# Thermal Physics

Heat can be transferred from one point to a another point using the following techniques:
Conduction
convection
radiation

## <u>Conduction</u>:

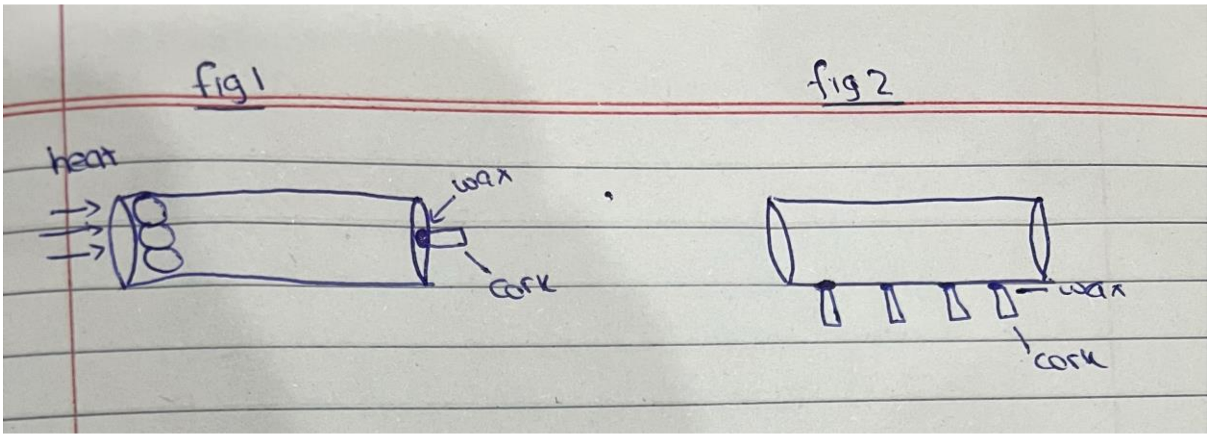
is a process which essentially takes place in solids that are great conductors where as liquids and gases are poor conductors and vacuum is a non conductor

In the process of conduction molecules absorb heat energy and vibrate with a greater amplitude about their mean position, this allows others to collide with the neighbouring molecules. This intermolecular collision is responsible for the transfer of energy

Metals are better conductors compared to non metals. This is because they have free electrons. These free electrons will absorb energy and will move through the solids. As they will move they will collide with the molecules and this collision allows transfer of energy

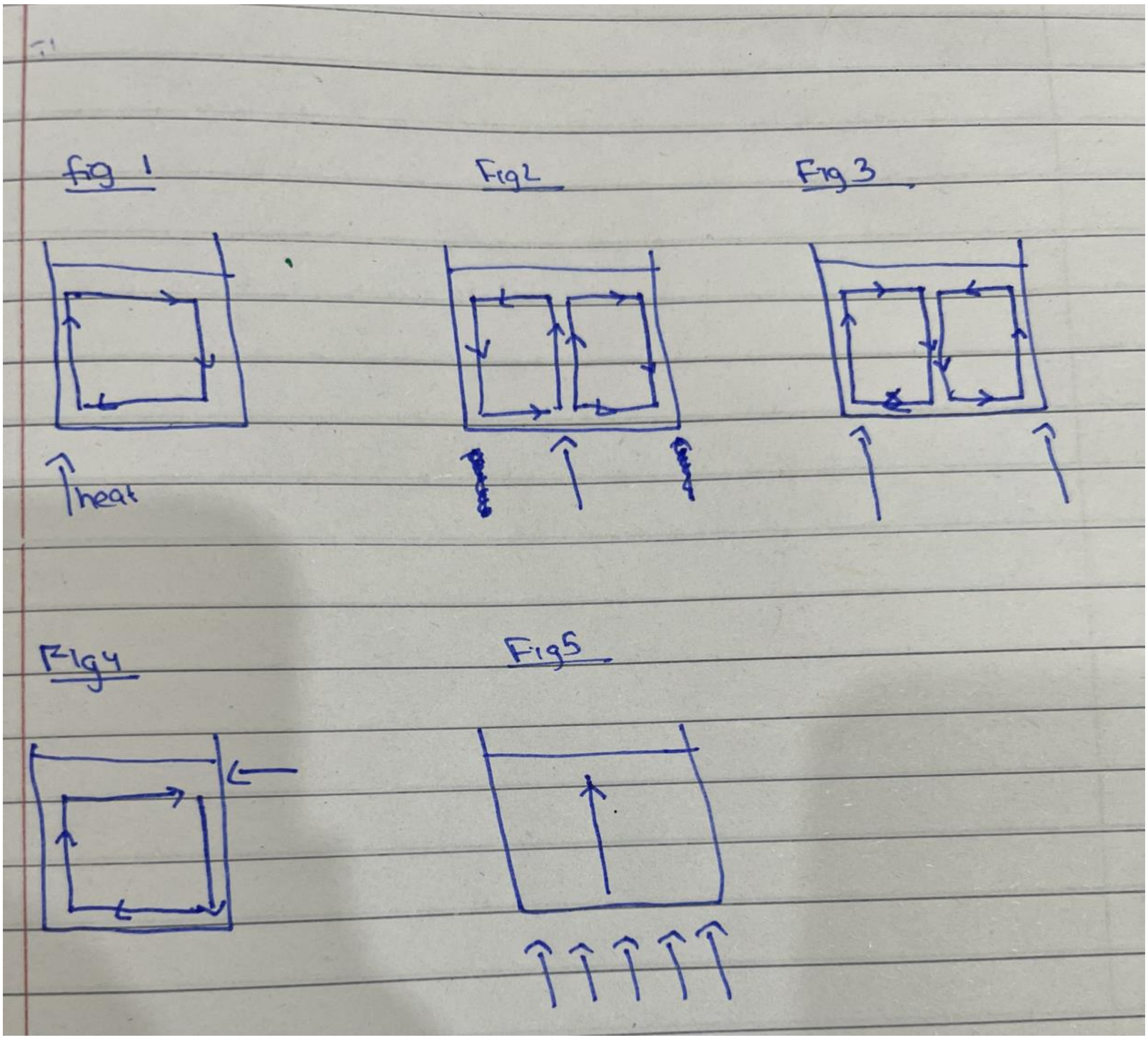
The term controls of variables refers to all the factors which are supposed to remain constant so that a fair trial can be conducted. These may include: same heat source, same distance from heat source, same diameter, same length, same amount of wax, same size of corks.

