VIVEKANAND EDUCATION SOCIETY'S POLYTECHNIC

Study Material

Program Code: Common to all 1st semester

Semester: 1

Course Name: Basic Science (Physics)

Course Code: 22102

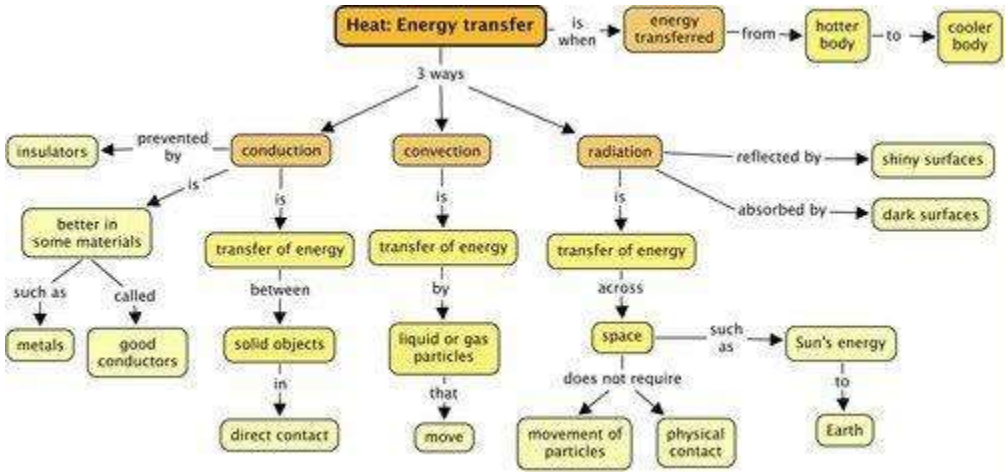
Topic Name: Heat and Optics

UO3b.Describe the properties of given good and bad conductors of heat

LO2: Students will be able to describe the modes of transfer of heat and explain good and bad conductors of heat.

Course Expert: Mrs. Deepa Gupte	**Date: 21/9/2020**

Concept Map:

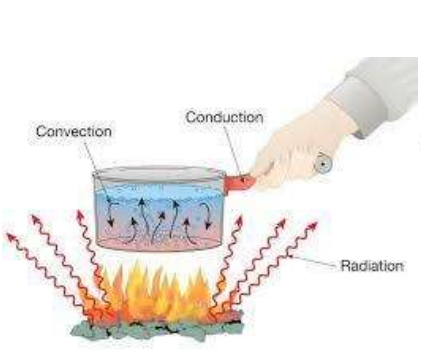


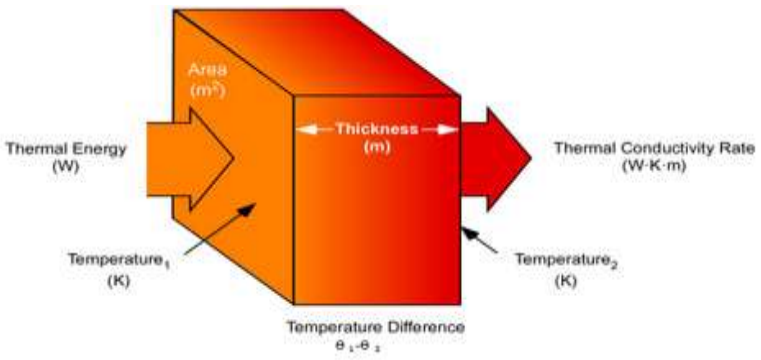
Key words: Conduction, Convection , Radiation

Key Questions: What are different modes of heat transfer?

Key Definition/Formula: Conduction, Convection, Radiation, coefficient of thermal conductivity

Diagram /Picture:





Notes:

Heat Transfer: Heat is transferred from one body to another or from one part of a body to another part, arising due to temperature difference. What are the different ways by which this energy transfer takes place? There are three distinct modes of heat transfer: conduction, convection and radiation

Conduction: Conduction is a process of transfer of heat from a part of body at higher temperature to a part of body at lower temperature without bodily (actual) movement of particles. It takes place through solids. Most metals are good conductors i.e they easily transmit heat energy by conduction. Bad conductors are called insulators i.e they do not easily transmit heat by conduction e.g. wool, wood, most liquids and gases

Applications of conduction:

Some of the everyday applications of conduction are as follows:

- If a frying pan is placed onto a stovetop, the pan becomes very hot due to the conduction of heat from the burner to the pan. When the handle of the pan is touched after it has been on for several minutes, the handle is hot, too. This is because heat was conducted through the portion of the pan in contact with the stovetop all throughout the rest of the pan.
- The thermometer is used to measure the temperature of the body when a person is having fever. It is because the metal tip of the thermometer transfers the body heat to the mercury at the tip of the thermometer, noting down the temperature.
- When it's too hot, taking a cold shower transfers the heat of the body to the cold water, cooling the body down. The same applies when fan is used as air reduces the hotness of the body instead of water.

