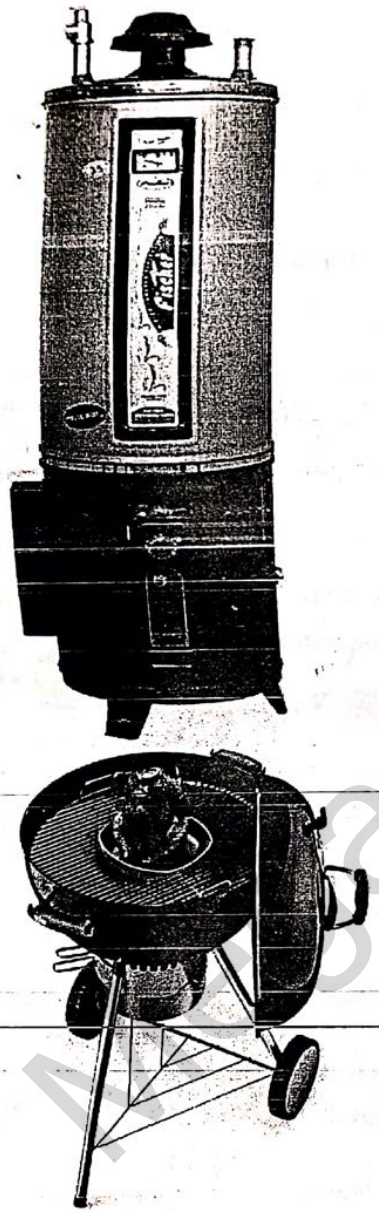
O Level Physics Syllabus Content for CAIE 2019-22 Exams

CHAPTER 9:
TRANSFER OF THERMAL ENERGY



Syllabus Content

9.1 Conduction
9.2 Convection
9.3 Radiation

Learning outcomes

Candidates should be able to:

(a) Describe how to distinguish between good and bad conductors of heat.
(b) Describe, in terms of the movement of molecules or free electrons, how heat transfer occurs in solids.
(c) Describe convection in fluids in terms of density changes.
(d) Describe the process of heat transfer by radiation.
(e) Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation.
(f) Describe how to distinguish between good and bad emitters and good and bad absorbers of infra-red radiation.
(g) Describe how heat is transferred to or from buildings and to or from a room.
(h) State and explain the use of the important practical methods of thermal insulation for buildings.

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Transfer of Thermal Energy

Heat energy flows form high temperature to low temperatures. This is done in three different ways:

1. Conduction
2. Convection
3. Radiation

1. Conduction:

If a metal rod is held in a flame it conducts heat rapidly, but a glass rod conducts very little amount of heat.

When a solid is heated, conduction occurs because each molecule transfers its vibrational energy to adjacent molecules and so on. In metals, which are good conductors, most of the heat energy is transferred due to the higher velocities and higher K.E. of the free electrons in the metal. This explains why metals are good conductors of heat and are also good conductors of electricity.

(a) The Metals are the best conductors of heat. The diagram shows an experiment to compare thermal conductivities of four different metals.

(b) The Non-metal solids tend to be bad conductors of heat, such as glass, plastics, rubber and wood. Materials containing trapped air such as wool, fiberglass, and expanded polystyrene are also very bad conductors.

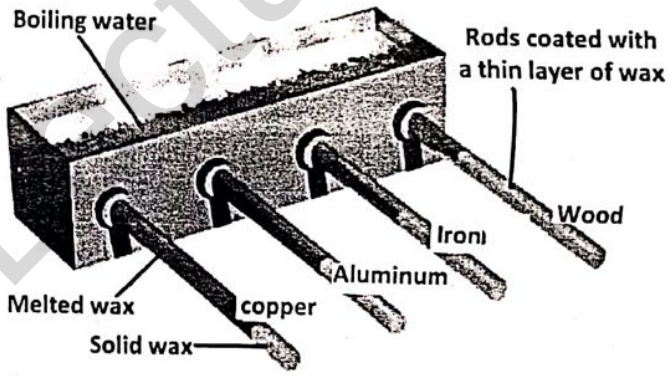
(c) The **Liquids** are mostly **poor conductors** of heat. The diagram shows water boiling at the top while the ice has not melted at the bottom, which proves that water is a bad conductor.

