

Textbook of
Physics
Grade
10

Based on National Curriculum 2022-23



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A Textbook of Physics for Grade 10

Based on National Curriculum of Pakistan (NCP) 2022-23

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PREFACE

This Grade 10 Physics textbook, developed by the National Book Foundation (NBF) in alignment with the National Curriculum of Pakistan 2022-2023, aims to deepen students' understanding of physics by building on concepts learned in earlier grades. Our goal is to foster logical thinking and higher-order reasoning by presenting physics concepts in a way that connects them to real-world applications, enabling students to relate their knowledge to daily life and prepare them for more advanced studies.

With contributions from dedicated experts and experienced authors, this textbook has undergone extensive review and refinement by professional educators. We focused on making the material engaging and accessible for students by introducing interactive concepts and real-life activities.

The National Book Foundation remains committed to enhancing the quality of its educational materials, and this edition features an improved design, clear illustrations, and meaningful activities that capture students' curiosity. We welcome suggestions from students, teachers, and the community to further enrich future editions of this textbook.

May Allah guide and help us (Ameen).

Murad Ali Mohmand
Managing Director

Practical applications for physics grade 10

Physics is more than a school subject; it's a gateway to understanding the mechanics of the world around us, from the minuscule particles within an atom to the vast networks of galaxies. As you *dive into* this Grade 10 textbook, you'll see that physics isn't just about memorizing equations or facts—it's about building a mindset for discovery and innovation. This subject provides the tools you need to solve real-world problems, and the skills developed here will open doors to fields as varied as engineering, medicine, and technology.

Every concept you'll study has a direct impact on everyday life and future career opportunities. Whether it's understanding the forces that hold buildings steady or the mechanics of electric circuits, each chapter will prepare you for roles that are essential in fields shaping Pakistan's future.

Chapter 10: HEAT CAPACITY AND MODES OF HEAT TRANSFER

This chapter delves into the science of how heat is stored and transferred. Understanding concepts like thermal conduction, convection, and radiation is essential in fields such as energy efficiency, HVAC (heating, ventilation, and air conditioning) design, and renewable energy. Careers in environmental engineering, energy conservation, and climate science rely heavily on the principles discussed here.

Chapter 11: THERMAL EXPANSION AND CHANGE OF STATE

In this chapter, you'll explore the kinetic theory of matter, thermal expansion, and latent heat, which are fundamental in materials science, engineering, and environmental studies. Concepts like thermal expansion of solids and liquids are particularly useful in civil and mechanical engineering, where they are used to design buildings, bridges, and machinery that withstand temperature changes.

Chapter 12: WAVES

Studying wave theory, reflection, refraction, and diffraction lays the foundation for work in telecommunications, sound engineering, and medical imaging. Professionals in fields like broadcasting, audio engineering, and seismology rely on a solid understanding of wave behavior to analyze sound waves, light waves, and seismic activity.

Chapter 13: SOUND

In this chapter, you'll learn about the production and propagation of sound, pitch, loudness, and applications of ultrasonic waves. This knowledge is essential in areas like acoustical engineering, medical ultrasonography, and environmental science. Careers in audio technology, noise pollution control, and even entertainment are built upon these principles.

Chapter 14: OPTICS

Here, you will study laws of reflection and refraction, lenses, and applications like gravitational and acoustic lensing. These topics are fundamental in fields such as optical engineering, vision sciences, and photography. Professionals in fields like ophthalmology, camera design, and fiber optics use these principles to create and refine imaging technologies.

Chapter 15: ELECTROSTATICS

Understanding electrostatics, electric fields, and electrical discharges is crucial for careers in electronics, telecommunications, and safety engineering. Applications of electrostatics are found in devices like photocopiers, air purifiers, and touch screens, opening paths to jobs in electronics design, environmental control systems, and industrial safety.

Chapter 16: CURRENT ELECTRICITY

This chapter covers current flow, potential difference, Ohm's law, and resistance—the backbone of electrical and electronic engineering. Knowledge in current electricity is vital for careers in power distribution, electrical engineering, and electronics. Whether working with power grids, household appliances, or complex electronic circuits, these concepts are widely applied.

Chapter 17: ELECTRIC CIRCUITS

In this chapter, you'll study the components and design of electric circuits, including resistors, potential dividers, and power applications. This knowledge is essential for careers in circuit design, computer engineering, and electrical safety. In Pakistan, the demand for skilled circuit designers and power engineers is growing in areas like renewable energy systems, automation, and telecommunications.

Chapter 18: ELECTRONICS

This chapter introduces students to the world of diodes, transistors, and Boolean logic, the building blocks of modern electronics. Careers in electronics, telecommunications, and even quantum computing are within reach for students who master the concepts of analogue and digital electronics.

Chapter 19: ELECTROMAGNETISM

This chapter explores magnetic fields, electromagnetic induction, and the operation of generators and motors. Understanding electromagnetism is crucial for careers in power generation, robotics, and transportation engineering. Applications in electric vehicles, magnetic storage devices, and energy systems make this field rich in opportunities for engineers and technicians alike.

Chapter 20: ELECTROMAGNETIC WAVES

The study of electromagnetic waves, spectrum applications, and light scattering is essential in fields like satellite communications, radiology, and space exploration. With Pakistan advancing in areas such as remote sensing and medical imaging, this chapter lays a solid foundation for careers in telecommunications, medical technology, and atmospheric sciences.

Chapter 21: NUCLEAR PHYSICS

The study of atoms, isotopes, and nuclear reactions offers a gateway to careers in energy production, medical imaging, and scientific research. By understanding radioactivity, students can contribute to fields like nuclear energy, healthcare, and space exploration, where the manipulation and safe handling of nuclear materials are essential.

In conclusion, the journey through Grade 10 physics prepares students not only for higher academic pursuits but also for impactful careers in diverse fields. Whether you're interested in energy solutions, medical technologies, or cutting-edge electronics, physics equips you with the tools to shape the future.

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Unit 10

HEAT CAPACITY AND MODES OF HEAT TRANSFER

Why does a person enjoy comparatively cooler weather near sea at day compared to land areas?

STUDENT LEARNING OUTCOMES

The students will:

- ✓ [SLO: P-10-C-01] Define and calculate specific heat.
- ✓ [SLO: P-10-C-02] Suggest experiments to measure the specific heat capacity.
- ✓ [SLO: P-10-C-03] Analyse everyday effects due to the large specific heat of water.
- ✓ [SLO: P-10-C-30] Justify experiments to distinguish between good and bad thermal conductors.
- ✓ [SLO: P-10-C-31] Explain thermal conduction in all solids.
- ✓ [SLO: P-10-C-32] Explain convection in liquids and gasses.
- ✓ [SLO: P-10-C-33] Explain convection in seawater to support marine life.
- ✓ [SLO: P-10-C-34] Describe the role of land breezes and sea breezes in maintaining moderate coastal climates.
- ✓ [SLO: P-10-C-35] Explain how birds are able to fly for hours without flapping their wings and gliders are able to rise by riding on thermal currents.
- ✓ [SLO: P-10-C-36] Describe the process of thermal energy transfer by radiation.
- ✓ [SLO: P-10-C-37] Describe the effect of surface color and texture on the emission, absorption and reflection of infrared radiation.
- ✓ [SLO: P-10-C-38] Justify qualitatively how the rate of emission of radiation depends on the surface temperature and surface area of an object.
- ✓ [SLO: P-10-C-39] Justify experiments to distinguish between good and bad emitters and absorbers of infrared radiation.
- ✓ [SLO: P-10-C-40] Analyze the consequence of heat radiation in the greenhouse effect and its effect in global warming.

- ✓ [SLO: P-10-C-41] Analyze everyday applications of conduction, convection and radiation.
- ✓ [SLO: P-10-F-23] Use ideas of convection to explain how cyclones are formed.
- ✓ [SLO: P-10-F-24] Explain how global warming contributes to extreme weather events.
- ✓ [SLO: P-10-F-25] Explain the phenomena of geothermal activity on the basis of conduction, convection and radiation.

Have you ever wondered why water takes time to boil or why metal feels colder than wood at the same temperature? These questions lead us to explore heat, specifically specific heat capacity and heat transfer methods.