Convection:

It is process of transfer of heat from part of boy at higher temperature to part of body at lower temperature with bodily (actual) movement of particles. It takes place only in fluids, i.e., in case of liquids and gases.

When a fluid is heated, the hot part of fluid below expands and becomes lighter and because of buoyancy, it rises up and replaces the upper colder part of fluid. This again gets heated, rises up and is replaced by the colder part of the fluid. The process goes on and is known as free or natural convention. Convection involves bulk transport of different parts of the fluid. In forced convection, material is forced to move by a pump orby some other physical means. The common examples of forced convection systems are forced-air heating systems in home, the human circulatory system, and the cooling system of an automobile engine.

Application of convection:

Some of the daily applications of convention are:

- **Heat Radiator:** The hot radiator sets up convection currents that transfer thermal energy to the rest of the room and eventually heat the entire room. The hot radiator warms the air that is closest to the radiator. The warm air expands, becomes lighter and rises to the top of the room and then it is pushed sideways towards the wall by the more recently warmed air rising from the radiator below. In this way warm air moves to the other side of the room and cools down little bit and the warmer air behind it continues to push on it. The air then continues to circulate back to the radiator and the process repeats. Thus in this way the entire room gets heat.
- **Domestic heating system:** With a convection circulation system set up, the hot water storage tank gradually becomes filled with hot water from the top downwards. When hot water is run off, an equal volume from the cold supply tank enters the hot storage tank at the bottom. The whole system is thus kept constantly full of water and no air can enter.
- **Formation of clouds and trade winds:** Convection currents in the atmosphere and in the oceans are responsible for most meteorological changes. Clouds are formed when convection currents over the earth's surface carry warm, moist ai upwards, where it expands and cools. Trade Winds are formed when hot air over the equator rises and colder air flows and takes its place.
- **Land and sea breezes:** The air above the respective land and sea is warmed or cooled by conduction with those surfaces. During the day, the warm land temperature results in less dense and lighter air above the coast as compared with the air over the surface of sea. As the warm air rises by convection, cool air is drawn from the ocean to fill the vacuum created by warm air on land. The warm air returns to sea at higher levels to complete convection current. Accordingly, during the day, there is usually a cooling sea breeze blowing from the ocean to the shore. After sunset, the air above the coastal land quickly loses heat while the air above the sea generally

remains much closer to it's daytime temperature. When the air above the land becomes cooler than the air over sea, the wind direction and convection currents reverse and the land breeze blows from land to sea. The greater the temperature differences between land and sea, the stronger the land breezes and sea breezes.

Radiation:

It is the process of transfer of heat in which heat is transferred from one place to another directly without the necessity of intervening medium e.g. heat from sun without affecting the intervening medium. Heat radiations can pass through vacuum, it is electromagnetic radiation emitted from the surface of a body by virtue of its temperature. The radiation by a red hot iron, radiator or electric heater and light emitted by a glowing incandescent light bulb is an example of heat radiation. When this thermal radiation falls on other bodies, it is partly reflected and partly absorbed. The amount of heat that a body can absorb by radiation depends on the colour of the body. We find that black bodies absorb and emit radiant energy better than bodies of lighter colour.

Application of radiation:

The fact that the amount of heat absorbed or emitted by a body depends on the colour of the body, finds many applications in our daily life. Some of the applications are:

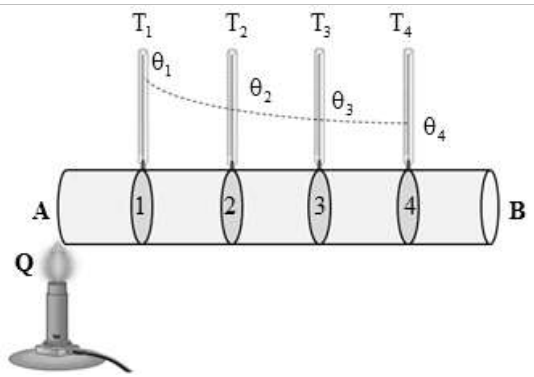
- **Summer and winter clothes:** We wear white or light coloured clothes in summer so that they absorb the least heat from the sun. However, during winter, we use dark coloured clothes which absorb heat from the sun and keep our body warm.
- **Blackened bottom utensils:** The bottoms of the utensils for cooking food are blackened so that they absorb maximum heat from the fire and give it to the vegetables to be cooked.
- **Thermos flask or bottle:** A thermos flask or bottle consists of a double-walled glass vessel with the inner and outer walls coated with silver. Radiation from the inner wall is reflected back into the bottle. The outer wall similarly reflects back any incoming radiation. The space between the walls is evacuated to reduce conduction and convection losses and the opening of the flask is an insulator like cork. Thus thermos flask or bottle is, therefore, used to preserve the hot contents (like milk) from getting cold, or alternatively to store cold contents (like ice).
- **Bonfire or electric lamp:** When we hold our hand above an open fire or an electric lamp, even though without touching them we feel warm, it is because the heat which reaches us is due to radiation. When we face the flames we feel the warmth of the fire on our faces due to the radiation, even when we are too far away.
- **Greenhouses:** In a greenhouse the solar radiation passes through a clear material such as glass or plastic. The sunlight heats the air and soil inside of the greenhouse, and the plants can also catch the radiation. The walls of the greenhouse keep the warm air inside from mixing with the cooler outside air. Greenhouses ensure that crops can be grown even when temperatures outside of the glasshouse might be cool.
- **Plant Growth:** Plants need to absorb energy from the sun in the form of solar radiation in order to grow (photosynthesis). Leaves of the plant absorbs maximum amount of radiation, and plants have a specific shape or structure in order to ensure the maximum absorption of sunlight. Some plants have the biological ability to change direction based upon the direction of the sun, the flower capable of this is the common sunflower.

Conduction of heat along a bar (metal rod) in steady state:

Consider a metal rod AB in which equidistant holes are drilled & thermometers T1, T2, T3 & T4 are inserted in it, before heating, all thermometers show same temperature

Now end A of rod is heated, compartment '1' is the first receiver of heat. Let us assume that 'Q' is the amount of heat absorbed by '1' and its temperature increases. Out of that heat 'Q', some amount of heat is given to the surrounding by way of radiation & convection and remaining heat is given (conducted) to the next compartment '2'. Therefore its temperature 2 □ also increase but will be less than 1 □ . As time for which heat provided increase, temperature, shown by all thermometers goes on increasing. This state is called variable state.

Variable state is the period during which temperature shown by all thermometers goes on increasing.



After some time a stage is reached as shown in Fig. above, where temperature in all the thermometers remains constant i.e. temperature will not increase further, this state is called **steady state**. In this steady state, heat absorbed by material is equal to heat given out. Thus in this state whatever heat is gaining is given to the surrounding & to next element without any absorption. In steady state, temperature remains constant but because of loss of heat due to radiation & convection, temperature shown by thermometers goes on decreasing from T1 to T4 But if this loss of heat due to radiation is avoided by covering rod using bad conducting material, then temperature shown by all thermometers will be nearly same.

Thermal conductivity and coefficient of thermal conductivity:

Consider a metal rod AB having area of cross-section (A) at steady state temperature such that no heat is lost to the surroundings by means of radiation.

As shown in Fig. Consider two planes C and D in the metal rod.

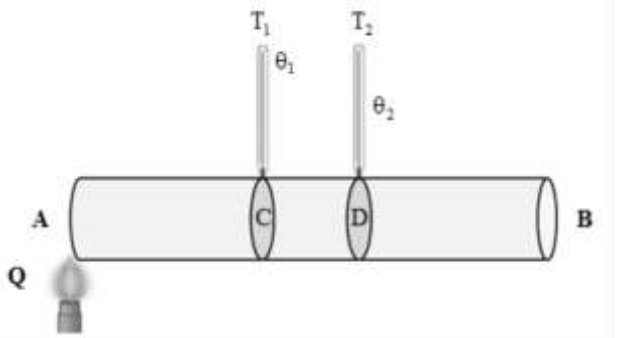
Let, Q = the amount of heat flowing from plane C to plane D.

t = time for which the heat flows from plane C to plane D.

d = distance between planes C and D or distance between two thermometers.

θ_1 = temperature of plane C and θ_2 = temperature of plane D.

Then, amount of heat (Q) flowing from plane C to plane D is directly proportional to cross-sectional area (A) of rod, temperature difference ($\theta_1 - \theta_2$) between two planes, time (t) for which heat flows and inversely proportional to distance (d) between two planes or distance between two thermometers.



Thus, $Q \propto KA(\theta_1 - \theta_2)t / d$

Where K is called coefficient of thermal conductivity

The value of K depends on the material of a metal rod. The above equation determines the amount of heat flowing or absorbed by the body and the factor $(\theta_1 - \theta_2)/d$ is called temperature gradient.