To obtain a more reliable result figure two is better than one because it is based on multiple trails and it allows us to monitor how heat energy is transferred along the outline length of the rod



# **Convection:**

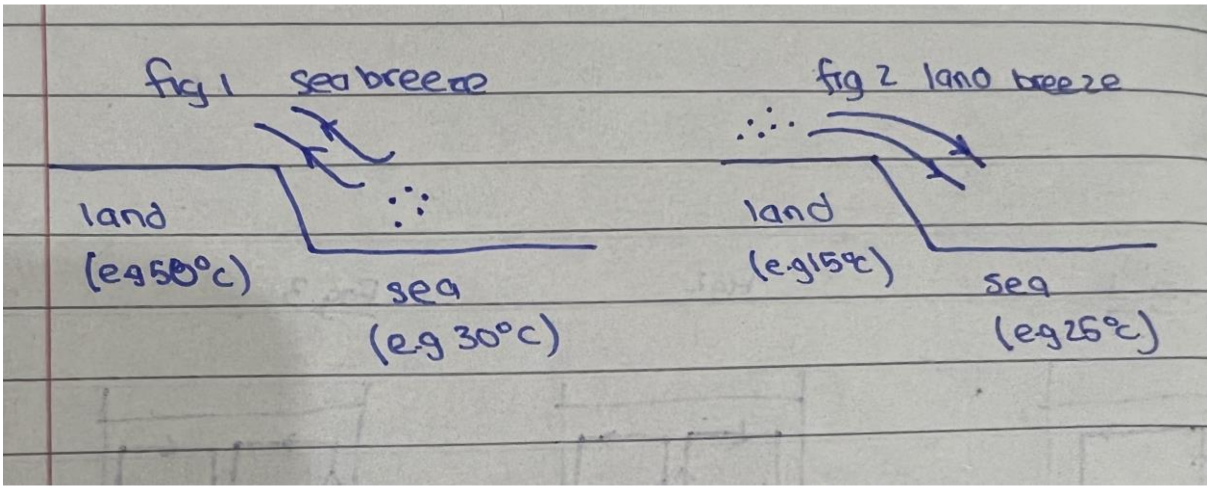
Convection is a process which essentially takes place in liquids and gases. This process occurs because of a difference in density




Important: In figure 1, the water molecules will absorb heat energy causing them to move further apart. This causes the volume to increase and the density decreases. As they become less dense they begin to rise. Upon reaching the surface they will cool down and start to sink. This circulation of molecules gives rise to the formation of upward convection current. ( figure 2 and 3 are also examples of upward convection current). Figure 4 shows a representation for downward convection current, in this diagram a cooling source for example an air conditioner is positioned at the top of the room and the cold air surrounding the ac is more dense therefore it sinks, the warm air at the bottom of the room, being less dense, begins to rise. This circulation in air results in creating a downward convection current.

If the container is heated uniformly as shown in figure 5 then this would result in the molecules reaching the surface to undergo the phenomena of boiling/evaporation.

### Explanation of how convection results in the formation of :
### Sea breeze
### Land breeze




During the day time, in figure 1, the land is at a higher temperature compared to the sea. Thus, the air molecules above the land surface rise and will create a vaccum. In order to fill this vaccum, the cold air molecules from the sea will move towards the land and this results in the formation of sea breeze

During night time, in figure 2 the land is cooler and sea is warmer. Air molecules from the sea rise to create a vaccum and the cooler air molecules from the land will flow towards the sea to fill the vaccum and this results in the formation of land breeze.

# Radiation

Every hot object emits energy, this energy is known as radiant energy, radiation or infrared radiation. This radiant energy is emitted in all directions. Infra red radiation can be measured either by using mercury thermometers or infrared thermometers.

Unlike conduction and convection radiation does not require a medium to travel because radiant energy can travel through a vaccum.

Experiments have shown that dull black dark and gray surfaces are good absorbers and emitters but poor reflectors of heat energy. Whereas white, silver, shiny and polished surfaces are poor absorbers and emitters but good reflectors of heat energy.

Figure 1 indicates an arrangement that can be used to confirm that black surfaces are better absorbers. Figure 2 indicates an arrangement that can be used to confirm that black surfaces are better emitters of radiation. Figure 3 can be used to confirm that black surfaces are better absorbers and better emitters of radiation. Figure 4 indicates how cooling curves can be constructed for different coloured materials. When the substance is at a higher temperature there is a larger temperature gradient therefore the shape of the graph is steeper. When the substance reaches close to room temperature there is a smaller temperature gradient hence making the graph less steep.

