HEAT

When you put a cup of very hot porridge on a table, the porridge cools down after sometime. This means that some energy has been transferred from the porridge to the surrounding. This form of energy that is transferred is called heat.

Definition:
Heat is the form of energy which flows from one point to another due to temperature difference between the two points.

Heat energy flows from a region of high temperature to a region of low temperature.
The **SI** unit of heat energy is a joule (**J**).

Effects of heat on a body:
When a body absorbs heat energy,
- Its temperature increases thus becoming hot.
- Its state changes e.g. solid changes to liquid.
- It makes the body to expand.

When a body loses heat energy,
- Its temperature decreases thus becoming cold.
- It makes the body to contract.

TEMPERATURE

Temperature is a number which expresses the degree of hotness or coldness of a body on a chosen scale.

Temperature of a body depends on the average kinetic energy of the molecules in that body. Therefore, temperature can also be defined as ***measure of the average kinetic energy of the molecules in the body.***

Measurement of temperature:
Temperature of a body is measured by an instrument called a **thermometer**.
The SI unit of temperature is the **Kelvin (K)**.

Other units include;
- Degrees Celsius ($°C$)
- Degrees Fahrenheit ($°F$)

Thermometers measure temperatures of a body basing on certain physical properties which change continuously with temperature. These physical properties are called thermometric properties.

Definition:
A **thermometric property** is a physical property which changes continuously with temperature.

Examples of thermometric properties:
They include;
→ Length of a liquid column (e.g. liquid-in-glass thermometer).
→ Electrical resistance of a wire (e.g. platinum resistance wire).
→ Pressure of a fixed mass of a gas at constant volume (e.g. constant-volume gas thermometer).
→ Volume of a fixed mass of a gas at constant pressure (e.g. constant-pressure gas thermometer).
→ Electromotive force of a thermocouple (e.g. thermocouple thermometer).

Qualities of a good thermometric property:
- It should vary continuously and linearly with change in temperature.
- It should vary considerably for a small change in temperature.
- It should vary over a wide range of temperatures i.e. both high and low temperatures.
- It should be accurately measurable over a wide range of temperature with a simple apparatus.

TEMPERATURE SCALES
A temperature scale is a scale in which the degree of hotness or coldness can be expressed.
These scales include:
- Fahrenheit scale.
- Celsius scale (centigrade scale).
- Kelvin scale (thermodynamic scale).

Fahrenheit scale:
Temperature on the Fahrenheit scale is measured in degrees Fahrenheit (°F).
To convert from degrees Celsius to degrees Fahrenheit, the formula below is used.

$$°\mathrm{F} = \frac{9}{5}C + 32$$

Celsius scale:
Temperature on the Celsius scale is measured in degrees Celsius (°C).
The lower fixed point (melting point of ice) is 0°C and the upper fixed (boiling point of water) is 100°C.
To convert from degrees Fahrenheit to degrees Celsius, the formula below is used.

$$°\mathrm{C} = \frac{5}{9}(F - 32)$$

Kelvin scale:
Temperature on the Kelvin or thermodynamic scale is measured in Kelvins (K).
The lower fixed point (melting point of ice) is $273K$ and the upper fixed (boiling point of water) is $373K$.

Relationship between the Celsius scale and Kelvin scale
If temperature, θ (°C) on the Celsius scale is related to temperature, T (K) on the Kelvin scale, then;
$T = \theta + 273$
$\theta = T - 273$

Examples:
1. Convert the following temperature readings to Kelvins.

i) 127°C $T = \theta + 273$ $T = 127 + 273$ $T = 400K$	ii) 30°C $T = \theta + 273$ $T = 30 + 273$ $T = 303K$	iii) −27°C $T = \theta + 273$ $T = -27 + 273$ $T = 246K$
iv) 0°C $T = \theta + 273$ $T = 0 + 273$ $T = 273K$	v) −240°C $T = \theta + 273$ $T = -240 + 273$ $T = 33K$	vi) 26.5°C $T = \theta + 273$ $T = 26.5 + 273$ $T = 299.5K$

2. Convert the following temperature readings to degrees Celsius.

i) $23K$ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 23 - 273}$ $\boldsymbol{\theta = -250}$℃	ii) $233K$ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 233 - 273}$ $\boldsymbol{\theta = -40}$℃	iii) $54K$ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 54 - 273}$ $\boldsymbol{\theta = -219}$℃
iv) 0℃ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 0 - 273}$ $\boldsymbol{\theta = -273}$℃	v) $600K$ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 600 - 273}$ $\boldsymbol{\theta = 327}$℃	vi) $574K$ $\boldsymbol{\theta = T - 273}$ $\boldsymbol{\theta = 574 - 273}$ $\boldsymbol{\theta = 301}$℃

FIXED POINTS OF A THERMOMETER

A **fixed point** is a constant temperature at which a physical change takes place at standard atmospheric pressure.

There are basically two types of fixed points namely;

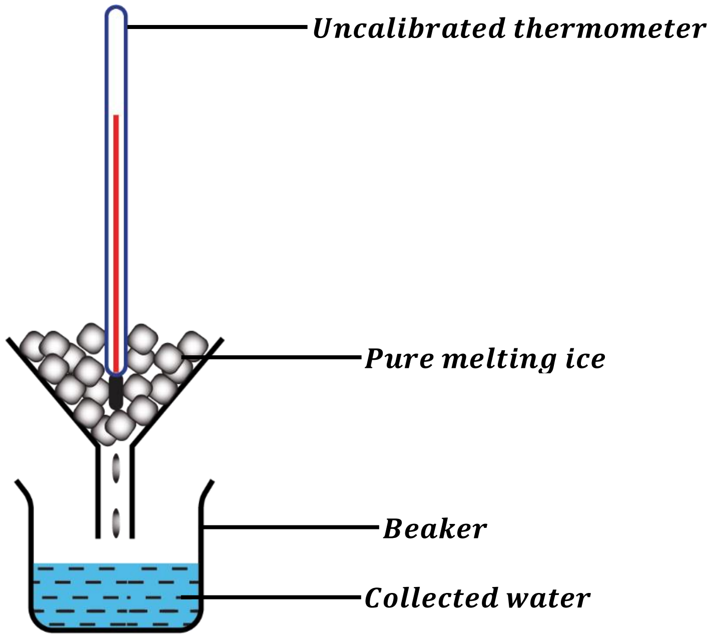
- Lower fixed point.
- Upper fixed point.

LOWER FIXED POINT (ICE POINT):

This is the temperature of pure melting ice at standard atmospheric pressure.

The lower fixed point is 0℃ on the Celsius scale and $273K$ on the Kelvin scale.

An experiment to determine the lower fixed point of an uncalibrated thermometer



- The thermometer to be marked is placed in pure melting ice inside a funnel with ice cubes packed around its bulb.
- The thermometer is left in ice for some time until the level of mercury remains stationary.
- This level is then marked and it is the lower fixed point of the thermometer.

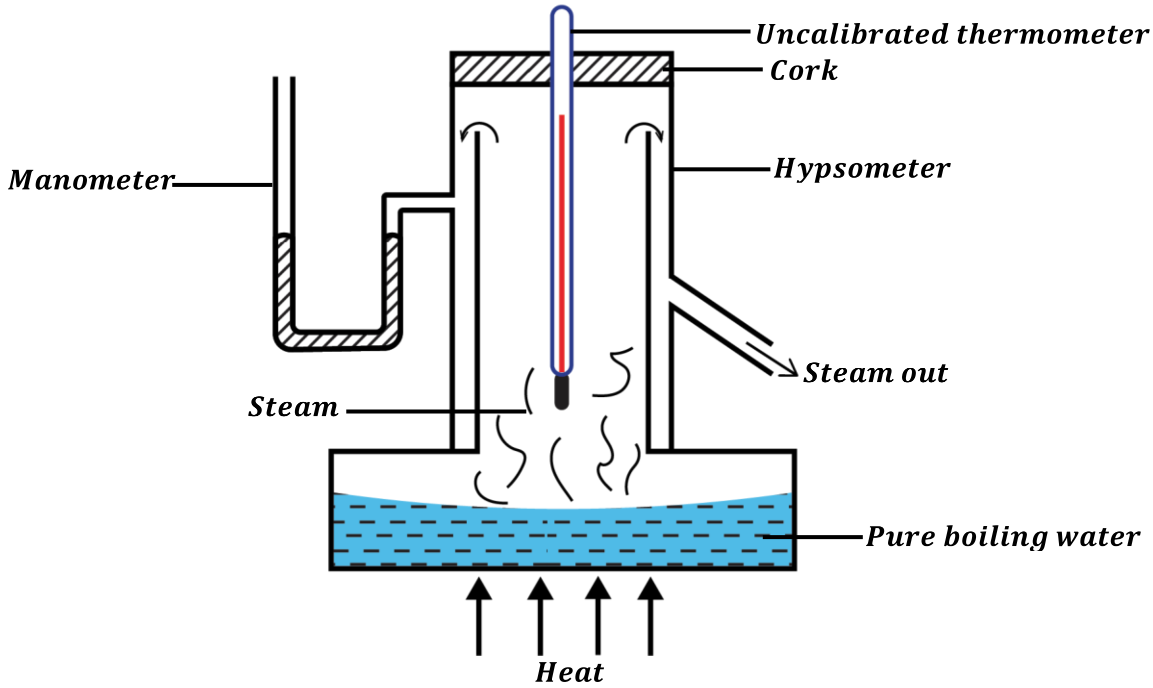
NOTE:

- The ice must be pure because impurities in ice lower the melting point of ice.

UPPER FIXED POINT (STEAM POINT):
This is the temperature of pure boiling water at standard atmospheric pressure.

The lower fixed point is 100℃ on the Celsius scale and $373K$ on the Kelvin scale.

An experiment to determine the upper fixed point of an uncalibrated thermometer

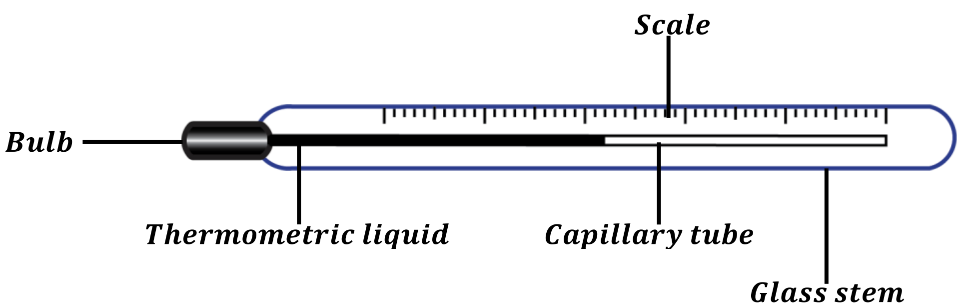


- Some water is poured into a hypsometer
- The thermometer to be marked is placed in the hypsometer through a hole in the cork.
- Water is boiled to generate steam that surrounds the bulb of the thermometer.
- The thermometer is left in steam for some time until the level of mercury remains stationary.
- This level is then marked and it is the upper fixed point of the thermometer.

NOTE:
- The double walls of the hypsometer ensure that the temperature of steam is always constant (i.e. it's always 100℃). Thus, they reduce heat loss to the surrounding.
- The manometer ensures that the standard pressure is always constant (i.e. it's always $76mmHg$).
- When performing the above experiment, the bulb should not touch the surface of boiling water.

LIQUID-IN-GLASS THERMOMETERS
These are the most commonly used thermometers in the world.
They use liquids in their capillary tubes to measure temperatures.

