S2 PHYSICS Continuation

HEAT TRANSFER

Heat travels from a region of high temperature to a region of low temperature.
Heat can be transferred in three different ways conduction, convection and radiation.

CONDUCTION

Conduction is the flow of heat through matter without movement of matter as a whole.
When you hold one end of a metal spoon immersed in boiling water, the end in the hand soon becomes too hot to hold. Heat is transferred from the boiling water to the hand by conduction.
There are two ways in which conduction takes place in solids;

(i) The free elections near the heat source gain extra kinetic energy and vibrate faster. As a result they push atoms in cooler parts, so passing on their energy and raising the temperature of the cooler parts.

(ii) The atoms near the source of heat vibrate and pass on energy to the next cold atoms which again pass it over to the next cold atoms as a result heat flows through matter.

Note: For conduction to take place there must be a material medium, i.e. conduction doesn't take place in a vacuum.

Applications of good and bad conductors of heat

Good conductors of heat

Metals are good conductors of heat because they have free elections which transfer heat from a hot region to a cool region.

Good conductors of heat are used where fast transfer of heat is needed. Metals are used in making kettles, saucepans, boilers, radiators and cooling fins.

Bad conductors (Insulators) of heat

Non-metals are poor conductors of heat because they don't have free elections. Wood, plastic and rubber are used for making handles of cooking utensils. Cork is used for table mats.

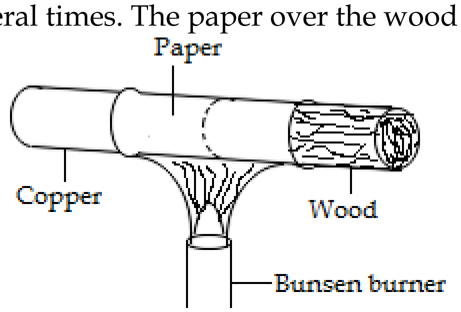
Air as a bad conductor of heat is trapped in double glazed windows and between walls of a double walled house making it warmer in winter and cooler in summer.

Some bad conductors of heat trap air eg; wool, felt, fur, feathers, polystyrene and fibre glass. They are used as lagging to insulate water pipes, hot water cylinders, ovens, refrigerators, roofs and walls of buildings.

Wool and fur are used for making warm winter clothes.

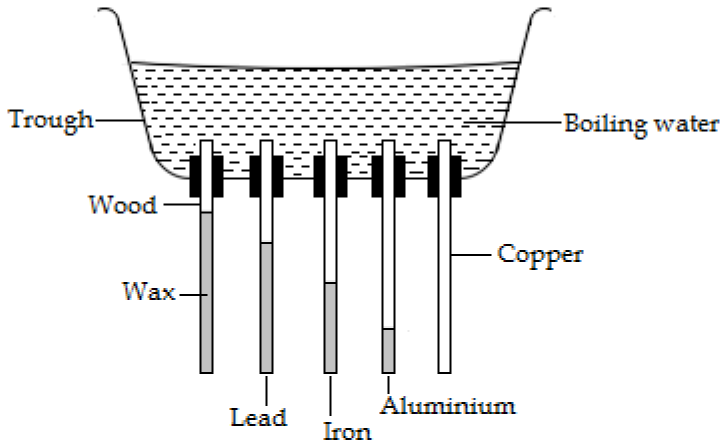
Demonstration showing the difference between a good conductor and a bad conductor

A small part of a wooden rod is fitted in a copper tube to form a single rod. A piece of paper is wrapped partly on copper and partly on the wooden rod. The rod is passed through a flame several times. The paper over the wood burns but that over the copper does not burn.



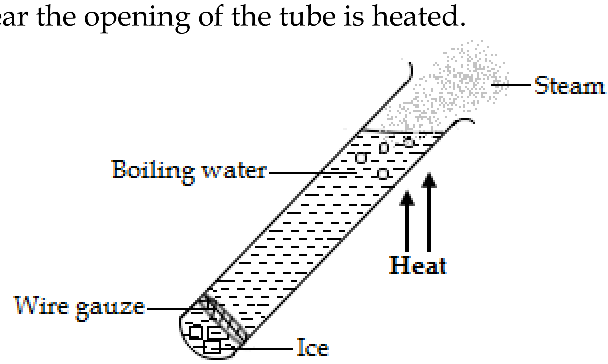
Explanation
The copper conducts heat away from the paper quickly and it does not reach the burning temperature. The wood only conducts heat away slowly hence the paper burns.
Note: A metal bar feels colder than a piece of wood at the same temperature.
The metal conducts heat away faster from the hand hence feeling colder. The wood only conducts heat away slowly.

Experiment to compare conducting power of different materials
Rods of different materials e.g. wood, lead, iron, aluminum and copper but of the same length and diameter are coated with equal amounts of wax. The rods are passed through corks inserted in the metal trough. Boiling water is then powered into the trough so that the ends of the rods are all heated to the same temperature.



After a short while the wax begins to melt down the rods. It melts fastest along copper and slowest on wood. This shows that copper is a good conductor of heat while wood is a poor conductor of heat. Silver is the best conductor but it can't be used extensively because it is very expensive.

