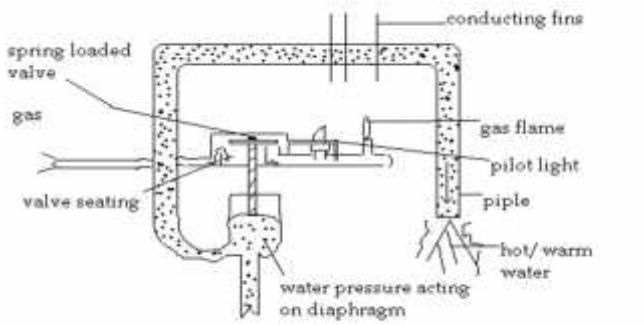
If for some reason, the cistern over fills, the over flow pipe H safely drain the excess water away thus preventing damage.

3. Water tap



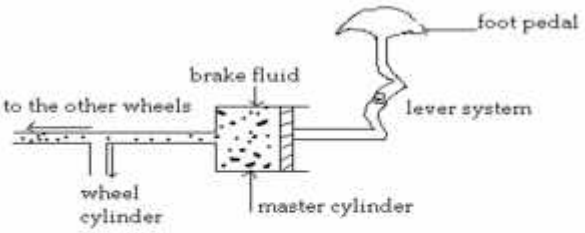
The movable part of the tap is called the jumper. This controls water flow and is supported by the washer. In cold water taps, the washer is made of leather but in hot water taps, the washer is made of composition fiber to withstand the temperature from the hot water and avoid wearing away easily. It's normally red or black in colour. It's made of a capstan head where we hold to adjust the movements of Hexagon head hence moving the jumper. Water flow is also controlled by the rubber value by touching or moving the washer nut.

4. Instanterious gas water heater



The water heater operates by water pressure. When the water tap is turned on, the water pressure presses on the soft diaphragm which causes the gas the flow by raising the spring loaded value away from the value seating. The gas in turn is lit by the water tap closes the gas supply by reducing the pressure around the diaphragm which enables the spring loaded value to sit back on the value seating which in turn blocks the passage of gas. Therefore, there will be no further burning and conducting of heat by the fins. When the fins conduct heat it's further absorbed by the water in a pipe so producing warm/hot water.

5. Hydraulic brake



This works on the principle of transmission of pressure in fluids which states that pressure exerted on a liquid is transmitted throughout the liquid in all directions as long as the liquid is enclosed.

When the foot-pedal is pushed, the lever system transmits this movement to the piston. The piston then exerts pressure on the brake fluid, and this pressure is transmitted throughout the whole fluid to the wheel cylinders of the four wheels of the car i.e. each wheel has got its own wheel cylinder, which is connected to the brake-shoe which then effects the braking.

Gas and Air pressure

The earth is surrounded by a layer of air or atmosphere. This layer of air has weight and is continually pressing on the earth's surface causing air or atmospheric pressure.

Experiment to demonstrate Air pressure

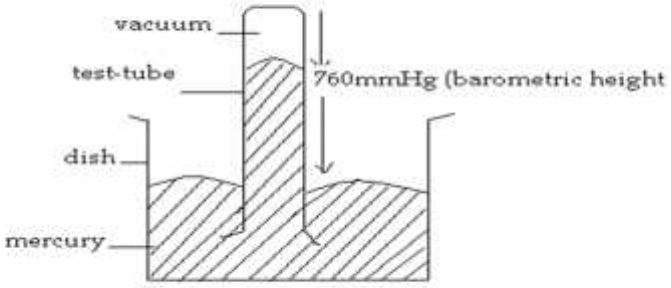
- Fill a glass tumbler to the brim with water and cover the top with a sheet of stiff paper.
- Press the paper with palm of hand making sure no air bubbles remain.
- Carefully turn the tumbler upside down
- It's observed that the water does not fall out of glass because the air pressure is acting on the paper.
- Therefore, air pressure is greater than the water pressure.

Constructing a simple mercury barometer

This is the instrument used to measure air pressure.