Structure of a liquid-in-glass thermometer:



It consists of a thin walled bulb at the end of a capillary tube.
The bulb and some part of the capillary tube is filled with a thermometric liquid which expands so as to measure temperature.
The common thermometric liquids used are mercury and alcohol.

How to use a liquid in thermometer:

- The bulb is kept in direct contact with the body whose temperature is to be measured.
- The thermometric liquid expands through the capillary tube.
- The thermometer is left in contact with the body for sometime until the level of thermometric liquid (mercury) remains stationary or steady.
- The thermometer reading becomes the temperature of the body

Precautions taken when designing (constructing) a liquid-in-glass thermometer:

- The walls of the glass bulb should be thin. This ensures that the thermometric liquid e.g. mercury is heated easily.
- The amount of thermometric liquid in the bulb should be small. This is because a small amount of the liquid takes less time to warm up therefore, it gives a quick response.
- The capillary tube should be uniform. This ensures that the expansion of the thermometric liquid is also uniform.
- The bore of the capillary tube should be made narrow. This makes the thermometer to be more sensitive in detecting small changes in temperature.
- The glass wall of the stem is made thick. This ensures that the inner parts of the thermometer are well protected.

NOTE:
The space above the thermometric liquid is usually evacuated to avoid excess pressure from being developed when mercury expands.

THERMOMETRIC LIQUIDS:

There are two liquids that are mainly used in a liquid-in-glass thermometer namely;

- Mercury.
- Alcohol.

Choice of a thermometric liquid:
The choice of the thermometric liquid depends on the range of temperature to be measured.
Mercury freezes at $-39°C$ (freezing point) and boils at $357°C$ (boiling point).
Alcohol freezes at $-115°C$ (freezing point) and boils at $78°C$ (boiling point).
Therefore, alcohol is suitable to measure very low temperatures and mercury is suitable to measure very high temperatures.

Qualities of a good thermometric liquid:

- It should be opaque so that it can easily be seen.
- It should not wet glass i.e. it should not stick on the walls of the thermometer.
- It should be a good conductor of heat. This ensures that it responds to any change in temperature.
- It should have a regular or uniform expansion. i.e. its expansion should be the same at different points of the scale.
- It should have a high boiling point so as to measure very high temperatures.
- It should have a low freezing point so as to measure very low temperatures.
- It should have a high expansivity i.e. it should expand so much for a small temperature change.

Reasons why water is not used as a thermometric liquid:

→ It is transparent (not opaque) so it cannot be easily seen.
→ It wets glass i.e. it sticks on the walls the thermometer.
→ It doesn't expand regularly.
→ It has a high freezing point (0°C) so it cannot be used to measure very low temperatures that are less than 0°C.
→ It has a low boiling point (100°C) so it cannot be used to measure very high temperatures that are beyond 100°C.
→ It is a poor conductor of heat.
→ Its meniscus is difficult to read.

Advantages of mercury over alcohol when used as a thermometric liquid:

- Mercury is opaque so it can easily be seen.
- Mercury does not wet the glass of the thermometer.
- Mercury has a high boiling point (357°C) so, it can be used to measure very high temperatures.
- Mercury has a regular or uniform expansion.
- Mercury is a good conductor of heat.

Disadvantages of mercury over alcohol when used as a thermometric liquid:

- Mercury has a high freezing point (−39°C) so it cannot be used to measure very low temperatures.
- Mercury has a low expansivity i.e. it expands less for a small change in temperature.

Advantages of alcohol over mercury when used as a thermometric liquid:

- Alcohol has a low freezing point (−115°C) so, it can be used to measure very low temperatures.
- Mercury has a high expansivity i.e. it expands so much for a small change in temperature.

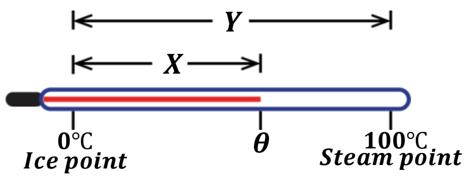
Disadvantages of alcohol over mercury when used as a thermometric liquid:

- Alcohol is not opaque (transparent) so it cannot easily be seen.
- Alcohol tends to wet the glass of the thermometer.
- Alcohol has a low boiling point (78°C) so, it cannot be used to measure very high temperatures.
- Alcohol has an irregular or non-uniform expansion compared to mercury.
- Alcohol is relatively a poor conductor of heat when compared to mercury.

DETERMINING TEMPERATURE ON AN UNCALIBRATED THERMOMETER:

The length between the lower fixed point and the upper fixed is called the **fundamental interval**.

Method 1:

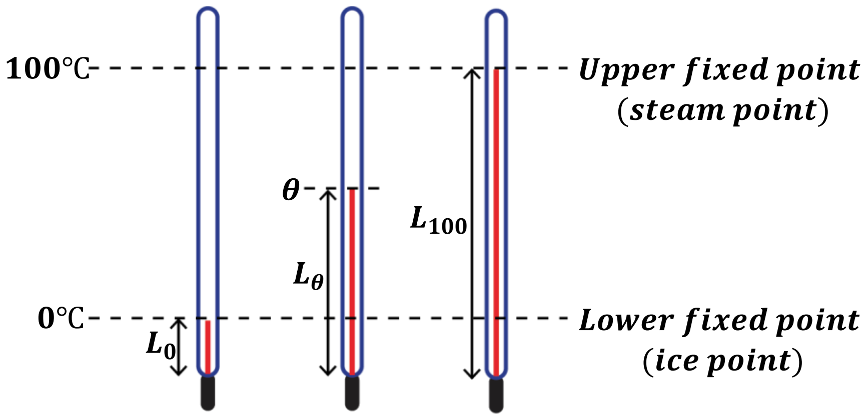


If $\boldsymbol{X}$ is the length of the mercury thread above the lower fixed point (ice point) and $\boldsymbol{Y}$ is the length between the lower and upper fixed points (fundamental interval), then the unknown temperature, $\boldsymbol{\theta}$ can be obtained from the expression below.

$$\theta = \frac{Length\ of\ mercury\ thread\ above\ the\ ice\ point}{Fundamental\ interval} \times 100°C$$

$$\boxed{\boldsymbol{\theta = \frac{X}{Y} \times 100°C}}$$

Method 2:



If L_0 is the length of mercury thread at lower fixed point (0°C), L_{100} is the length of mercury thread at the upper fixed point (100°C) and L_θ is the length of mercury thread at unknown temperature, θ, then the unknown temperature can be obtained from the expression below;

$$\theta = \frac{\text{Length of mercury thread above the ice point}}{\text{Fundamental interval}} \times 100°C$$

$$\boxed{\theta = \frac{L_\theta - L_0}{L_{100} - L_0} \times 100°C}$$

Examples:

1. When a thermometer is placed in a boiling liquid, the mercury thread rises above the lower fixed point by $18.5cm$. Find the temperature of the liquid if the fundamental interval is $20cm$.

$$X = 18.5cm, \qquad Y = 20cm$$
$$\theta = \frac{X}{Y} \times 100°C$$
$$\theta = \frac{18.5}{20} \times 100°C$$
$$\theta = 92.5°C$$

2. The length on the stem of a mercury-in-glass thermometer between the lower and upper fixed points is 18cm. when the bulb is dipped in a hot liquid, the mercury level is found to be $10cm$ above the ice point. Calculate the temperature of the liquid.

$$X = 10cm, \qquad Y = 18cm$$
$$\theta = \frac{X}{Y} \times 100°C$$
$$\theta = \frac{10}{18} \times 100°C$$
$$\theta = 55.6°C$$

3. The fundamental interval of the thermometer is $18cm$. How far above the ice point will the mercury level be when the bulb is in a region at a temperature of 60°C?

$$Y = 18cm, \qquad \theta = 60°C$$
$$\theta = \frac{X}{Y} \times 100°C$$
$$60 = \frac{X}{20} \times 100°C$$
$$X = \frac{60 \times 20}{100}$$
$$X = 12cm$$

4. The length of the mercury thread of a thermometer at ice point is $22cm$ and that at steam point is $62cm$. Calculate the reading of the thermometer when the mercury thread is $42cm$ long.

$$\boldsymbol{L_0 = 22cm, \quad L_{100} = 62cm, \quad L_\theta = 42cm}$$

$$\boldsymbol{\theta = \frac{L_\theta - L_0}{L_{100} - L_0} \times 100°C}$$

$$\boldsymbol{\theta = \frac{42 - 22}{62 - 22} \times 100°C}$$

$$\boldsymbol{\theta = \frac{20}{40} \times 100°C}$$

$$\boldsymbol{\theta = 50°C}$$

5. In an uncalibrated thermometer, the length of the mercury above the bulb is $38mm$ at lower fixed point and $138mm$ at upper fixed point. When the thermometer is placed in a hot liquid, the length of the mercury thread above the bulb is $78mm$. Calculate the temperature of the hot liquid.

$$\boldsymbol{L_0 = 38mm, \quad L_{100} = 138mm, \quad L_\theta = 78mm}$$

$$\boldsymbol{\theta = \frac{L_\theta - L_0}{L_{100} - L_0} \times 100°C}$$

$$\boldsymbol{\theta = \frac{78 - 38}{138 - 38} \times 100°C}$$

$$\boldsymbol{\theta = \frac{40}{100} \times 100°C}$$

$$\boldsymbol{\theta = 40°C}$$

6. A mercury thermometer is calibrated by immersing it in melting pure ice and then in boiling pure water. If the mercury columns are $6cm$ and $16cm$ respectively, find the temperature when the mercury column is $8cm$ long.

$$\boldsymbol{L_0 = 6cm, \quad L_{100} = 16cm, \quad L_\theta = 8cm}$$

$$\boldsymbol{\theta = \frac{L_\theta - L_0}{L_{100} - L_0} \times 100°C}$$

$$\boldsymbol{\theta = \frac{8 - 6}{16 - 6} \times 100°C}$$

$$\boldsymbol{\theta = \frac{2}{10} \times 100°C}$$

$$\boldsymbol{\theta = 20°C}$$

7. The resistance of a platinum resistance thermometer is 5.7Ω at ice point, 5.2Ω at steam point and 5.5Ω at unknown temperature. Determine the unknown temperature.

$$\boldsymbol{R_0} = 5.2\Omega, \quad \boldsymbol{R_{100}} = 5.7\Omega, \quad \boldsymbol{R_\theta} = 5.5\Omega$$

$$\boldsymbol{\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100°C}$$

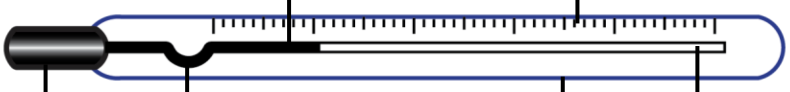
$$\boldsymbol{\theta = \frac{5.5 - 5.2}{5.7 - 5.2} \times 100°C}$$

$$\boldsymbol{\theta = \frac{0.3}{0.5} \times 100°C}$$

$$\boldsymbol{\theta = 60°C}$$

CLINICAL THERMOMETER

This is an example of liquid-in-glass thermometer since it uses mercury as its thermometric liquid. It is designed to be used in clinics and hospitals to measure the temperature of human beings.



The clinical thermometer measures a small range of temperatures i.e. 35°C *to* 42°C since the temperature of the human body cannot go outside that.

<u>How to use a clinical thermometer</u>:

- The thermometer is placed in the person's arm pit (or other parts of the body) for about 2 minutes.
- The mercury from the bulb expands until it reaches a level when it is no longer changing (stationary).
- The thermometer is withdrawn from the human body and the level of mercury thread is read off.
- This mercury level gives the temperature of the human body.