We will start with specific heat capacity, which is the heat needed to raise a substance's temperature. Water, with its high specific heat capacity, heats slowly but retains warmth longer, linking kitchen mysteries to broader climate issues. We will conduct experiments to measure the specific heat capacities of various materials. Next, we will look at the three main heat transfer methods: conduction, convection, and radiation. These principles explain why hot coffee cools, why upper floors feel warmer, and how the sun's energy reaches us. Understanding these concepts is crucial for grasping their roles in greenhouse effects and global warming. Finally, we'll explore geothermal phenomena, where the Earth's hot core drives magma movements and tectonic shifts, leading to earthquakes and volcanic eruptions. Throughout this chapter, consider how heat and its movement impact your daily life and the world around you.

10.1 SPECIFIC HEAT CAPACITY

Specific heat capacity or specific heat of a material is the amount of heat absorbed or lost to change the temperature of 1 kg of its substance by 1 kelvin or 1 degree celsius.

$$c = \frac{Q}{m \Delta T} \quad \text{--- 10.1}$$

Where 'c' is the specific heat of the material, 'Q' is the amount of heat absorbed or lost, 'm' is the mass of the substance and ' ΔT ' i.e. ($T_{\text{Final}} - T_{\text{Initial}}$) is the change in temperature of the substance.

Its SI unit is joule per kilogram per kelvin ($\text{J kg}^{-1} \text{K}^{-1}$). Its other units in use are $\text{J kg}^{-1} \text{°C}^{-1}$ and $\text{Jg}^{-1} \text{°C}^{-1}$. For example, specific heat of aluminum is $900 \text{ J kg}^{-1} \text{K}^{-1}$. Its value in other units can be written as $900 \text{ J kg}^{-1} \text{°C}^{-1}$ and $0.9 \text{ J g}^{-1} \text{°C}^{-1}$.

Some materials require small amount of heat like metals (for example aluminium, copper, iron and diamond etc) . These materials have low value of specific heat. Such materials are good conductor of heat. We can say that these materials cannot retain heat for longer time with them. These materials heat up and cool down quickly. Therefore, such materials are used in heat sinks.

Some substances require large amount of heat like water to raise its temperature by one kelvin. They have large specific heat. These materials absorb or loose large amount of heat for small change in their temperature. They cannot be easily heated up or cooled down. It means that these materials can retain heat in them. These materials are used for controlling the temperature

UNIT
OPENER?

Why does a person enjoy comparatively cooler weather near sea at day compared to land areas?

The cooler daytime temperatures experienced in coastal areas, compared to inland regions, result from the interplay between the high specific heat capacity of water and the moderating effects of sea breezes. Coastal areas tend to be cooler during the day than areas further inland due to the differing heat capacities of water and land.

Water's higher specific heat capacity means it takes more energy to raise its

temperature compared to land. Therefore, the water temperature rises much more gradually. This results in cooler air temperatures near coastal areas, influenced by the slower-warming water bodies.

The temperature difference between land and sea creates a pressure gradient that drives sea breezes. As the land absorbs solar radiation and heats up, the air above it warms, becomes less dense, and rises, forming a low-pressure zone. In contrast, the cooler sea surface maintains a cooler, denser air mass above it, establishing a high-pressure area. This pressure difference propels the cooler air from the sea towards the land, generating a sea breeze. This influx of cooler, more humid air from the ocean moderates coastal temperatures, keeping them lower than inland areas.



in different devices. For example, water has large specific heat therefore it is used in cars as engine coolant.

10.1.1 USES OF LARGE SPECIFIC HEAT OF WATER

Water has large specific heat ($4200 \text{ J kg}^{-1} \text{ K}^{-1}$). Due to it, it has significant uses in our daily life.

A. Temperature Variation in Land and Coastal Areas:

The specific heat of dry soil ($800 \text{ J kg}^{-1} \text{ K}^{-1}$) is smaller than that of water. It is about five times smaller than that of water. It is why land area quickly heats up in summer and temperature rises from about 45°C to 50°C , and also because land quickly cools down in winter, leading to low temperatures from 5°C to 0°C . But in coastal areas, temperature variation is small. In Karachi, average temperature variation is from 19°C to 32°C . So, oceans and large lakes absorb a lot of heat from the sun during the summer and keep the heat stored in them. On the other hand, in winters, oceans and lakes release heat into the atmosphere. This phenomenon keeps the temperature moderates between summer and winter in coastal areas.

Table 10.1: SPECIFIC HEATS OF
SELECTED SUBSTANCES

Materials	Specific heat J /kg K
Aluminum	910
Copper	387
Glass	840
Gold	129
Iron/ steel	452
Lead	128
Silver	235
Ethanol	2450
Glycerin	2410
Mercury	139
Water	4190
Air	721
Carbon dioxide	638
Oxygen	651
Steam (100°C)	1520

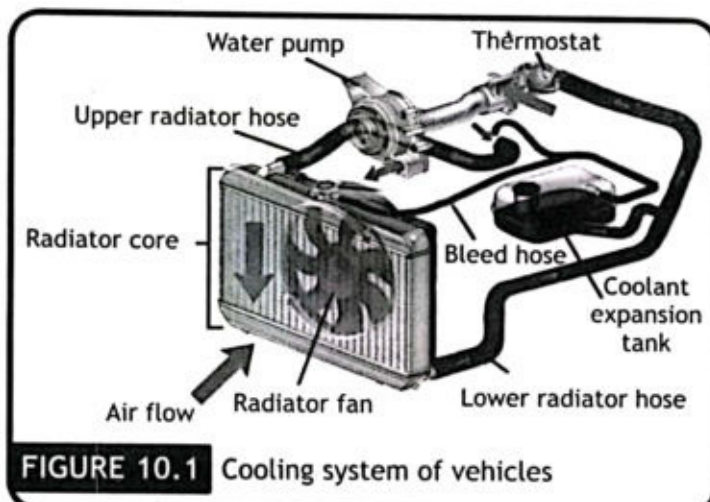
B. Maintaining stability of Ocean and Lake Temperatures: Lakes and oceans heat up and cool down slowly due to high specific heat of water. This prevents changes in the temperature of the lake and oceans and thus provides a suitable environment for aquatic life.

C. Human Body Temperature Regulation:

The human body contains approximately 60 % water. A healthy body maintains its temperature about 37 °C. Now, we can relate how can our body maintain its temperature due to high specific heat of water.

D. Cooling system and Heat Exchangers:

Water is used as coolant in power plants, different industrial process and cooling system of automobiles (radiators) as shown



in figure 10.1. Water takes large amount of excess heat from the machines and effectively transfer heat using heat exchanger. It prevents overheating in the machinery and maintain their high efficiency.

E. Cooking Process: Water is good for cooking because of its high specific heat. It heats up slowly and distributes heat evenly. It ensures food cooking without burning. Hot drinks like tea and coffee stay hot for long time. Can you explain it?

Example 10.1

A 200 g sample of a solid metal is heated from 25 °C to 75 °C. If 3,500 joules of heat energy is required to raise the temperature of the metal, what is the specific heat of the metal?

GIVEN:

Mass 'm' = 200 g = 0.2 kg

Change in temperature ' ΔT ' = 75 °C - 25 °C = 50 °C = 50 K

(Change in temperature in celsius and kelvin scales is same)

Heat energy ' Q ' = 3,500 J

SOLUTION:

Specific heat capacity is given by:

$$c = \frac{Q}{m \Delta T} \quad \text{putting values} \quad c = \frac{3,500 \text{ J}}{(0.2 \text{ kg})(50 \text{ K})}$$

Therefore $c = \frac{3,500 \text{ J}}{(0.2 \text{ kg})(50 \text{ K})}$ **ANSWER**

Therefore, the specific heat of the metal is 350 J kg⁻¹ K⁻¹.

Example 10.2

A half kilogram sample of aluminum (specific heat capacity $c = 900 \text{ J kg}^{-1} \text{ K}^{-1}$) is heated from room temperature of 25°C to 100°C . How much heat is absorbed by the aluminum to raise its temperature?