Experiment to show that water is a poor conductor of heat
Ice below 0^oc is put in a boiling tube filled with water to a level which is near the top. The ice is held at the bottom of the boiling tube by wire gauze. The tube is slightly tilted such that water near the opening of the tube is heated.

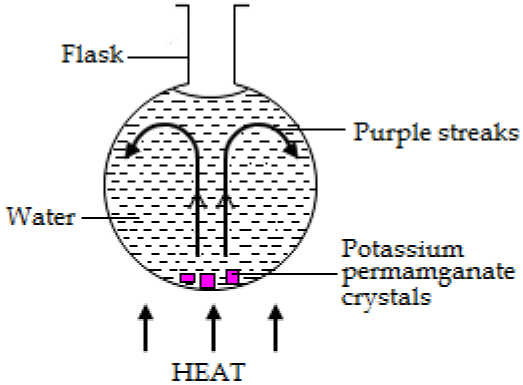


Observation:
- Water at the top becomes hot and eventually boils.
- The water at the bottom of the tube remains cold and the ice does not melt.

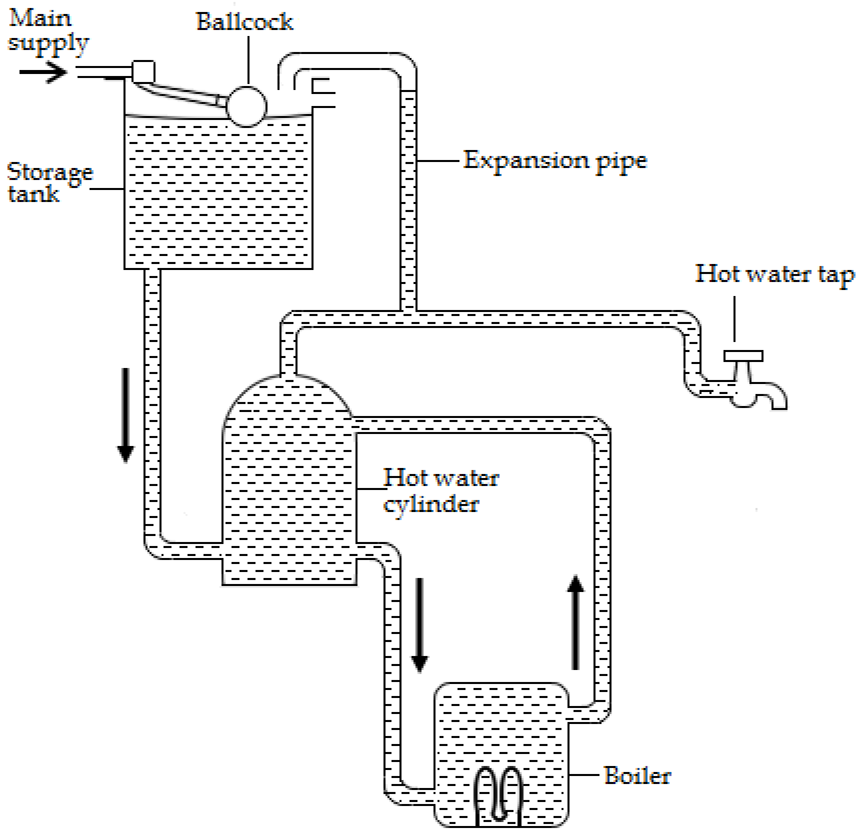
Explanation:
When water on the surface is heated it becomes less dense and will remain on the surface without sinking to transfer heat until it eventually boils.

Heat can only reach the ice by conduction through water which is a poor conductor of heat. Hence it takes a long time for heat to reach the ice which remains solid for a long time.
Conclusion: water is a poor conductor of heat.

CONVECTION
This is the flow of heat through a fluid by movement of the fluid itself.
Note: A fluid can either be a gas or a liquid.
Experiment to demonstrate convection in liquids
Crystals of potassium permanganate are carefully dropped down a tube to the bottom of a flask containing water. The flask is then heated from the bottom.



Observation
Purple streaks of potassium permanganate are seen rising and then spreading out in water. After a short time they circulate down the sides of the flask showing that convection current has been set up.
Explanation
As the heated water expands it becomes less dense and rises, transferring the heat upwards. Cold more dense water sinks to the bottom to take the place of warm water. This cycle is repeated until the liquid is at the same temperature and eventually boils.
Applications of convection in liquids
The domestic hot water supply