(d) The Gases are much poorer conductors than liquids

(e) The Vacuum does not conduct heat at all.

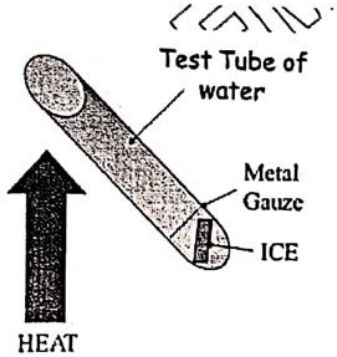
(f) In the case of the metal, along with the conduction energy is also transferred by the movement of free electrons at its surface.

Conduction of Heat through Solids



Observation

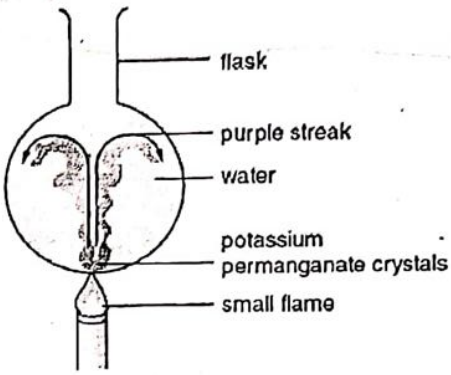
Observe the lengths of wax that have melted on t the different rods in a given interval of time.



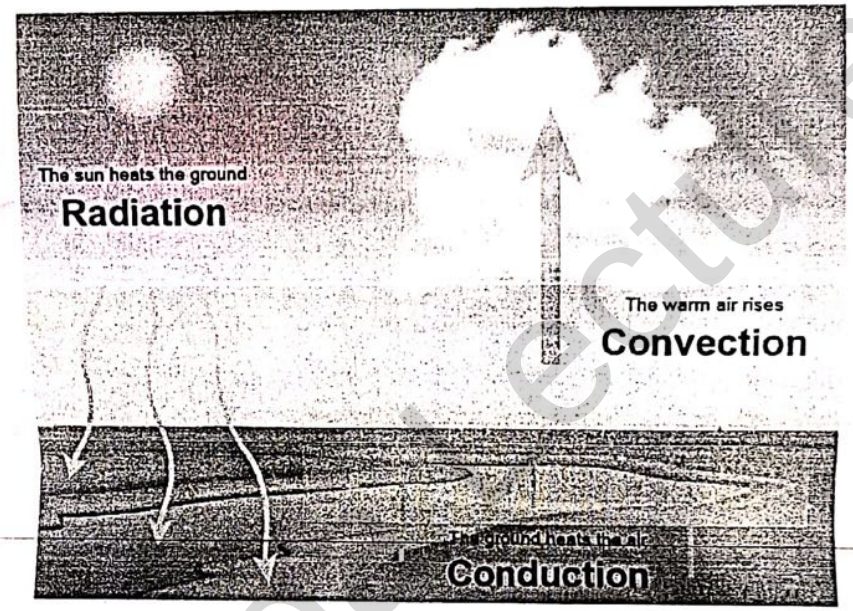
The ice down not melt as the water is a terrible conductor and convection only works up.

2. Convection

Convection occurs in gases and liquids only. When a liquid is heated at the bottom, it expands, becomes less dense and therefore rises to the top and is replaced by cooler liquid. The stream of warm liquid flows up and cool liquid flowing down sets up currents called convection currents.