GIVEN:

Mass ' m ' = 0.5 kg , Specific heat ' c ' = $900 \text{ J kg}^{-1} \text{ K}^{-1}$

Initial temperature ' T_{initial} ' = 25°C

Final temperature ' T_{final} ' = 100°C

Change in temperature ' ΔT ' = $100^\circ\text{C} - 25^\circ\text{C} = 75^\circ\text{C} = 75 \text{ K}$

SOLUTION:

Specific heat capacity is given by: $c = \frac{Q}{m\Delta T}$ or $Q = mc\Delta T$

putting values $Q = (0.5 \text{ kg}) \times (900 \text{ J kg}^{-1} \text{ K}^{-1}) \times (75 \text{ K})$

Therefore $Q = 33,750 \text{ J} = 33.75 \text{ kJ}$ — **ANSWER**

The amount heat required by sample of aluminum is 33.75 kJ .

10.1.2 MEASUREMENT OF SPECIFIC HEAT OF SOLIDS AND LIQUIDS

There are different experiments which can be used to determine specific heat of solids and liquids. The most common methods are "method of mixtures" and "electrical heating method".

A. Method of mixtures: The experiments for measurement of unknown specific heat capacity of solids and liquids by method of mixtures are discussed below:

i. Measurement of unknown specific heat capacity of solids: This method uses a calorimeter to determine the heat capacity of a substance. In this method, when the hot sample e.g. a solid is added to water in the calorimeter, heat is exchanged between them as well as the calorimeter. From the law of conservation of energy, the heat lost by hot bodies will be equal to the heat gained by cold bodies. Then we form the equation after measuring the change in temperature of the water in calorimeter and masses of substances. After careful analysis, we can calculate the specific heat capacity of the sample.

Apparatus: A Bunsen burner or hot plate, copper calorimeter with lid stirrer and insulating cover, a metallic solid cylinder (e.g. brass or copper cylinders), weighing machine, water, beaker, laboratory stand and two thermometers

Key Variables:

- Independent Variable is the temperature of the metal block.
- Dependent Variable is the energy supplied to the metal block by heating.

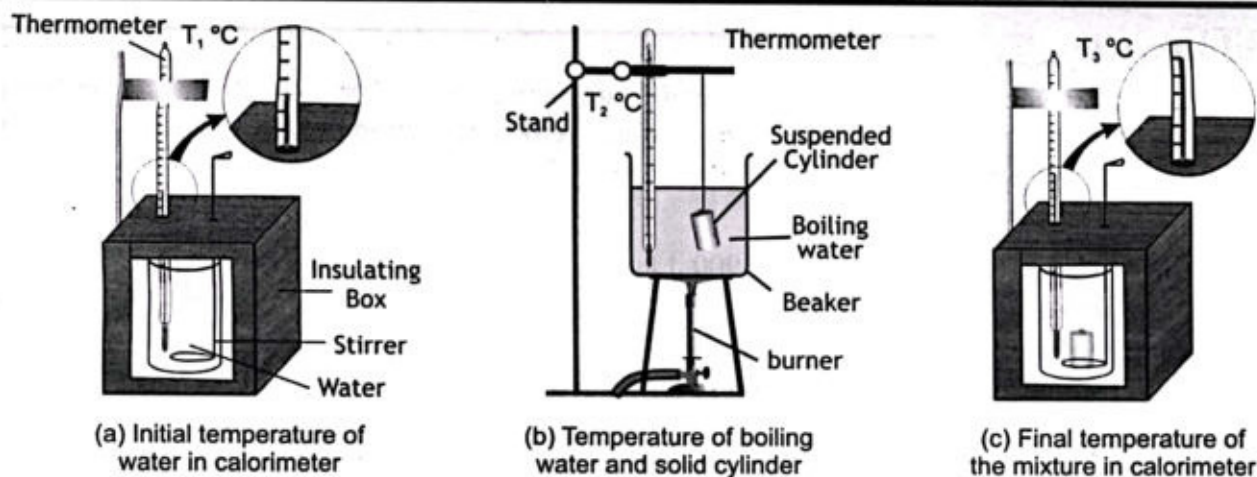


FIGURE 10.2 Measurement of specific heat capacity of a solid with mixture method.

Procedure:

1. Take an empty calorimeter of known heat capacity C_c . Measure the mass of calorimeter m_c with the stirrer and lid.
2. Fill the calorimeter with enough water to completely submerge the solid later. Weigh (m) the calorimeter with water. Difference of masses ($m - m_c$) is equal to the mass of water (m_w) in the calorimeter.
3. Place the calorimeter in its insulating cover and insert thermometer in it. Measure the temperature of water T_1 °C (equal to the temperature of the surroundings) as shown in figure 10.2 (a).
4. Measure the mass of the given solid using a weighing machine and note down its mass as m_s .
5. Boil water in a beaker with the solid submerged. Measure the boiling water temperature (T_2 °C). In this step, ensure that the solid attains the same temperature as the boiling water on heating as shown in figure 10.2 (b).
6. Remove the solid from boiling water, shake off excess water, and quickly place it in the calorimeter. Cover the calorimeter immediately.
7. Stir the water continuously with the stirrer for uniform distribution of heat (and temperature).
8. Measure the final temperature of the mixture once it becomes constant on attaining equilibrium, record this temperature as T_3 °C as shown in figure 10.2 (c).
9. Now we calculate the increase in temperature of water and calorimeter that is equal to $(T_3 - T_1)$ and decrease in temperature of solid is equal to $(T_2 - T_3)$.
10. From principle of calorimetry i.e. law of conservation of energy, heat given by solid in cooling from T_2 to T_3 is equal to heat gained by the water and calorimeter in raising their temperature

from T_1 to T_3 . Such that:

Heat loss by solid = Heat gained by water in calorimeter + Heat gained by calorimeter

$$Q_s = Q_w + Q_c$$

$$\text{or } m_s c_s (T_2 - T_3) = m_w c_w (T_3 - T_1) + m_c c_c (T_3 - T_1)$$

By rearranging the above equation, we can find the specific heat capacity of solid.

$$c_s = \frac{m_w c_w (T_3 - T_1) + m_c c_c (T_3 - T_1)}{m_s (T_2 - T_3)}$$

$$\text{Hence, } c_s = \frac{(m_w c_w + m_c c_c)(T_3 - T_1)}{m_s (T_2 - T_3)} \quad \text{--- 10.2}$$

Result: Equation 10.2 is used to find specific heat of a solid (c_s). By putting the measured masses of solid, water and calorimeter, specific heat capacities of water and calorimeter, and temperatures T_1 , T_2 and T_3 in equation 10.2, we can calculate the specific heat capacity of the solid.

ii. Measurement of unknown specific heat capacity of a liquid: To measure the unknown specific heat capacity of a liquid, we follow the same procedure. But in this experiment, we take solid of known specific heat capacity but liquid of unknown specific heat capacity c_l is taken. Same experiment is performed to measure the unknown specific heat capacity of a liquid. From this experiment, law of conservation of energy can be written as:

$$m_s c_s (T_2 - T_3) = m_l c_l (T_3 - T_1) + m_c c_c (T_3 - T_1)$$

By rearranging the above equation, we get: $m_l c_l (T_3 - T_1) = m_s c_s (T_2 - T_3) - m_c c_c (T_3 - T_1)$

$$\text{Hence, } c_l = \frac{m_s c_s (T_2 - T_3) - m_c c_c (T_3 - T_1)}{m_l (T_3 - T_1)} \quad \text{--- 10.3}$$

Example 10.3

A 150 g piece of an unknown solid cylinder is heated to 100 °C and then placed into a calorimeter containing 200 g of water at 25 °C. The calorimeter has a mass of 50 g and a specific heat capacity of 0.9 J/g°C. The final temperature of the system (solid, water, and calorimeter) is 30 °C. Assume no heat is lost to the surroundings. Calculate the specific heat capacity of the solid.

GIVEN:

Mass of solid cylinder ' m_s ' = 150 g

Mass of water in calorimeter ' m_w ' = 200 g

Mass of calorimeter ' m_c ' = 50 g

Initial temperature ' T_1 ' = 25 °C

Temperature of solid cylinder ' T_2 ' = 100 °C

Final temperature ' T_3 ' = 30 °C

Specific heat of water ' c_w ' = 4.18 J/g °C

Specific heat of calorimeter ' c_c ' = 0.9 J/g °C

REQUIRED:

Specific heat capacity ' c_s ' = ? (in J/g °C)

SOLUTION:

From principle of calorimetry, we have: $c_s = \frac{(m_w c_w + m_c c_c)(T_3 - T_1)}{m_s(T_2 - T_3)}$

$$\text{putting values } c_s = \frac{\{(200 \text{ g})(4.18 \text{ J/g}^\circ\text{C}) + (50 \text{ g})(0.9 \text{ J/g}^\circ\text{C})\} \times (30^\circ\text{C} - 25^\circ\text{C})}{(150 \text{ g}) \times (100^\circ\text{C} - 30^\circ\text{C})}$$

Therefore

$$c_s = 0.42 \text{ J/g}^\circ\text{C}$$

ANSWER

The specific heat capacity of solids is $0.42 \text{ J/g}^\circ\text{C}$

B. Electrical Heating Method: The experiments for measurement of unknown specific heat capacity of a solid and liquids are discussed below:

i. Measurement of unknown specific heat capacity of solids: In this method, we measure the amount of heat transferred to a material and measure its temperature change.