Temperature Gradient:

The temperature gradient is defined as change in temperature per unit length of rod. The expression for temperature gradient for length of wire having distance or length (d) and the temperature difference theta1- theta2 across the end of conductor is given as $(\theta_1 - \theta_2)/d$

Coefficient of thermal conductivity:

If d=1,A=1, $\theta_1 - \theta_2 = 1$, t=1 then K =Q

The **coefficient of thermal conductivity (K)** of material is defined as amount of heat conducted in one second in steady state of temperature through unit cross-sectional area of an element of material of unit thickness with unit temperature difference between in opposite faces

Link to YouTube/ OER/ video/e-book:
https://nptel.ac.in/content/storage2/courses/105107122/modules/module2/lesson1.htm

Key Take away: Conduction, Convection Radiation, Coefficient Of Thermal Conductivity

Formative Assessments

<22102>: < Common to all 1st semester>: <Common to all>: <Heat and Optics>: <UO3b: Describe the properties of given good and bad conductors of heat>: <Assessments>: <Formative>

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Assessment Type: Formative Assessments:

Set 1: Question No 1	Set 1: Question No 2	Set 1: Question No 3
_____ is the process of transfer of heat in which heat is transferred from one place to other directly without the necessity of intervening medium	A cold steel spoon is dipped in a cup of hot milk. It transfers heat to its other end by the process of_____	Formation of clouds and trade winds works on the principle of _____
a) conduction	a) conduction	a) conduction
b) convection	b) convection	b) convection
c) radiation	c) radiation	c) radiation
d) transmission	d) All of the above	d) transmission
Ans: <c>	Ans: <a>	Ans: <b>

Set 2: Question No 1	Set 2: Question No 2	Set 2: Question No 3
SI unit for K is	Which one among the following statements about thermal conductivity is correct?	A metal rod of length 0.20 m has one of its ends at 20 °C while the other is at 50 °C. Find the temperature gradient?
a) cal/m°C-sec	a) Steel >Wood >Water	a) 100 °C/m
b) kcal/m°C-sec	b) Steel >Water >Wood	b) 150 °C/m.
c) W/m°K	c) Wood > Steel > Water	c) 20 °C/m
d) All of the above	d) Water >Wood >Steel	d) 50 °C/m
Ans: <c>	Ans: <b>	Ans: <b>

Practice Worksheet

<22102> : <Common to all 1st Semester> : < Common to all 1st Semester>: <Heat and optics>: <UO1b> : <Assessments> : <Worksheet>

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Assessment Type: Practice Worksheets:

A) MKS unit for K is a. cal/m°C-sec b. kcal/m°C-sec c. W/m°K d. All of the above	B) A metal rod of length 0.20 m has one of its ends at 20 °C while the other is at 50 °C. Find the temperature gradient? a. 100 °C/m b. 150 °C/m. c. 20 °C/m d. 50 °C/m
Ans A: b	Ans B: b
C) Temperature of water in a breaker is 40 °C. Its value in Fahrenheit_____ a. 127°F b. 212°F c. 273°F d. 373°F	D) Scale which is divided into equal 180 parts between the freezing point and boiling point and each division is called_____ a. degree Celsius b. degree Fahrenheit c. degree Kelvin d. degree Absolute
Ans C: b	Ans D: b
E) If the thickness of the material through which heat is transferred is increased by a factor of 2, then the rate of heat transfer is_Temperature of water in a breaker is 40 °C. Its value in Fahrenheit scale is a. increased by a factor of 4 b. decreased by a factor of 4 c. increased by a factor of 2 d. decreased by a factor of 2	F) A window pane is 100 cm X 30 cm. Its thickness is 3 mm. If the difference between inside & outside temperature is 50K, calculate the amount of heat conducted in 1 hour. K for glass = 1 W/ m°K. a. 10×106 J b. 15×106 J c. 18×106 J d. 20×106 J
Ans E: d	Ans F: c
G) A cooking pot is coated black at the outer surface because - a. black substances absorb more heat b. black substances reflect more heat c. black surfaces are easier to clean d. the material of the pot would not be damaged	H) A cube of ice placed into the hand melts due to _____ a. Conduction b. convection c. radiation d. transmission
Ans G: a	Ans H: a
I) The car hood becomes warm when engine of car is turned on. In this example which process of heat transfer takes place? a. Conduction b. convection c. radiation d. transmission	J) Solids are not heated by convection because _____ a. solid are not free to move from one place to another b. molecules only vibrate about fixed position c. Both (A) and (B) d. None of the above
Ans I: a	Ans J: c