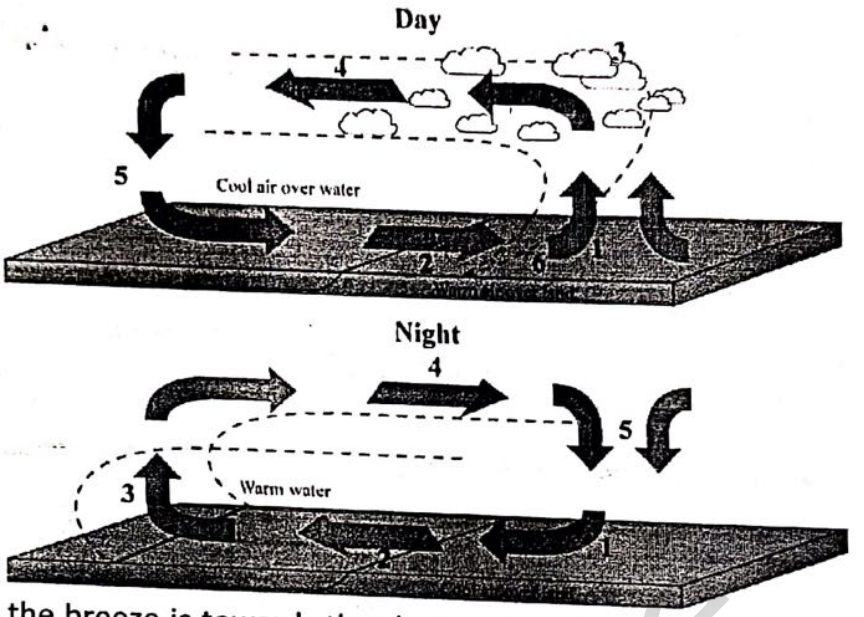


To produce convection currents, one must heat the gas or liquid from the bottom but when cooling, the convection currents are produced when cooling at the top.



Examples:

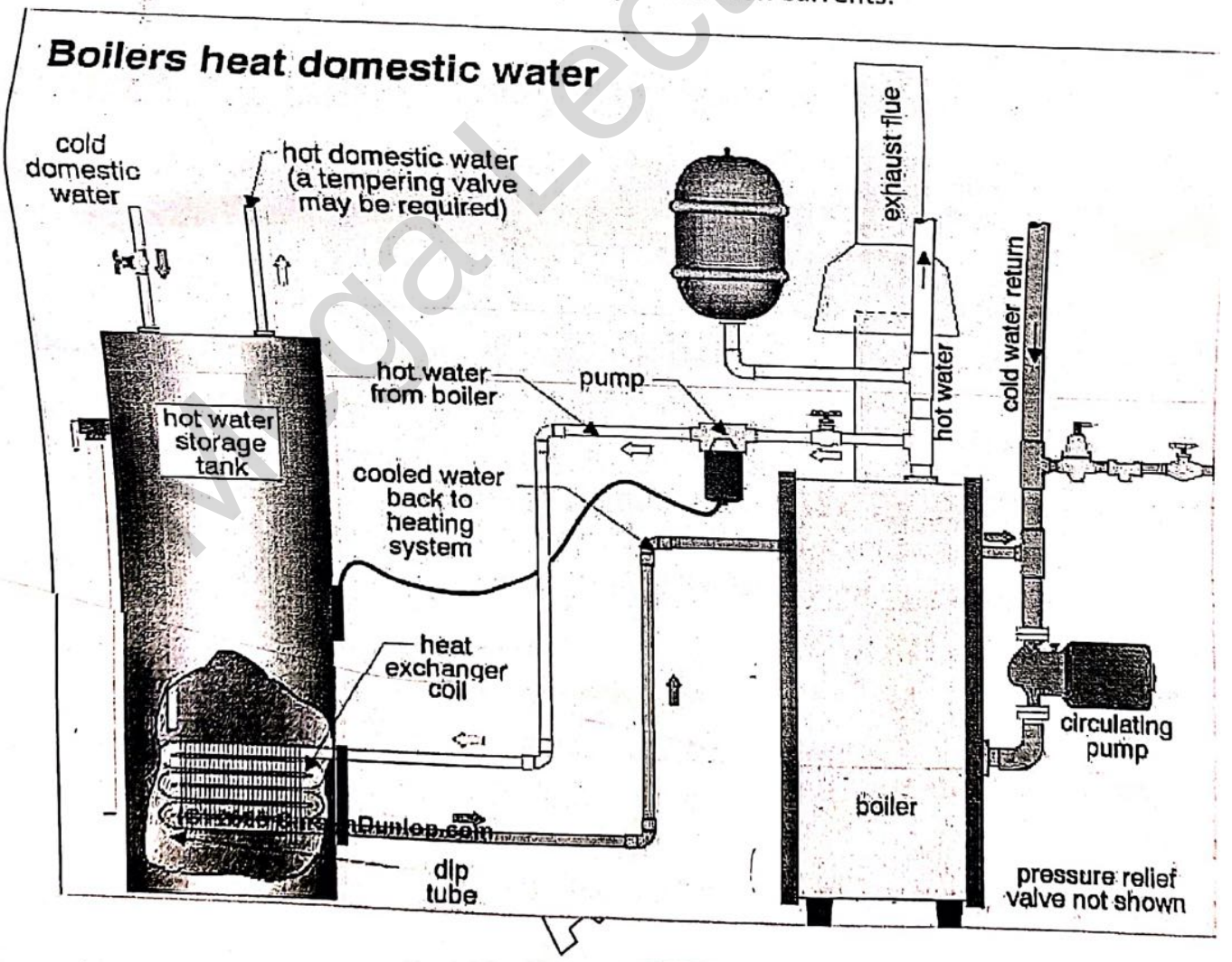
1. In the refrigerator when the air around the freezer gets cooler, it contracts, becomes more dense and drops to the bottom of the refrigerator and warmer air takes its place producing convection currents.
2. In coastal areas: During the day, when the sun is shining, the land gets hot more quickly than the sea. As the warmer air rises above the land, cooler air from the sea takes its place, the breeze moves towards the land. During the night, the land cools more quickly than sea. As the warmer air rises above the sea, it is replaced by cooler air from the land.