**How to maintain the transfer of heat**

Place a lid

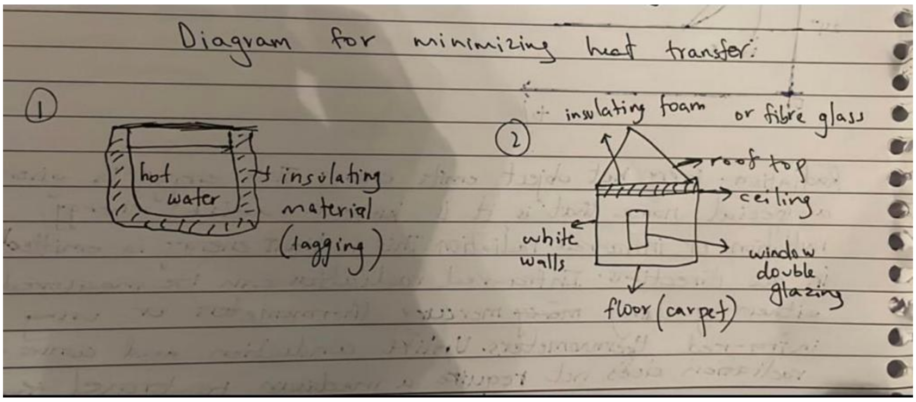
Cover the surface of the container with an insulating material(lagging)

Use of double glazed windows

Carpeted floor(the fibres of the carpet can be good insulators)

Painting the walls inside and outside white

Placing insulation foam or fibre glass between the rooftop and ceiling



# Evaporation

The energetic molecules in the liquid will break the intermolecular forces when heat energy is applied to the liquid. Most molecules will evaporate and leave the surface thus the kinetic energy is lost and the temperature will decrease thus evaporation leads to a cooling effect

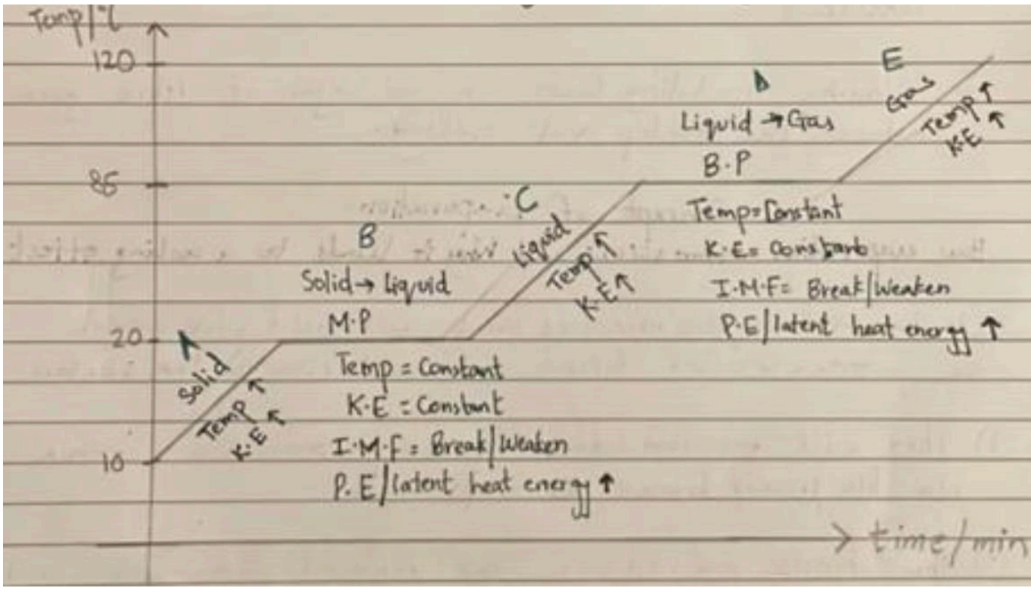
## Factors affecting rate of evaporation

The higher the temperature, the higher the rate of evaporation

A larger surface area allows more evaporation

If an air current is present evaporated molecules will be carried away, thus presence of an air current results in a faster rate of evaporation

# Melting and boiling




In **A** the temperature increases causing an increase in kinetic energy of the molecules

