Notes for Class 9th

Physics

Chapter 9

NAME: _____

F.NAME: _____

CLASS:_____ SECTION: _____

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TRANSFER OF HEAT
COMPREHENSIVE QUESTIONS

Q1. Explain conduction of heat and its mechanism. Describe its practical applications.

Ans: - Conduction of Heat:

The process by which heat energy is transferred from particle to particle by collision is called conduction of heat.

Mechanism of Heat Conduction:

The mechanism of heat conduction can be explained by the behavior of atoms within the material.

There are two ways by which heat is transferred

(i) Vibration of atoms in the metals

(ii) Motion of free electrons present in the metals.

Vibration of atoms in the metals:

A metal rod consists of large number of closely packed atoms. These atoms vibrate about their mean position inside the material.

Now if we supply heat to the one end of the rod, then due to this heat the vibration of atoms increases as a result the kinetic energy and amplitude of vibration of atoms increases. These atoms collide with their neighbor atoms and transfer their heat to the neighboring atoms. In this way, heat is transferred from one end of the metal rod to the other end easily. Such type of heat transfer is known as conduction of heat.

Motion of Free Electrons in the Metals:

The metals also consist of large number of free electrons. These free electrons play an important role in the transfer of heat from one point to another by conduction.

Example:

When one end of the metal rod is heated, the atoms in the heated part vibrate more with greater speeds. The free electrons that collide with these atoms gain kinetic energy and move faster. They diffuse into the colder part of the metal where collisions with other free electrons and atoms occur which result in the transfer of energy. In this way heat is transferred from one location to another location such type of heat transfer is known as conduction of heat.

Practical applications of Heat Conduction:

i. **Cooking pots and pans:** cooking pots and pans are made of metals which are good thermal conductors. They conduct heat readily to the food inside and to spread it evenly.

ii. **Plastic Foam:** Plastic foam and fiberglass (plastic material containing glass fiber) are good insulators because they contain tiny pockets of trapped air. These materials are used in the walls and ceilings of our homes to keep them cool in summer and warm in winter season.

iii. **Wire Gauze:** Wire gauze is often placed over a flame to conduct heat outwards from flame. A glass beaker can safely be heated on the gauze because this protects it from the concentrated heat of the flame.

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iv. **Pot Holders and Table Mats:** Pot holders and table mats for hot pans are made of poor conductors such as clothes and wood. The uses of poor conductors avoid burning of hands and table top.

v. **Woolen Clothes:** Woolen clothes have fine pores filled with air. Air and wood are bad conductors of heat. Thus the heat from our body does not flow out and our body remains warm in winter.

vi. **Igloos:** Igloos type of shelter (house or hut) built of snow. Igloos are constructed from ice and snow to provide protection from wintery conditions. One reason that igloos do their job so well is that the ice and snow act as a thermal insulation and minimize the loss of heat from the inside due to conduction.

vii. **Ice box:** Ice box has a double wall made of tin or iron. The space between the two walls is filled with cork which is the poor conductor of heat.

The cork prevents the flow of outside heat into the box, thus keeping the ice from melting.

viii. **Soldering:** During soldering objects are in direct contact, such as the soldering iron and the circuit board, heat is transferred by conduction

Q2. Explain thermal conductivity of a substance and its mathematical description.

Ans: - Thermal Conductivity: -

The thermal conductivity of a substance is a measure of the ability of the substance to conduct heat energy.

Explanation: -

Consider a rod of length "L" having area of cross section 'A' and let "ΔT" be the temperature difference.