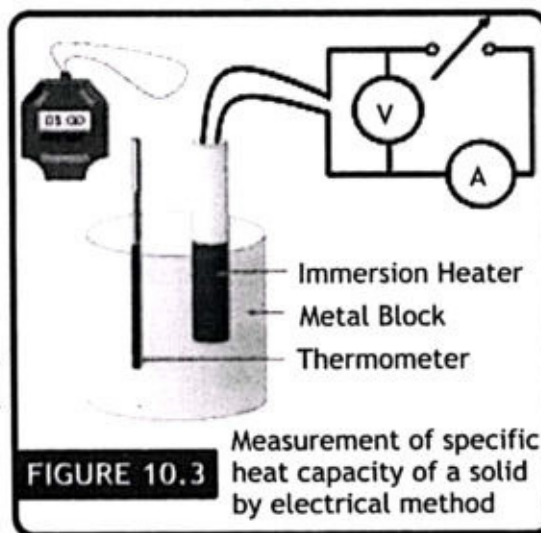
Apparatus: A solid block or cylinder e.g. aluminium with a hole in it for a heater and a smaller hole for a thermometer, an immersion heater, voltmeter, ammeter, thermometer.

Procedure:

1. Calculate the mass of the solid block.
2. Place an electrical immersion heater into the central hole at the top of the weighed metal block. Connect the heater with an ammeter to measure current and with a voltmeter to measure voltage (potential difference) applied on the heater as shown in figure 10.3.
3. Place the thermometer into the smaller hole. Add few drops of oil into the hole to make sure the thermometer is surrounded by hot material.
4. Insulate the block by wrapping it with cotton wool.
5. Record the initial temperature of the block.
6. Connect the heater to the power supply and turn it on for ten minutes. Record the current and potential difference.
7. After ten minutes, turn the heater off. Record the highest temperature that it reaches (temperature readings will rise even after the heater is turned off).
8. Calculate the heat energy generated by water.

Result: Calculate the specific heat capacity of the solid block using the formula:

$$c = \frac{Q}{m\Delta T} \quad \text{--- 10.4}$$



ii. Measurement of unknown specific heat capacity of liquids:

Apparatus: An immersion heater, voltmeter, ammeter, thermometer, water and calorimeter.

Procedure:

1. Calculate the mass of empty calorimeter (m_c).
2. Add some liquid e.g. water in calorimeter and measure the mass of calorimeter plus liquid (m). Difference of the masses ($m - m_c$) gives the mass of liquid (m_w).
3. Measure the initial temperature of the calorimeter plus liquid using thermometer.
4. Place electrical heater inside the liquid, and connect ammeter and voltmeter with it. Switch it ON. Measure the voltage and current passing through the heater as shown in figure 10.4.
5. Temperature will start to rise. When temperature rises for 10°C , switch off the heat and stir the liquid well and measure the highest temperature of the liquid. Then find the temperature difference between highest temperature and initial temperature of liquid.
6. From law of conservation of energy:

*Energy Supplied = Heat gained by liquid
+ Heat gained by calorimeter*

$$Q_{\text{Heater}} = Q_w + Q_c$$

$$Q_{\text{Heater}} = m_l c_l (T_f - T_i) + m_c c_c (T_f - T_i)$$

Result: By rearranging the above equation, we get:

$$c_l = \frac{Q_{\text{Heater}} - m_c c_c (T_f - T_i)}{m_l (T_f - T_i)} \quad \text{10.5}$$

By putting the measured values of heat energy produced by heater, masses of liquid and calorimeter and initial and final temperatures, we can measure the specific heat capacity of liquid.

10.2 TRANSFER OF HEAT

Heat transfer occurs when thermal energy is transferred from one object to another because of a difference in temperature. This process continues until both objects reach the same temperature, which is known as thermal equilibrium. There are three methods of heat transfer i.e. conduction, convection and radiation.

INFORMATION

Heat generated by heater is calculated by:

Heat energy = electrical energy supplied to heater

Heat energy = Voltage $\times$ current $\times$ time

You will study this formula in detail in unit 16: Current electricity

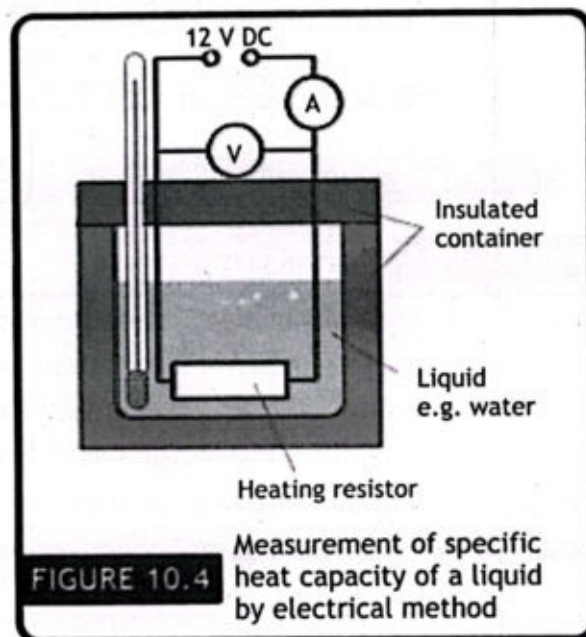


FIGURE 10.4

Measurement of specific heat capacity of a liquid by electrical method

10.2.1 THERMAL CONDUCTION

A cooking pot's top edges get extremely hot when we touch them after it has been on the stove for a while, even if they are not getting heat directly. It happens because heat is transferred to these top edges due to the phenomenon of conduction. Similarly, when frying vegetables in a pan as shown in figure 10.5. Heat transfer takes place from the flame to the pan and then to the vegetables due to conduction.

This method of heat transfer takes place in solids. In conduction, heat is transferred from atoms to atoms. Metals are good conductors of heat because they have a large number of free electrons that travel faster across the metal when metal is heated. That's why heat energy is transferred quickly in metals. We can define thermal conduction as: 'It is method of transfer of heat due to collisions of atoms or molecules and motion of free electrons in solids from its hot part to cold part'.



FIGURE 10.5 Thermal Conduction

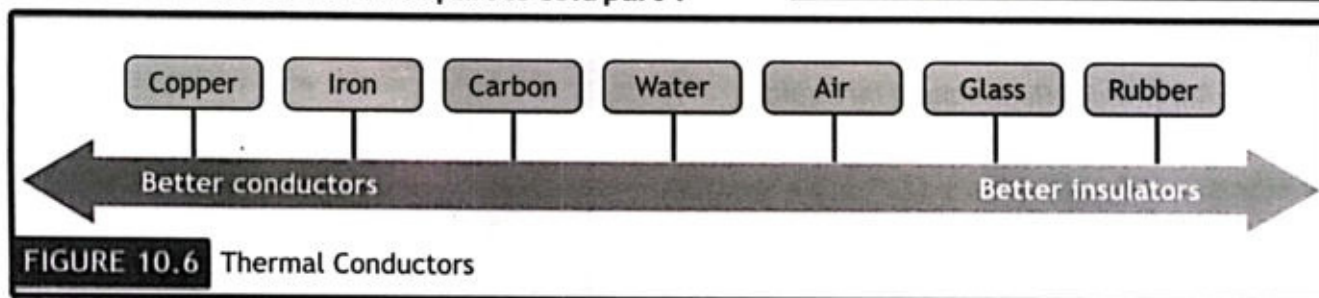


FIGURE 10.6 Thermal Conductors

When one of the ends of a rod is heated, atoms at this end start vibrating with larger amplitude. These atoms hit their neighbouring atoms and transfer their heat energy as shown in figure 10.7. Now, these atoms vibrate with larger amplitude and hit their nearby atoms, and process continues. Heat energy is transferred between the two ends in this manner.