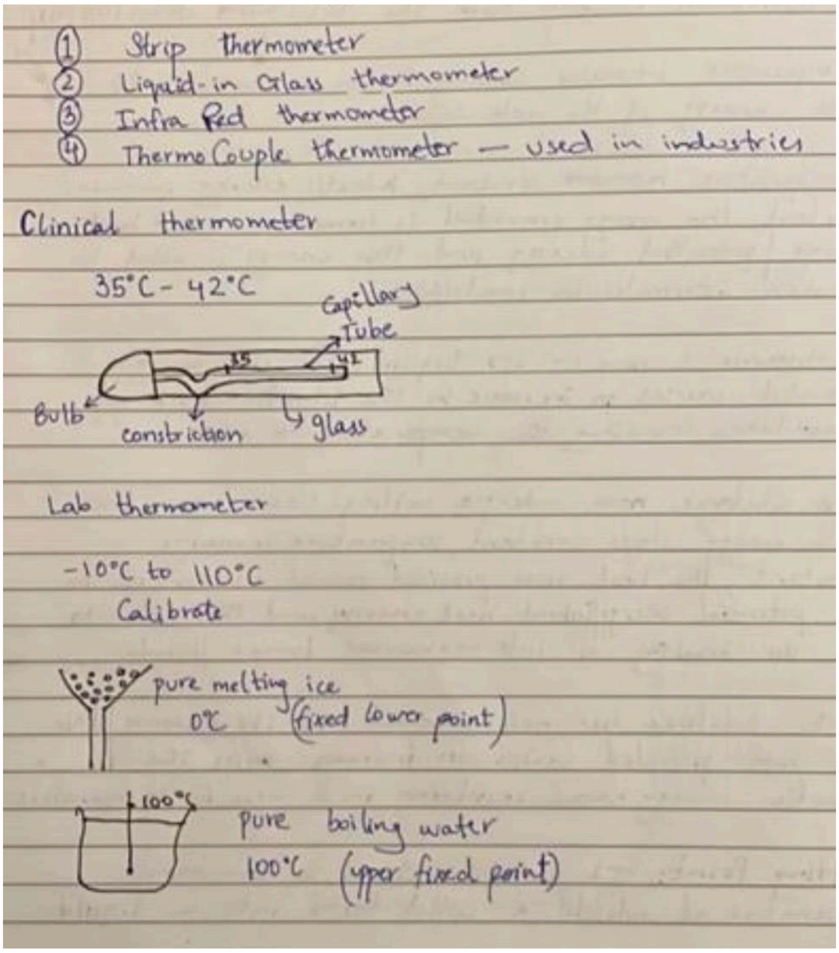
In **B** temperature remains constant, kinetic energy is constant this is because the energy being provided is being converted to potential energy/latent heat and this potential energy is being sued to weaken the intermolecular forces

In **C** the substance is in its liquid state, this energy provided causes an increase in kinetic energy and so the temperature rises as well

In **D** the substance undergoes the process of boiling. The kinetic energy and temperature remain constant the heat energy provided is converted to potential energy in order to break the intermolecular forces

In **E** the substance is now in its gas state, the heat provided increases kinetic energy and temperature