Now the amount of heat 'Q' that flows across the rod depends upon the following factors.

i. **Temperature Difference:**

The amount of heat 'Q' flows is directly proportional to the temperature difference "ΔT".

i.e. $Q \alpha \Delta T$ …….. eq (1)

ii. **Area of Cross-Section:**

The amount of heat 'Q' flows is directly proportional to the cross-sectional area 'A 'of the rod

i.e. $Q \alpha A$ ……. eq (2)

iii. **Time Interval: -**

The amount of heat 'Q' flows is directly proportional to the time interval 't'

i.e. $Q \alpha t$ …….. eq (3)

iv. **Thickness/Length: -**

The amount of heat 'Q' flows is inversely proportional to the length 'L' of the rod.

i.e. $Q \alpha \frac{1}{L}$ …….. eq (4)

By combining equations (1), (2), (3) and (4), we get

$$Q \alpha \frac{\Delta T A t}{L}$$

$$Q \alpha \frac{A t \Delta t}{L}$$

$$Q \alpha \frac{A t (T_1 - T_2)}{L} \qquad (\therefore \Delta T = T_1 - T_2)$$

$$Q = \frac{kAt(T_1 - T_2)}{L} \quad \text{…….. eq (5)}$$

Where "k" is the constant of proportionality and is known as thermal conductivity of the substance. Its value depends upon the nature of the material. Such that

$$k = \frac{Q.L}{At(T_1 - T_2)}$$

Special Case: -

If L = 1m, A = $1m^2$, $T_1 - T_2 = 1^{\circ}C$ or 1 K and t =1s, then equation (5) becomes

$$Q = k$$

Thus the thermal conductivity 'k' of a substance is defined as "The quantity of heat which flows through one square meter of area of the substance in one second when a temperature difference of one Kelvin is maintained across a thickness of one meter.

Unit: - The S.I unit of thermal conductivity is $JK^{-1}m^{-1}s^{-1}$.

Since Js^{-1} is equal to watt

i.e. Js^{-1} = watt

The thermal conductivity is also express in unit $\mathbf{WK^{-1}m^{-1}}$.

Q3. Explain convection of heat and its mechanism. Explain its practical applications.

Ans. Convection of Heat: -

The transfer of heat from one place to another by the actual motion of the heated particles is called convection of heat.

Mechanism of Heat Convection: -

The mechanism of convection of heat can be explained by the behavior of the medium between the hot and cold objects. Convection occurs only in fluids (liquid and gases). Convection cannot occur in solids as the atoms in a solid are located in fixed positions and cannot change place.

Let us examine the heating of water in a beaker by the process of heat-convection.

The heated portion of water at the bottom of the beaker expands and becomes less dense. Being less dense, the warm water moves upward. It is replaced by the cold and dense water around it. The cold water flowing to the point of heating in its turn absorbs heat energy, expands and is pushed upward. Thus a continuous circulatory flow is established from the bottom to the top of the water in the beaker.

Practical Applications of Heat Convection: -

i. **Heating Water:**

If it were not for convection currents, it will be very difficult to boil water. The lower layers of water in an electric kettle are warmed first. This heated water expands and move upward to the top because its density is lowered. Meanwhile dense cool water replaces the warm water at the bottom of the kettle so that it can also be heated.

ii. **Sea Breeze:**

Convection causes coastal breeze. During the day the land heats up more quickly than the sea. The hot air over the land rises and the cold air from the sea blows to replace it. Thus there is a sea breeze during the day. At night, the reverse happens. The land cools more quickly than the sea.

The hot air over the sea rises and the cold air from the land blows to replace it. This movement of air is called the land breeze.

iii. Riding on Thermals:

Thermals are streams of hot air rising in the sun. They are convection currents. Birds are able to fly for hours on thermals without flapping their wings. Similarly, glider airplanes are able to rise by riding on the thermals.

iv. Refrigerator:

In a refrigerator, convection is used to circulate cold air around the food. Air is cooled by the freezer compartment the top of the refrigerator. As it sinks, it is replaced by warmer air rising from the below. The circulating air carries heat energy away from all the food in the fridge.

v. Ventilation:

Convection currents are used in ventilation classrooms or rooms in houses have ventilators installed near the ceiling. The warm and stale air inside the room rises and escapes through the openings near the ceiling. Fresh and cold air is drawn into the room through the doors and windows. Similarly, smoke and hot gas from the fires in houses and factories rise up and escape through the chimneys.

Q4. Explain radiation of heat and its mechanism. Describes any three of its practical applications.

Ans: Radiation of heat: -

The heat transfers from a hotter place to a colder place with or without having material medium in between is called radiation of heat.

