PHYSICS MINI HOLIDAY NOTES TO COPY

INTRODUCTION TO ORDINARY LEVEL HEAT

Heat is a measure of energy given to or removed from a body due to temperature differences between the body and the surroundings.

This energy may result into system's temperature change or change in state of the body at constant temperature.

Generally accepted definition of heat is "a form of energy which is transferred from one point to another due to a temperature difference between them".

Alternatively heat can be defined as the form of energy that flows from areas of high temperature to areas of low temperature.

The S.I unit of heat is **joules (J)**

Effects of heat energy on a body

- It increases the temperature of a body
- It makes the body to expand
- It changes the state of a substance

CHAPTER ONE: TEMPERATURE

The extent to which the body feels hot depends on the; average kinetic energy of the individual atoms or molecules with in that body. This means that the body's kinetic energy is directly proportional to its thermal dynamic temperature i.e. ($T \alpha$ k.e)

Temperature of a substance can be defined as a number which expresses the degree of hotness or coldness of a substance on some chosen scale.

However it can also be defined as *a measure* of the average kinetic energy (K.e.) of the molecules of the body.

Measurement of temperature.

It is measured using a thermometer and usually in degrees Celsius (ºC). The S.I unit of temperature is Kelvin (K).

There are different types of thermometers which measures temperature basing on different physical properties which change continuously with temperature. Such physical properties are called **thermometric properties**.

Thermometric properties

Definition: A thermometric property is a physical property that changes linearly and continuously with temperature. It remains constant at constant temperature.

Examples of thermometric properties

1. Length of a liquid column for a liquid in glass thermometer
2. Electromotive force of a thermocouple
3. Electrical resistance of a wire for a resistance wire thermometer
4. Volume of a fixed mass of a gas at constant pressure for a pressure gas thermometer
5. Pressure of a fixed mass of a gas at constant volume for a volume gas thermometer.

A good thermometric property should;

- Considerably vary for small changes in temperature.
- Vary over a wide range of temperature (both high and low)
- Vary linearly, uniformly and continuously with temperature
- Be accurately measurable over a wide range of temperature with a simple apparatus

Liquid in glass thermometers.

It is the most commonly used thermometer.

It consists of a bulb at the end of a capillary tube whose upper end is sealed.

The bulb and part of the capillary tube is filled with a **thermometric liquid** which change in volume to measure temperature. The two commonly used thermometric liquids are **mercury and coloured alcohol**.

Qualities of a good thermometric liquid

- Should be opaque so as to be seen in glass easily
- Should have regular expansion with temperature
- Should be a good conductor of heat

- Should not stick on the walls of glass
- Should have a low freezing point and a high boiling point

Advantages of mercury over alcohol when used as a thermometric liquid

Mercury	Alcohol
It is opaque	It is colourless but can be coloured
Good conductor of heat	Poor conductor of heat as compared to mercury
Has a high boiling point, thus can measure high temperature	Has a low boiling point, thus cannot measure high temperature
Expands uniformly	It does not expand uniformly as mercury
Does not wet glass	Tends to stick on the walls of the glass hence wets glass.

Advantages of alcohol over mercury when used a thermometric property

Alcohol	Mercury
Has a high linear expansivity (Expands so much for a small temperature range)	Has a low linear expansivity (expands little for the same temperature range)
Has a low freezing point, hence can measure low temperature	Has a higher freezing point as compared to alcohol, hence cannot be used to measure very low temperature

Note:

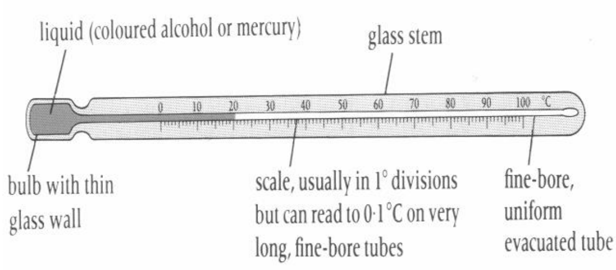
-Mercury freezes at −39 ºC and boils at 357 ºC.

-Alcohol freezes at −115 ºC and boils at 78 ºC and is therefore more suitable for low temperatures.

Reasons why water is not used as a thermometric liquid

- It is transparent, the meniscus is hard to see and read
- Does not expand regularly
- It sticks on glass hence wets glass
- Has relatively low boiling point
- It is a poor conductor of heat

Structure of a liquid in glass thermometer



Note the following design details.

(a)The liquid is contained in <u>a thin walled glass bulb</u> to help conduction of heat through the glass to the liquid.

(b)The <u>amount of liquid should be small</u> in order to obtain a quick response because a small quantity takes less time to warm up.

(c) The <u>fine tube should be uniform</u> to give even expansion along it.

(d)The <u>space above the liquid is evacuated</u> during manufacture to prevent a high pressure of the trapped air when the liquid expands.

(e) The <u>bore of the capillary tube (fine bore) is made narrow</u> to increase the sensitivity of the thermometer.

(f) They cover a range from -40ºC to 300ºC.

Note; A clinical thermometer has a bore with a kink/constriction/bend which prevents the back flow of mercury to the bulb before the reading is taken.

Other common types of thermometers are

- Gas thermometer
- Thermoelectric thermometers.
- Resistance thermometer

Advantages of a thermo-electric meter are:

(i)It can measure very high temperatures such as those in furnaces of molten metals.

(ii)The junction is very small and therefore the thermometer can measure temperature at a point.

(iii)It can follow rapid changes of temperature.

Properties/qualities of a thermometer

(i) Quick action: This is the ability of a thermometer to measure temperature in the shortest time possible. This is attained by using a thin walled bulb and a liquid which is a good conductor of heat e.g. mercury

(ii) Sensitivity: this is the ability of a thermometer to detect a very small temperature change. It is attained by;

- ✓ Using a thermometer with a big bulb
- ✓ Use of a liquid which has a high linear expansivity
- ✓ Using a narrow bore

In such a sensitive thermometer, a very small change in temperature should produce a visible (relatively big) expansion.

Note:

Thermometers have a scale on them called a **temperature scale** which we read to determine the temperature.

Temperature scales

These are scales in which the measure of hotness or coldness of a body can be expressed .i.e. the measure of hotness or coldness of a particular body can be expressed in;

- Degrees centigrade **(℃)** forming a Celsius scale of temperature.
- Kelvin **(K)** forming a thermodynamic scale of temperature.
- Degrees Fahrenheit **(℉)** forming a Fahrenheit scale of temperature.

Note:

(i) The *S.I unit* for temperature is <u>"Kelvin"</u> with symbol "K".

(ii) The fundamental scale in physics is called the **thermodynamic scale**. It is sometimes called the **Kelvin scale** and its unit is the **Kelvin (K)**

(iii) On the thermodynamic scale the melting point of ice is 273K and the boiling point of water is 373K.

<u>**Absolute zero**</u> **(0 K)** is the temperature below which no gas can ever exist.

It is the lowest temperature which can be reached in practise.

Definition: Absolute zero is the temperature at which molecules of a gas have the least (zero) kinetic energy.