When a copper rod and a wooden stick are heated simultaneously, we find that the copper rod's other end heats up more quickly than the wooden stick's other end.

This is due to the fact that metallic rods, such as copper rods, have a lot of free electrons. In comparison to vibrating atoms, these free electrons get energy from the hot end and transfer energy fast from one end of the rod to its second end.

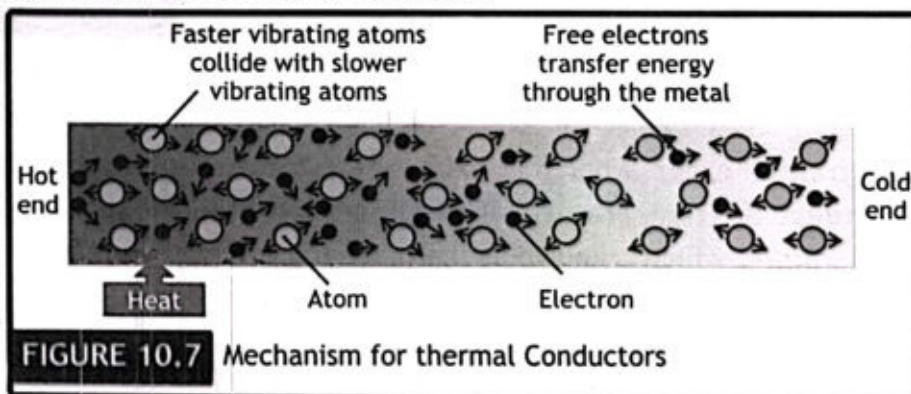


FIGURE 10.7 Mechanism for thermal Conductors

We can say that metals transfer heat energy quickly than other solids like wood, glass etc.

Experiment: Let's discuss an experiment to differentiate between good and bad conductors (figure 10.8).

Apparatus: Three long thin strips of different metals (for example copper, iron, and aluminium rods), Vaseline or wax, drawing pins and a Bunsen burner.

Control variables: length of metal rod, diameter of rods, position in the Bunsen flame.

Method: The following procedure is adopted.

1. Apply small dots of wax at the ends of metal rods and fix the drawing pins in them.
2. Position the other end of the metal rods into a Bunsen flame. Make sure that heat can reach every metal rods in the same amount.

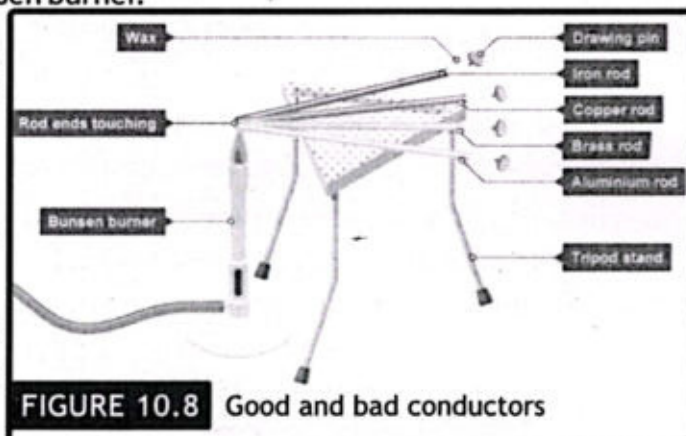


FIGURE 10.8 Good and bad conductors

3. As the heat flows through metal rods, wax will melt and pin will drop. Record the time taken for the wax to melt and the drawing pin to drop off. The fastest time shows the best conductor of heat. It happens because good conductors allow heat to flow fast through them and cause Vaseline to melt soon.

Result: The drawing pin falls off the copper rod first followed by the aluminium.

Conclusion: From this we can conclude that copper conducts better than aluminium, while aluminium conducts better than iron and brass.

10.2.2 CONVECTION

When we heat water on the stove, we can see the movement of water. Water molecules at the bottom receive heat immediately. According to KMT, intermolecular forces between these water molecules decrease as temperature rises, and the distance between molecules increases. This makes the water less dense at bottom. This less dense water

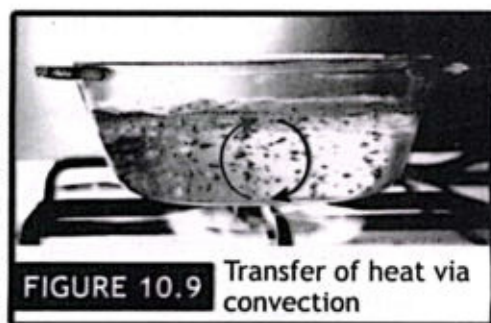


FIGURE 10.9 Transfer of heat via convection

moves from bottom to top after taking heat energy. The dense cold water at the top sinks to fill the gap and gains heat energy. In this way, the molecules of the water move themselves to transfer heat energy due to differences in densities in two parts of the fluid.

'The method of transfer of heat due to bulk movement of molecules in fluids is called convection'. We can also define it as "convection is the transfer of heat energy due to the transfer of fluid itself." Convection only takes place in liquids and gases. It cannot take place in solids.

Experiments: As illustrated in the figure 10.10, put some potassium permanganate crystals in the bottom of a beaker filled with water. A stream of potassium per manganate travels upward and produces a convectional current when the beaker is heated.

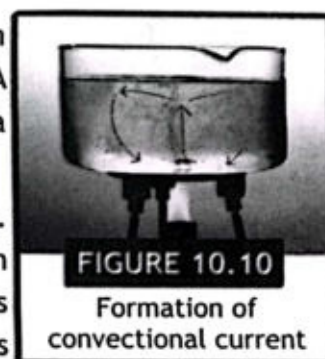


FIGURE 10.10

Formation of convectional current

Water at bottom of beaker heats up, it expands and becomes less dense. This less dense water rises up and transfer heat energy from the bottom to the top of the container. Then cold water (denser water) flows downward from the sides and replaces the hot water. This process continues and heat continuously transfers due to the continuous flow of fluid.

You can perform another experiment at home to understand the convection process as shown in figure 10.11. Take blue and red food colours. Use blue food colour to make blue colour ice cubes. Now take the water in a transparent bowl or box and put blue ice cubes on one of its sides. Add warm water on the other side. Place the ink pot filled with red food colour on the warm water side at the bottom of the container. You will see that red food colour on the warmer side will rise first and then it will move towards the cooler blue ice side. And cold water, being denser, sinks, and its left place is filled by the red colour water. This process continues and shows the transfer of heat due to the motion of molecules.

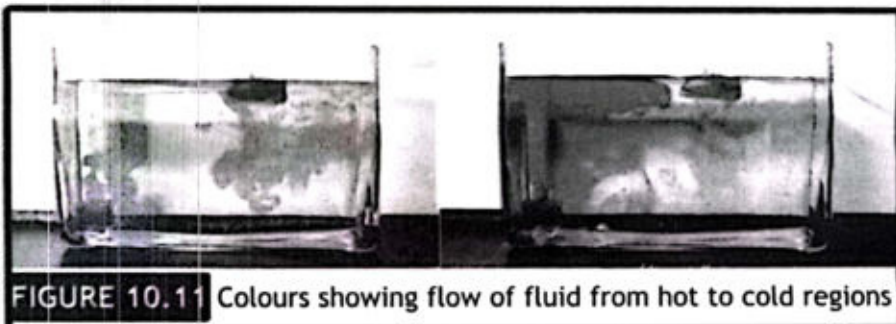


FIGURE 10.11 Colours showing flow of fluid from hot to cold regions

A. Convection and Marine Life: Convection is a crucial process that helps support marine life in the oceans. It involves the movement of seawater driven by differences in temperature and salinity across the globe as shown in figure 10.12. Salty water is denser than fresh water. In some areas, seawater becomes saltier and denser, especially where a lot of water evaporates due to hot weather.

Warm water is less dense than cold water. When the sun heats the surface of the ocean, the water at the surface becomes warmer and less dense. This warm water rises and spreads out across the surface. Cold water is denser than warm water.