Procedure:

- Take a thick walled glass tube about 1M long and fill it carefully with liquid mercury.
- Place the index finger over the open end of the tube; invert it in dishes of mercury.
- The mercury is kept up to a certain height by the air pressure acting on the surface of mercury in the dish. The space above the mercury is a vacuum.
- If the height of the mercury is measured from the mercury surface in the dish, it's found to be about 760mm or 76cm of Hg, this is called the barometric height.



Units of measuring Air pressure

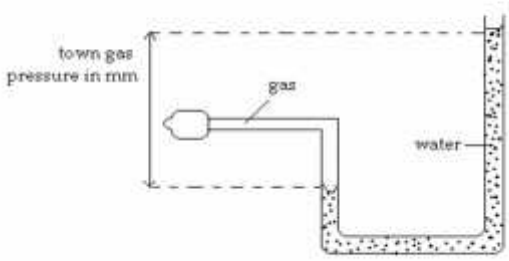
The method of measuring the mercury column is convenient for many purposes where gas pressure is measured in mmHg. Normal air pressure = 760mmHg = 100KN/m^2 or 100kpa

Applications of gas pressure

1. **Town gas supply**

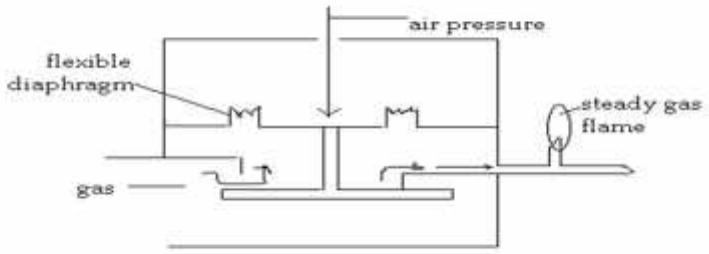
Town gas is held in a large gas holder over a water seal. The main pipe carries gas to the residents, the flow being controlled by a gas cork situated near the gas meter.

2. Pressure of gas supply



When a u-shaped tube is half full of water, the water levels will be equal as the same air pressure is acting on the water on each half of the tube. When one end of the gas tube is connected to the gas tap and gas turned on, the gas and air pressure will force the water level down in one arm and up in the other. The difference in level in millimeters is an indication of the town gas pressure which is about 200mm of water or 2kp. The true pressure of town gas supply is equal to the water pressure plus atmospheric pressure. Therefore, true town gas pressure is equal to air pressure plus water height in millimeter.

3. Gas Governors



These are fitted to gas appliances to provide a steady flow of gas into the appliance and to prevent fluctuation in the size of the flame due to the changing pressure of the gas supply. The gas governor contains a flexible diaphragm which moves under the influence of changing gas pressure thus providing a steady flow independent of the fluctuations in the main gas pressure.

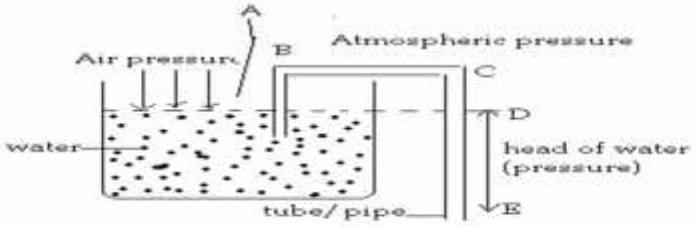
4. Pressure Gauges

Pressure gauges are fitted in most boilers and pressure cookers. Inside the gauge is a thin flexible copper tube which extends like a partly blower toy when the gas pressure is increased. The movement of the flexible tube is magnified by a series of rods and levers which move the pointer over the pressure scale.

5. Attitude

As an aeroplane ascends, the air pressure becomes less. This decrease in air pressure with attitude has a number of effects i.e. therefore cooking at a higher attitude is affected e.g. cakes will not rise quickly and less raising agent must be used.

6. Siphon/Automatic flash Cistern



The Siphon is a device used for drawing liquid from larger containers from a higher to a lower level. A long rubber tube full of the liquid has one end placed in the container of the liquid to be Siphoned. The other end is then lowered and opened.