During the day, the breeze is towards the shore and during the night, the breeze is towards the sea

Domestic hot water system:

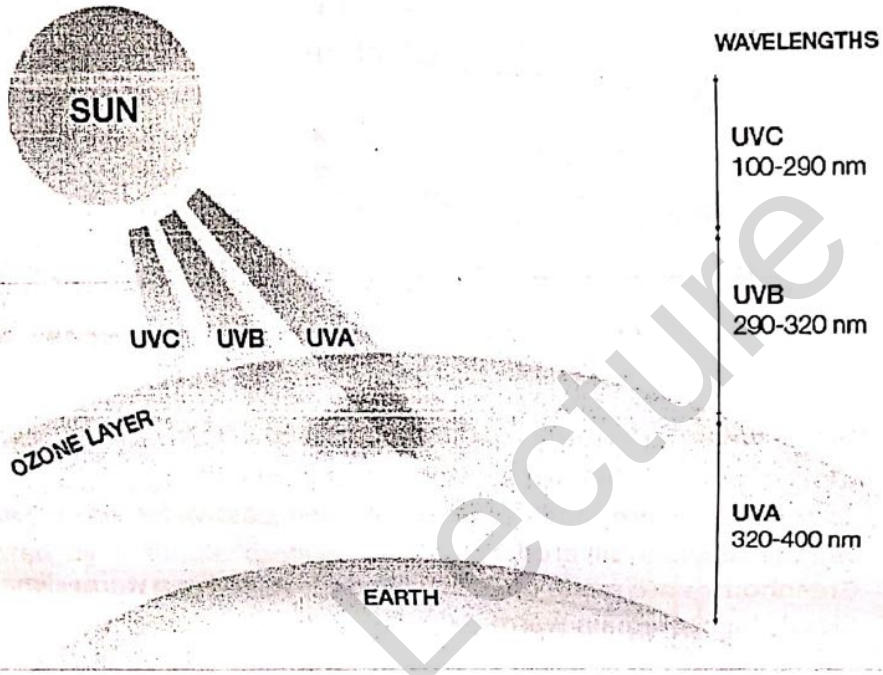
Hot water from the boiler reaches the taps by convection currents.