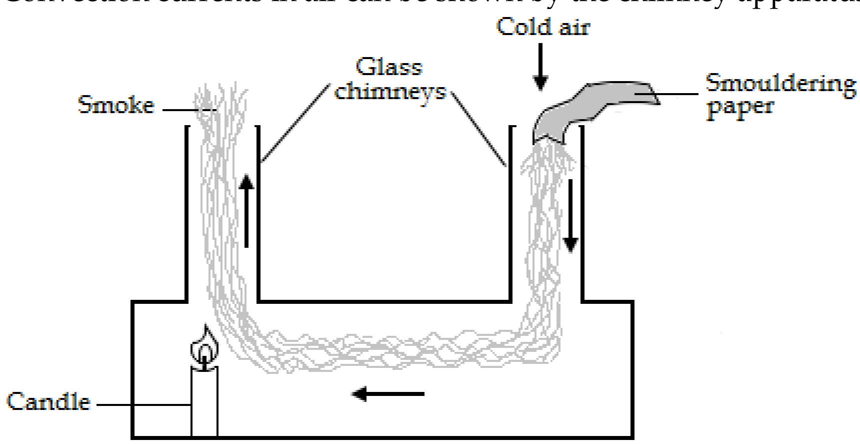
The boiler heats the water which rises by convection up to the water cylinder. Cold dense water flows from the storage tank into the boiler via the lower part of the hot water cylinder. In this way a supply of hot water collects in the upper part of the hot water cylinder. Hot water is collected for use through the hot water tap.

NOTE:

- The pressure needed to force hot water out of the tap is provided by the storage tank outside which is relatively raised above the ground.
- The amount of water in the storage tank is controlled by the ballcock which opens and closes to maintain the level of water in the tank.
- The expansion pipe is a safety precaution which allows steam to escape into the storage tank.

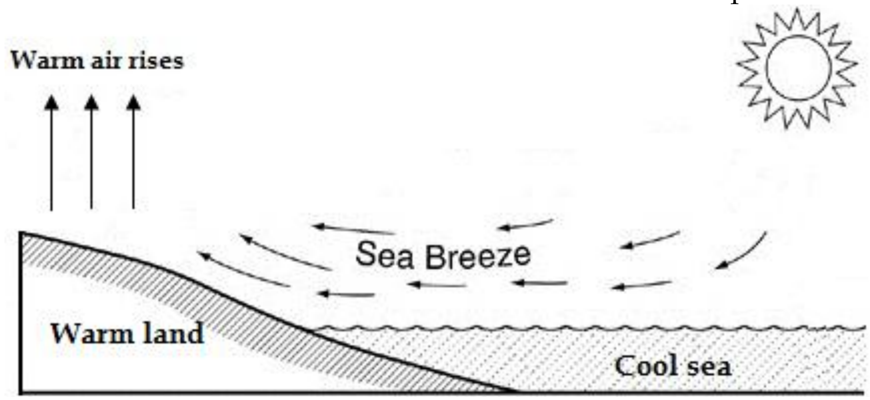
CONVECTION IN GASES

Convection currents in air can be shown by the chimney apparatus.

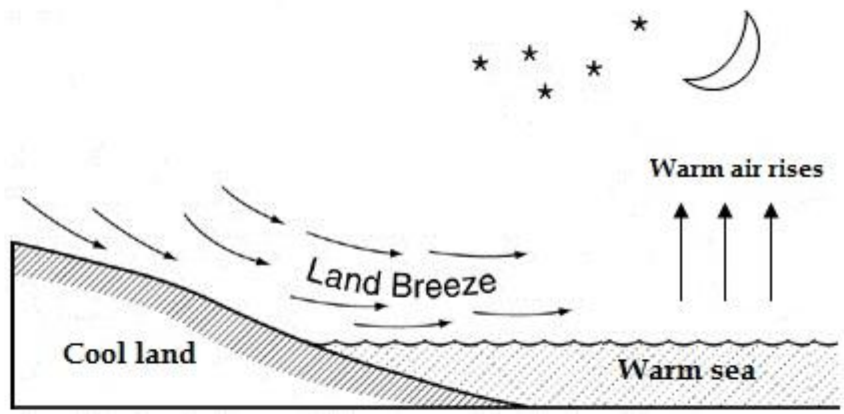


The heat from the candle warms up the air around it causing it to rise. The rising air current is observed by help of the smoke ash particles that rise along with it.

Applications of convection in gases
1. Sea breeze: During the day the temperature of the land increases more quickly than that of the sea. The land heats up the air above it which expands, becomes less dense and rises. Cooler air from the sea then blows towards the land to take the place of rising warm air.



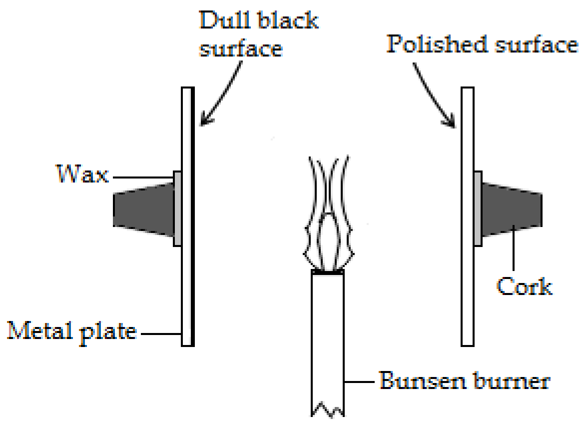
2. Land breeze
During the night the sea cools down more slowly than the land and so it's warmer than the land. The sea heats up the air above it which expands and rises. Cooler air from the land blows towards the sea to take up the place of the rising warm air.