While in polar regions, the seawater cools down and becomes denser, causing it to sink to ocean depths. These movements of water

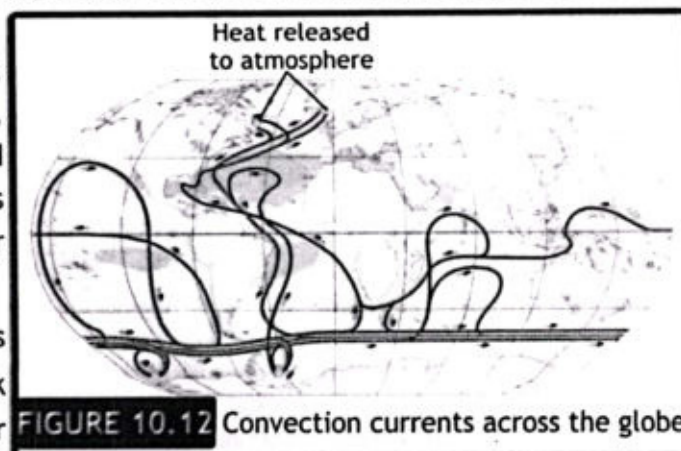


FIGURE 10.12 Convection currents across the globe

cause convectional currents. Upward movement of sea water is called upwelling and downward movement of sea water is called downwelling as shown in figure 10.13.

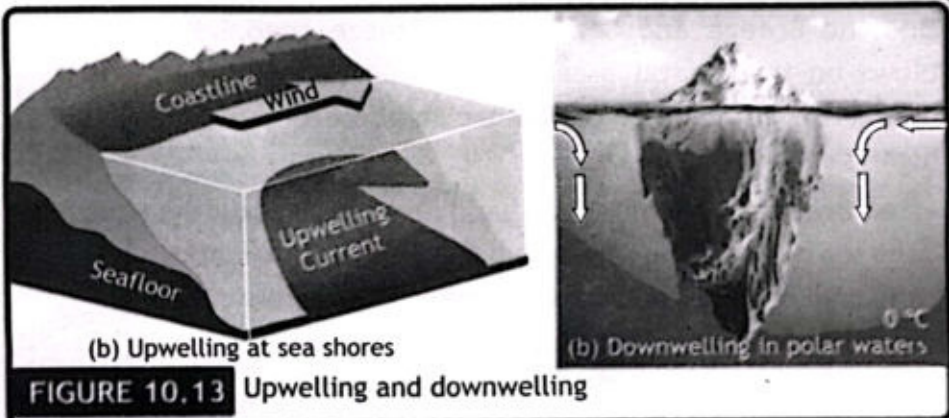


FIGURE 10.13 Upwelling and downwelling

Distribution of food:

Upwelling typically occurs along coastlines where winds blow parallel to the shore. As surface water is pushed away from the coast, it is replaced by water rising from below. This deeper water is usually colder and richer in nutrients (containing nitrogen, phosphate and organic materials) as compared to the surface water. Phytoplankton (a tiny plant like organism) uses these nutrients and sunlight to grow and multiply shown in figure 10.14. Phytoplankton is food source for many marine creatures from small (zooplankton) to large (whales).

Distribution of oxygen: Marine animals, like fish need oxygen to live. Most oxygen is dissolved in top water exposed to air. Convection causes this water to go deep into the ocean floor. Without convection, deep waters would lack oxygen, making it difficult for marine life to survive.

Distribution of heat: Due to upwelling warm water rises up and takes heat to top. Convection distribute heat throughout the ocean. This helps to stabilize the temperature. Also, the movement of warm and cold water around the globe effects climate patterns, which can affect the habitats of marine life.

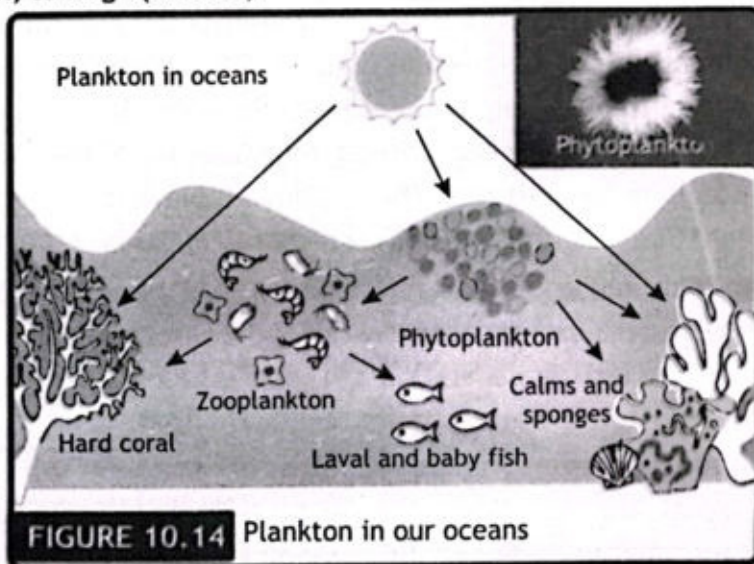
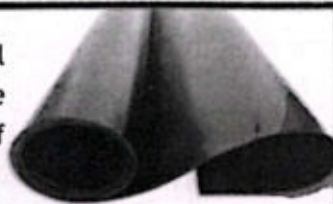


FIGURE 10.14 Plankton in our oceans

INFORMATION

Rubber is generally a better insulator than air. Rubber has a lower thermal conductivity than air, meaning it can reduce the transfer of heat energy more effectively. Rubber has tightly bound electrons which helps to resist transfer of heat. Rubber can resist the flow of heat energy about 4-8 times better than air.



B. Land Breeze and Sea Breeze: Breeze continuously blows on the coastal areas due to convection. Breeze during the day is called sea breeze and breeze during the night is called land breeze.

- **Sea Breeze:** During the day, land heats up quickly than the sea due to its low specific heat. Therefore, air above the land becomes hot, expands and becomes less dense. This hot air above land rises up and cool air above sea moves towards the land to fill the gap.
- **Land Breeze:** At night, temperature of land quickly falls than the water (water can maintain its temperature for long time due to its high specific heat capacity). Due to this, air above the sea is hotter than the air above the land. Therefore, hot air above the water rises up and cool air from the land moves towards the sea to fill the gap.



FIGURE 10.15 Sea and land breeze

These breezes continuously blow across the coastal areas and help to maintain the moderate climate there as shown in figure 10.15. These natural wind patterns help to cool coastal areas during the day and moderate temperatures at night, resulting in a more temperate and stable climate. Sea breeze carries moisture from the ocean, influencing coastal humidity and precipitation patterns. This continuous blowing of breezes exchanges gases from land to sea and sea to land (and prevents the stagnancy of gases in the region).

C. Thermal and Bird's Flight: During the day, Sun heats the land unevenly, dark and concrete structures absorb more heat than other areas like grass or water. Therefore, air above hot areas become less dense and rises from the ground. This rising hot air surrounded by the cooler air around it, forms an air column called thermal.

Birds like eagles, hawks, vultures, etc are expert thermal riders. These birds have large and wide wings. By spreading their wings and tilting them slightly upwards, they ride on this rising air (thermals) as shown in figure 10.16. To stay within the thermal in this rising air, they fly in circles. They glide between thermals and maintain their high altitude without flapping their wings for a long period of time.

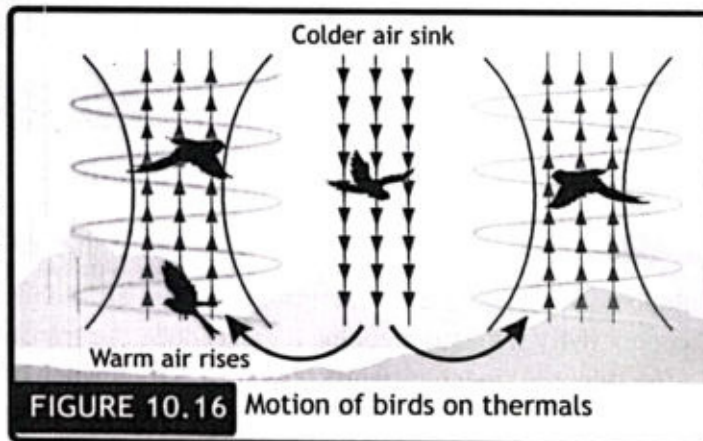


FIGURE 10.16 Motion of birds on thermals

D. Hurricanes and Cyclones: Hurricanes form over warm ocean waters. The warm water causes evaporation and this moist air rises due to convection. As it rises, it cools and forms clouds through condensation. This condensation releases latent heat which warms the surrounding atmosphere, making the air there lighter. As a result, the air continues to rise, lowering the atmospheric pressure at its surface. This decrease in pressure increases the rate of evaporation and causes more warm, moist air from oceans to move up. The Earth's rotation causes this rising air to spin, forming a cyclonic system. As the system gathers strength, it can develop into a hurricane with high wind speeds.