Comparison of temperature scales (degrees Celsius and kelvin)

The Celsius scale of the temperature is defined so that

(i) If we write ϑ(C) for the temperature value on the Celsius scale and T (K) for one on the thermodynamic scale then $T = \theta + 273$

Note that the degree sign is not put on the Kelvin.

(ii) The interval 1 degree Celsius equals the interval 1 kelvin.

Conversions

Convert the following to kelvin

(i) 110°C (ii) 0°c (iii) 127°C (iv) -27°C

Convert the following to °C

(i) 400K (ii) 500K (iii) 127 (iv) 600K

Fixed points

A scale and unit of temperature are obtained by choosing two temperatures, called the <u>fixed points</u>, and dividing the range between them into a number of equal divisions or degrees.

Fixed point is defined as constant temperature at which a physical state of pure water is expected to change at standard atmospheric pressure (of 760mmHg).

Fixed points are basically two i.e. lower fixed point i.e. 0℃ and upper fixed point i.e. 100℃.

(i) Upper fixed point.

The upper fixed point is the temperature of the steam above water boiling at normal atmospheric pressure, 760mmHg, and is taken as 100°C.

(ii) Lower fixed point.

The lower fixed point is the temperature of pure melting ice and is taken as 0 °C. The ice must be pure since impurities like salt lower the melting point.

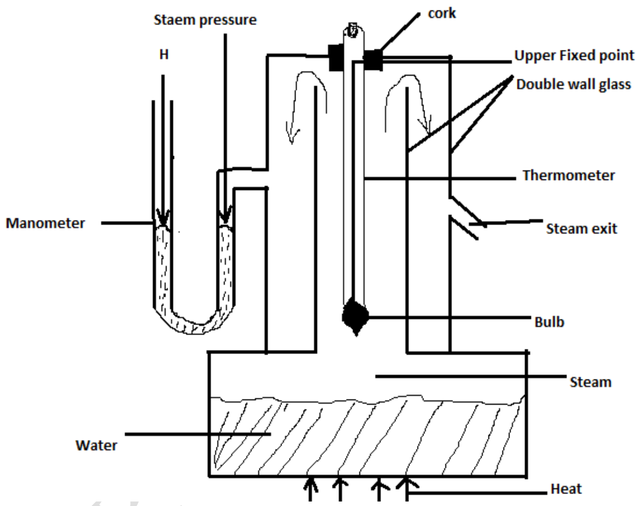
Note 1:

- The interval between the upper fixed point and the lower fixed point is the **fundamental interval**.
- The interval is subdivided into 100 equal intervals. This is the Centigrade (Celsius) scale.

Note 2:

- The boiling point of pure water at atmospheric pressure is 100°C and it is the upper fixed point.
- Dissolved impurities would raise the boiling point of water.
- The boiling point of water increases with atmospheric pressure.
- The freezing point of pure water is 0°C and it is the lower fixed point.
- Dissolved impurities lower the freezing point of water.

Determination of the upper fixed point.



The upper fixed point is obtained by the use of **hypsometer**.

The thermometer is passed through the cork and made to hang in steam (not in boiling water) just above the water and kept inside a double walled vessel.

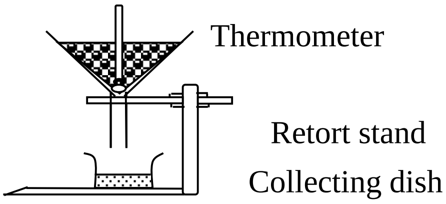
The double walls help to keep the steam at exactly 100°C

A water manometer is attached to the hypsometer and used to measure the pressure of the steam, if it is not 760mmHg, an adjustment should be made.

The apparatus is left running until the mercury level in the thermometer remains stationary.

This level is marked and it gives the upper fixed point.

Determination of the lower fixed point.



The thermometer is placed in a glass funnel kept full of small pieces of pure ice blocks having a beaker underneath to catch the water.

The mercury thread is allowed to show just above the top of the ice.

When the level of the thread has remained steady for some time its position is marked. That indicates the lower fixed point.

Determination of temperature from un-calibrated thermometer.

$if\ lo\ is\ the\ length\ of\ liquid\ column\ at\ ice\ point, l100\ is\ t$

The length at unknown temperature θ, then the un - known temperature is obtained from;

$\theta = \frac{L_\theta - lo}{L_{100} - l0}\ x\ 100^oC.$

Where $L_{100} - lo$ is the fundamental interval.

ALT

If x is length of mercury thread above the lower fixed point (ice point) and y is the length between the upper and lower fixed points (fundamental interval), the unknown temperature ϑ can be determined from the expression

$\Theta = \theta = \frac{length\ of\ liquid\ column\ above\ ice\ point}{fundamental\ interval}$ x 100°C

$\vartheta = \frac{x}{y} x 100^0$C for a thermometer with 100 equal parts, with a Celsius scale.

Example

1. The top of a mercury thread of a given thermometer is 3 cm from the ice point, if the fundamental interval is 5cm, find the unknown temperature, θ.
2. In a un calibrated thermometer, the length of the mercury above the bulb is 18mm at ice

ivanzizinga@gmail.com
0785437960, An extract of "Student's O'Level physic pass book" A publication in development stages-by Ivan Zizinga (MPOMA)

point and 138mm at steam point. When the thermometer is placed in hot liquid, the length of the liquid thread above the bulb is 78mm. calculate the temperature of the hot liquid.

3. The fundamental interval of a liquid in glass thermometer is 25cm. calculate the temperature corresponding to a mercury thread of;
   (a) 10cm above lower fixed point
   (b) 2.5cm below the lower fixed point
   (c) 2.5cm above the upper fixed point

Student's Exercise one

1.a) List the advantages and disadvantages of mercury and alcohol as thermometric liquids.

b) Ice and steam *points* on an ungraduated thermometer are found to be 192mm apart. What temperature is recorded in ºC when the length of mercury thread is 67.2mm above the ice point mark?

2a).Describe an experiment to determine the fixed points of a thermometer.

b)i) Give any three reasons why water is not used a thermometric liquid.

ii) 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.

CHAPTER TWO: TRANSMISION OF HEAT/MODES OF HEAT TRANSFER

Heat transfer is the net transfer of heat energy from hot regions to cold regions.

Methods of heat transfer

Heat is basically transferred in three (3) different ways, namely;-

1. Conduction
2. Convection
3. Radiation

CONDUCTION

The handle of a metal spoon held in a hot drink soon gets warm. Heat passes along the spoon by conduction.

Definition:

Conduction is the transfer of heat by direct contact of particles of matter without the movement of matter as a whole.

Alt. *Conduction is the flow of heat through matter from places of higher temperature to places of lower temperature without movement of matter as a whole.*

<u>Note:</u> <u>Heat conduction</u> is best in metals and worst in gases/air because of the distant spread of molecules in air.

Conduction in solids

Heat conduction takes place through a material that does not require movement of the material medium, for example in metals when they are heated their molecules vibrates faster about their mean position and pass on heat to the molecules on the cooler parts of the metal.

It should be noted that conduction is due to <u>free electrons</u> in the electron cloud or vibration of adjacent atoms against one another within a metal lattice.