3. Ventilation
When the room heats up, the warm air rises and leaves the room through the ventilators at the top. Cool fresh air enters the room through the door and windows.
4. Room heaters help to warm houses by setting up convection currents.
RADIATION
Radiation is the transfer of heat without a material medium.
Heat radiation can take place through a vacuum. Heat is transferred by means of electromagnetic waves. Radiation is emitted by all bodies above absolute zero and consists mostly of infrared radiation but light and ultra violet are also present if a body is very hot e.g. the sum.
Good and bad absorbers of radiation
Black and dull bodies are good emitters and absorbers of radiant heat.
Polished and white bodies are bad emitters and absorbers of radiant heat. They are good reflectors of radiant heat.

Experiment to compare heat absorption powers
A cork is fixed at the back of a metal plate with a dull black front surface by use of melted wax and another cork is fixed at the back of a metal plate with a polished front surface.

The plates are set up vertically facing one another at a small distance a part with a Bunsen burner flame mid way between them. Both plates receive the same amount of heat.



Observation:
In a short time the wax on the dull black plate melts and the cork falls off. The polished plate remains cool and the wax unmelted.
Conclusion
Dull black surfaces are good absorbers of heat while polished surfaces are good reflectors of heat.
In general surfaces that are good absorbers of radiant heat are good emitters when hot.
Factors affecting radiation

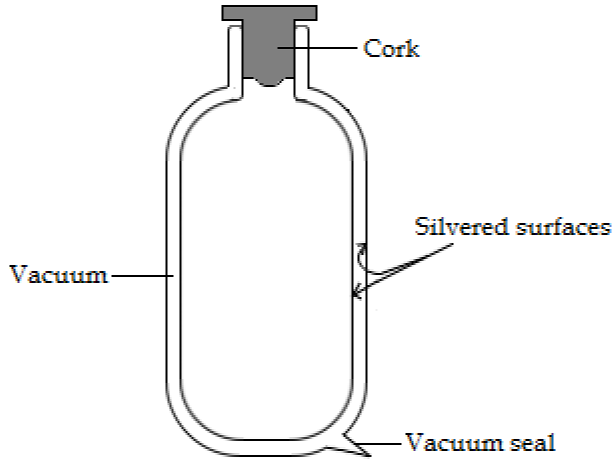
- Temperature of source of radiation.
- Nature of the body either a black body or shiny body.
- Surface area.
- Distance between the body emitting heat radiation and the body receiving.

Applications of radiation
1. The cooling fins on the heat exchanger of a refrigerator are painted black so that they lose heat more quickly.
2. A car radiator is painted black to absorb heat from the engine and emit heat to the surroundings in order to cool the engine.

3. Polished tea pots and kettles are poor emitters and keep their heat longer.

4. White clothes reflect heat and are preferred in very hot countries. Similarly white walls of houses reflect heat making the interior cool during summer.

5. The vacuum flask.
The vacuum flask also known as a thermos flask is used for keeping hot substances hot or cold substances cold. The flask makes it difficult for heat to move into or out of the flask.



- The cork is a poor conductor of heat; it minimizes heat loss by conduction and evaporation.
- The vacuum minimizes heat loss by convection and conduction since it is an empty space.
- The double silvered surface minimizes heat loss by radiation. Heat radiation is reflected back by the silvering on the inner wall while the silvering on the outer wall reflects heat away from the flask.

Note: The vacuum seal is the point where the vacuum is closed. If it breaks air enters and the flask stops working.

6. A green house

This is a glass building in which plants that need protection from cold weather are grown.

A greenhouse acts as a radiation trap. The sun emits radiation in form of visible light and short wave length infrared which easily penetrate glass.

The radiation is absorbed by the soil, plants and other objects inside the greenhouse which in turn raise the temperature of the enclosed air by conduction and convection.

The warm objects inside also emit long wave length infrared radiation that cannot penetrate glass. Hence the interior of the green house is kept warm by enclosed warm air and trapped long wave length infrared radiation.

Greenhouse effect (Global warming)

The earth's atmosphere behaves like a green house. The sun's radiation easily passes through the atmosphere and is absorbed by the earth which warms up. The warm earth radiates energy of longer wave length that is absorbed by the atmosphere's water vapour, Carbondioxide, methane and other gases. The warm atmosphere in turn radiates heat back to the earth making it warmer than it would be.

PRESSURE

Pressure is the force acting normally per unit area.

The term normally here means perpendicularly or at right angles to the area of contact.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

The S.I unit of pressure is N/m^2 (Nm^{-2}) which is known as a Pascal (Pa)

$1Nm^{-2} = 1Pa$

Solid pressure

Solid pressure depends on the force exerted and the area of contact on which the force acts

If a large force is exerted on a small area the pressure will be very high. When the same force is exerted on a large area, the pressure will be small.
The effect of area on solid pressure explains the following facts of life

(i) Knives have sharp edges, spears are pointed, nails and pins have pointed tips to exert more pressure and easily penetrate surfaces.
(ii) A heavy hippopotamus with wide feet exerts less pressure thus can easily walk on soft muddy ground while a light weight goat with narrow heels will find difficulty because it exerts more pressure .
(iii) A man wearing flat shoes exerts less pressure thus walks easily on soft ground while a lady wearing pointed heeled shoes will find difficulty because she exerts more pressure which makes her heels sink.
(iv) Farm tractor tyres have a large surface area to move easily on the farm land by exerting less pressure.