Mechanism of Radiation of heat: -

The mechanism of radiation is energy transfer by electromagnetic waves. Electromagnetic radiation comes from accelerating electric charges. Unlike conduction and convection transfer of heat by radiation, does not necessarily require a material medium. Heat energy transferred through radiation is as familiar as the light; in fact, it is the light but not visible or barely visible. Electromagnetic waves can transfer energy via vacuum or empty space as well as via a material medium like glass.

Every object around us is continually radiating, unless its temperature is at absolute zero (0) K.

Example:

A scoop of ice cream has temperature of about 237K, therefore it radiates. Even we radiate all the time, but that radiation isn't visible as light because it's in the infrared part of spectrum.

Practical application of radiation of heat:

(i). Colouring materials: -

The cooling fins on the heat exchanger at the back of a refrigerator are painted black so that they lose heat more quickly. By contrast, saucepans that are polished are poor emitters and keep their heat longer. In general, surfaces that are good absorbers of radiation are good emitters when hot.

(ii). Texture of the surface: -

One type of radiant barrier material, ARMA foil, produced by Energy Efficient solutions.

(iii). Satellite Protective coating: -

The highly reflective metal foil covering the satellite minimizes the temperature changes.

(iv). Thermos flask: -

The vessel which is used to prevent heat transfer due to conduction, convection and radiation is called thermos flask.

It consists of a double-walled glass vessel silvered on the inside. The purpose of the silvering is to reflect all radiant heat trying to enter or leave the vessel. The space between the walls is highly evacuated to prevent convection. The glass, being a poor conductor minimizes conduction of heat.

The heat loss through the flask is so small that a hot liquid placed in the flask will remain hot for a very long time. A cold thing placed in the flask will remain cold for a long time because flow of heat from the outside will also be very small.

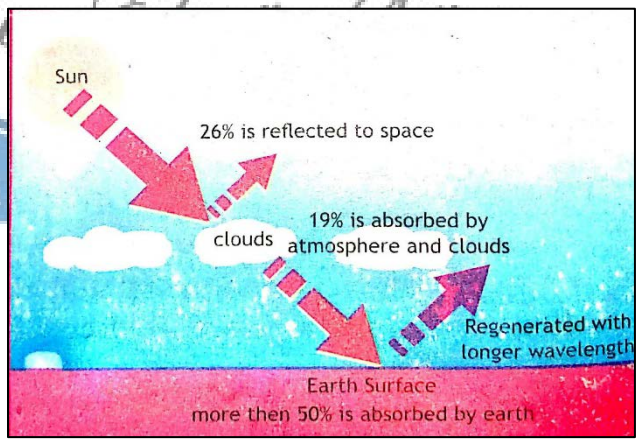
Q5. Discuss the greenhouse effect. Explain its importance and global warming concern.

Ans: Greenhouse Effect:

The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.

Mechanism of Greenhouse Effect:

Earth receives energy from the sun in the form of ultraviolet, visible and near infrared radiation. Of the total amount of solar energy available at the top of the atmosphere, about 26% reflected to space by the atmosphere and clouds and 19% is absorbed by the atmosphere and clouds. More than 50% of the remaining energy or short wavelengths radiations from the sun are absorbed at the surface of earth.



Because the earth's surface is colder than the photosphere of the sun, it radiates at wavelength that are much longer than the wavelengths that were absorbed. Most of this thermal radiation is absorbed by the atmosphere, thereby warming it. In addition to the absorption of solar and thermal radiation, the atmosphere gains heat by latent heat fluxes from the surface.

The atmosphere radiates energy both upwards and downwards, the part radiated downwards is absorbed by the surface of earth. This leads to higher the temperature of earth.

Importance of Greenhouse Effect:

Greenhouse effect is important for the survival of life on earth. Earth atmosphere containing naturally occurring greenhouse gases (water vapour, CO_2, CH_4, and O_3) causes air temperature near the surface to be about 33°C warmer. Without the Earth's atmosphere, the Earth's average temperature would be well below the freezing temperature of water.