<u>EXPERIMENT TO COMPARE CONDUCTION IN METALS</u>

Various metals conduct heat at different rates and simple demonstration of the different conducting powers of various metals can be carried out.

To demonstrate this, a match stick, melted wax, rods made of copper, iron, aluminium and brass are used.

A match stick is fixed to one end of each rod using a little melted wax. The other ends of the rods are heated by a burner.

When the temperatures of the far ends reach the melting point of wax, the match sticks drop off. The match stick on copper falls first, showing it is the best conductor, followed by aluminium, brass and then iron[1].

This proves that different solids/metals have different rates of conductivity of heat.

Note: The rods should be of equal length and cross sectional area.

Good and bad conductors

(a) **Good conductors.**

Most metals are good conductors of heat. Saucepans, boilers and radiators are made of metals such as aluminium, iron and copper.

(b) **Bad conductors (insulators)**

Materials such as wood, glass, cork, plastics and fabrics are bad conductors.

The handles of some saucepans and frying pans are made of wood to prevent heat transfer by conduction.

Applications of heat conduction

1) Used in cooking and frying pans (for good conductors)
2) Used on handles of frying pans (for bad conductors)

Factors affecting conduction in metals

1) Increase in the temperature difference between ends of a metal.
2) Increase in the cross sectional area of the metal.
3) Decrease in the length of the metal bar.
4) Nature of the metal (different metals conduct heat differently)

Note: Metal objects below body temperature feel colder than those of bad conductors -even if all the objects are at exactly the same temperature. This is because metal objects carry heat away faster from the hand and the hand feels cold.

Conduction by liquids and gases.

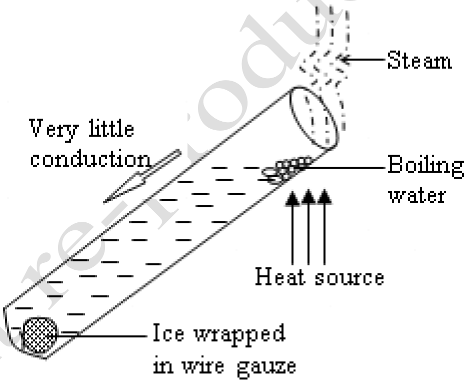
Liquids and gases also conduct heat but only very slowly. I.e. they are poor conductors.

Water is <u>a very poor</u> conductor of heat. The water at the top of the tube can be boiled before the ice at the bottom melts.

N.B. Liquid metal mercury is an exception.

An experiment to demonstrate/show that water is a poor conductor of heat.

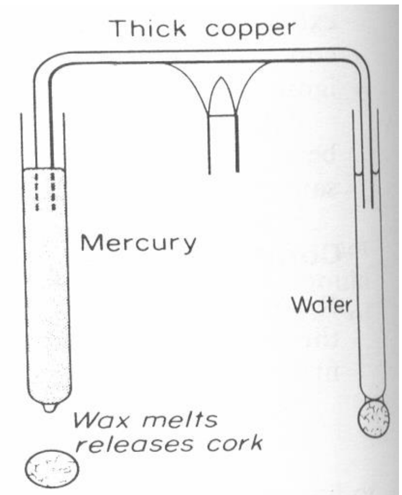
Wrap ice in a wire gauze and place it in a test tube. Pour water in a test tube and heat the water at the top as shown. Convection currents are seen at the top of the tube as water begins to boil.



Water will begin to boil at the top while ice will remain un-melted.

This shows that water does not conduct heat.

An experiment to demonstrate that mercury is better conductor of heat than water.



[1] ***See diagram in tom Duncan, P.97,*** *Figure 23.1*
Comparing conducting powers

ivanzizinga@gmail.com
0785437960, An extract of "Student's O'Level physic pass book" A publication in development stages-by Ivan Zizinga (MPOMA)

A piece of thick copper wire bent twice at right angles is then placed in mercury and water at either end. The centre of the wire is heated with a Bunsen flame and heat is conducted through the metal equally into the water and mercury.

In a short time wax on the mercury filled tube melts and the cork falls off. With further heating the cork on the test tube with water will fall off. This shows that mercury is a better conductor of heat than water.

Note:

1. Air is one of the worst conductors. This is why houses with cavity walls (two walls separated by an air space) keep warmer in cold seasons and cooler in hot seasons.
2. Materials that trap air, such as wool, felt, fur, feathers, polystyrene foam, fibreglass, are also very bad conductors. Some of these materials are used as 'lagging' to insulate water pipes, hot water cylinders, ovens, refrigerators and the walls and roofs of houses. Others are used to make warm winter clothes like 'fleece' jackets
3. 'Wet suits' are worn by divers and water skiers to keep them warm. The suit gets wet and a layer of water gathers between the person's body and the suit. The water is warmed by body heat and stays warm because the suit is made of an insulating fabric, such as neoprene, a synthetic rubber.

Conduction and the kinetic theory.

Metals consist of free electrons. When one end of the metal is heated, the kinetic energy of the electrons increases and they move faster. They collide with atoms in cooler parts, so passing on their energy and raising the temperature of these part and as the metal is heated further the amplitude of vibration of the atoms increases and hence the temperature of the metal rises.

Qn. Explain why metallic objects feel colder in the morning than wooden objects.

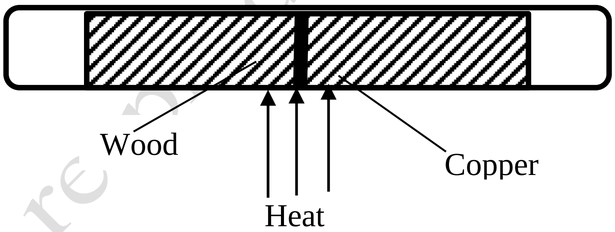
Ans. This is because metals carry heat away from hands due to high degree of conduction while bad conductors do not conduct heat.

This also explains why a cemented floor feels colder than a carpeted floor.

Qn. Explain why in cold weather, the metal blade of a knife feels cooler than the wooden handle.

Ans. Because metal is a better conductor of heat than wood. Heat is conducted from the hand to the metal blade and this gives the sensation of coldness.

Qn. Heat is applied for a short time to the paper wrapped partly on a copper bar and partly on the wooden bar as shown below. Explain what will be observed.



Ans. Copper is a good conductor of heat while wood is a poor conductor of heat. Copper conducts away heat quickly and the part of paper on it does not char. The part of paper on wood chars as heat is not conducted away from the paper.

Convection

<u>Convection</u> is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

Recall: Fluids are <u>liquids and gases</u>.

The molecules of the fluid move from warmer regions to cool regions inform of convection currents.

Definition: *<u>Convection currents</u> are a flow of fluid caused by a change in density in which the whole medium moves and carries heat energy with it.*

Alt. Convection currents *are cyclic motion of a raising hot fluid and falling cold fluid* ***or*** *these are streams of warm moving fluids.*

Note:

1. When a fluid is heated, it expands and becomes less dense. The heated fluid is forced upwards by the

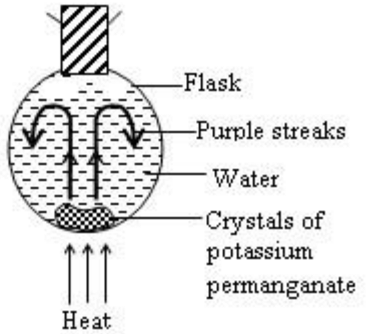
ivanzizinga@gmail.com
0785437960,

surrounding cooler fluid which moves under it. As the warmer fluid rises, it gives heat to the surrounding cooler fluid. This results into a cyclic movement called convectional current.