Calculating solid pressure
To calculate pressure in Nm^{-2} (Pa), the force must be in Newtons (N) and area in square metres (m^2)
Examples
1. Force of 3000N acts over an area of 0. $60m^2$. what is the pressure exerted?

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{3000}{0.6}$$

$$P = 5000\ Nm^{-2}$$

2. Calculate the pressure exerted on the ground by a man of weight 800N given that the area of both feet is $0.0285m^2$. What pressure does he exert when standing on one leg? (Give your answer in Pascals (pa))

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{800}{0.0285}$$

$$P = 28070\ Nm^{-2}$$

3. A woman of weight 700N is wearing a pair of shoes. Given that each shoe has an area of $0.035m^2$. Calculate the pressure the woman exerts on the floor if she is;
(i) Standing on one leg
(ii) Standing on both legs

(i) $$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{700}{0.035}$$

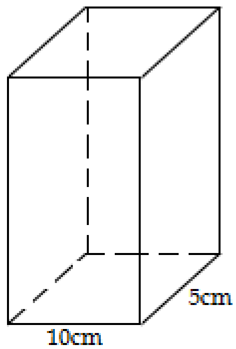
$$P = 20000\ Pa$$

(ii) Area= 2 x $0.035m^2$
Area= $0.07m^2$

$$P = \frac{700}{0.07}$$

$P = 10000\ Pa$
$P = 1.0 \times 10^4 Pa$

4. Consider a rectangular block of metal of mass 25kg shown in the diagram below



The force acting on its base will be its weight given by W=mg. W=25x 10=250N
base area is $\frac{10}{100} \times \frac{5}{100} = \frac{50}{10000}$
Area = $0.005M^2$

$$P = \frac{F}{A}$$

$$P = \frac{250}{0.005} = 50000\ Pa$$

5. A wooden cube of side 5cm, weighs 600g. Calculate the pressure it would exert when placed on a flat horizontal surface.

Leave two (2) pages for an exercise

Maximum and Minimum pressure

The pressure exerted by a solid depends on the area on which the force acts. If a given force acts on a large area, the pressure exerted is minimum. If the same force acts on a very small, area then a maximum pressure is exerted

$$\text{Minimum pressure} = \frac{\text{Force}}{\text{Largest Area}}$$

$$\text{Maximum pressure} = \frac{\text{Force}}{\text{Smallest Area}}$$

Examples

1. A rectangular block of weight 350N measures 0.14m x 0.2m x 0.3m calculate the

(i) Minimum pressure exerted

Minimum pressure = $\frac{\text{Force}}{\text{Largest Area}}$

Largest area = 0.2 x 0.3
= $0.06m^2$

Minimum pressure = $\frac{350}{0.06} = 5833\text{Pa}$

(ii) Maximum pressure exerted

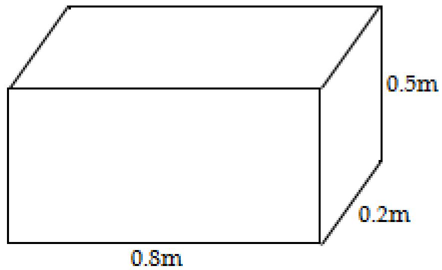
Maximum Pressure = $\frac{\text{Force}}{\text{Smallest Area}}$

Smallest area = 0.14 x 0.2

= $0.028m^2$

Maximum Pressure = $\frac{350}{0.028} = 12500$ Pa

2. Find the greatest and least pressure exerted on the floor by a rectangular metallic block of mass 80kg resting on one of its faces.



Force = Weight = mg

Force = 80 X 10 = 800N

Smallest area = 0.2 X 0.5 = $0.1m^2$

Largest area = 0.8 X 0.5 = $0.4m^2$

Maximum Pressure = $\frac{\text{Force}}{\text{Smallest Area}}$

Maximum Pressure = $\frac{800}{0.1} = 8000$ Pa

Minimum pressure = $\frac{\text{Force}}{\text{Largest Area}}$

Minimum pressure = $\frac{800}{0.4} = 2000$Pa

Leave two (2) pages for an exercise

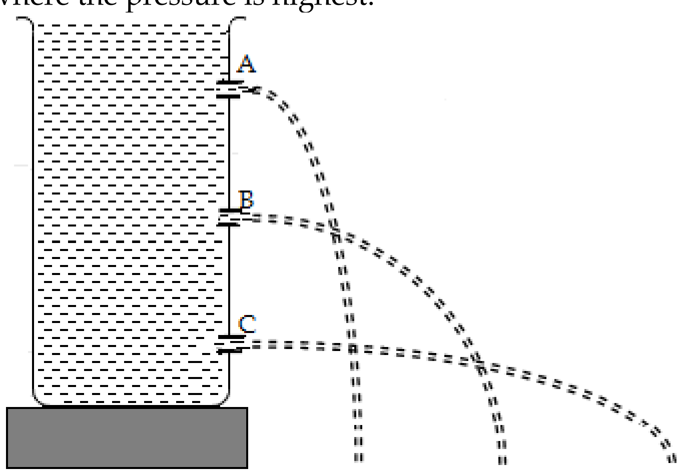
PRESSURE IN LIQUIDS

The weight of a liquid exerts pressure on the base of the container or on any object below the liquid surface.