# Types of thermometers

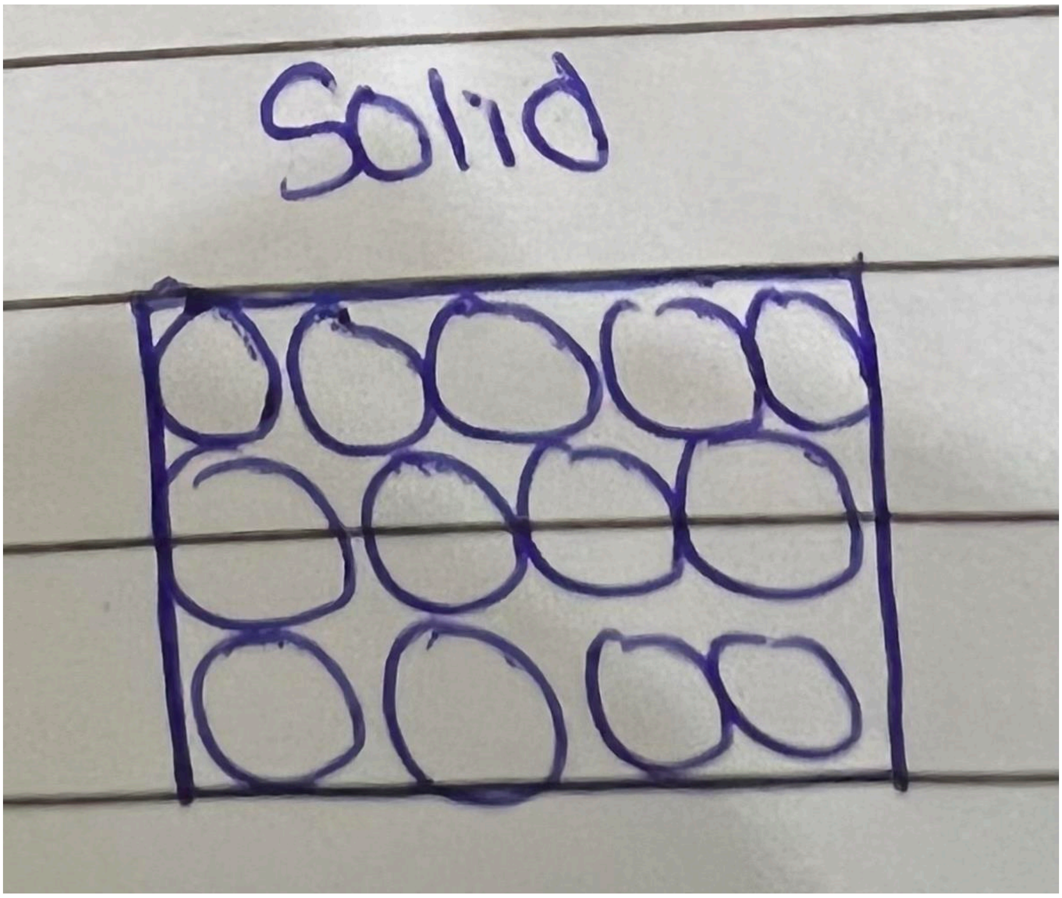



# Phases of matter and their properties

## Solids:

Fixed shape
fixed volume

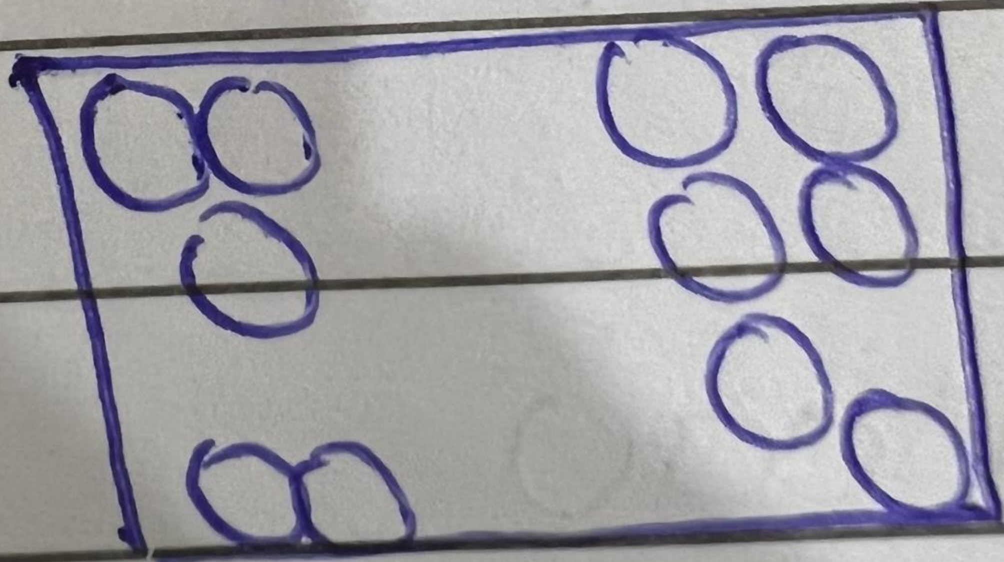
high density
strong intermolecular forces
Arranged in a regular repeated pattern
Cannot be compressed
Molecules perform vibratory position




## **Liquid**:

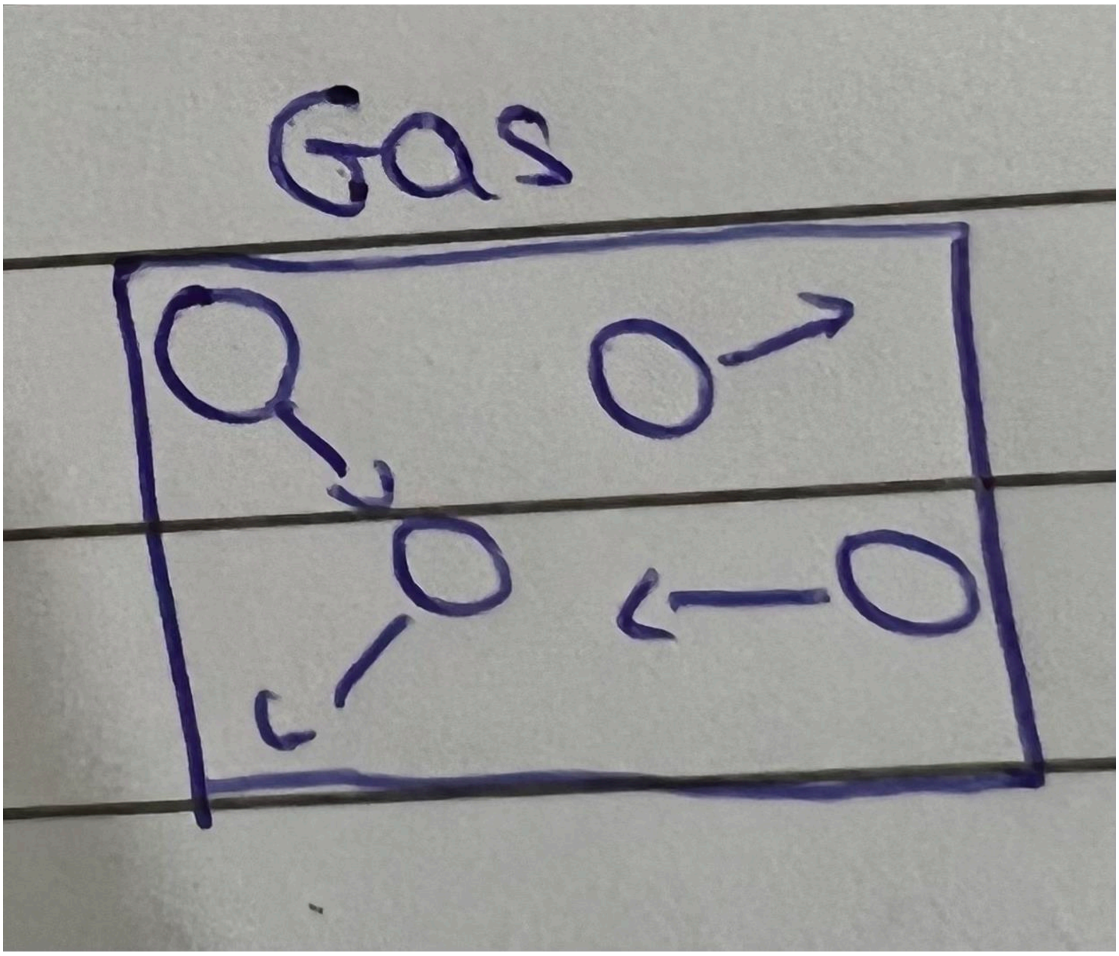
Fixed volume
No fixed shape
Moderate to high density
Moderate to strong intermolecular forces
Do not follow any regular repeated arrangement
Can only be compressed under very high pressure
Molecules perform translatory motion (they can Slide Over each other) they are arranged in the form of clusters.