2. Convection cannot occur in vacuum because it requires a material medium.

3. It occurs in fluids (liquids and gases) because they flow easily.

Experiments to demonstrate convection in fluids.



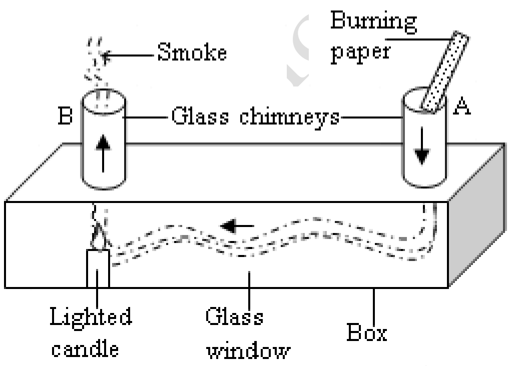
Fill a beaker with water and drop a single crystal of potassium permanganate at the bottom of it.

Heat the bottom of the flask. An upward current of coloured water will ascend from the place where the heat is applied.

This coloured stream reaches the top and spreads out.

After a short time it circulates down the sides of the flask showing that a convection current has been set up.

Convection currents in air/gases[2].



-The hot air above the candle rises up and gets out through B.

-A lighted piece of paper will produce smoke at point A. -Cold air enters at point A and sweeps all the smoke to go and replace the hot air.

-The movements of smoke from A across the box and out through B shows convection of gases.

Explanation of how smoke moves:

Smoke moves by convection because;

-The air above the candle warms up, becoming less dense and then rises up through C.

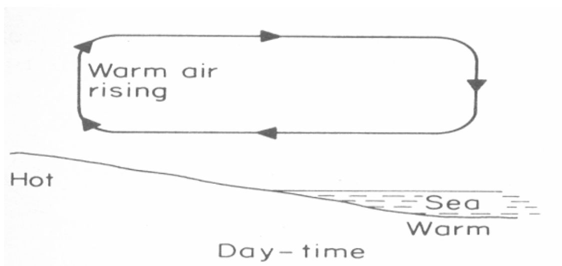
-The dense cold air from the paper (smoke) enters X through chimney A to replace the risen air (smoke) causing convection currents.

Applications of convection Current

1. Domestic hot water supply system
2. Sea and land breezes
3. Chimneys in kitchens/factories, circulates fresh air by replacing heated air and smoke with fresh cold air.
4. Ventilation in VIP latrines
5. Ventilators in houses, windows and ventilators are used to circulate fresh air by replacing warm polluted air with fresh cold air.
6. Car cooling system, it helps in circulating water in car radiators hence cooling car engines.
7. Refrigeration system, the cooling box of a refrigerator is near the top to help cool air inside the refrigerator.
8. Convection currents in the atmosphere are responsible for formation of winds

(a) Sea Breezes[3]

A sea breeze is a cool air that blows inland from sea during the daytime.



[2] Clear illustration in Tom Duncan p.100, **Figure 23.6** Demonstrating convection in air

Occurs during day when the land is warmer than the surface of the sea water.

During day the land is heated by the sun to a higher temperature than the sea.

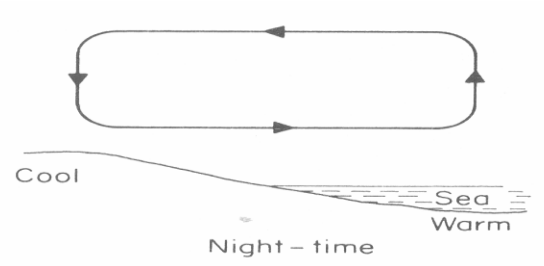
This is because land absorbs more heat from the sun than the sea water because water has a higher S.H.C than the earth and the surface of the sea is in constant wave motion leading to mixing of the warm surface water and the colder layer.

Air over the land is therefore heated, expands and rises while cooler air blows in from the sea to take its place.

The circulation is completed by the wind in the upper atmosphere blowing in the opposite direction.

(b) Land Breezes

This is a warm air that blows from the land to the sea during the night time.



It occurs at night.

At night the land is no longer heated by the sun and cools very rapidly.

On the other hand the sea shows no change in temperature, therefore the air above the sea is warmer than that over the land hence less dense so it rises.

The air above the land which is cold replaces warm air above the sea hence resulting into land breeze

(c) Domestic hot water supply system

Qn. Describe the mode of operation of a domestic hot water supply system.

The domestic hot water supply system works on the principle of convection current of hot water rising through on pipe and cold water descending through another**.** **(Leave twenty lines for a diagram)**

It consists of a boiler, a hot water storage tank, and interconnected pipes.

Cold water is supplied to the boiler along the cold water supply pipe.

On warming, in the boiler the cold water warms up, expands and becomes less dense so it rises up.

As more water is supplied to the boiler, hot water is displaced upwards and supplied to the hot water taps along hot water pipes.

Note

- When hot water is run off, an equal volume of water from the cold supply tank enters the hot supply tank from the bottom.
- The expansion pipe permits the escape of dissolved air which comes out of water when it is heated, as otherwise this might cause trouble since some air locks in pipes and may explode
- Pipe A leaves the boiler at the top and enters the hot water tank at the top because it carries less dense hot water.
- Pipe B is connected to the bottom of the hot water tank and from the bottom of the boiler because it carries more dense cold water.
- When warming a liquid, the heating element of an electronic kettle is placed at the bottom.

(d) Ventilation

Air inside a room gets heated up on hot day. Rooms are usually provided with ventilators above the floor through which warm air finds its way out while fresh air enter through doors and windows. In this way a circulation of air convection is set up.

Radiation

Definition: Radiation is the flow of heat from one place to another by means of electromagnetic waves. For example the means by which heat energy from:

- ✓ The sun reaches the earth
- ✓ A hot object or fire is lost to the surrounding

Radiation is a form of heat transmission that does not require a material medium.

The waves are partly reflected and partly absorbed by objects on which they fall as they travel from the sun.

ivanzizinga@gmail.com
0785437960, An extract of "Student's O'Level physic pass book" A publication in development stages-by Ivan Zizinga (MPOMA)

The part which is absorbed becomes transferred into internal energy called *radiant energy*.

Radiant energy consists of electromagnetic waves which pass through a vacuum.

It consists of infrared which makes the skin feel warm (causes the sensation of warmth).

Radiant energy travels as fast as light and it's the fastest means of heat transfer.

Laws of radiation/Characteristic of radiation as a mode of heat transfer.

1. Heat radiation travels in a straight line
2. Good absorbers of heat radiation are also good emitters.
3. Temperature of the body remains constant when the rate at which it absorbs heat radiation is equal to the rate at which it radiates heat energy.
4. Bodies only radiate heat when their temperatures are higher than those of the surroundings and absorbs heat from the surroundings if their temperatures are low.