Properties of pressure in liquids

1. Pressure in liquids increases with depth.

This can be demonstrated by drilling three holes at various heights on a tall can and filling it with water. It will be observed that the water jets and lands farthest through the lowest hole, C where the pressure is highest.

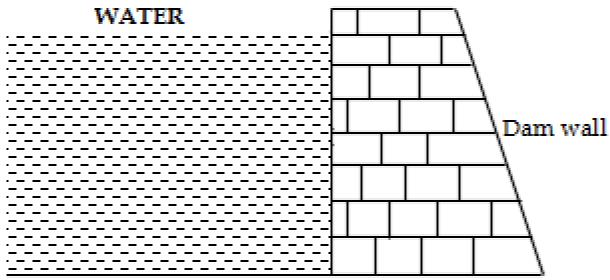


Water flows slowly through the first hole, A because it is at shorter depth below the liquid surface hence the least pressure.

It is common experience that water from a tall tank flows faster when the tank is full then when half full.

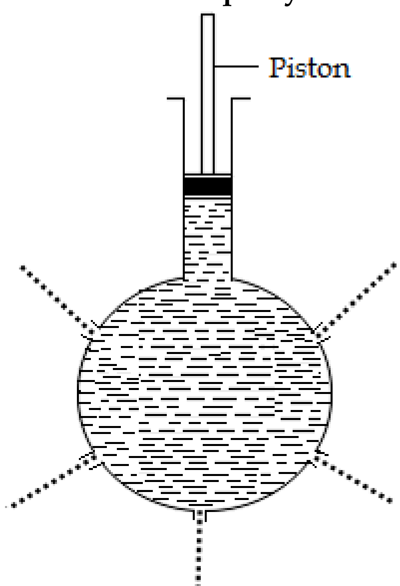
Safety measures (precautions) against high pressure at greater depths

(i) The dam wall is built thicker at the bottom than at the top to withstand the greater pressure.



(ii) A diver breathes in compressed air from a cylinder. As he goes deeper the cylinders have to provide air to the lungs at a greater pressure to avoid being crushed by water pressure.

2. Pressure acts equally in all directions in a liquid.

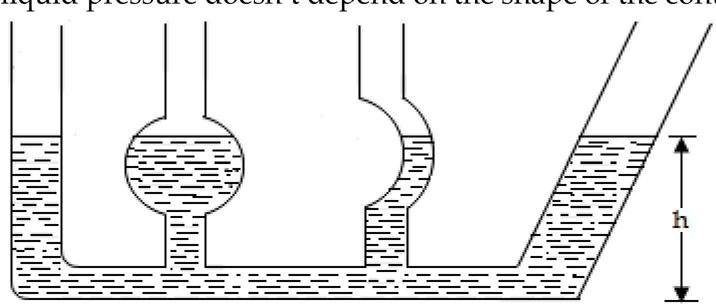


Because the molecules of a liquid are free to move they can transmit pressure in all directions. A perforated glass vessel fitted with a piston is filled with water by dipping the bulb in water and slowly raising the piston.

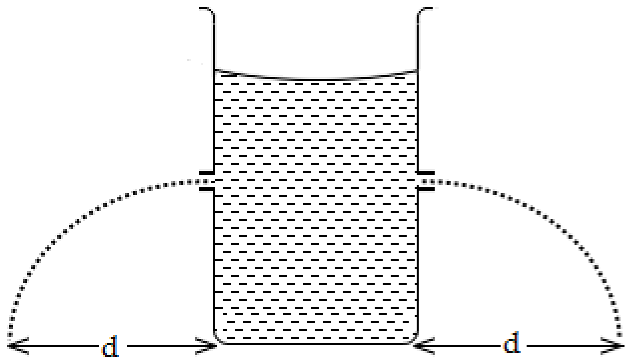
When a downward force is applied to the piston, the pressure exerted on the water is transmitted equally throughout the water so that water comes out of all the holes with equal pressure.

3. A liquid finds its own level.

When water is poured into a communicating vessel with tubes of different shapes, the liquid rises to the same level in each tube represented by height h above the base of the vessel. This is due the pressure being equal at the same horizontal level of the liquid. This fact shows that liquid pressure doesn't depend on the shape of the container.