3. Radiation

Heat can be radiated as a form of electromagnetic energy, these are called infra-red waves. Heat radiations can travel through vacuum, it is the way by which heat reaches the earth from the sun.

All hot objects emit heat radiations in the form of EM waves. The hotter the object, the shorter is the wavelength of the emitted wave and the greater is the amount of radiation energy. When heat radiation falls on an object it is partly reflected, and partly absorbed (the absorbed radiation raises the temperature of the object).



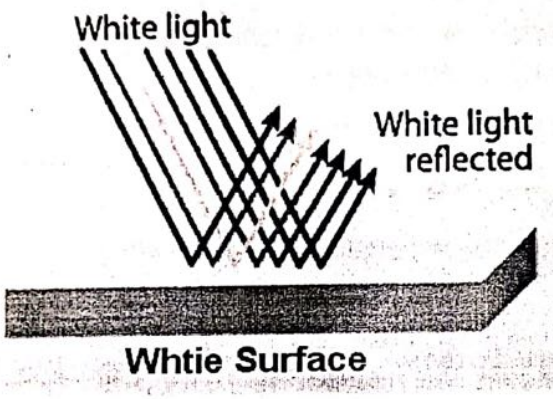
Rediation is the transfer of thermal energy by electromagnetic waves. Conduction and convection require a medium to transfer thermal energy. However radiation dows not required any medium. It can take place ina vacuum.

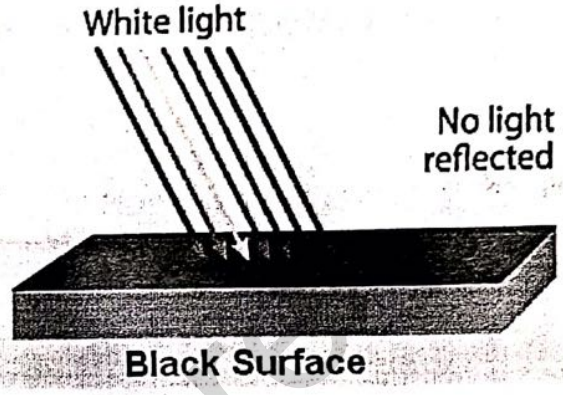
Heat radiations can be detected by:

(a) A thermopile,
(b) A blackened-bulb thermometer.

Properties of Surfaces:

a) The Black rough surfaces are good absorbers and good emitters of heat radiations (they are bad reflectors).
b) The Shiny (& white) surfaces are good reflectors of heat radiations (they are bad absorbers and ad emitters).