Absorption of radiation by a surface.

Some surfaces are *good absorbers* of heat like dull black surfaces while others are *bad absorbers* like polished surfaces.

Absorbing powers of a dull black and polished surface can be compared using two sheets of tin plate, one polished and the other painted black.

(Leave twenty lines for diagrams)

Two pieces of cork are fixed onto two metal plates using molten wax.

The metals are placed vertically facing each other.

A burning candle is placed at mid-point of the metal plates.

When the burner is lit both surfaces receive equal quantities of radiation.

After some time, the wax on the dull black plate melts and the cork slides off.

The polished plate remains cool and the wax unmelted.

This shows that a dull black surface is a good absorber of heat while polished surface is a poor conductor of heat radiation.

This is because shinny surfaces reflect heat radiation instead of absorbing it.

Comparison of radiation of different surfaces

One side of the cube is dull black, the other end is dull white and the third one is made shiny, polished.

The cube is filled with hot water and radiation from its surface is detected by a thermopile.

When the radiated heat falling on a thermopile is mush, it registers a large deflection of the pointer.

With the different surfaces of the cube made to face the thermopile one at a time, the greatest deflection at the pointer is obtained when a dull dark surface faces the thermopile.

The least deflection is obtained when a highly polished shinny surface faces the thermopile.

Hence a dull surface is a *good radiator or emitter* of heat radiation while a polished shiny surface is *a poor emitter* of heat radiation.

Definition: A thermopile is a device which converts heat to electrical energy.

Factors that affect the rate at which bodies radiate energy

1. Temperature of the body. A hotter body radiates heat faster compared to a cold body.
2. Surface area of the body. Large surface area allows much energy to be radiated per second.
3. Nature of the surface of the body. Dull surfaces radiate heat energy faster than polished surfaces.

Applications of Radiation

The following are the various applications of radiation as a mode of heat transfer.

1. Thermos flask
2. Black and dull surfaces
   (i) Car radiators are painted black to easily emit heat
   (ii) Cooling fins of a refrigerator are black to easily emit heat
   (iii) Solar panels are black to easily emit heat

ivanzizinga@gmail.com
0785437960, An extract of "Student's O'Level physic pass book" A publication in development stages-by Ivan Zizinga (MPOMA)

3. Polished and white surfaces
    (i) White washed buildings keep cool in summer
    (ii) White coloured clothes are worn in summer to keep us cool
    (iii) Petro tanks are aluminium painted to reflect radiant heat
    (iv) Silver tea pots, kettles and saucepans retain heat for a long time

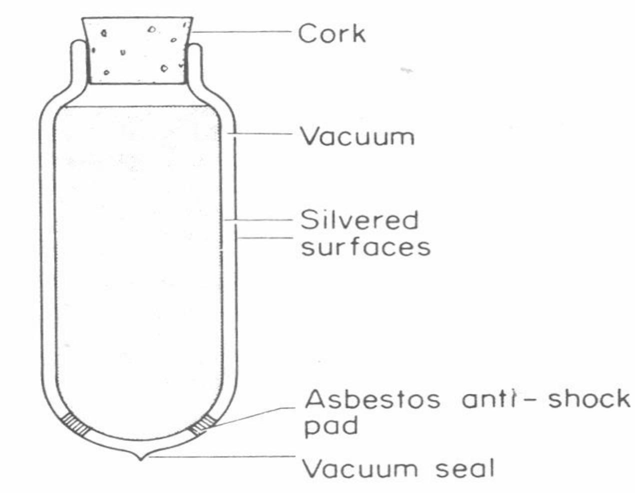
(a) The vacuum flask.

A vacuum flask is a flask with two walls enclosing the vacuum used for keeping the contents at a fairly constant temperature.

Facts about a vacuum flask

- ✓ It consists of a double walled glass having a vacuum between the walls
- ✓ Both sides are silvered on the vacuum side
- ✓ Heat gain and heat loss are minimised by the cork at the top, vacuum between the walls and the silvered surfaces.

Structure of a vacuum flask



How a vacuum flask minimises heat loss

To keep a drink or food hot inside a flask, heat losses by all three processes must be reduced to a minimum.

Conduction is totally prevented through the sides of the flask by the vacuum between the double glass walls of the bottle and the cork or plastic stopper which contains a lot of trapped air which is a bad conductor of heat.

Convection is also totally prevented by the vacuum. The cork also minimises heat loss by convection. It can cause heat loss through the top of the flask only while the stopper/cork is removed.

The radiation loss of heat is greatly reduced by the two silvered walls on the glass walls of the flask.

Note:

The vacuum seal seals the vacuum, if broken the vacuum will no longer exist and heat loss by conduction and convection will occur. This renders the vacuum seal useless.

Despite the above attempts to minimize heat loss and heat gain by the vacuum flask, hot contents of the vacuum flask ultimately get cold after along time.

Reason: little heat escapes by a process of conduction through the thin glass wall at the neck and poorly conducting cork.

The greenhouse effect.

Green houses are used to help certain plants grow better by providing a warmer air temperature.

In summer greenhouses do not need internal sources of heat because they are able to trap enough solar radiation to keep them very warm inside.

Greenhouse effect Explanation

When the short wavelength infra-red radiation from the sun passes through the green house, the radiation is absorbed by the plants and the soil hence raising their temperature and makes them warmer.

The warm soil and plants now also re-emits long wavelength infra-red radiation because of low temperature and therefore it cannot pass through the green house glass. Since the infra-red radiation is prevented from escaping from the earth's atmosphere, it causes global warming.

In this way solar radiation becomes trapped inside the green house and causes its temperature to rise.

Choice of dress:

Dresses are selected depending on the conditions of the environment.

On hot days, a white dress is preferable because it reflects most of the heat radiations falling on it.

On cold days, a dull black woollen dress is preferred because it absorbs most of the heat incident on it and can retain it for a longer time.

Chapter summary

State and define the methods of transfer of heat energy

Describe experiments to:

(i) Compare thermal conductivity of solids

(ii) Show convection in fluids (liquids and gases)

(iii) Show that-dull/black surfaces are good absorbers and radiators, - shiny surfaces are good reflectors.

Define and differentiate between sea breeze and land breeze

Explain how sea breeze and land breeze occur

Draw and label the diagram of a vacuum flask

Explain how the vacuum flask keeps hot liquids hot and cold liquids cold.

Revision questions

Section A: 1988 qn 12, 18, 31, 1991 qn 4,33, 1999 qn 9, 2004 qn 11, 33, 2006 qn 17, 2007, qn 36

Section B: 1989 qn 2, 1994 qn 1, 1998 qn 3, 5.

CHAPTER FOUR: MEASUREMENT OF HEAT/QUANTITY OF HEAT

Recall: Heat is a form of energy that flows from one end of a body to another due to temperature difference.

S.I unit of heat is joule (J).

Terms used in measurement of heat

(i) Heat capacity
  - ✓ Specific heat capacity

(ii) Latent heat
  - ✓ Specific latent heat of fusion
  - ✓ Specific latent heat of vaporization

(a). Heat Capacity (C)

Heat capacity is the quantity of heat required to raise the temperature of a body by 1 Kelvin.

i.e $Heat\ capacity = \frac{Quantity\ of\ heat}{change\ in\ temperature}$

$C = \frac{Q}{\Delta\theta}$.