NOTE:

- The use of the <u>kink or constriction</u> is to prevent the back flow of mercury when temperature is being read.
- It is not advisable to <u>sterilize</u> a clinical thermometer in boiling water, since this makes mercury to expand far beyond the space provided in the bore. Hence, this may lead to bursting of the thermometer.
- The thermometer should be shaken before it is used on another patient so as to allow mercury go back to bulb.

SENSITIVITY OF A THERMOMETER

A thermometer is said to be sensitive if it can detect or measure very small changes in temperature.

<u>Conditions for a thermometer to be sensitive</u>.

- The thermometer should have a large bulb.
  If the bulb is large, it will contain a greater volume of mercury thus leading to greater expansion of mercury per degree.
- The thermometer should have a very narrow bore.
  If the bore of the capillary tube is made narrow, a small change in volume of mercury will fill a greater length of the capillary tube.

<u>Other types of thermometers</u>:

Apart from liquid-in-thermometers, other thermometers include;

→ Thermocouple thermometers.
→ Platinum resistance thermometers.
→ Constant-volume gas thermometers.
→ Constant-pressure gas thermometers.

EXERCISE:

1. a) "A thermometer is sensitive". Explain what is meant by the statement.
   b) State two ways of increasing the sensitivity of a thermometer.
2. a) What is meant by the term thermometric property?
   b) State any three thermometric properties that you know.
   c) List two properties of a good thermometric liquid.
3. a) Define the following terms.
      i) Lower fixed point.
      ii) Fundamental interval.
   b) With the aid of a diagram, describe how the upper fixed point of an uncalibrated can be determined.
4. The interval between the ice and steam points on a thermometer is 192mm. Find the temperature when the length of the mercury thread is 67.2mm from the ice point.
5. The distance between the lower and upper fixed points on the Celsius scale on an unmarked mercury glass thermometer is 25cm. If the mercury level is 5cm below the upper fixed point, calculate the temperature value at that level.
6. Convert the following temperature readings to the Celsius scale.
   a) 283K b) 167K c) 973K d) 3960K
7. Convert the following temperature readings to the Kelvin scale.
   i) $-25°C$ ii) $353°C$ iii) $237°C$
8. a) For a liquid in glass thermometer, what are the governing factors for choosing the liquid to be used?
   b) Give three reasons why water is not used as a thermometric liquid.
   c) When a Celsius thermometer is inserted in a boiling liquid, the mercury thread rises above the lower fixed point by 19.5cm. Find the temperature of the boiling liquid if the fundamental interval is 25cm.
9. a) Define a fixed point as used in thermometry.
   b) Under what circumstances could alcohol be preferred to mercury as a thermometric liquid?
   c) When determining the lower fixed point of a mercury-in-glass thermometer, why should the ice be pure?
10. In an uncalibrated thermometer, the length of the mercury above the bulb is $22mm$ at lower fixed point and $134mm$ at upper fixed point. When the thermometer is placed in a hot liquid, the length of the mercury thread above the bulb is $68mm$. Calculate the temperature of the hot liquid.
11. When marking the fixed points of a thermometer, it is observed that at 0°C, the mercury level is 1cm and 6cm when at 100°C. Calculate the temperature that would correspond to a length of 4cm.
12. a) In determining the upper fixed point of an unmarked thermometer, why is the hypsometer made with double walls.
    b) Why is it that boiling water is not used for sterilization of a clinical thermometer?
    c) Why is the range of a clinical thermometer usually 35°C to 42°C?
13. A mercury thermometer reads 10°C when dipped into melting ice and 90°C when in steam at normal pressure. Calculate the thermometer reading when it is dipped in a liquid at 20°C.
14. The length of mercury column at the lower and the upper fixed points are 2cm and 5cm respectively. Given that the length of mercury at unknown temperature, θ. Determine the value of θ.

HEAT TRANSFER

Heat transfer refers to the flow of heat through matter from a region of high temperature (hot body) to a region of low temperature (cold body).

Modes of heat transfer:

There are three ways by which heat is transferred and these are;

- Conduction.
- Convection.
- Radiation.

CONDUCTION:

This is the transfer of heat through matter from a region of high temperature to a region of low temperature without movement of matter as a whole.

NOTE:

In conduction, heat flows as a result of direct contact of molecules of a substance i.e. heat is transferred when one molecule contacts another molecule.

Therefore, conduction is best in solids (closely packed particles) and worst in liquids and gases (widely spaced particles).

CONDUCTION IN SOLIDS:

Heat transfer in solids occurs a result of;

- Excess energy of vibrations being passed from one atom to another.
- The excess kinetic energy given to the free electrons near the source of heat being carried by these electrons as they move to the colder region.

Explanation of conduction in a metal (solid) using kinetic theory of matter:

When one end of a metal is heated, the temperature of the molecules of the metal near the heat source increases.

The increased temperature increases the kinetic energy of the molecules of the solid thus they begin to vibrate violently. These molecules start to collide with the nearby molecules transferring heat to them. The process continues until heat is transferred to molecules at the other end of the metal.

NOTE:

- Heat transfer in conduction takes place by vibration of molecules but not actual movement of the heated molecules.
- Conduction is faster in good conductors than in bad conductors.

Factors that affect the rate of heat in metals:

- **Temperature difference between the ends of a metal:**
  Heat is transferred quickly when the temperature difference between the ends of the metal is high.
- **Length of the metal:**
  Much heat is transferred in a short time when the metal bar is short. Therefore, the rate of heat transfer increases when the metal is of smaller length than when the metal is of longer length.
- **Cross-sectional area of the metal:**
  When the metal is thicker, much heat is transferred in a shortest time than a thin metal at the same time. The rate of heat transfer in metals with large cross-sectional area and vice versa.
- **Nature of material of the metal:**
  Different materials used to make the metal have different thermal conductivities thus different rates of heat transfer.

Good conductors of heat:
These are materials that allow heat to pass through them easily. i.e. they conduct heat easily.
Examples include;
- All metals e.g. Iron, Aluminium, Copper, Steel etc.

Bad conductors of heat:
These are materials that do not allow heat to pass through them easily. i.e. they don't conduct heat easily.
Examples include;
- All non-metals e.g. Wood, Rubber, Plastics, Glass etc.

Applications (uses) of good and bad conductors of heat:
- Good conductors of heat are used in making of cooking utensils e.g. saucepans, kettles, frying pans, etc.
- Bad conductors of heat are used in making handles of cooking utensils, insulators since they don't allow heat to pass through them.

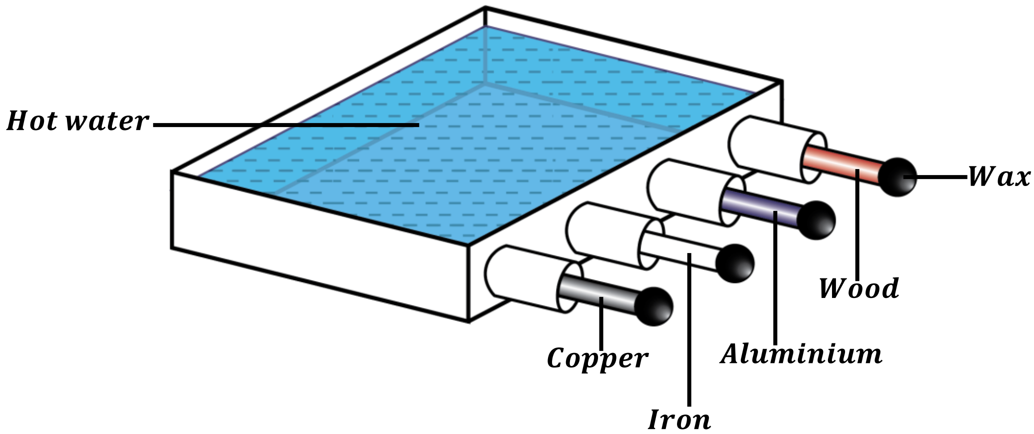
Question 1:
Explain why a metal feels cold when touched on a cold day.

Since a metal is a good conductor of heat, it conducts all the heat away from the hands. Thus, our hands lose heat and this gives a sensation of coldness.

Question 2:
Explain why a cemented floor feels colder than a carpeted floor.

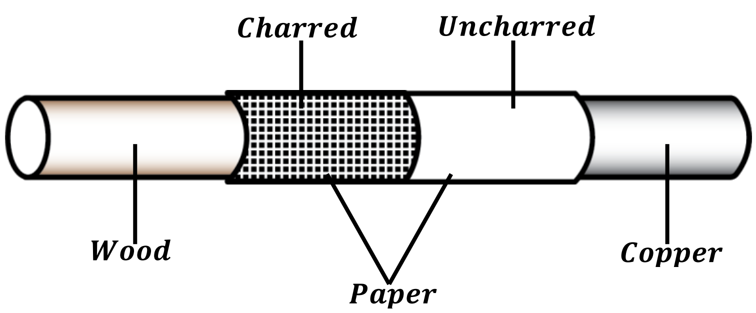
When we put our feet on a cemented floor, it conducts all the heat away from our feet since it is a good conductor of heat. Therefore, our feet lose heat and become cold.
When we put our feet on a carpeted floor, it doesn't conduct any heat from our feet since it's a bad conductor of heat. Therefore, our feet do not lose heat thus they remain warm.

An experiment to compare conductivities of different solids
QN: Describe an experiment to compare the rate of heat transfer in different conductors.



- Identical rods of different materials coated with wax are dipped in hot water.
- After sometime, the wax starts to melt along the rods.
- Wax melts fastest along the copper rod and slowest along the wood rod.
- This shows that copper is the best conductor of heat and wood is the worst conductor of heat.

Experiment to show that wood is a poor conductor of heat:



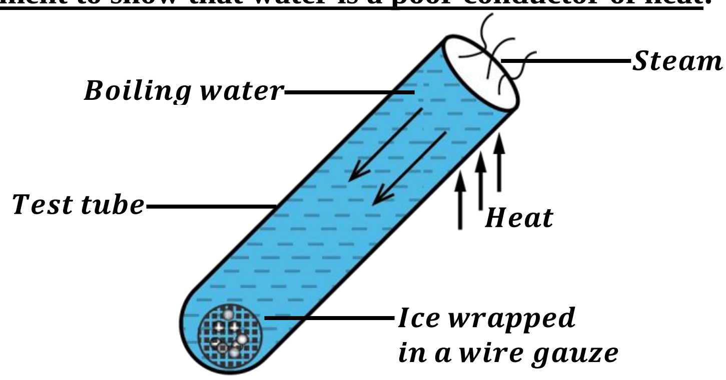
- A composite rod is made by joining a wooden rod with a copper rod.
- A piece of paper is wrapped round the composite rod around the joint so that the wooden and copper rod share the paper equally as shown below.
- The composite rod is passed through a Bunsen burner flame several times.

Observation:
- The part of the paper on the wood gets charred (burnt) while the part of paper on copper remains uncharred (not burnt).

Explanation:
- Copper is a good conductor of heat. Therefore, copper conducts away heat quickly from the paper thus the temperature of part of the paper on it remains low. Hence, the part of the paper on copper does not char.
- Wood is a poor conductor of heat. Therefore, wood does not conduct away heat from the paper thus the temperature of part of the paper on it remains high. Hence, the part of the paper on wood chars.