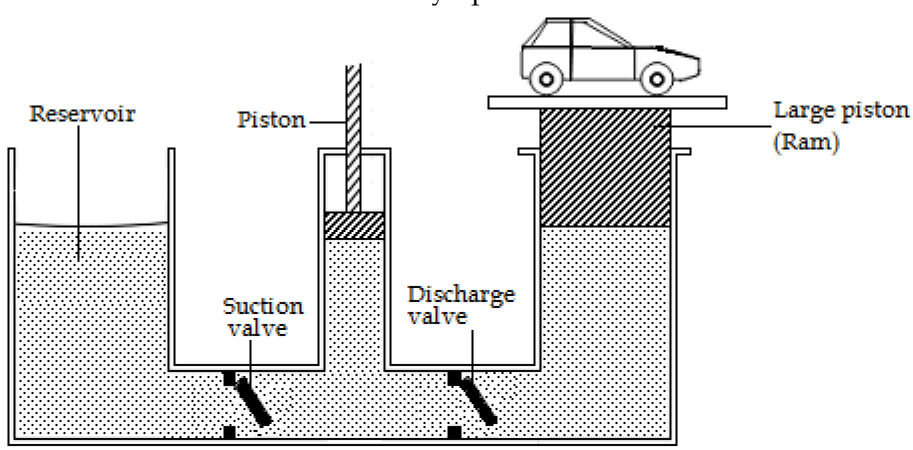


If two holes are drilled on opposite sides of a can at the same level and the can is filled with water, the water jets out from each of the holes to the same distance, d from the can. This shows that pressure is the same at the same depth.

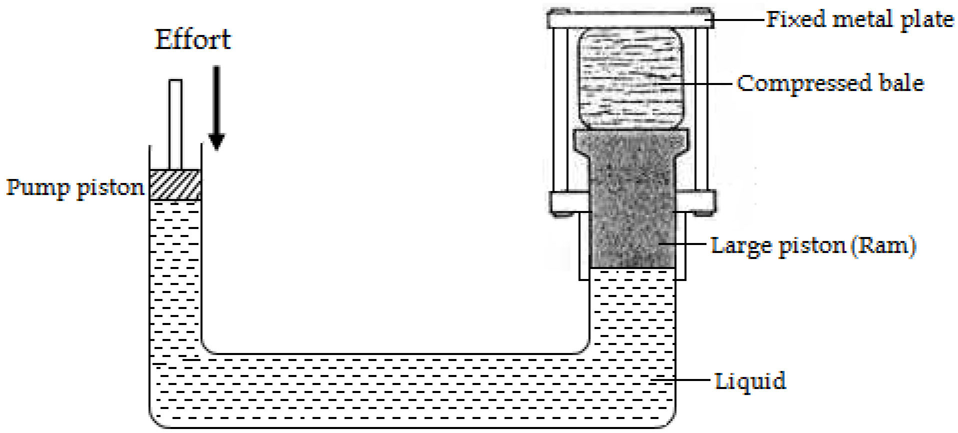


4. The principle of transmission of pressure
States that:
When a pressure is exerted at any point on the surface of a confined liquid, the pressure is transmitted equally throughout the liquid.
This principal explains why inflated tyre tubes and balls fill out evenly.

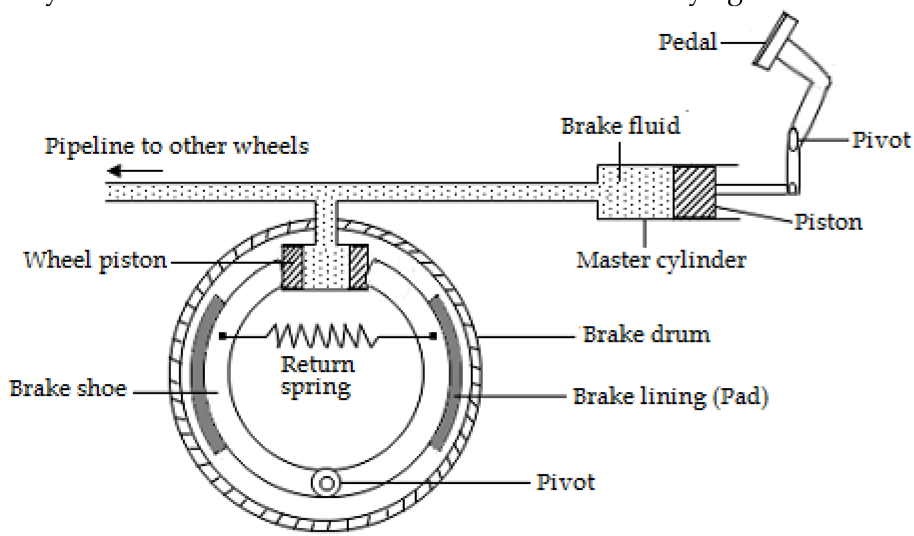
Applications of the principle of transmission of pressure
The principle is applied during the operation of hydraulic machines that use the fact that liquids are almost incompressible and transmit the pressure exerted on them. Examples of hydraulic machines are;
(i) Hydraulic car jack
(ii) Hydraulic press
(iii) Hydraulic brake system
(iv) Hydraulic lift
The hydraulic car jack
It is used to raise cars in a garage. When the piston is moved up, the suction valve opens and oil moves below the piston the discharge valve is closed.
When the piston is moved down, the discharge valve opens and the oil transmits the pressure to the ram where a large force is created that raises the car. The suction valve is closed. To lower the car the valves are mechanically opened to allow the oil to flow back to the reservoir.