liquid

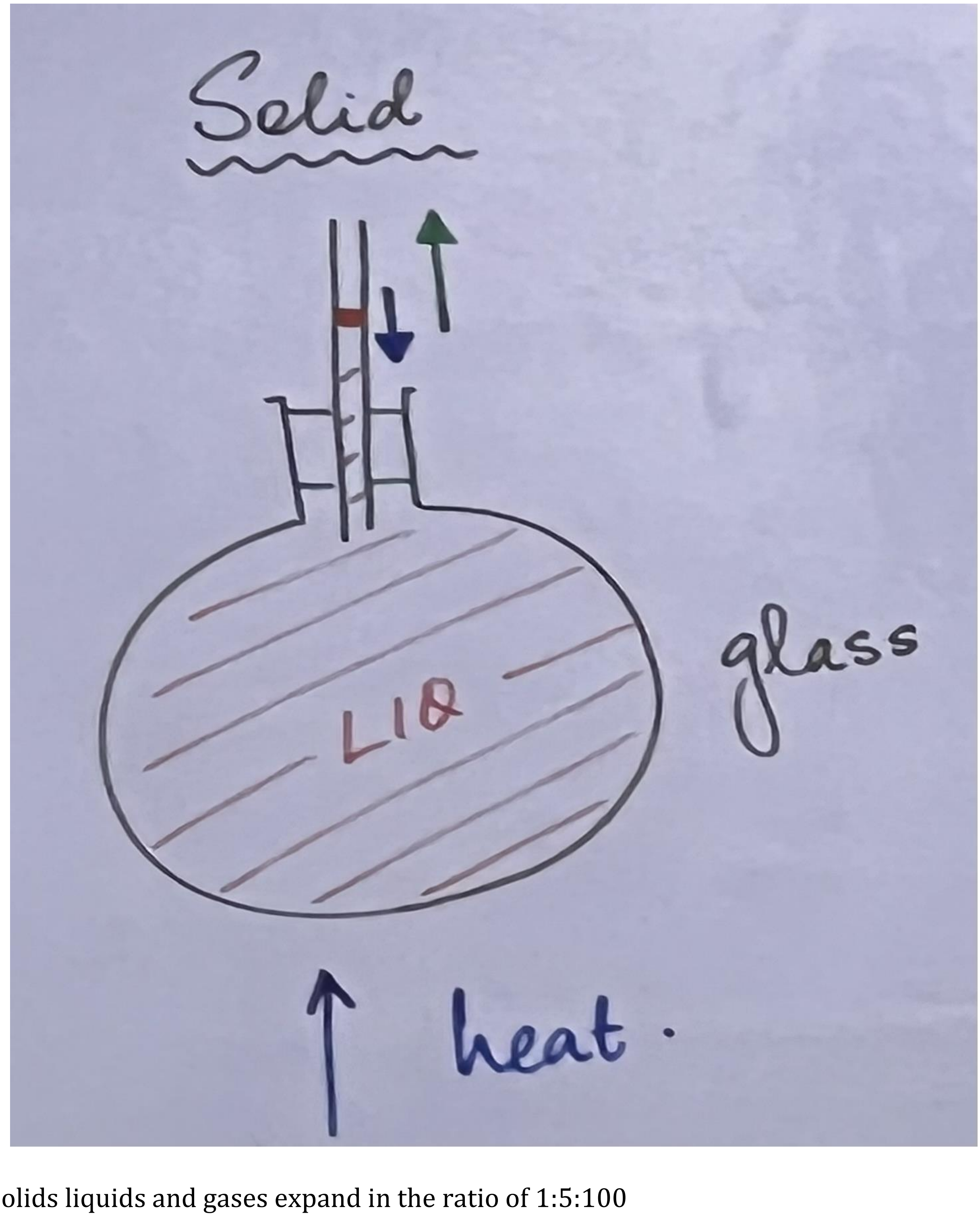


## Gases:

No fixed shape
No fixed volume
Has low density
Weak/ negligible intermolecular forces
Can be compressed easily
Molecules perform random motion that is they can move in any direction with different speeds as shown in figure 3



# Thermal expansion of solids liquids and gases




Solids liquids and gases expand in the ratio of 1:5:100

The expansion of solids and liquids can be confirmed using the arrangement shown in figure 1.

In the beginning glass undergoes expansion, due to an increase in kinetic energy, which causes the liquid level to fall.

After some time the liquid will then obsorb the heat energy and undergoes expansion which now causes the liquid level to rise until the liquid overflows. This indicates that liquids expand more(5 times more) than solids.