The S.I. unit of heat capacity is Joules per Kelvin (**JK^{-1}**).

Example

A body of mass 200kg gains 4000J when its temperature rises from 20˚C to 60˚C.Calculate its heat capacity and find the specific heat capacity of the substance.

Solution:

Heat capacity = $\frac{Q}{\theta} = \frac{4000}{60-20} = \frac{4000}{40} = \frac{400}{4} =$ $100JK^{-1}$.

From $\frac{Q}{\theta} = mc$

100 =200 c,

c = $\frac{100}{200} = 0.5Jkg^{-1}K^{-1}$.

(b). Specific Heat Capacity, c

The word specific refers to a unit quantity of physical property.

Specific Heat Capacity is the quantity of heat required to raise the temperature of a 1Kg mass of a substance by 1K.

$shc = \frac{quantity\ of\ heat,Q}{mass\ x\ change\ in\ temperature}$.

$c = \frac{Q}{m\Delta\theta}$.

The S.I unit of specific heat capacity is Joules per kilogram per Kelvin (**$JKg^{-1}K^{-1}$**).

$c = \frac{Q}{m\Delta\theta}$.

Relationship between c and C

$Q = mc\Delta\theta$.

$c = \frac{C}{m}$.

Note:

When using Q = **$mC\Delta\theta$;**

1. The mass, m must be in in S.I unit (Kg).
2. In questions with the phrase "the temperature rises by …^{0}C or the temperature rose by…^{0}C; the temperature value given is the change in temperature, **Δθ.** E.g. If the temperature of substance change from 20^{o}c to 40^{o}c. Then the temperature rise is;

$\Delta\ \boldsymbol{\theta} = (\theta_2 - \theta_1) = (40 - 20) = 20^0C$

Example

How much thermal energy is required to raise the temperature of 3 kg of aluminum from 15˚C to

25˚C.The specific heat capacity of aluminum is 900 $Jkg^{-1} K^{-1}$.
Solution:
Q= mcϴ
Q= mc (Θ_2 - Θ_1)
= 3 x 900 x (25 – 15);assuming that 1˚C=1K rise in temperature.
=3 x 900 x 10
= 27,000J

Example
A 0.5 kg block of aluminum at a temperature of 100˚C is placed in 1.0kg of water at 20˚C.Assuming that no thermal energy is lost to the surroundings, what will be the final temperature of the aluminum and water when they come to the same temperature?

Solution:
Let the final temperature reached be ϴ˚C.
The temperature of aluminum falls by (100 –ϴ) ˚C.
The temperature of water rises by (ϴ – 20) ˚C.
Therefore heat lost by aluminum = heat gained by water.

$m_a c_a(100-\Theta) = m_w c_w(\Theta - 20)$

$0.5 \times 900 \times (100 - \Theta) = 1 \times 4200 \times (\Theta - 20)$

$450 (100 - \Theta) = 4200 (\Theta - 20)$

$45,000 - 450\Theta = 4200\Theta - 84000$

$45,000+84000 = 4200\Theta + 450\Theta$

$129,000 = 4650\Theta$

$\Theta = \frac{129,000}{4650}$

$\Theta = 27.7˚C.$

N.B: The high specific heat capacity of water makes water a very good liquid for cooling machines.

Importance of the high specific heat capacity of water

The high specific heat capacity of water makes the temperature rise and fall to be slower for water.

-This is one of the major reasons why water is used in the cooling system of engines and radiator of central heating system. This is because less amount of liquid is needed to draw heat energy from the engine as compared to other liquids.

-The other reason why water is used is because it is cheaper and available.

Word problems
Example 1

Calculate the quantity of heat required to raise the temperature of a metal block with a heat capacity of $460JK^{-1}$ from 15^0C to 45^0C.

Solution
Heat capacity, $C=460JK^{-1}$
Temperature change, $\theta = (45-15) = 30^0C$

$Q = C\theta$

$= 460 \times 30$

$= 13800J$

Example 2

A piece of copper of mass 60g and specific heat capacity $390JKg^{-1}K^{-1}$ cools from 90^0C to 40^0C.Find the quantity of heat given out.

Solution

$Q = mc\theta$

$= \frac{60}{1000} \times 390 \times (90-40)$

$= 1170J$

Example 3

How many joules of heat are given out when a piece of zinc of mass 50g and specific heat capacity 380J/kgK cools from 60ºC to 20ºC?

Q = mcθ

$= \frac{50}{1000} x 380 x (60 - 20).$

= 760Joules

Example 4

How much heat is needed to rise the temperature from 300c to 0oc for an iron of 5kg. Specific heat capacity of iron is 440J/KgK.

Solution:

$\Delta\boldsymbol{\theta} = (\theta2 - \theta1) = (40 - 30) = 100C$

Heat Energy = $\mathbf{mC\Delta\theta}$

$= 5 \times 440 \times 10 = 22000J$

Example 5: (2000 Qn. 4)

When a block of iron of mass 2Kg absorbs 19KJ of heat, its temperature rises by 100C. Find the specific heat capacity of iron.

Solution:

Q = 19KJ = 19 × 1000 = 19000; $\Delta\boldsymbol{\theta}$ = 100C; C?

Example 6: (2003 Qn. 13) Find the amount heat required to raise the temperature of a 0.5Kg salt solution from −50C to 150C. Specific heat capacity of salt solution is 4000JKg−1K−1. Example 7: (1992 Qn. 4) Find the amount heat required to raise the temperature of a 20g of water from 300C to 600C. Leave 10 lines. Example 9. Uneb 2003 qn. 13 (Leave 20 lines). Example 10.uneb 2000 qn 4 (Leave 10 lines)

Calorimetry

Calorimetry is the measurement of the quantity of heat exchanged.

The device used in calorimetry is a calorimeter. It is usually made of copper.

The calorimeter is lagged with an insulator and placed in a jacket with a plastic cover which has two holes for a thermometer and a stirrer.

Methods of Measuring Specific Heat Capacity

There are two common methods used to measure shc of substances and these are;

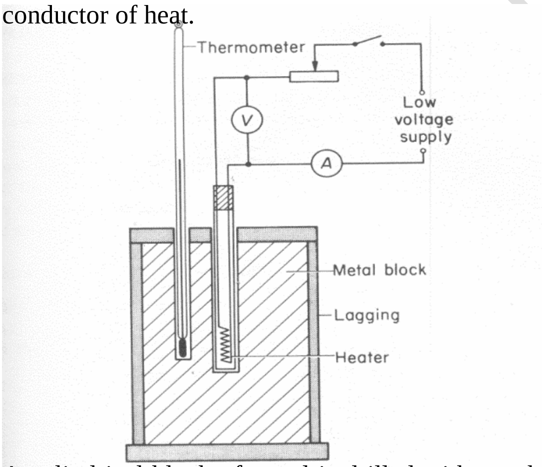
(i) Method of mixtures

(ii) Electrical Method

Measurement of specific heat capacity by the electrical method.