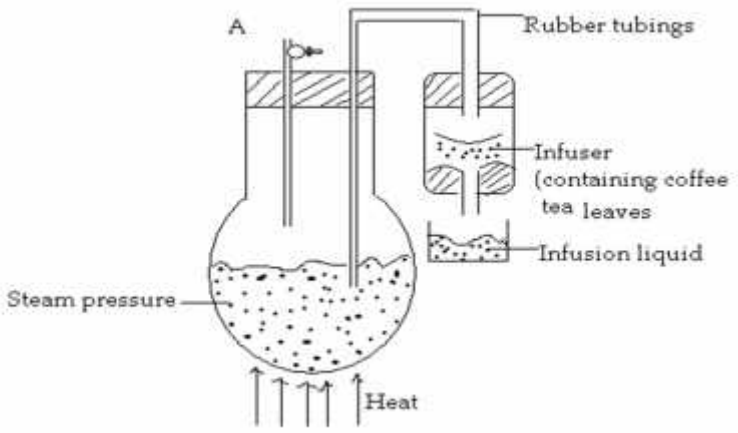
A continuous flow of the liquid takes place until the tube is empty. Therefore, Siphonic action is due to the combined action of the air pressure of water in the container and the water pressure or head of water in the tube.

Explanation

The flow of the liquid occurs sowing to a greater force of gravity on the column Ct, which pulls the shorter column AB by the cohesion (attractive force) between the liquid molecules.

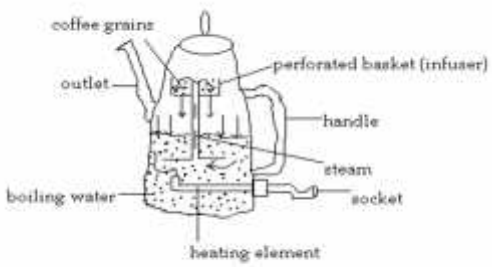
STEAM PRESSURE

If water is boiled in a closed container, steam pressure accumulates which can be used to drive boiling water to infuser tube, which can contain tea leaves or coffee grains and provide a rapid infusion of tea or coffee.



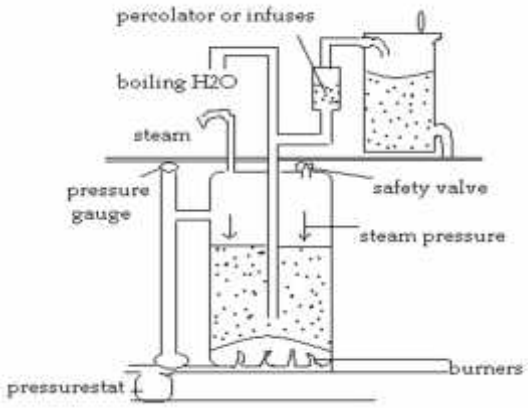
Applications of steam pressure

1. A coffee percolator



The coffee grains are put in the infuser or perforated basket, hot boiling water is made to boil/percolate through the infuser by steam pressure. When the water is yet to boil and the outlet closed, steam is left to build up in the percolator so creating steam pressure acting on the surface of the liquid. When the steam pressure on the surface of the liquid increases, it forces the liquid to rise via the tube mixing with the coffee grains in the infuser. The liquid and coffee percolate out via the perforations of the infuser mixing back with the liquid. The process continues till all the water has mixed well with the coffee grains. At this point, it can be served straight or just poured into the tea cups.