The hydraulic press
A force is applied on a pump piston which exerts pressure on the liquid surface. This pressure is transmitted and pushes the large piston (ram) which in turn presses the bale against a fixed metal plate with a great force.
The hydraulic press is used to compress soft materials such as waste paper and cotton into compact bales for easy transportation. It is also used in shaping car bodies, forging steel armour and light alloys.

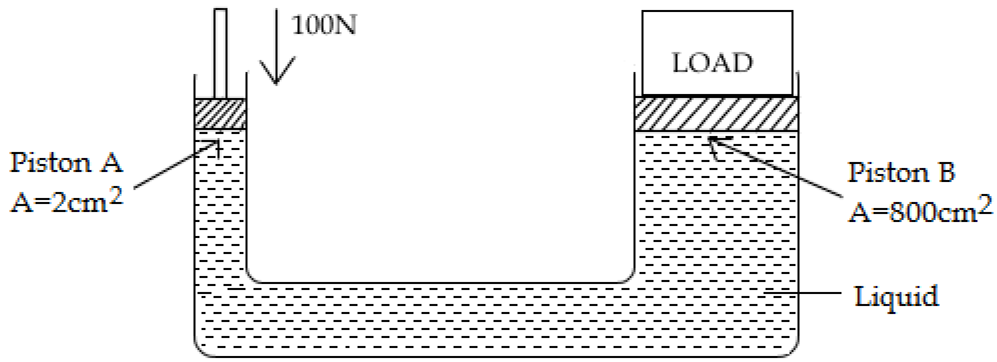


The hydraulic car brake system
When the brake pedal is pushed the piston in the master cylinder exerts a force on the brake fluid and the resulting pressure is transmitted equally to all the wheel pistons where the force created causes the brake lining to press against the brake drum. This slows down the wheels and the car stops. When the foot is taken off the pedal, the return spring pulls the brake lining away from the brake drum and the wheels move freely again.



The hydraulic lift
A hydraulic lift is a machine where a small force applied on a small piston creates a pressure that is transmitted through the liquid to a large piston where a great force is created. A hydraulic lift is used to raise heavy materials in industries and in modern garages it is used to raise cars.

How large forces are produced
Consider a hydraulic lift where a force of 100N is applied on a small piston A of cross-sectional area 2cm^2, using Pascal's principle this pressure is transmitted through the liquid to the large piston of cross-sectional area 800cm^2 on which the load rests.



The pressure exerted by piston A = $\frac{\text{Force on A}}{\text{Area of A}}$

Pressure exerted on piston B = $\frac{\text{Force on B}}{\text{Area of B}}$

Using Pascal's principle,
Pressure at A = Pressure at B

$$\frac{\text{Force on A}}{\text{Area of A}} = \frac{\text{Force on B}}{\text{Area of B}}$$

$$\frac{100}{0.0002} = \frac{F_B}{0.08}$$

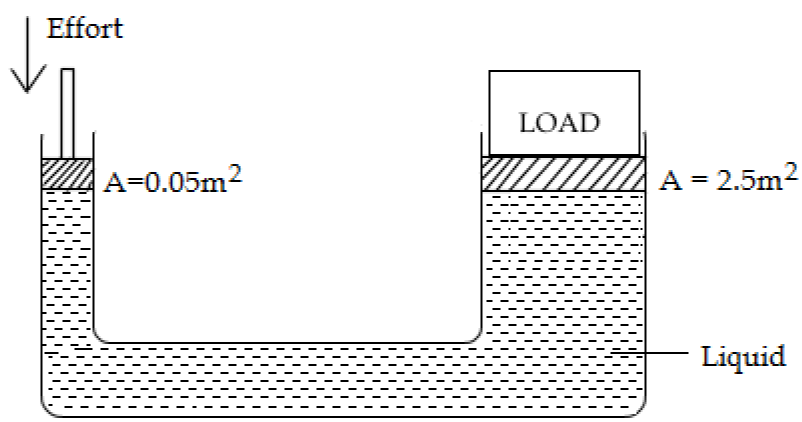
$$F_B = \frac{100 \times 0.08}{0.0002}$$

F_B **= 40,000N.** This force is obtained by exerting a force of 100N.

Leave three (3) pages after these questions for discussion of the solutions

Questions

1. The piston of a hydraulic press has a diameter of 0.40m and the small piston a diameter of 0.06m. A force of 45N is exerted on the small piston calculate the upward force on the piston produced by this force.
2. A hydraulic press has one piston Q with a cross-sectional area 0.0154m² while another piston has a cross-sectional area of 6.16m². If a force of 77N is applied on piston Q calculate the force exerted on the other piston.
3. The diagram below shows a hydraulic lift system. Determine the effort applied to raise a load of 1000N



4. A hydraulic press has a two pistons C and D of radii 0.06m and 0.08m respectively. Calculate the maximum force at D that can be overcome by a force of 52N applied at C.