(a) For a solid

This method is suitable for a metal which is a good conductor of heat.



A cylindrical block of metal is drilled with two holes one for an electric heater and the other a thermometer.

A metal block of mass, m with two holes is used.

The heater is placed in one of the holes and the thermometer in the other hole.

The initial temperature, θ1 on the thermometer is then recorded.

The heater is then switched on by closing switch, k until the temperature changes to θ2 in time, t

The ammeter and voltmeter readings I and V respectively are noted and recorded

Assuming there are no heat losses

Electrical heat supplied = heat gained by the solid

$mc(\theta_2 - \theta_1) = VIt$

Specific heat capacity of metal, $c = \frac{VIt}{m(\theta_2 - \theta_1)}$

Precautions

(i)The metal block must be heavily lagged to prevent heat loss to the surroundings.

(ii)The two holes should be filled with a light oil to improve thermal contact with the heater and thermometer.

Example 1

98,000J of electrical heat are needed to raise the temperature of 2kg of a substance from 51˚C to 65˚C. Calculate the specific heat capacity of a substance. Ans. 3500JKg^{-1}**K^{-1}**

Example 2

An electrical heater rated 48W, 12V is placed in a well-insulated metal of mass 1.0kg at a temperature of 18 degrees celcius. When the power is switched on for 5 minutes, the temperature of the metal rises to 34 degrees celcius. Find the specific heat capacity of the gas.

Example 3

An electric drill takes 300s to make a hole in a piece of brass of man 9.5kg and the average power delivered from the mains in 45w.

i) Calculate the amount of energy used in drilling the hole.

ii) If 80% of the energy supplied to the drill is used to raise the temperature of the brass.

Calculate the average temperature rise. State any assumption made.

(S.H.C of brass = 390JKg^{-1}K^{-1}).

Example 4

A block of metal of mass 1.5kg which is insulated is heated from 30^0C to 50^0C in 8minutes and 20 seconds by an electric heater coil rated 54W.Find:

(a)the quantity of heat supplied by the heater.

(b)the heat capacity of the block.

(c)its specific heat capacity.

Solution

(a)Quantity of heat supplied = power x time

$$Q = 54 \times 500$$
$$= 27000J$$

(b) $Heat capacity, C = \frac{Q}{\theta}$

But $Q = 27000J$ and $\theta = 50 - 30 = 20$

$$C = \frac{27000}{20}$$
$$= 1350JK^{-1}$$

(c) Specific heat capacity, $c = \frac{C}{m}$

$$c = \frac{1350}{1.5} = 900JKg^{-1}K^{-1}.$$

(b) For a liquid

A liquid of mass, m is poured in a copper calorimeter of mass, Mc and specific heat capacity, Cc

The temperature, θ1 of the liquid is then recorded from the thermometer immersed in the liquid

The electrical heater is switched on until the thermometer changes to θ2 in time t

The ammeter and voltmeter readings I and V respectively are noted and recorded

Assuming there are no heat losses

Electrical heat supplied = heat gained by the liquid + heat gained by copper calorimeter

IVt = mlcθ +mcccθ

Example 1

An electric heater of 1.8kW was used to heat 5kg of a liquid. It takes 6 minutes to raise the temperature of the liquid from 20 to 110. Calculate the shc of the liquid. Ans 1440

Example 2

Find the final temperature of water if a heater source rated 42W heats 50g water from 20ºC in five minutes.(Specific heat capacity of water is 4200JKg^{-1}K^{-1})

Solution

Heat supplied by the heater = Heat gained by the water.

$$42 \times 5 \times 60 = mc\theta$$
$$42 \times 300 = 50 \times 10^{-3} \times 4200 \times \theta$$
$$\theta = 60^0$$

But $\theta = T - 20$

$$T = 80^0C$$

Determination of specific heat capacity of a solid by the method of mixtures.

-The method of mixture involves mixing a solid with a liquid at different temperature but the specific heat capacity of either solid or liquid should be known.

-In this method a hot substance is mixed with a cold substance and then stirred. Then heat will flow from a hot substance to the cold substance until both are at the same temperature.

-If no heat is lost to the surrounding then heat lost by the hot substance = heat gained by cold substance.

(**Leave 25 lines for a diagram**)

-Weigh the solid metal block and record its mass m_s .Place the block in a beaker containing water and heat the water as shown above in (a).Allow the water to boil. Weigh the calorimeter together with the stirrer and record their mass as m_c.

Add water to the calorimeter. Determine the mass of calorimeter with water m_l.

Mass of water= $m_w = m_l - m_c$.Place the calorimeter in the insulating jacket.

Measure the temperature of the cold water in the calorimeter and record it as θ_1. When the water in the beaker has boiled for some time, quickly transfer the metal block from the beaker into the cold water in the calorimeter.

Place a thermometer in the beaker to measure the temperature of the boiling water as θ_2. Record the final temperature of the mixture in the calorimeter as θ_3.

Assuming no heat losses to the surroundings during the transfer of the metal block from the beaker to the calorimeter and thereafter, the specific heat capacity of the solid can be calculated as follows;

Heat lost by metal bock = heat gained by calorimeter with stirrer + Heat gained by water in calorimeter.

$$m_s c_s(\theta_2-\theta_3)=m_c c_c(\theta_3-\theta_1)+m_w c_w(\theta_3-\theta_1)$$

Where c_c, c_s anc c_w are specific heat capacities of the calorimeter, the solid and water respectively. The specific heat capacity of the material of the cube can therefore be calculated as

$$c_s=\frac{(\theta_3-\theta_1)(m_c c_c+m_w c_w)}{m_s(\theta_2-\theta_3)}.$$

Determination of the specific heat capacity of a liquid by the method of mixtures.

Procedure.

(Leave 25 lines for a diagram)

Weigh the solid metal block and record it's mass as m_s.

Place a liquid in a beaker and immerse the block attached to a string into the liquid as shown in figure (a) below. With the beaker on a tripod stand heat the beaker and its contents until the liquid starts to boil. Record the temperature θ_1 of the boiling liquid.

Weigh the calorimeter and stirrer and then pour some liquid into it and again weigh the calorimeter with liquid. By subtraction determine the mass of the liquid m_l in the calorimeter alone. Place a thermometer in the calorimeter and take note of the temperature of the cold water θ_2.

When the liquid in the beaker has boiled for some time, transfer the block from the beaker into the cold liquid in the calorimeter.

Cover the calorimeter with a piece of cardboard as in figure (b) below.

Stir the mixture and record the final temperature θ_3

The specific heat capacity of the liquid can be calculated as follows;

Heat lost by the hot solid =

Heat gained by calorimeter and stirrer + Heat gained by liquid in the calorimeter.

$$m_s c_s(\theta_1-\theta_3)=m_c c_c(\theta_3-\theta_2)+m_l c_l(\theta_3-\theta_2)$$

Where c_s, c_c and c_l are the specific heat capacities of the solid, calorimeter and liquid respectively.

Since all the other quantities are known the unknown quantity c_l can be determined.

Example 1

What is the final temperature of the mixture if 100g of water at 70 degrees is added to 200g of cold water at 10 degrees and well stirred. (neglect heat absorbed by the container.