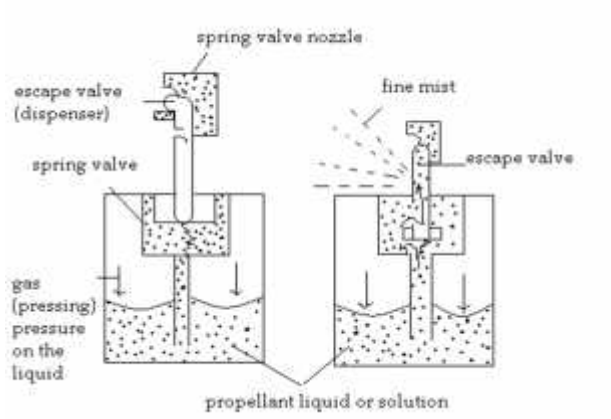
2. <u>Steam-pressure type café set</u>



The boiler is heated y gas or electricity. The gas heating is automatically controlled by the pressure state where the diaphragm is affected by the steam pressure and high pressure automatically turns the gas down. The boiler has a pressure gauge which indicates the working pressure to be approximately 100 Kpa or 100KN/m^2. The water supply to the boiler is automatically controlled by a ball valve fitted to a Cistern tank. The amount of water in the boiler is indicated by the glass water-level gauge. Safely valves which release steam when the pressure becomes excessive are fitted to all steam boilers. A café set operates by boiling water being driven, under pressure into the infuser or filter followed by the collection of the infusion glass tea, coffee or milk containers.

Boiling-hot water can be drawn from the café set for warming tea or coffee.

3. Aerosol sprays



These are popular forms of devices for dispersing a variety of products like insecticides, air fresheners, cleaners, perfumes, e.t.c.

The aerosol contains a propellant liquid which is a liquidified gas that evaporates or changes into a gas simply by releasing some of the gas pressure or by the heat of hand. Therefore that is why they should be stored in a cool dry place.

Principle of operation

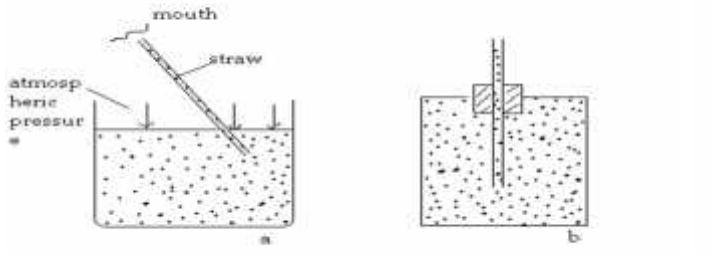
When the nozzle is depressed, the propellant gas pressure forces a fine mist of volatile liquid out of the dispenser.

Immediately the hand is released from the nozzle, the aerosol gas pressure closes the escape valve.

The commonest liquefied gas used as a propellant known as Arcton or dichlorotetraflourethane which is also used as a refrigerator.

Other Applications of pressure (Atmospheric Pressure)

a) Sucking

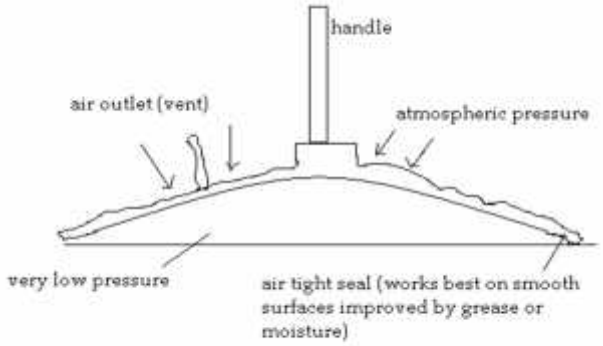


Principle of operation/working mechanism

a) When you suck, you increase the volume of your lungs which reduces the air pressure inside your lungs and mouth. This therefore, makes the atmospheric pressure acting on the surface of the liquid is now greater than the reduced air pressure inside your mouth so the liquid is pushed up the straw by the pressure excess of the atmosphere over your mouth pressure.