10.2.3 THERMAL RADIATIONS

Heat transfer through electromagnetic waves doesn't require any physical contact. For example the sun heats the Earth through radiation, and you feel warmth from a fireplace even at a distance (figure 10.17). 'The process of transfer of heat in the form of electromagnetic radiation (infra-red radiation) is called radiation'.

Heat transfer through conduction and convection requires a medium, however heat transfer through radiation does not require a material medium. There is vacuum between the Earth and the Sun but still heat (infra-red radiation also known as IR radiation) and light reaches the Earth.



FIGURE 10.17 Examples of sources of thermal radiations

Light is the fastest entity in nature. All forms of electromagnetic radiation (figure 10.18), including heat, move at the speed of light. Therefore, radiation is the fastest method for transferring heat. Every object emits infrared radiation, but hotter objects emit a greater amount of it. For example, Sun emits large amount of radiation whereas less hot objects like human body emits small amount of radiation.

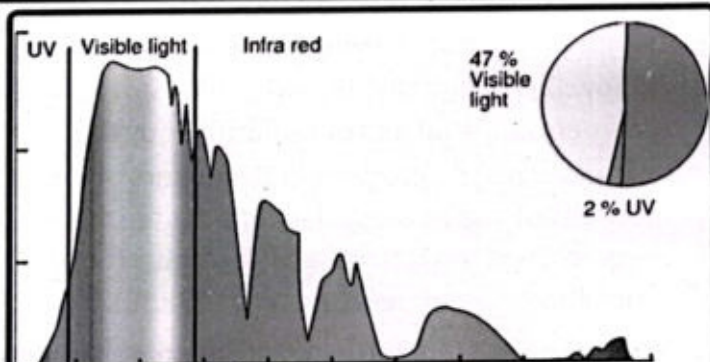


FIGURE 10.18 Solar spectra

A. Effect of Different Surfaces: All the objects absorb as well as radiate heat energy in the form of infra-red radiations. The amount of thermal radiation emitted by an object depends on different factors:

MINI LAB



Materials: Three identical hot water bottles, three different insulating materials (e.g., bubble wrap, foam sheet, and newspaper etc), Thermometers, Hot water

Procedure:

1. Fill the three hot water bottles with hot water (around 80°C to 90°C).
 - Bubble wrap (conduction insulation)
2. Wrap each bottle with a different insulating material:
 - Foam sheet (convection insulation)
 - Newspaper (radiation insulation)
3. Measure and record the initial temperature of the water in each bottle using a thermometer.
4. Place the bottles in a room with a consistent temperature (around 20°C to 25°C).
5. Measure and record the temperature of the water in each bottle every 15 minutes for an hour.
6. Compare the temperature changes in each bottle to see which insulating material performed best.

- **Surface colour of the object:** Different coloured surfaces have different absorption and emission abilities as shown in table 10.2. A good absorber is a good emitter, but it is a bad reflector. For example, wearing black clothes on a sunny day absorbs more heat and warms us. Black-coloured surfaces are good emitters; that's why laptop chargers are made up of black-coloured surfaces. It helps

Table 10.2: EFFECTS OF RADIATION ON DIFFERENT SURFACE COLOURS

Colour	Absorbing	Emitting	Reflecting
Black	Best	Best	Worst
Dull/Dark	Good	Good	Bad
White	Bad	Bad	Good
Shiny silver	Worst	Worst	Best

to cool it quickly. Similarly, the worst absorber is also the worst emitter, but it is a good reflector. Shiny silver surfaces are good reflectors; that's why car windscreen shades are made from silver-coloured surfaces.

- **Texture of the surface:** Texture is the quality of something that can be known by touch, or the degree to which something is rough or smooth or soft or hard. Texture of a surface can be rough, bumpy, slick, scratchy, smooth, silky, soft, prickly etc. Rough, dull, and dark surfaces are good absorbers and emitters of radiation, but they are the worst reflectors. While smooth and shiny surfaces are bad absorbers and emitters of radiation, they are good reflectors. Before painting the walls of the houses, they are made smooth and usually painted white. So that they could become good reflectors and less absorbers. It helps controlling the temperature of the houses.
- **Surface area of the object:** At the same temperature, a hot body with a big surface area emits more radiation than a body with a small surface area. Therefore, heat radiators installed in houses, car radiators etc have large surface area, which helps them to radiate quickly.

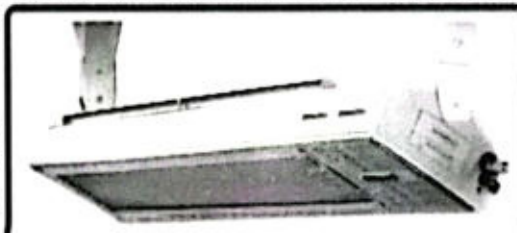


FIGURE 10.19 Infra-red heater

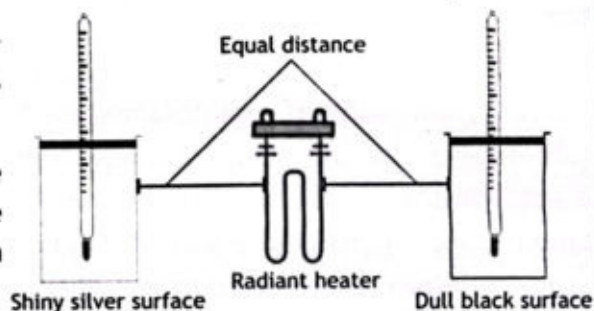
MINI LAB



Materials: Two similar cans (one can have shiny silver surface and the other is painted dull black) with lid, thermometer and radiant heater.

Procedure: Pour an equal amount of water into two cans. Place both cans at the same distance from an electric heat source. Insert thermometers into the cans as shown in the figure. There are two experiments that can be conducted with this setup:

1. Turn on the heater and after ten minutes, the water in the can with the dull black surface will be significantly hotter than the water in the other can.
2. Keep the heater off and pour boiled water into the cans. After ten minutes, the water in the can with the dull black surface will be much cooler than the water in the other can.



What can you conclude from these experiments, that which surface is a good absorber and which surface is a good reflector of heat?

For example, infrared heater (figure 10.19) that primarily emits infrared waves have large plate area so that it could radiate more heat.

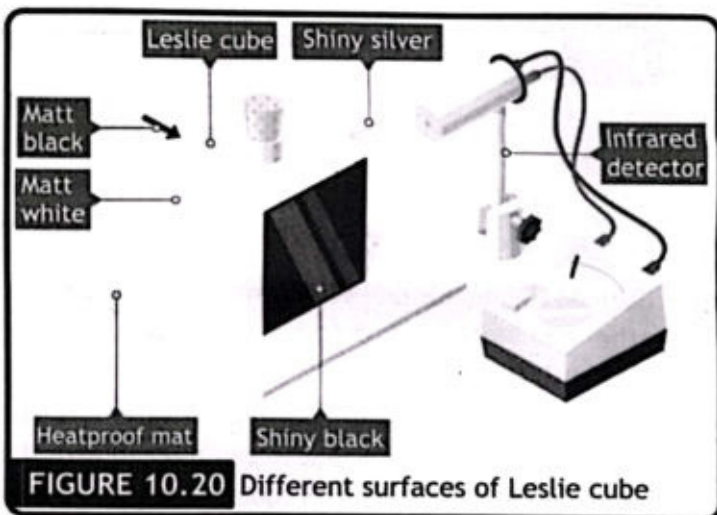
B. Effect of temperature on the rate of radiation: As we know that all objects absorb as well as radiate heat. Rate of radiation emitted by an object is directly proportional to temperature of the object. High temperature objects radiate more than low temperature body. Sun has high temperature and large surface area, it emits large amount of radiation while a cooking stove has low temperature and small surface area than the Sun, it emits less amount of radiation.