Example 2

The temperature of a piece of copper of mass 250g is raised to 100 degrees and it is then transferred to a well lagged aluminium can of mass 10g containing 120g of methylated spirit at 10 degrees. Calculate the final steady temperature after the spirit has been well stirred. State any assumptions made. (Take SHC of copper and aluminium to be $400JKg^{-1}k^{-1}$ and 900 respectively, for spirit is 2400)

Example 3

A 0.56kg block of copper at a temp of 100 degrees is dropped into the container and the temp is observed to increase to 22.5 degrees. If a copper calorimeter of mass 0.30kg containing 0.50kg of water at a temp of 15 degrees was used, find the SHC of copper.

Example 4

A copper colorimeter of mass 0.30kg contains 0.50kg of water at a temperature of 15ºC. A 0.56kg block of copper at a temperature of 100ºC is dropped into the colorimeter and the temperature is observed to increase to 22.5ºC. Find the specific heat capacity of copper.

$$m_c = 0.30kg, m_s = 0.56kg, c_c = 3.8x10^2\ Jkg^{-1}K^{-1}, m_w = 0.50kg, \theta_2 = 100^0C, c_w = 4.2x10^3\ Jkg^{-1}K^{-1}$$

$$\theta_1 = 15^oC, \theta_3 = 22.5^oC$$

$$m_s c_s(\theta_2 - \theta_3) = m_w c_w(\theta_2 - \theta_1) + m_c c_c(\theta_2 - \theta_1)$$

$$c_s = \left(\frac{m_w c_w + m_c c_c}{m_s(\theta_2 - \theta_3)}\right)(\theta_3 - \theta_1)$$

$$c_s = \frac{(0.5x4.2x10^3 + 0.3x3.8x10^2)(22.5 - 15)}{0.56(100 - 22.5)} = 3.83x10^2\ Jkg^{-1}K^{-1}$$

Example 5

A lady wanted to have a warm bath at 40ºC.She had 5kg of water in a basin at 85ºC.What mass of cold water at 25ºC must she have added to the hot water to obtain her choice of bath? Neglect heat losses and take specific heat capacity of water to be $4200Jkg^{-1}K^{-1}$.

Example 6

A bath contains 100kg of water at 60ºC.Hot and cold taps are then turned on to deliver 20kg per minute each at temperatures of 70ºC and 10ºC respectively. How long will it be before the temperature in the bath has dropped to 45ºC?

Example 7

The temperature of a brass cylinder of mass 100g was raised to 100ºC and transferred to a thin aluminium can of negligible heat capacity containing 150g of paraffin at 11ºC. If the final steady temperature after stirring was 20ºC, calculate the specific heat capacity of paraffin.(Neglect heat losses and assume specific heat capacity of brass=380J/kgK)

Example 8

0.2kg of iron at 100^0C is dropped into 0.09kg of water at 20^0C inside a calorimeter of mass 0.15kg and specific heat capacity $800Jkg^{-1}K^{-1}$.Find the final temperature of the water(Specific heat capacity of iron is $460JKg^{-1}K^{-1}$ and that of water $4200JKg^{-1}K^{-1}$)

Example 9

What is the final temperature of the mixture if 100g of water at 70ºC is added to 200g of cold water at 10ºC and well stirred?(Neglect heat absorbed by container)

Heat given out by hot water = Heat received by cold water.

$0.1x4200x(70 - \theta) = 0.2x4200x(\theta - 10)$

$7 - 0.1\theta = 0.2\theta - 2$

$9 = 0.3\theta$

$\theta = 30^oC$

Example 10

The temperature of a piece of copper of mass 250g is raised to 100ºC and it is then transferred to a well lagged aluminium can of mass 10.0g containing 120g of methylated spirit at 10.0ºC.Calculate the final temperature after the spirit has been well stirred. Neglect the heat capacity of the stirrer and any losses from evaporation.

Solution.

Heat given out by copper $= 0.25x400x(100 - \theta)$.

Heat received by aluminium = $0.01x900x(\theta - 10)$.

Heat received by spirit = $0.12x2400x(\theta - 10)$.

Heat given out =heat received

$100x(100 - \theta) = 9x(\theta - 10) + 288x(\theta - 10)$

$10{,}000 - 100\theta = 297\theta - 2970$

$12970 = 397\theta$

$\theta = 32.7^o$C.

Student's Exercise three

1. Calculate the heat given out when 50g of iron cools from 45ºC to 15ºC. (C for iron 460J/kgK).
2. Calculate the specific heat capacity of gold if 108J of heat raise the temperature of 9g of the metal from 0ºC to 100ºC.

Try out: Uneb 2000 Qn 3, 4, 38, uneb 1993 Q3, uneb 1997 qn 7 & 15.uneb 2000 qn34. Uneb 2002 qn 26, 2003 qn33, 39. 2007 qn 7, 28. 2008 qn 2.

Revision Questions

1. (a) Define *temperature* in terms of kinetic theory. (1)

(b) Give four reasons why water is never used in thermometers. (4)

(c) The fundamental interval of a thermometer is 30cm long, on a mercury column; find the temperature that corresponds to the length of 12cm from the lower fixed point. (3)

(d) (i) Define *specific latent heat of fusion*. (1)

(ii) Calculate the amount of heat absorbed by 200g ice at -4^{0}C to 123^{0}C. (5)

(e) State one instance that shows that evaporation causes cooling. (2)

2. (a) Differentiate between *convection* and *radiation*. (4)

(b) Describe an experiment which can be performed to show convection in a liquid. (5)

(c) (i) Draw a well labeled diagram of a vacuum flask (2)

(ii) Explain how a vacuum flask minimizes heat losses. (5)

(d) Explain why a car radiator is made of metal fins and painted black. (4)

3. (a) Define the following;

(i) Heat capacity (1)

(ii) Specific latent heat (1)

(b) 0.6kg of water at 70^{0}C is contained in a well insulated container made of a poor conductor of heat. 0.2kg of ice is added to the water. When all the ice has melted the temperature of water is 40^{0}C. Calculate the specific latent heat of fusion of ice. (4)

(c) (i) Describe an experiment for the determination of the upper fixed point. (4)

(ii) The length of the mercury column when in melting ice and boiling water is 5cm and 30cm respectively. What is the temperature reading if the length is 25cm? (4)

(d) State two qualities of a good thermometric liquid. (2)

4. (a) Define the following terms as applied to the curved mirrors.

(i) Principal focus:

(ii) Radius of curvature:

(b) Describe an experiment to determine the focal length of concave mirror using an illuminated object placed at the centre of curvature.

(c) The focal length of a concave mirror is 4cm. An object 1.5cm high is placed 12cm in front of the mirror. Using a graphical method, determine;

(i) the position of the image.

(ii) the magnification.

(c) (i) Define critical angle.

(ii) State the conditions necessary for total internal reflection to occur.

(iii) A coin in a beaker of water appears to be at a depth of 9cm. What is the real depth of water if the refractive index of water is 1.33?

(iv) Explain why diamond sparkles more than a piece of glass with the same shape and therefore is a better gemstone.

End (Control your movements to stay COVID-19 free)