   In the absence of atmospheric pressure on surface of closed bottle.

b) Rubber sucker / Phinger



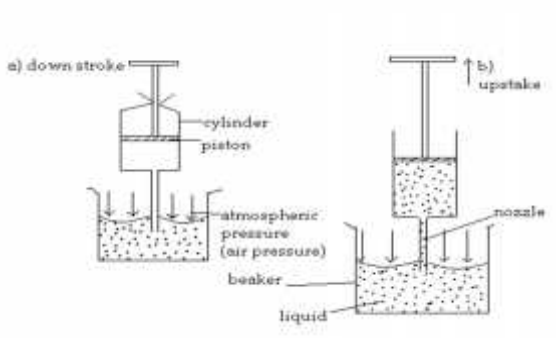
Rubber suckers can be used to lift heavy objects with flat smooth surfaces or for hanging things on walls or windows or the plunger for unblocking the sinks. This can be used to lift motor frames.

<u>Operation/working mechanism</u>

A sucker is pressed against the surface to squeeze out, the air from behind it (beneath it). The atmospheric pressure on the outside of the surface/sucker holds its rim firmly against the smooth surface. As the smooth rim forms an air tight seal with the smooth surface, no air can return and a vacuum will be formed behind the suck. Any pull/force on the sucker away from the surface is opposed by atmospheric pressure which holds the sucker firmly on the surface. So at this point one will be in position to lift the heavy object from one place to another because the sucker is firmly attached to the object surface.

The plunger can be used to unblock the sink i.e. a slight pull will put out the dirt and other materials that have blocked the sink.

c) Syringe (Hypodermic pump)



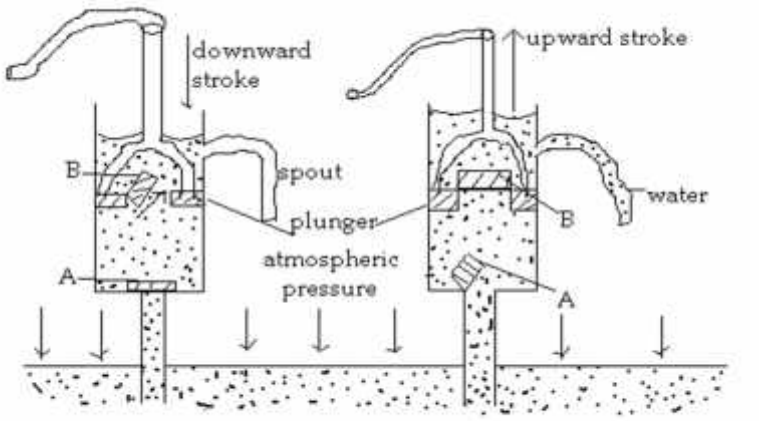
It's a simple pump because it does not need any value. A value will allow a liquid/gas to flow in one direction but not in the other. The commonest type of syringe is the hypodermic syringe used by doctors when giving infections. It consists of a cylinder with a closely fitting piston.

The end of the cylinder has a hollow, very thick needle mounted in it.

Operation/Mechanism

The syringe is filled by pushing the piston down, forcing air out of the cylinder as seen in (a) above. The piston is then drawn upwards as shown in diagram (6). A vacuum is created underneath the piston so the air pressure forces the liquid up the hole/nozzle in the centre of the needle into the cylinder. The liquid can be forced/pushed out by pushing the piston down.

d) The common lift pump/common pump



This type of pump uses the atmospheric and water pressures. It consists of a metal barrel which is cylindrical in shape; aside tube, two valves A and B and the handle C.
The working of a lift pump involves a down stroke and up stroke.

The working

Before the pump starts working, some small amount of water is poured into the top of the cylinder onto the plunger so that a good air tight seal is made around the piston/plunger and valve B.

Down stroke

As the plunger or piston moves down, valve B opens allowing more water to pass upwards, while valve A closes due to its own weight. Valve B opens due to increased pressure on the cylinder below the piston.

Up stroke

The plunger/piston moves upwards. Valve B closes due to its own weight of water above it. Therefore, water which is above the plunger is pushed upwards and it comes out through the spout. Valve A is opened allowing more water from the pool.
The reduced pressured in the cylinder below the rising pistons allows atmospheric pressure on the water surface to push water past valve A into the cylinder.
The lift pump cannot raise water to a height greater than 10m because atmospheric pressure can only support a column of water of about 10m.