### Examples of thermal expansion

Gaps are left in railway tracks and suspension bridges to allow for expansion in summer

The electricity cables on the roads, are left loose/sagged this is so that in winters the wire will correct and become straight, in summers it will become sagged again

Gaps are left between tiles during installation

Material used in tooth filling must expand by the same amount as the tooth itself

## Relationship between temperature and kinetic energy

As the temperature of a substance increases it’s kinetic energy also increases and vice versa

When the temperature drops down to 0 kelvin or -273 degrees it reaches absolute 0 temperature, and at this absolute 0 state the kinetic energy of an object is completely stopped

To convert temperature from degree Celsius to kelvin we add 273, to convert kelvin to Celsius we minus 273

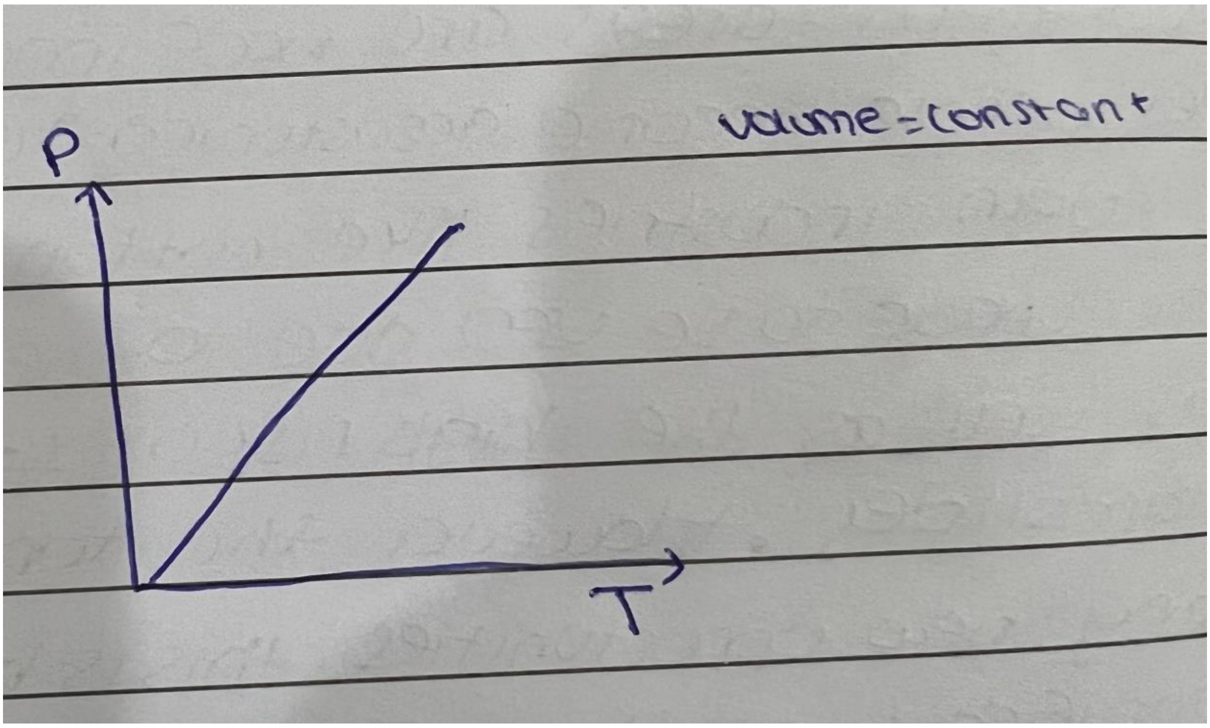
## Gas laws

Gas laws are used to help us develop a relationship between the pressure of the gas, the volume of the gas and the temperature of the gas

## Pressure law

The pressure of a gas is directly proportional to the temperature provided that the volume of the gas remains constant

Hence the gas of pressure vs temperature must be a straight line passing through the origin as shown in the diagram below:




In this diagram as the temperature increases the molecules gain kinetic energy and move at a faster speed.

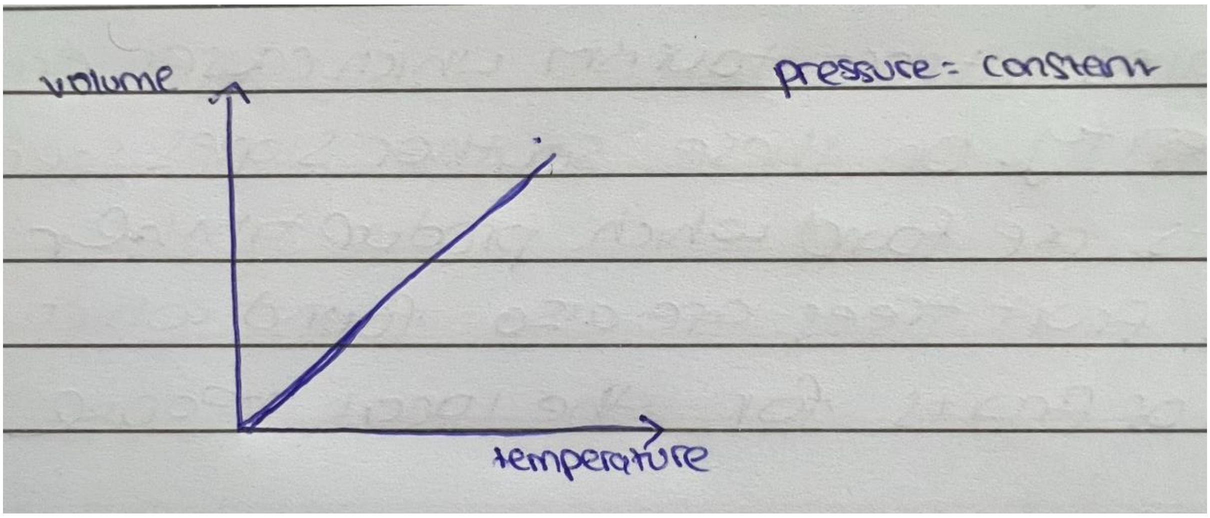
When the speed increases they collide with the walls of the container, this increase in collision frequency allows the molecules to exert more force on the wall of the container