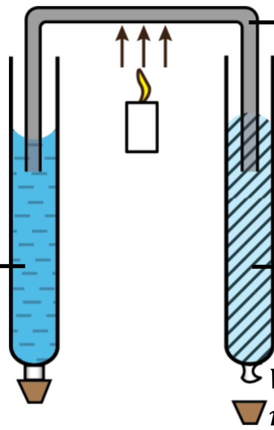
CONDUCTION IN LIQUIDS AND GASES:
Liquids and gases transfer heat at a very slow rate i.e. they are relatively poor conductors of heat. This is because their molecules are apart.

An experiment to show that water is a poor conductor of heat:



- Ice is wrapped in a wire gauze and then placed in the test tube. The wire gauze is used to keep ice at the bottom of the test tube.
- The test tube is then filled with water.
- The water near the mouth of the test tube is heated.
- It is observed that water at the top starts to boil before the ice at the bottom starts to melt.
- This shows that there is little conduction of heat from the top to the bottom by water hence water is a poor conductor of heat.

An experiment to show that mercury is a better conductor of heat than water:



- Two test tubes are filled with equal volumes of water and mercury respectively.
- A cork is attached to the bottom of each test tube.
- A piece of thick copper rod is bent twice at right angles and its ends are put in the test tubes respectively as shown above.
- The centre of the copper rod is heated such that heat is conducted equally into water and mercury test tubes.
- After a short period of time, wax on the mercury-filled test tube melts and the cork falls while that on the water-filled test tube remains attached for a long period of time.
- This shows that heat reaches the wax faster through mercury than in water hence mercury is a better conductor of heat than water.

CONVECTION:

This is the transfer of heat through a fluid from a region of high temperature to a region of low temperature by movement of the fluid itself.

NOTE:

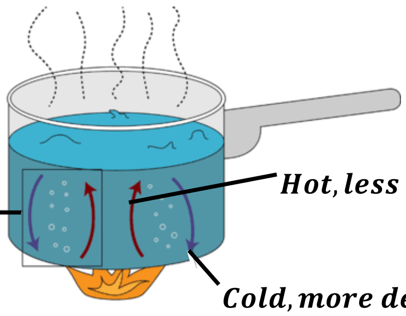
- Convection occurs in only fluids (i.e. liquids and gases) because they can flow easily and cannot occur in solids since they can't flow.
- Convection cannot occur in a vacuum because it requires a material medium.

Explanation of convection in fluids:

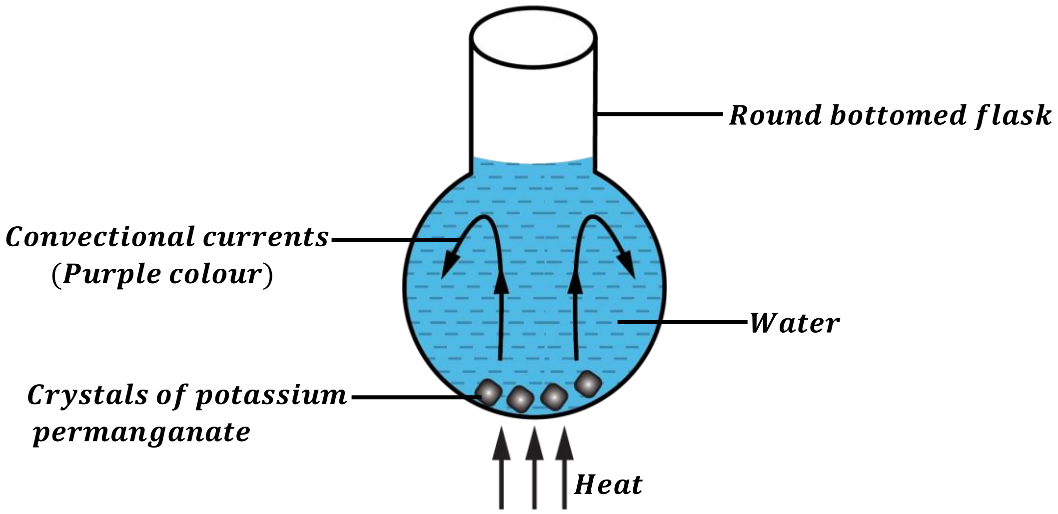
When a fluid is heated, it expands and becomes less dense than the surrounding cold fluid.
The heated fluid rises upwards and the space left is filled with the surrounding cold fluid.
As the warm fluid rises, it gives heat to the surrounding cold fluid thus forming a cyclic movement called **convectional currents**.

Definition:

Convectional currents are rising and falling fluid caused by a change in temperature and density of a fluid.



An experiment to show convectional currents in liquids:

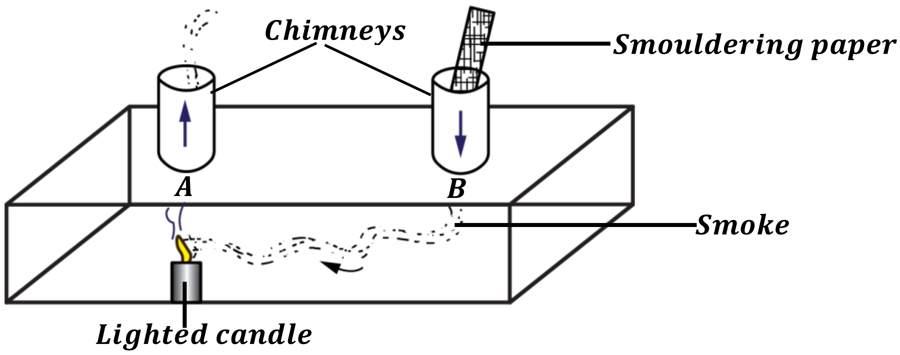


Procedures:
- A round bottomed flask is filled with clean water.
- A few crystals of potassium permanganate are placed at the bottom of the flask using a glass tube.
- The bottom of the flask is gently heated.

Observation:
- It is observed that the purple colour of potassium permanganate is seen moving upwards and on reaching the top, it spreads and then moves downwards forming convectional currents.

Explanation:
- When the solution at the bottom of the flask is heated, it expands and become less dense than the surrounding water thus moving upwards. The surrounding cold and dense water flows to the bottom to replace the risen water.
- So, the water circulates in the flask hence forming convectional currents.

An experiment to show convectional currents in gases:



Procedures:
- Fit two glass chimneys to the top of a box with a glass window.
- Light a candle and place it below chimney A.
- Introduce smoke into the box by placing a piece of smouldering paper in the other chimney B.

Observation:
- It is observed that all the smoke from chimney B moves out of the box through chimney A above the candle.

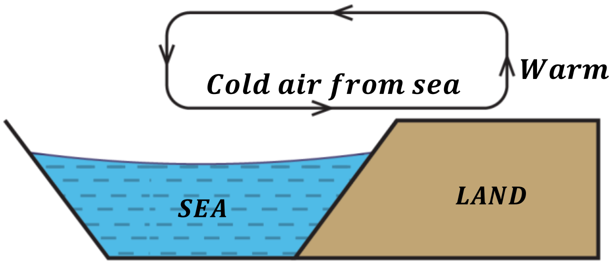
Explanation:

- When the air above the candle is heated, it expands and becomes less dense than the surrounding air thus rises and moves out through chimney A.
- Since the surrounding air (smoke) is cooler and denser, therefore, it sinks into the box through chimney B to replace the risen hot air.
- The difference in densities of the air at the different chimneys sets up a convectional current.

NOTE:
Convection occurs much more readily in gases than in liquids because they expand much more than liquids when heated.

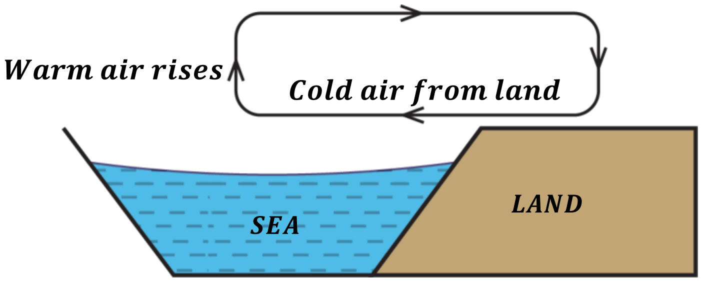
APPLICATIONS OF CONVECTIONAL CURRENTS IN DAILY LIFE

a) **Sea breeze**:
This is the cool air that blows from sea to land during day time.



- During day, the land is heated more than the sea by the sun because land is a good absorber of heat and has a lower specific heat capacity than the sea.
- The increase in temperature of land causes the air above the land to expand and become less dense thus rising up.
- The space left by the warm air above the land is filled up by the cold air that blows from sea.
- This results into a sea breeze during day time.

b) **Land breeze**:
This is the cool air that blows from land to sea at night.



- At night, the land is no longer heated by the sun so it cools very rapidly than the sea since land is a good emitter of heat than the sea. Therefore, the sea is warmer than the land at night.
- The warm air above the sea rises up since it is less dense.
- The space left by the warm air above the sea is filled up by the cold air that blows from land.
- This results into a land breeze at night.

c) **Ventilation**:

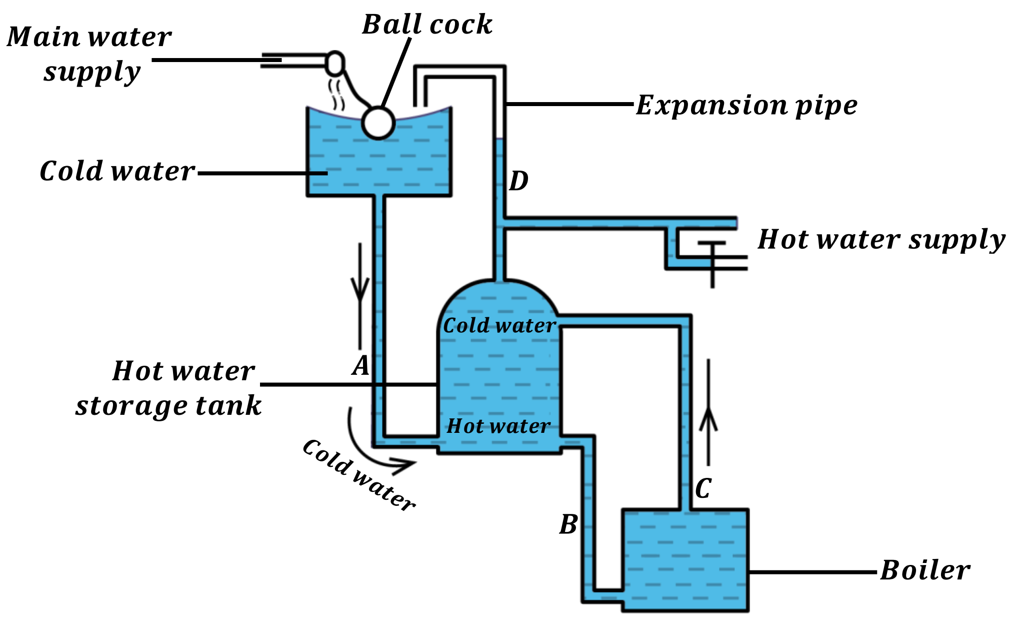
- Air inside a room is heated up on a hot day. This heated air (warm air) expands and becomes less dense thus rising up and flow out through the ventilators.
- The space left by the risen warm air is filled up with fresh cool air which passes through the windows and the doors.
- This results into circulation of air in the room thus forming convectional currents.

Question1:
Explain why ventilators are constructed above the windows and doors.