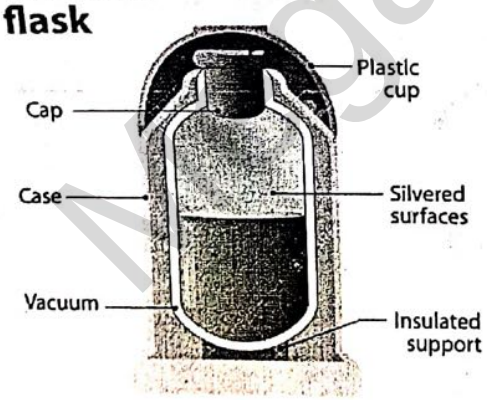


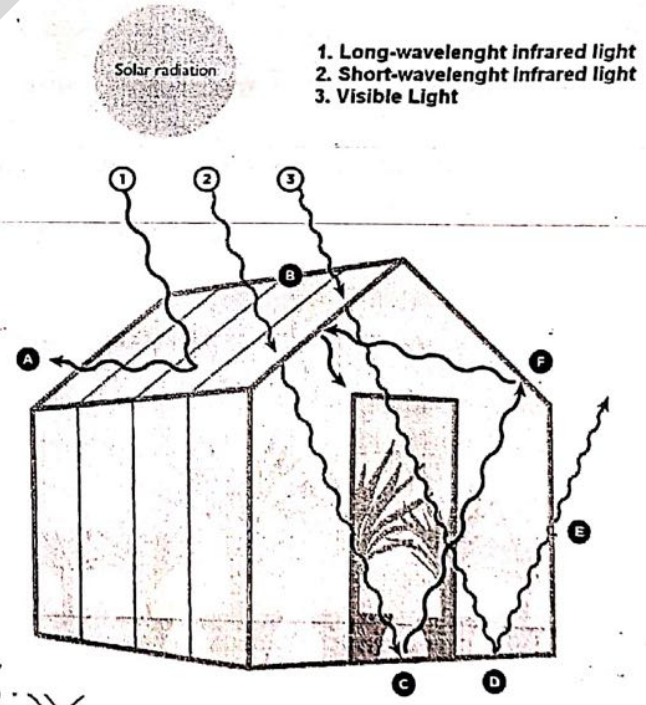


Explain the following Applications:

1) *People wear dark clothes in winter and white clothes in summer.*
2) *Roofs of petrol tanks are painted in shiny aluminum.*
3) *Vacuum flasks are made of double-walled glass vessels with vacuum between the walls and the walls are silvered.*
4) *Greenhouses are made of glass walled rooms to keep warm climate in cold nights.*
5) Cloudy nights remain warm.

Vacuum flask





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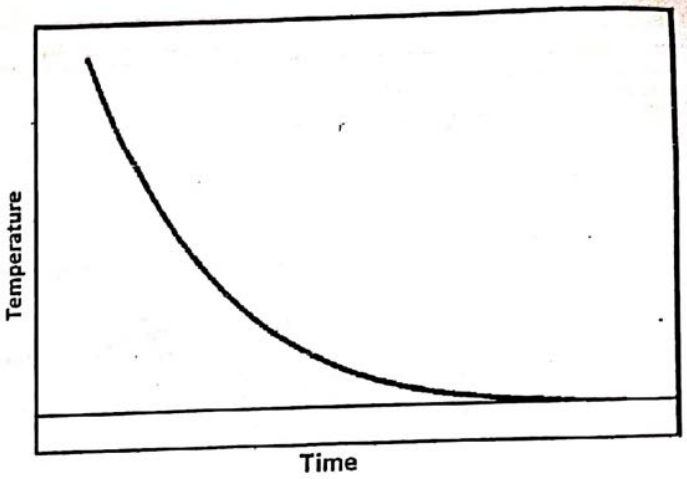
Cooling Curve:

A hot body loses its heat energy gradually to the surroundings. The experiment is done by measuring temp. (using a thermometer) at equal time intervals (using a stopwatch). The temp. decreases until the body reaches the room temperature.

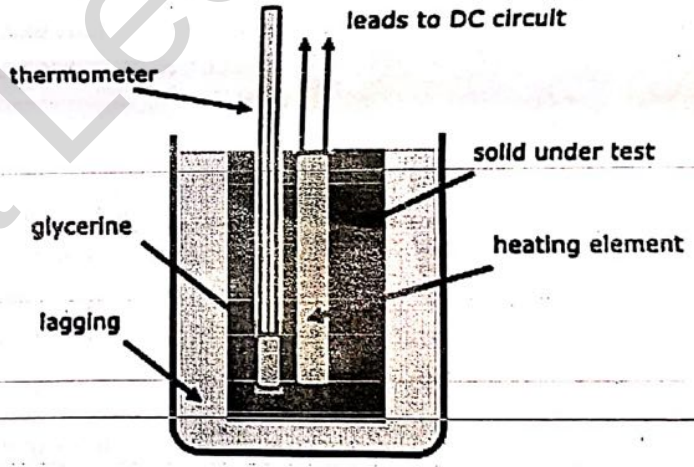


The rate of cooling of a body depends upon:

1. The difference in temperature between the body and surroundings.
2. The exposed area of the body.
3. The nature of the radiating surface (black is a good radiator).

Comparison of lagging materials:

A new material for thermal insulation is to be tested by a simple cooling experiment. Some of the apparatus which is used is shown in Fig. Hot water is contained in two identical small metal cans. One of the cans is lagged with the insulation being tested. Both systems are allowed to lose heat to the atmosphere.