Concerns of Global Warming:

Human activity has increased the amount of greenhouse gases in the atmosphere leading to the global warming (increase in the temperature of earth). Due to human activities in the period from 1880 to 2012, the global average temperature has increased by 0.85°C.

The largest human influence has been the emission of carbon dioxide from factories and motor vehicles. Currently, about half of the carbon dioxide released from burning of fossil fuels is not absorbed by the vegetation and the oceans and remains in the atmosphere.

Now in order to decrease global warming we have to reduce the emission of greenhouse gases and to plant more vegetation to absorb the produced carbon dioxide.

IMPORTANT TOPIC WISE QUESTIONS

Q6: What are good and bad conductors?

Ans: Good Conductor:

Some materials allow heat to pass through them easily. They are called heat conductor or good conductors.

Examples:

Metals such as silver, iron, copper and aluminum etc. are the best heat conductors.

Bad Conductor or Insulator:

Some materials do not allow heat to pass through them easily. They are called heat insulator or bad conductor.

Examples: Wood, rubber, plastic, paper etc.

Q7. Discuss the conduction of heat in solids, liquids and gases?

Ans: Conduction in solids:

The metallic solid contains closely packed atoms and free electrons. These atoms and free electrons play an important role in the conduction of heat from one location to another. Thus the metallic solids are good thermal conductors. Non-metallic solids like plastic, wood glass etc. are poor conductors of heat because they do not have free electrons.

Conduction in liquids:

In liquids the inter-molecular distance is larger as compare to solids. Thus the rate of conductive collision in liquids is smaller than that of metallic solids. Thus the liquids are poor conductor of heat. So water is a poor conductor of heat.

Conduction in gases:

In gases the separation between particles is very large. Thus the rate of conductive collision in gases is very smaller as compare to solids and liquids. Thus the gases are the poorest conductor of heat. The conductivity of air is twenty times smaller than that of water. Many materials such as, wood, cloth, fiberglass and plastic foam etc. are poor conductors because they contain tiny packets of trapped air.

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Q8. What are good and bad absorbers?

Ans: Good Absorber (good radiator):

The body which absorbs all radiation or maximum radiation fall upon it is called good absorber.

Example:

i. A dull black kettle absorbs heat better than a silver kettle.

ii. Standing in the sun, a black car warms up more quickly than any other.

iii. Black or dark coloured clothes are worn in cold climates, because black or dark colour is good absorber.

A perfectly black body absorbs all radiations falling on it. It does not reflect any radiation striking it.

Bad Absorber (poor radiator):

The body which absorbs minimum radiation and reflects maximum radiation falling upon it is known as bad absorber.

Example:

i. Silver mirror like surface are poor absorber, which reflect almost all the radiations falling on it.

ii. White clothes are worn in hot climates because white is a good reflector and a poor absorber.

CONCEPTUAL QUESTIONS:

Q1. Why white clothes are preferred wearing in summer? Explain briefly.

The white and light coloured clothes are most suitable in summer because they reflect maximum sun radiation and absorb minimum sun radiation and thus keep our body cool. That's why we feel comfort by wearing white clothes in summer.

Q2. Why is the freezer compartment kept at the top of a refrigerator? Explain briefly.

The freezer compartment kept at the top of a refrigerator, because it cools the surrounding air and makes it denser as compare to the air at the bottom. Convectional currents are used to circulate cold air in a refrigerator. The cool denser air moves down while the warmer air at the bottom moves up, where it is cooled. That is why, the freezer compartment is kept at the top of a refrigerator.

Q3. A black car standing in the sun warms up more quickly than any other. Why?

A black car standing in the sun warms up more quickly than any other car because the black surface is a good absorber of heat radiations than any other surface.

Q4. Why a tile floor feels colder to bare feet than a carpeted floor?

A carpet is a bad conductor of heat as compared to tile floor. When bare feet are put on the tile floor more heat is lost by the feet which is absorbed by the tile floor and as a result we feel cool. If we put the feet on a carpeted floor, we feel less coldness because in this case our feet losses no heat or very less amount of heat to the carpet. That is why a tile floor feels colder to bare feet than a carpeted floor.

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Q5. How woolen sweaters keep us warmer in winter?