The ventilators help to move out hot air from the room. Since hot air is less dense than cold air, it rises up and moves out of the room through these ventilators. The cool air which is denser sinks into the room through the windows and doors. This circulation of air helps to cool the room.
If the ventilators were put near the floor, the hot air would not leave the room but just stays at the upper part of the room thus keeping the room hot.

Question 2:
Explain how a chimney makes life comfortable in a kitchen.
A chimney helps to drive out smoke and oily-filled air during cooking thus reducing indoor pollution in the kitchen.
During cooking, smoke and some oily-filled air which are denser are produced thus rising up and moves out of the kitchen through the chimneys thus making the kitchen more conducive.

d) **Hot water domestic supply system**:



- Cold water is supplied to the boiler through the cold-water supply pipes A and B.
- In the boiler, cold water is heated, expands and becomes less dense thus raising up to the hot water storage tank through pipe C. At the same time an equal volume of cold water flows to the boiler through the supply.
- As more cold water is supplied to the boiler, hot water is displaced upwards and supplied to the hot water supply taps.

NOTE:

- ❖ The expansion pipe D allows escape of dissolved air which comes out of the water when it is heated. Therefore, if the expansion pipe is not there, the dissolved air which comes out when water is heated may cause air locks in the pipes thus causing explosion.

- Pipes A and B are connected to bottom part of hot water storage tank and boiler respectively because they carry cold water which is denser.
- Pipe C leaves the boiler at the top and enters the hot water storage tank at the top part because it carries hot water which is less dense.

e) **Electric kettles have their heating coil at the bottom:**
The heating coil (element) of an electric kettle is placed at the bottom. Therefore, one can boil any amount of water that can cover the element effectively. Hot water which is less dense than cold water rises above the hot element to the top of the water and the denser cold water sinks down to the hot element. This sets up convection currents which make the water to boil uniformly.

Question: State one difference between convection and conduction.

Conduction:	**Convection:**
Heat is transferred from a region of high temperature to region of low temperature without the movement of matter as a whole.	Heat is transferred from a region of high temperature to region of low temperature by the movement of fluid itself.

RADIATION:

This is the transfer of heat from one place to another by means of electromagnetic waves.

Since electromagnetic waves do not require a material medium to transfer their energy, therefore radiation does not need a material medium for heat energy to be transmitted.

Examples of heat transfer by radiation include;

→ Heat from the sun reaching the earth.
→ A hot body or fire losing heat to the surrounding.

NOTE:

- Heat transferred by means of radiation can travel through a vacuum.
- Radiation is the fastest means of heat transfer since it travels at the speed of light.
- The energy from a hot body is called radiant energy.

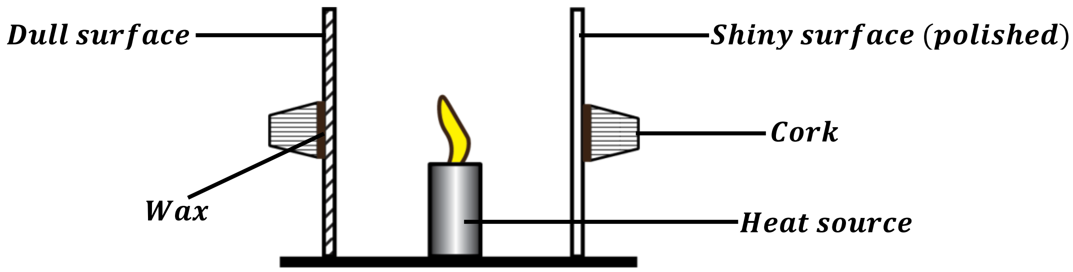
Factors affecting the rate of heat transfer by radiation:

- Temperature of the body: *A hotter body radiates heat faster compared to a cold body.*
- Surface area of the body: *Bodies with large surface areas (bigger areas) radiate much heat energy per second.*
- Nature of the surface of the body: *Dull surfaces radiate heat energy faster than highly polished surfaces.*

GOOD AND BAD ABSORBERS OF HEAT

Good absorbers:	These absorb most of the heat radiations and reflects less heat energy. Dull and black surfaces absorb most of the heat and reflect a few so they are good absorbers of heat.
Bad absorbers:	These don't absorb most of the heat radiations but reflect most of heat radiations. Shiny or polished surfaces reflect most of the heat radiations so they are bad absorbers of heat.

An experiment to show the absorption of radiation in a surface:



Procedures:

- A dull and shiny (polished) surface are placed vertically at a short distance from each other.
- A cork is fixed on the back side of each surface by using wax.
- A heat source is placed mid-way between the two surfaces so that each surface receives the same amount of radiation.

Observation:

- It is observed that the wax on the dull surface melts first and the cork falls off before the wax on the shiny surface melts.

Explanation:

- A dull surface absorbed much heat faster than the shiny surface thus a dull surface is a good absorber of heat radiation than the shiny one. The shiny surface just reflects the heat away from it.

Applications of good and bad absorbers

- Buildings in hot countries are painted white and roof surfaces are made shiny because white and shiny surfaces are bad absorbers of heat radiation thus keeping the rooms cool.
- Petrol tanks on vehicles are polished to reflect away radiant heat.
- White coloured clothes are worn in dry season so that they reflect away heat thus keep us cool
- Sweaters and blankets are made with dull colours to absorb heat.
- The bottoms of cooking utensils are made black to absorb heat from the fire.

GOOD AND BAD EMITTERS OF HEAT

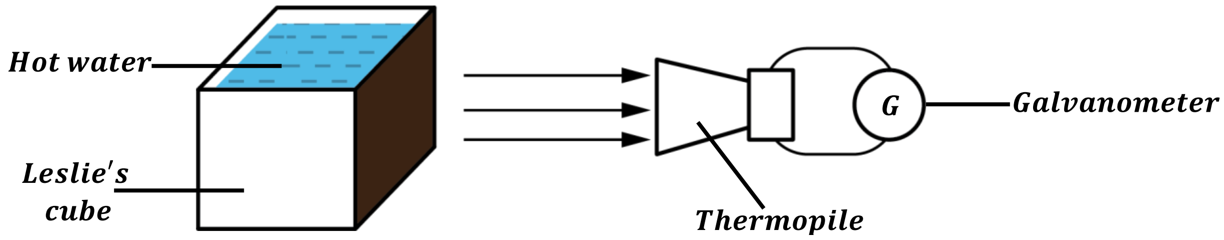
Basically, we say that the body emits heat if it can cause the temperature of a nearby body to increase. A body relatively can't emit heat if it can't absorb it.

Good emitters:	These absorb most of the heat radiations and reflects less heat energy. Dull and black surfaces emit most of the heat so they are good emitters of heat.
Bad emitters:	These don't absorb most of the heat radiations but reflect most of heat radiations. Shiny or polished surfaces reflect most of the heat radiations so they are bad emitters of heat.

NOTE:

- Good absorbers of heat are also good emitters of heat.
- Bad absorbers of heat are also bad emitters of heat.

An experiment to show good and bad emitters of heat (radiators of heat)



Procedures:
- A hollow copper cube (Leslie's cube) with each side having a different surface (i.e. black, white and shiny surface) is used.
- The cube is filled with hot water.
- The radiation from each surface is detected by a thermopile and the deflection of the galvanometer observed.

Observation:
- The deflection of the galvanometer is greatest when the thermopile is facing the black surface and least when facing the shiny surface.

Explanation:
- The dull black surface emits a lot of heat radiation than the shiny surface thus a great deflection of the thermopile. Therefore, the dull and black surface is a good radiator or emitter of heat while a shiny or polished surface is a poor emitter of heat radiations.

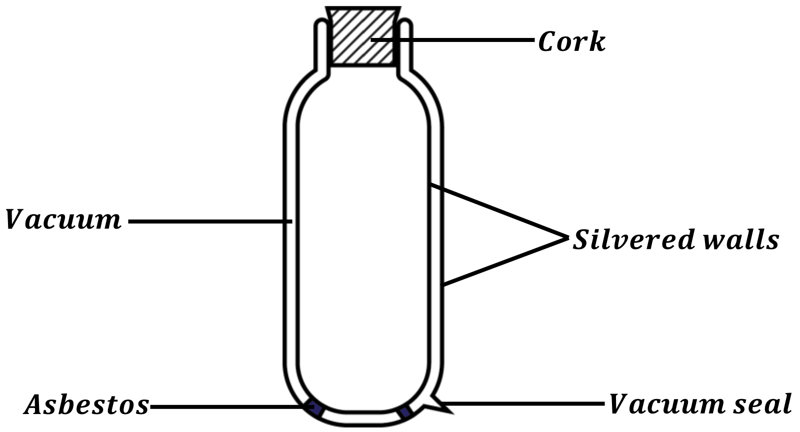
NOTE:
- A thermopile is a device which converts heat energy to electrical energy.
- A galvanometer is a device which measures small currents and small voltages.

Applications of good and bad emitters
- Tea pots and kettles are polished so that they don't emit heat to the surrounding thus keeping liquids inside hot.
- Cooling fins on refrigerators are painted black so that they can emit heat quickly to the surrounding.

APPLICATIONS OF RADIATION

a) VACUUM FLASK (THERMOS FLASK):

This is a flask with two silvered walls enclosing a vacuum which keeps its contents at a fairly constant temperature.
The vacuum is designed to either keep hot things hot or cold things cold.



How heat losses are minimised in a vacuum flask:

- **Cork:** A cork is a poor conductor of heats so it doesn't allow heat to pass through it. Therefore, it minimizes heat loss by conduction.
- **Vacuum:** A vacuum is a space without air. It minimizes heat loss by convection and conduction.
- **Silvered surfaces:** These are highly polished surfaces which minimize heat loss by radiation.
  Silvered surfaces are poor radiators (emitters) of heat, therefore no heat is allowed to go in and out of the flask.

NOTE:

- The vacuum seal seals the vacuum. Therefore, if its broken, the vacuum will no longer exist thus causing heat losses through convection and conduction.
- When the hot liquid is kept in a vacuum flask for a long period of time, it eventually gets cold. This is because little heat is lost at a smaller rate since all flasks are not too perfect whereby some corks may conduct some heat, frequent opening of the flask etc.

b) CHOICE OF DRESSES AND CLOTHES:

On a hot day, a white dress is preferred to a dull dress because it reflects most of the heat radiations that fall on it hence keeping the body cool.
On cold days, a dull or black woollen dress is preferred because it absorbs most of the heat radiations thus retaining it for a longer period of time.

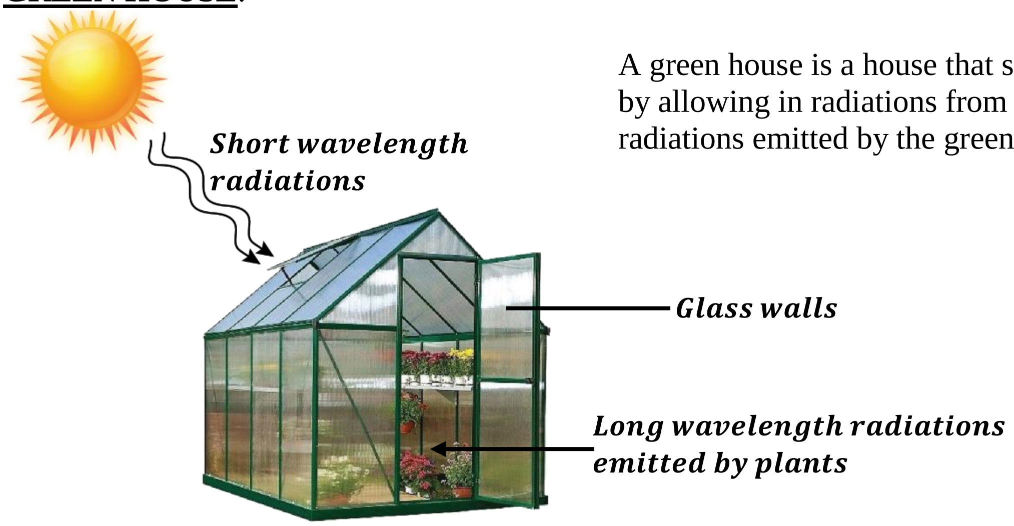
c) GREEN HOUSE EFFECT:

The greenhouse effect is a natural process that warms the Earth's surface. When the radiations from the sun reaches the earth's atmosphere, some it is reflected back and the rest is absorbed by the greenhouse gases in the atmosphere. The greenhouse gases include water vapour, carbon dioxide, ozone and other gases.
After absorbing the radiations from the sun, these greenhouse gases re-radiate these heat radiations to the earth thus warming the atmosphere of the earth's surface.