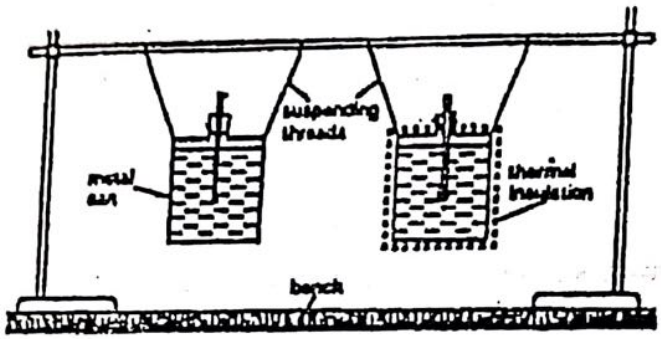
There are several advantages in using small cans for the test.

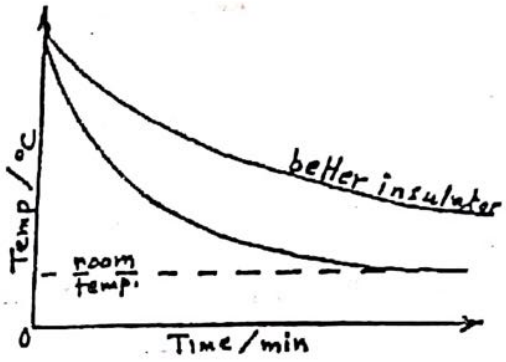
For example:

(i) The cans may be held so that they are not in contact with the bench.
(ii) A small amount of lagging is used.
(iii) A small amount of water is used
(iv) Shorter time is needed.

The apparatus used should include:

(a) Thermometers,
(b) A stopwatch,
(c) Stirrers.





Drawing the cooling curves for the two cans as in Figure shows the material which is a better insulator (which cools slowly).

Heating Precautions:

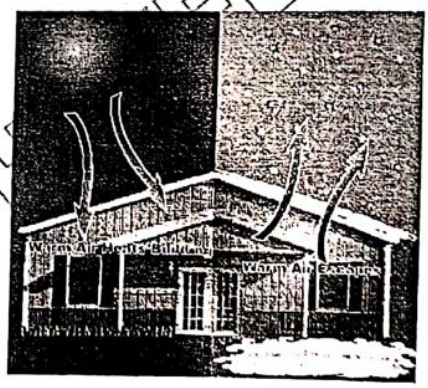
1. When heating a liquid, immerse the heater completely in liquid.
2. Keep the thermometer away from the heater.
3. The liquid should be stirred to distribute the heat evenly.
4. Usually, one can reduce heat loss to surroundings by lagging.
5. When boiling alcohol or benzene, use an electric heater (avoid benzene flame which may cause fire)

Building Insulation

Building Insulation is any object in a building used as insulation for any purpose. While the majority of insulation in buildings is for thermal purposes, the term also applies to acoustic insulation, fire insulation, and impact insulation (e.g. for vibrations caused by industrial applications). Often an insulation material will be chosen for its ability to perform several of these functions at once.

What is Thermal Insulation of Buildings?

In general, people living in hot regions wants to make their inside atmosphere very cool similarly people living in cold regions, wants warmer atmosphere inside. But, we know that the heat transfer takes place from hotter to colder areas. As a result, heat loss happens. To overcome this loss in buildings thermal insulation is provided to maintain required temperature inside the building. The aim of thermal insulation is to minimize the heat transfer between outside and inside of building.



Materials and Methods of Thermal Insulation of Buildings

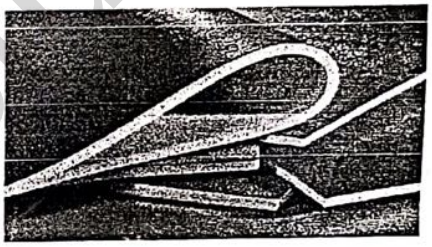
There are many forms of thermal insulation materials are available in the market as follows:

1. Slab or block insulation
2. Blanket insulation
3. Loose fill insulation
4. Bat insulating materials
5. Insulating boards
6. Reflective sheet materials
7. Lightweight materials

1. Slab or Block Insulation

The blocks are made of mineral wool, cork board, cellular glass, and cellular rubber or saw dust etc. These are fixed to the walls and roofs to prevent heat loss and maintains required temperature. These boards are available in 60cmx120cm (or more area) with 2.5cm thickness.