Woolen sweaters have fine pores filled with air. Air and wool are bad conductors of heat. Thus heat from our body does not flow out to atmosphere. Thus woolen sweaters keep our body warm in winter.

Q6. In certain places, birds can fly for hours without flapping their wings, Explain.

In certain places, there are streams of hot air which are arising from the sun such streams of hot air is known as thermals. Thermals are convection currents. The birds can fly for hours on thermals without flapping their wings. And this phenomenon occurs due to the convection of heat.

Q7. Good quality thermos bottle is double walled and evacuated between these walls, and the internal surfaces are like mirrors with a silver coating. How does this configuration combat heat loss for all three transfer methods and keep the bottle's contents your coffee hot?

Ans:-A thermos bottle consists of a double walled glass vessel silvered on the inside. The silvered surface reflects all the radiant heat trying to enter or leave the vessel by radiation. The space between the walls is highly evacuated to prevent convection. The glass being a poor conductor minimizes the conduction of heat. That is why a liquid placed in the thermos bottle will remain hot for a long time.

Q8. A piece of wood lying in the sun absorbs more heat than a piece of shiny metal. Yet the metal feels hotter than the wood when you pick it up. Explain.

Ans:-A material with high thermal conductivity will transfer heat at a much faster rate than a body with lower thermal conductivity. So, the metal has a high thermal conductivity and the wood has a low thermal conductivity. Even though the piece of wood lying in the sun absorbs more heat than a piece of shiny metal, but on touching the metal feels hotter than the wood. This is because the heat flows from metal to our hand more quickly due to its high thermal conductivity. On the other hand, wood is bad conductor of heat. When it is touched, heat flows slowly to our hand. So the metal feels hotter than the wood due to the difference of their thermal conductivities.

Q9. Some pot handles remain cool during cooking while others become unpleasantly hot. What determine which handles remain cool and which become hot?

Ans:-The thermal conductivity of the material of handles determines which handle remain cool and which become hot. When a pot handle is made of material which has high value of thermal conductivity such as metal, then it becomes hot quickly.

On the other hand, if the pot handle is made of material which has low thermal conductivity such as wood, then it does not get hot. Thus the handle of good conductors becomes hot and the handles of bad conductors remain cool.

Q10. When sunlight warms the land beside a cool body of water, a breeze begins to blow from the water towards the land. Explain.

Ans: Convection causes coastal breeze. During the day the sun shines equally on land and sea. The land heats up more quickly than the sea. The hot air over the land rises and the cold air from the sea blows to replace it. Thus there is a sea breeze during the day time.

ASSIGNMENT

9.1). Find the amount of heat transferred in one hour through a concrete wall of area 6.9m^2 and 0.20m thick. One side of the wall is held at 20^{o}C and the other side is at 5^{o}C. The thermal conductivity of concrete is 1.3JK^{-1}m^{-1}s^{-1}.

Data:

Area of concrete wall = A = 6.9m^2

Thickness off concrete wall = L = 0.20m

Temperature of one side of wall = $T_h = 20^0C$

Temperature of other side of wall = $T_c = 5^0C$

Thermal conductivity of concrete wall = k = 1.3JK^{-1}m^{-1}s^{-1}

Time taken = t = 1hour

$= 1 \times 60 min$

$= 1 \times 60 \times 60\ sec$

= 3600sec

Find:

The amount of heat transferred through a concrete wall = Q = ?

Solution: -

By using formula

$$\mathbf{Q = \frac{kAt\ T_h - T_c}{L}}$$

putting Values

$$Q = \frac{(1.3)(6.9(3600)(20-5)}{0.20}$$

$$Q = \frac{(1.3)(6.9(3600)(15)}{0.20}$$

$$Q = \frac{484380}{0.20}$$

Q = 2421900 J

Q = 2.4 × 10^6 J

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NUMERICAL QUESTIONS

1. A person's body is covered with 1.6m^2 of wool clothing. The thickness of the wool is 2.0× 10^{-3} m. The temperature at the outside surface wool is 11^{0}C, and the skin temperature is 36^{0}C. How much heat per second does the person lose due to conduction? Thermal conductivity of wool is k = 0.04 Wm^{-1}K^{-1}.