NOTE:

- When human activities like land clearing, deforestation, and burning fossil fuels increase, they increase the concentration of the greenhouse gases in the atmosphere thus causing them to absorb more heat from the sun. This increased absorption of heat radiations from the sun leads to excessive warming of the earth. This is called **global warming**.

GREEN HOUSE:



A green house is a house that supports plant growth by allowing in radiations from sun and preventing radiations emitted by the green plants from escaping.

How a green house works:

- The sun emits radiations of short wavelength to the earth. These radiations enter the green house through the glass walls.
- The plants and soil in the green house absorb these radiations hence their temperature is raised thus becoming warmer.
- The warm plants and soil in the green house re-radiate (re-emit) radiations of long wavelength.
- Since long wavelength radiations are less penetrative, they are unable to pass through the glass walls of the green house thus causing the temperature inside to continue rising.

EXERCISE:

1. a) Explain why the sea remains cooler than land during daytime and warmer than land at night.
   b) State two factors that affects the rate of heat transfer along a metallic rod.
   c) Describe an experiment to show that water is a poor conductor of heat.

2. a) Draw a well labelled diagram of a thermos flask.
   b) Explain how the features on the thermos flask above enables to keep a liquid warm.
   c) State two circumstances where the warm liquid in the flask above can get ultimately cold.

3. Explain the following observations;
   i) A person should crawl on the floor in a smoke-filled room.
   ii) Ventilators are put near the ceilings of houses.
   iii) Houses in North-African countries like Egypt are painted white.
   iv) Flames of fire move upwards.

4. a) Distinguish between Conduction and radiation.
   b) Explain why the metallic blade of the knife feels cold on a cold day.
   c) Describe an experiment to show that wood is poor conductor of heat than copper.

5. a) Explain why a black coat is usually worn on a cold otherwise not on a hot day.
   b) In an experiment to demonstrate the poor conductivity of water, ice is wrapped in a wire gauze. Explain why this is so.

6. a) Define the term radiation.
   b) Explain how a vacuum flask is able to keep a cold liquid cool for a long period of time.
   c) Explain how global warming occurs in the earth's atmosphere.

7. Explain the following observations;
   i) Blankets are made of dull colours.
   ii) Car radiators are coiled and painted black.
   iii) A swimmer prefers to put on a wet cloth when diving in cold water.

8. a) Define the term good emitter of radiation.
   b) Describe how a green house is able to support plant growth.

9. a) Explain the greenhouse effect and how it affects the earth's atmosphere.
   b) Explain why solar panels are painted black.

10. a) Describe an experiment to show convection in liquids.
    b) Explain why electric kettles have their heating element at the bottom.

THERMAL EXPANSION OF MATTER

All the three states of matter (solids, liquids and gases) change in volume when heated

Definition:

Expansion is the increase in size of matter whenever matter is heated.
This increase in size of an object occurs in all directions.

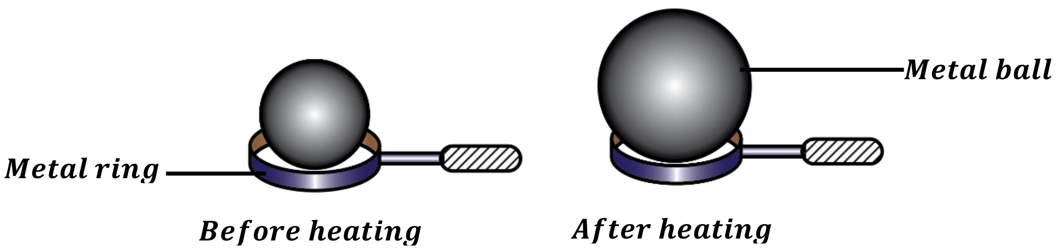
Definition:

Contraction is the decrease in size of matter whenever matter is cooled.

EXPANSION IN SOLIDS

All solids expand when heated. Some solids expand greatly and others very little.

An experiment to demonstrate thermal expansion in solids:



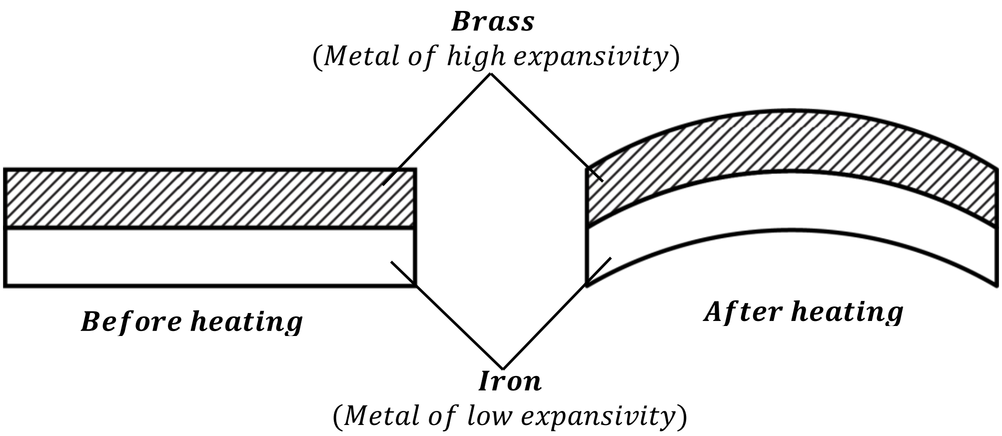
- A metal ball which just passes through the metal ring is used.
- The metal ball is heated for some time.
- It is observed that after heating the ball, it could not pass through the metal ring. This is because the ball has expanded when heated.
- When the metal ball is cooled, it passes through the metal ring again. This indicated that on cooling, the metal ball had contracted.

APPLICATIONS OF THERMAL EXPANSION

Thermal expansion in solids is applied in the following;

a) **Bimetallic strip:**

This is a strip made when two metals of different expansion rates are joined together e.g. Brass and Iron.

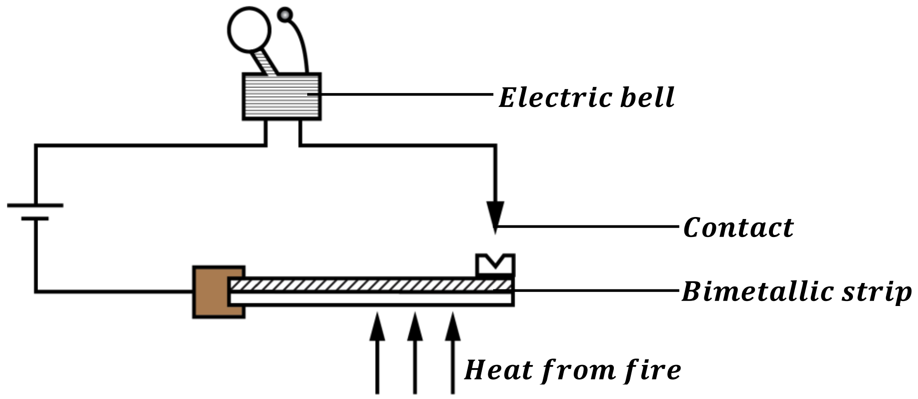


When a bimetallic strip is heated, it forms a curve with a metal that expands more on the outside and the metal that expands less on the inside.

Uses of bimetallic strips:

→ They are used in ringing bells of fire alarms.
→ They are used in thermostats in electrical appliances.

Fire alarms:

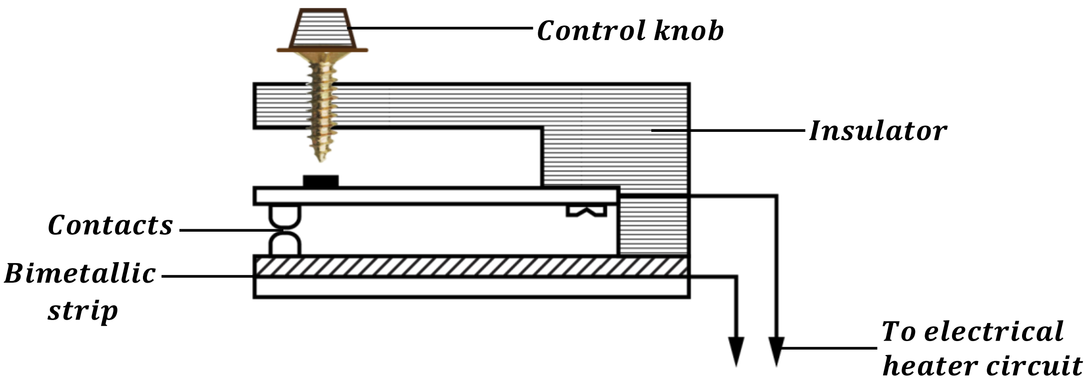


- When there is a fire outbreak in a room, the bimetallic strip is heated by fire. This causes it to bend outwards thus completing the electrical circuit.
- When the circuit is complete, current flows to the electric bell thus causing it to ring.

Thermostats:

A thermostat is a device that keeps the temperature of a room or an electrical appliance to remain constant.

Thermostats are used in the heating circuits of electric flat irons.

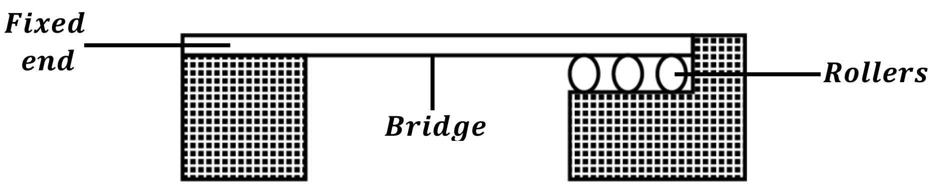


- The control knob is set to the required temperature.
- On reaching the required temperature, the bimetallic strip bends away thus breaking the circuit at the contacts. This switches off the heater.
- On cooling, the bimetallic strip makes returns back to its original shape and makes contact again thus completing the circuit. This switches on the heater.