2. Blanket Insulation

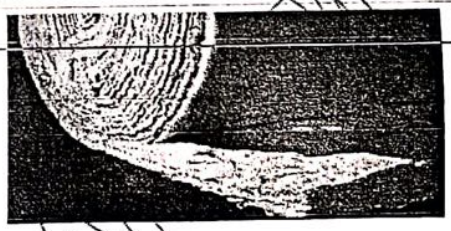


Blanket insulation materials are available in blanket shape or like paper rolls which are directly spread over the wall or ceilings. They are flexible and having a thickness about 12 to 80mm. these blankets are made of animal hair or cotton or wood fibers etc..

3. Loose Fill Insulation

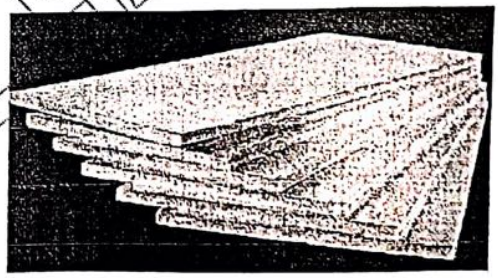
Stud space is provided in wall where windows and doors are to be provided. In that studding space of wall loose fill of some insulating materials is provided. The materials are rock wool, wood fiber wool, cellulose etc.

4. Bat Insulating Materials



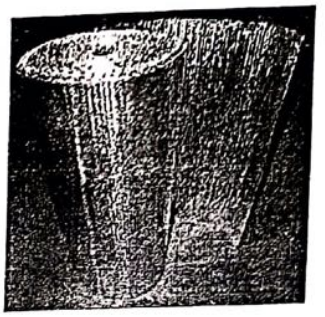
These are also available as blanket rolls but bat insulating rolls are having more thickness than blanket type materials. These are also spreader over the walls or ceilings.

5. Insulating Boards



Insulating boards are made from pulp of wood, cane or other materials. These pulp is pressed hard with some stress at suitable temperature to make it as a solid boards. They are available in many sizes in the market. And these are generally provided for interior lining of walls as well as for partition walls.

6. Reflective Sheet Materials



Reflective sheet materials like aluminum sheets, gypsum boards, steel sheet Materials will have more reflectivity and low emissivity. So, these materials are having high heat resistance. The heat gets reduced when solar energy strike and gets reflected. These are fixed outside of the structure to stop the heat entrance into the building.

7. Lightweight Materials

By using light weight aggregates while preparing concrete mixture will also results good results in heat loss preventions. Concrete will have more heat resistance if it is made of light weight aggregates like blast furnace slag, vermiculite, burnt clay aggregates etc.

Other General Methods of Building Thermal Insulation

Without using any thermal insulating materials as said above we can achieve the thermal insulation from the following methods.

- By providing roof shading
- By proper height of ceiling
- Orientation of building

8. By Providing Roof Shading

By providing roof shading for the building at the place where sun directly strikes the building during peak hours, we can reduce the heat by shading of roof. Accurate angle should be provided for shading to prevent from sun light.

9. By Proper Height of Ceiling

The heat gets absorbed by the ceiling and emitted downwards that is into the building. But, the point should be noted is, the vertical gradient of radiation intensity is not significant beyond 1 to 1.3 m. it means it can travel up to 1 to 1.3 m downward from the ceiling. So, provision of ceiling at 1 to 1.3m height from the height of occupant will reduce some heat loss.

10. Orientation of Building

The building orientation with respect to sun is an important thing. So, the building should be constructed in an orientation in such a way that it shouldn't subject to more heat losses.