Data: -

Area = A = 1.6m^2

Thickness = L = 2.0×10^{-3}m

Inside Temperature = T_h = 36^{0}C

Outside temperature = T_c = 11^{0}C

Temperature difference = $T_h - T_c$ = (36-11)^{0}C

= 25^{0}C

Thermal conductivity of wool = k = 0.04 Wm^{-1}K^{-1}

Find:

Rate of flow of heat = $\frac{Q}{t}$ = ?

Solution: -

By using formula:

$$Q = \frac{kAt\,(T_h - T_c)}{L}$$

Or

$$\frac{Q}{t} = \frac{kA(T_h - T_c)}{L}$$

putting values

$$\frac{Q}{t} = \frac{(0.04)(1.6)(25)}{2.0 \times 10^{-3}}$$

$$\frac{Q}{t} = \frac{1.6}{2.0 \times 10^{-3}}$$

$$\frac{Q}{t} = \frac{1.6}{2.0} \times 10^3$$

$$\frac{Q}{t} = 0.8 \times 10^3$$

$$\frac{Q}{t} = 8 \times 10^{-1} \times 10^3 \text{ J/s} \qquad \therefore \mathbf{J/s = watt}$$

$$\frac{Q}{t} = 8 \times 10^{3-1}$$

$$\boldsymbol{\frac{Q}{t} = 8 \times 10^2\ W}$$

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2. The external wall of a brick house has an area of $16m^2$ and thickness 0.3m. The temperatures inside and outside the house are respectively 20^0C and 0^0C. Calculate the rate of heat loss through the wall. Thermal conductivity of brick is k= $0.84Wm^{-1}K^{-1}$

Data: -

Area of wall = A = $16m^2$

Thickness = L = 0.3m

Inside Temperature = $T_h = 20^0C$

Outside Temperature = $T_c = 0^0C$

Temperature difference = $T_h - T_c = (20 - 0)^0C$

$= 20^0C$

Thermal conductivity of brick = k = $0.84Wm^{-1}K^{-1}$

Find:

Rate of heat loss = $\frac{Q}{t}$ = ?

Solution: -

By using formula:

$$\frac{Q}{t} = \frac{kAt\,(T_h - T_c)}{L}$$

$$\frac{Q}{t} = \frac{\mathbf{kA(T_h - T_c)}}{\mathbf{L}}$$

putting values

$$\frac{Q}{t} = \frac{(0.84)(16)(20)}{0.3}$$

$$\frac{Q}{t} = \frac{268.8}{0.3}\ J/s$$

$$\frac{Q}{t} = \mathbf{896\ W}$$

3. Window glass has thermal conductivity of $0.8 Wm^{-1}K^{-1}$. Calculate the rate at which heat is conducted through a window of area is $2.0 m^2$ and thickness 4.0mm. The temperature inside an air-conditioned room is 20^0C. The outdoors temperature is0^0C 35^0C.

Data: -

Thermal conductivity = k = $0.8 Wm^{-1}K^{-1}$

Area = $2.0 m^2$

Thickness = L = 4.0mm

= 4.0×10^{-3}m

Inside Temperature = $T_c = 20^0$C

Outside Temperature = $T_h = 35^0$**C**

Temperature difference = $T_h - T_c = (35 - 20)^0$C

= 15^0C

Find:

Rate of heat conduction = $\frac{Q}{t} = ?$

Solution: -

By using formula:

$$\frac{Q}{t} = \frac{kA(T_h - T_c)}{L}$$

putting values

$$= \frac{(0.8)(2.0)(15)}{4.0 \times 10^{-3}}$$

$$= \frac{24}{4.0 \times 10^{-3}} \text{ J/s}$$

$$= \frac{24}{4.0} \times 10^3 \text{ J/s}$$

$$\frac{Q}{t} = 6 \times 10^3 \text{ J/s}$$

$$\mathbf{\frac{Q}{t} = 6 \times 10^3 \text{ W}} \qquad (\therefore \mathbf{J/s = watt})$$

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