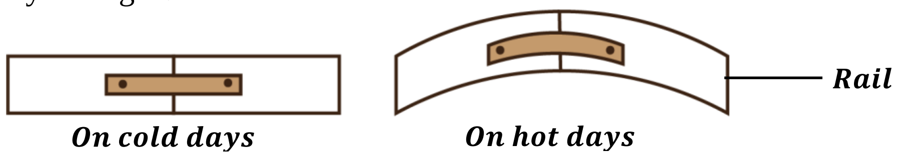
Other applications of thermal expansion (Disadvantages of expansion):

b) **Bridges**:

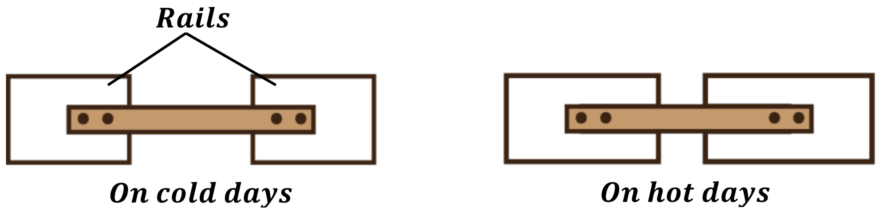
Girders in bridges are made of mainly steel. During cold days bridges contract and during hot days, the bridges expand. In order to allow room for expansion and contraction in bridges, the bridge is constructed with one end fixed and the other end placed on rollers. This helps it contract and expand freely without damaging the bridge.



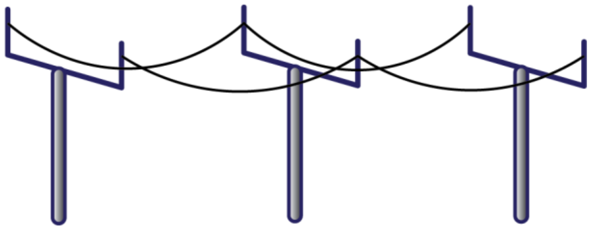
c) **Railways**:
On a hot day, the rails are heated and they and they are bent due to expansion. This causes them to get seriously damaged.



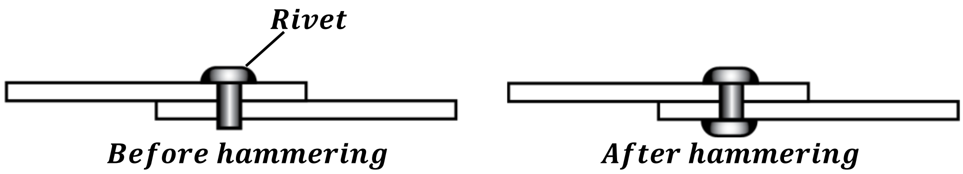
In order to give room for expansion during hot days, railway lines are constructed with gaps between the rails.



d) **Transmission wires**:
The wires used in transmission of electricity and telephone cables are loosely fixed (sag) in order to allow them expand freely during hot days and contract freely during cold days.



e) **Rivets**:
Rivets are tight joints obtained by riveting two metals together.
A hot rivet is pushed through a hole between two metals to be joined together and its end is hammered flat. On cooling, it contracts and pulls the two metals together.



LINEAR EXPANSIVITY OF A METAL:
When a metal is heated, its length increases after expansion and this increase in length is called linear expansion. We distinguish between the rates of expansion of different metals by finding their linear expansivities (coefficient of linear expansion).

Definition:
Linear expansivity of a material is the fraction of its original length which increases when its temperature rises by 1K.

Therefore, linear expansivity depends on;

- Length of a material.
- Rise or change in temperature.
- Natural of material

$$Linear\ expansivity = \frac{Change\ in\ length\ (Linear\ expansion)}{Original\ length \times Change\ in\ temperature}$$

$$\boxed{\boldsymbol{\alpha = \frac{\Delta L}{L_O \times \Delta\theta}}}$$

Where;

$\boldsymbol{\Delta L = L_1 - L_O}$ $(New\ length - Original\ length)$

$\boldsymbol{\Delta\theta = \theta_1 - \theta_O}$ $(Final\ temperature - Initial\ temperature)$

The SI unit of linear expansivity is $\boldsymbol{K^{-1}}$ or $°C^{-1}$.

<u>Examples</u>:

1. The length of a metal rod is 800mm. It is found to increase to 801.36mm when heated from 15°C to 100°C. Calculate the linear expansivity of the metal rod.

$\boldsymbol{L_O = 800mm}$, $\boldsymbol{L_1 = 801.36mm}$, $\boldsymbol{\Delta L = (801.36 - 800) = 1.36mm}$
$\boldsymbol{\theta_O = 15}$°C, $\boldsymbol{\theta_1 = 100}$°C, $\boldsymbol{\Delta\theta = (100 - 15) = 85}$°C

$$\boldsymbol{\alpha = \frac{\Delta L}{L_O \times \Delta\theta}}$$
$$\boldsymbol{\alpha = \frac{1.36}{800 \times 85}}$$
$$\boldsymbol{\alpha = 0.00002}\ /°C$$

2. Calculate the linear expansion (change in length) of aluminium cable 50m between two electric poles when its temperature rises by 40°C. The linear expansivity of aluminium is $2.6 \times 10^{-5}°C^{-1}$.

$\boldsymbol{L_O = 50m}$, $\boldsymbol{\Delta L}$ =?
$\boldsymbol{\Delta\theta = 40}$°C, $\boldsymbol{\alpha = 2.6 \times 10^{-5}°C^{-1}}$

$$\boldsymbol{\alpha = \frac{\Delta L}{L_O \times \Delta\theta}}$$
$$\boldsymbol{2.6 \times 10^{-5} = \frac{\Delta L}{50 \times 40}}$$
$$\boldsymbol{\Delta L = 50 \times 40 \times 2.6 \times 10^{-5}}$$
$$\boldsymbol{\Delta L = 0.052m}$$

3. A metal rod has length of 100cm at 200°C. At what temperature will its length be 99.4cm if the linear expansivity is 0.00002 K^{-1}?

$\boldsymbol{L_O = 100cm}$, $\boldsymbol{L_1 = 99.4cm}$, $\boldsymbol{\Delta L = (99.4 - 100) = -0.6cm}$
$\boldsymbol{\theta_O = 200}$°C, $\boldsymbol{\theta_1}$ =?, $\boldsymbol{\alpha = 0.00002\ K^{-1}}$

$$\boldsymbol{\alpha = \frac{\Delta L}{L_O \times \Delta\theta}}$$
$$\boldsymbol{0.00002 = \frac{-0.6}{100 \times \Delta\theta}}$$
$$\boldsymbol{\Delta\theta = \frac{-0.6}{100 \times 0.00002}}$$
$$\boldsymbol{\Delta\theta = -300}°C$$

$$\boldsymbol{\Delta\theta = \theta_0 - \theta_1}$$
$$\boldsymbol{300 = 200 - \theta_1}$$
$$\boldsymbol{\theta_1 = (200 - 300)}$$
$$\boldsymbol{\theta_1 = -100}°C$$

4. A steel bridge is 2.5m long. If the linear expansivity of steel is $1.1 \times 10^{-5} K^{-1}$, how much will it expand when temperature rises by 5°C?

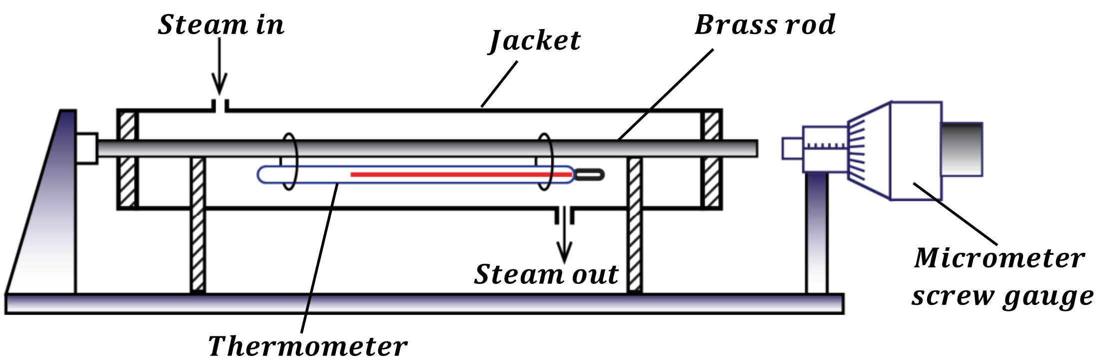
$L_O = 2.5m$, $\Delta L = ?$
$\Delta\theta = 5°C$, $\alpha = 1.1 \times 10^{-5} K^{-1}$

$$\alpha = \frac{\Delta L}{L_O \times \Delta\theta}$$
$$1.1 \times 10^{-5} = \frac{\Delta L}{2.5 \times 5}$$
$$\Delta L = 2.5 \times 5 \times 1.1 \times 10^{-5}$$
$$\Delta L = 0.0001375m$$

EXERCISE:

1. Calculate the new length of the metal given that its new length is 50cm when heated from 0°C to 25°C. (α *for metal is* 1.8×10^{-5}/°C).
2. A metal rod is 64.5cm long at 12°C and 64.6cm at 90°C. Find the coefficient of linear expansion, (α) of its material.
3. A rod is found to be 0.04cm longer at 30°C than it was at 10°C. Calculate its length at 10°C if the linear expansivity is 2.0×10^{-5}°C^{-1}.
4. The length of iron rod is 100°C is 300.36cm and at 150°C is 300.54cm. Calculate its length at 0°C.

<u>**An experiment to measure the linear expansivity of a metal**</u>**:**



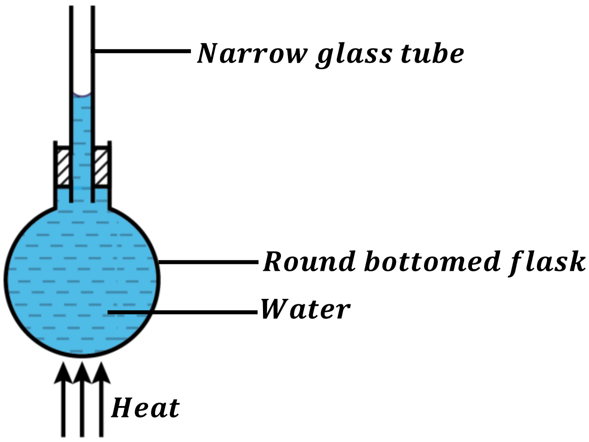
- The original length, L_0 of the brass rod is measured using a metre rule.
- The brass rod with a thermometer is placed in a steam jacket.
- The micrometer screw gauge is screwed up so that there is no gap at either ends of the brass rod. The reading, l_1 of the micrometer screw gauge is recorded.
- The initial temperature of the brass rod, θ_1 is recorded.
- The micrometer screw gauge is unscrewed to leave room for expansion of the brass rod.
- The steam is passed through the jacket for a few minutes.
- The micrometer screw gauge is screwed up again so that there is no gap at either ends of the brass rod. The reading, l_2 of the micrometer screw gauge is recorded.
- The final temperature of the brass rod, θ_2 is recorded.
- Then linear expansivity of the metal is got from;

$$\textit{Linear expansivity} = \frac{(l_2 - l_1)}{L_0\Delta\theta}$$

EXPANSION IN LIQUIDS:

Liquids expand when heated. Different liquids have different expansion rates when equally heated. Liquids expand more than solids since their molecule are far apart compared to those of solids thus their intermolecular forces are weak.

An experiment to demonstrate expansion of a liquid e.g. water:



Procedure:

- The flask is completely filled with coloured water.
- A narrow glass tube is passed through the hole of the cork and the cork is fixed tightly into the flask.
- The initial level of water in the narrow glass tube is observed.
- The bottom of the flask is then heated.
- The new level of water in the narrow glass tube is observed.