Since pressure is force upon area, as the force increases the pressure exerted by the molecules also increases

# **<u>Charles law</u>**

The volume of a gas is directly proportional to the temperature of the gas provided that the pressure of the gas remains constant

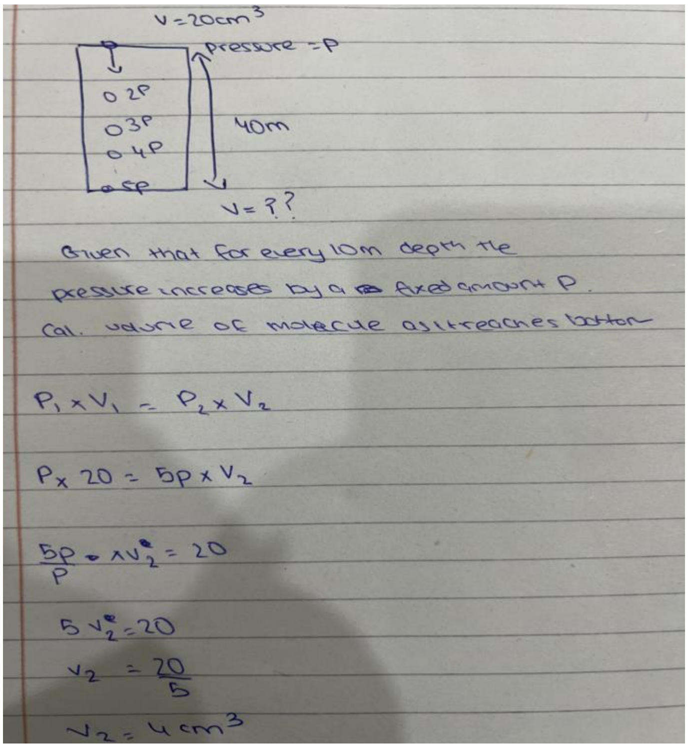
Hence a graph of volume against temperature is a straight line passing through the origin




As temperature increases the gas undergoes expansion, this causes the volume to increase

# Boyles law

The pressure of a gas is inversely proportional to its volume provided that the temperature remains constant. Hence the graph against volume follows a curve, in inverse proportional of one value gets doubled the other is halved. To check for inverse proportionality multiply the 2 quantities if the result is constant throughout it is inversely proportional
The formula is **<u>P1 x P2 = V1 x V2</u>**




Given that for every 10m depth the pressure increases by a fixed amount P. Cal. volume of molecule as it reaches bottom

$P_1 \times V_1 = P_2 \times V_2$

$P \times 20 = 5p \times V_2$

$\frac{5p}{p} \times V_2 = 20$

$5 V_2 = 20$

$V_2 = \frac{20}{5}$

$V_2 = 4\ cm^3$

# Specifc heat capacity

It's symbol is C
It is the amount of energy required by a mass of 1 kg to raise its temperature by 1 degree Celsius
It's formula is:

$$\frac{\text{amount of energy } (E \text{ or } Q)}{\text{mass } (m) \times \text{change in temp } (\Delta T \text{ or } \Delta\theta)}$$

$$C = \frac{Q}{m \times \Delta\theta} \qquad Q = m \times C \times \Delta\theta$$

Q) Power = 1kW

time = 7mins

$\theta_i = 40°C$ $\theta_f = 60°C$

mass = 5kg

cal. C

$$C = \frac{Q}{m \times \Delta\theta}$$

$$C = \frac{P \times T}{m \times \Delta\theta} = \frac{(1000W) \times (7 \times 60(s))}{5kg \times (60-40)} = \frac{420000}{100}$$

$$= 4200 J/kg°C$$

1A) A persons wants to a make a cup of coffeee for which he heats up 0.4 kg of water from 20 degree Celsius to 90 degrees. Calculate the energy required given that specifc heat capacity of water for water is 4200 j/kg degree

B) If the person makes cups of coffe per day for 1 year calculate the total energy required

1) a) $4200 = \dfrac{Q}{0.4 \times (90-20)}$

$4200 \times 0.4 \times 70 = Q$

$Q = 117600J$

b) one cup of coffee requires 117600 J. 5 will need 117600 × 5 = 588000J. for 365 days the energy required will be 588000 × 365 = 214,620,000 J

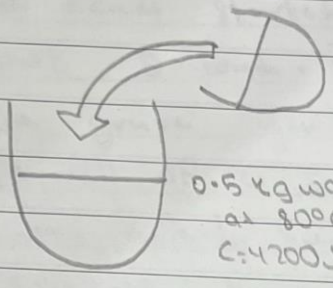
1 kwh = 3,600,000 J

e.g 214,620,000 J to kwh

214,620,000 ÷ 3,600,000 = 59.6 kwh

## Heat loss and heat given

concept of Heat loss = Heat gain



0.3 kg of ethanol
at 10°c c = x

0.5 kg water
at 80°c
C = 4200 J/kg°c

After mixing both reach 54°c cal specific heat capacity for ethanol

Heat lost (water) = $Q = 0.5 \times 4200 \times (80-54) = 54600$ J

Heat given (ethanol) = $Q = 0.3 \times x \times (54-10) = 13.2x$

$13.2x = 54600$ J

$x = 4136$ J/kg°c