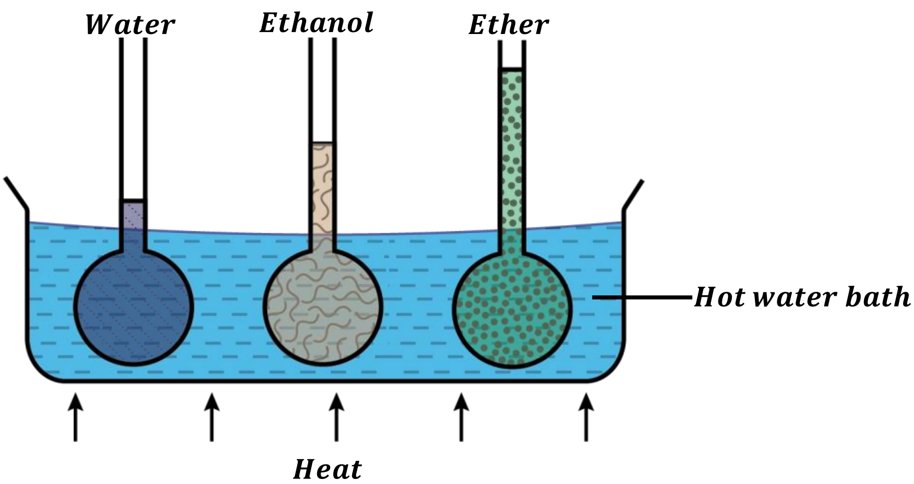
Observation:

It is observed that the level of water in the narrow glass tube first falls and then starts to rise again.

Explanation:

- When the flask is heated, the flask gets heated first before the heat is passed to the water inside it. Therefore, the flask expands first and increase in volume before the water causing a fall in the water level.
- However, when the heat reaches the water, it expands and increase in volume thus its level starts to rise in the narrow tube.

An experiment to compare the expansions of different liquids:



- Three identical glass flasks are filled with water, ethanol and ether respectively to the same level.
- The glass flasks are heated by placing them in hot water which is maintained at the same temperature.
- It is observed that after some time, the liquid levels rise to different levels. This shows that different liquids expand differently for the same temperature change.
- It is also observed that ether expands more than ethanol and water.

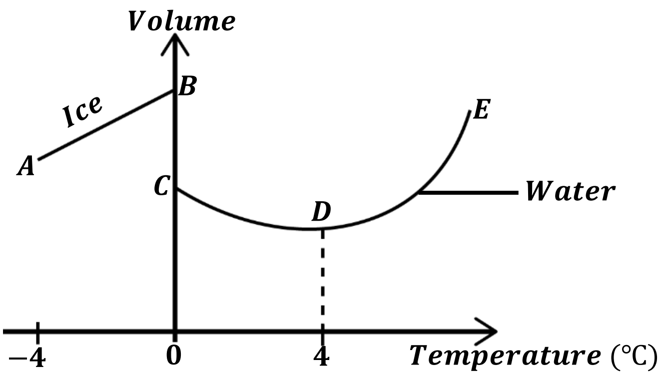
ANOMALOUS (ABNORMAL) EXPANSION OF WATER

Liquids expand steadily when heated i.e. when their temperature increases.
Water has an abnormal behaviour whereby when its temperature rises from 0°C to 4°C, it contracts instead of expanding. This situation is referred to as the **anomalous expansion of water**.

Definition:

Anomalous expansion of water is the abnormal behaviour of water whereby it contracts instead of expanding when its temperature rises from 0°C to 4°C.

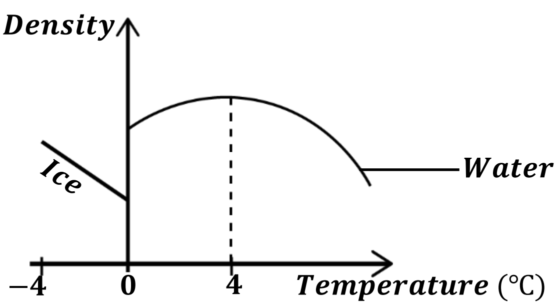
Volume against temperature graph showing expansion of water



AB: As ice is heated, it expands until when its temperature reaches 0°C where it melts to form water.
BC: Ice melts to form water at 0°C.
CD: As the temperature rises, the water 0°C contracts until 4°C.
DE: As the temperature exceeds 4°C, water starts to expand steadily.

From the graph, water has its minimum volume at 4°C. Thus, the density of water is maximum when the temperature is 4°C.

Density against temperature graph showing expansion of water



From the graph, the density of water is maximum at 4°C.

NOTE:

- At 0°C, the volume of ice is greater than the volume of water. Therefore, the density of ice is less than the density of water. This explains why ice floats when mixed with water.

Question: Explain why ice floats on water.

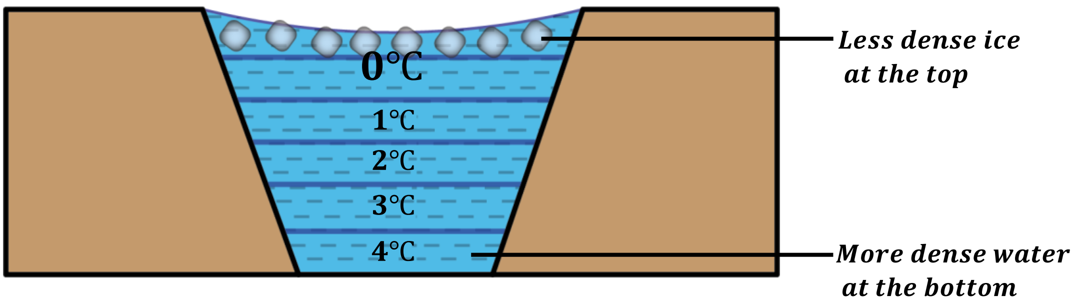
This is because for a given mass of ice at 0°C, its volume is always greater than the volume of water. Therefore, the density of ice is always less than the density of water thus causing it to float on water.

Biological importance of anomalous expansion of water

QN: ***Explain how anomalous expansion of water helps to preserve the lives of aquatic animals.***

Preserving aquatic life in ponds and lakes:

The effect of anomalous expansion of water is that the coldest water always floats on top of the surface of the other water since it is less dense.
Since water at 4°C is the heaviest (denser), this water settles at the bottom of the lake and the lightest (less dense) water settles at the top layer of the lake.
During winter, the water at the top is the first to freeze to ice. Since ice is a poor conductor of heat, it insulates the rest of the water below it from the coldness of the winter.
This helps to preserve the lives of aquatic animals in water.



NOTE: Anomalous expansion also helps in weathering of rocks.

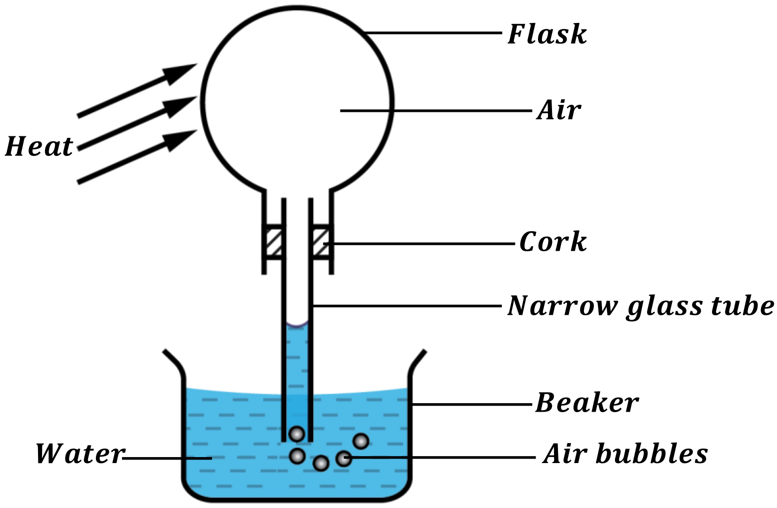
Disadvantages of the abnormal expansion of water:

- It prevents water from being used as a thermometric liquid.
- It causes the bursting of water pipes when water flowing through them freezes.

EXPANSION IN GASES

When a gas is heated, the gas molecules gain more energy and move further apart thus occupying more space. Therefore, gases expand more than the liquids and solids since their molecules are widely spaced and their intermolecular forces are very weak.

<u>An experiment to show expansion in gases</u>:



- Water is poured in a beaker.
- A narrow glass tube is passed through the hole of the cork and the cork is fixed tightly into the flask.
- The flask is then inverted and dipped in the beaker filled in water.
- The flask is then gently heated.
- It is observed that level of water in the narrow glass tube falls and air bubbles are seen coming out from the other end of the tube. This shows that air expands when heated and pushes the water in the tube downwards.
- On cooling the flask, air in the flask contracts and water rises up in the narrow glass tube since more space has been created in the flask.

APPLICATIONS OF EXPANSION IN GASES:

It is applied in;

<u>Hot air balloons</u>:

When air in the balloon is heated, it expands and becomes less dense thus rising.

EXERCISE:

1. a) Explain why gases expand much more than solids for the same temperature change.
   b) State and explain the advantages and disadvantages of anomalous expansion of water.

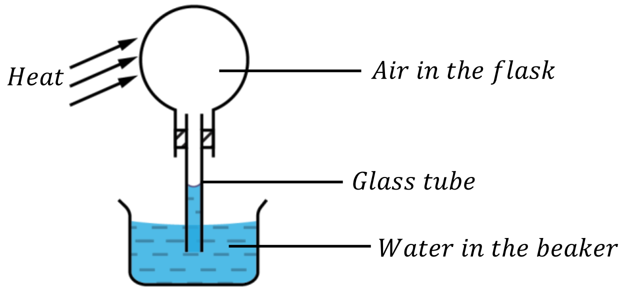
2. The figure below shows a strip of copper and iron bonded together.

   a) Redraw the diagram to show what happens when the strip is heated.
   b) Why does the change you have shown in (a) above takes place?

3. a) Define the following terms;
      i) Contraction of a material.
      ii) Expansion of a material.
   b) Describe an experiment to demonstrate expansion and contraction in solids.
   c) State any one application of expansion in solids.

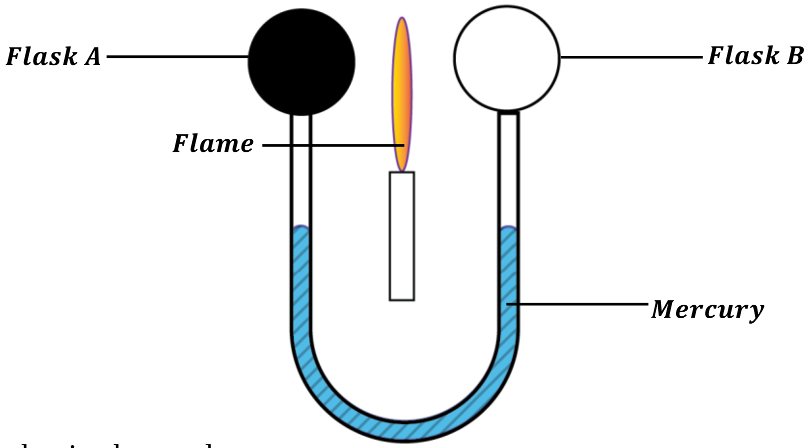
4. a) Describe an experiment to show expansion in liquids.
   c) Explain anomalous expansion of water and give its importance to aquatic life.

5. Air was trapped in a round bottomed flask as shown below. The flask is inverted in a beaker of water and then gently heated.



   a) State what was observed when the flask is heated.
   b) Explain your observation in (a) above.

6. Two flasks with a mercury manometer are arranged as shown in the figure below. Flask A is painted black while flask B is polished white. A flame is then placed midway between them.



   a) State what is observed.
   b) Explain your observation.