When an object is absorbing more heat than radiating, its temperature will rise. When the object is emitting more radiation than absorbing, its temperature will drop i.e. it will cool down. An object will remain at same temperature if it is absorbing and radiating heat at equal rate. This state is called thermal equilibrium. A hot cup of tea is placed on table, initially its temperature is higher than its surroundings. It will be emitting radiations at faster rate. Its temperature will decrease. After a while, its temperature will reach the temperature of surroundings (i.e. it will reach thermal equilibrium).

C. Leslie cube: The Leslie cube is used to demonstrate how different surface textures affect the emission of thermal radiation. It consists of four sides having different surfaces usually they are black and white painted surfaces, a matte black or dark coloured surface and shiny metal surface. It is hollow cube with lid at its top. Hot water is used usually to heat the interior of the cube. An 'infrared (IR) thermometer' as detector is used to measure the amount of IR radiation emitted from each surface of the cube.

The experiment on the Leslie cube (figure 10.20) follows the following procedure.

1. Boiling water is added to the Leslie cube for heating it.
2. Wait until the cube reaches the desirable temperature.
3. Measure the quantity of radiation emitted from each surface by placing the IR thermometer at the same distance from each one in turn. (The infrared thermometer detects the infrared radiation emitted by each surface. Higher



radiation translates to a higher temperature reading.)

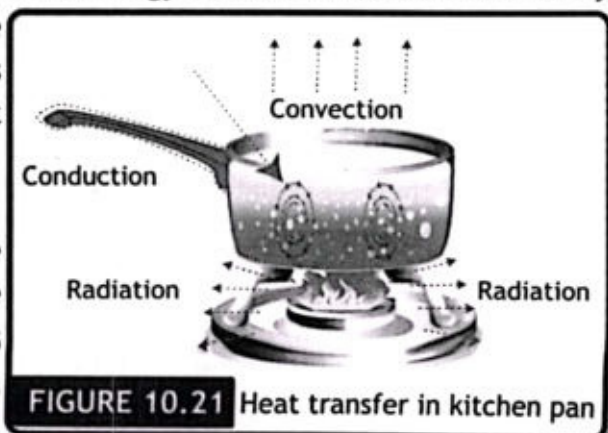
The surfaces which is better at emitting radiation show a higher temperature reading on the infrared thermometer, while the surfaces which are bad at emitting radiations have a lower reading. After performing the experiment, we can have the following conclusions:

- Black surface is the best absorber and emitter but worst reflectors.
- Dark coloured surface is good absorber and emitter but bad reflector.
- White surface is good reflector while bad absorber and emitter.
- Shiny metal (shiny silver) surface is the best reflector while worst absorber and emitter.

10.3 APPLICATIONS OF HEAT TRANSFER

A. Cooking in kitchen pan using conduction, convection and radiation: When you place a kitchen pan on a stove burner, heat from the burner conducts through the base of the pan as shown in figure 10.21. The metal of the pan absorbs the heat energy due to direct contact with the hot surface. Hot metal surface transfers the heat energy to food in contact with it by conduction. Also, this heat travels to whole surface of the pot and handle. This explains why the handles are composed of materials that are poor heat conductors, such plastic or wood.

When heating water in a pan or pot on the stove, convection currents occur. As the water near the bottom of the pan heats up, it becomes less dense and rises, while cooler water from the top sinks. This circulation helps distribute heat evenly and speeds up the boiling process.



Heat from the flame also reaches the pot through radiation process. In outdoor grilling or broiling in an oven, heat radiates from the hot charcoal or heating element directly onto the surface of the metal pan through radiation. The pan absorbs the radiant heat, which then transfers to the food inside the pan. So the kitchen pans can use all heat transfer methods for cooking as shown in figure 10.22.

B. Heating a room by convection: In winter, gas heaters are commonly used in Pakistan to keep rooms warm. When a gas heater is ignited, it heats the air surrounding it. The heated air becomes less dense and rises, generating convection currents. As the hot air rises, cooler air moves in to take its place near the heater. This cooler air then gets heated by the heater,

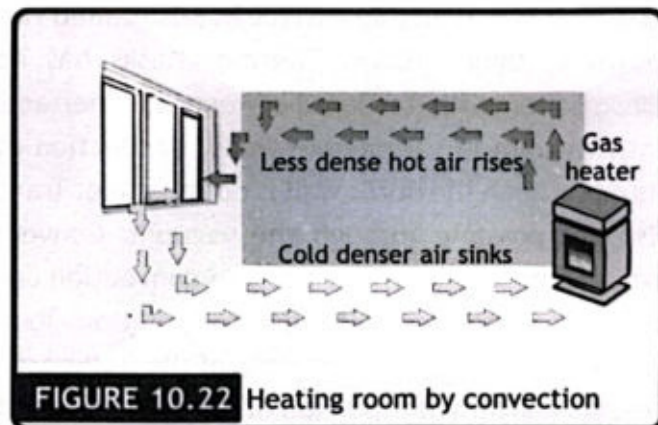


FIGURE 10.22 Heating room by convection

rises. The air that has risen eventually cools down becomes denser and sinks back towards the heater. This continuous cycle of hot air rising and cool air sinking creates a convection current that helps distribute heat throughout the room, gradually raising the overall temperature.

C. Mechanism of a household hot-water system: The most common hot water system is the storage tank water heater as shown in figure 10.23. Cold water enters your house and splits into hot and cold lines. The storage tank holds this cold water and heats it with an electric element or gas burner controlled by a thermostat. Hot water naturally rises to the top of the tank. When you turn on a hot water tap, the hot water from the top flows out. As hot water is used, cooler water from the bottom refills the tank and is reheated. This cycle keeps a steady supply of hot water available.

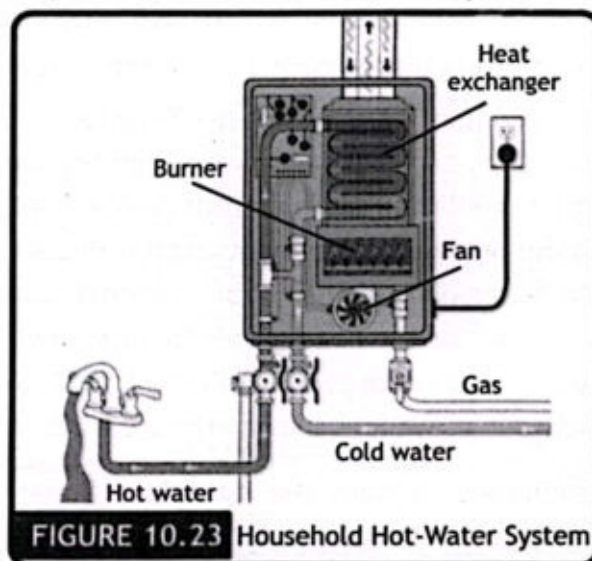


FIGURE 10.23 Household Hot-Water System

POINT TO PONDER



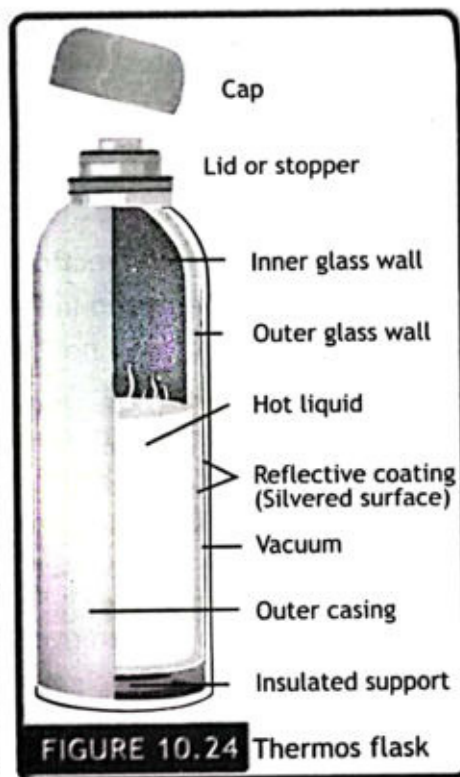
Why are freezer compartment at the top of refrigerator?

The freezer is located at the top of a refrigerator to take advantage of convection, the cold air from the freezer travels down and cools the bottom of the refrigerator. The warm air from the bottom rises and gets cooled again in the freezer.

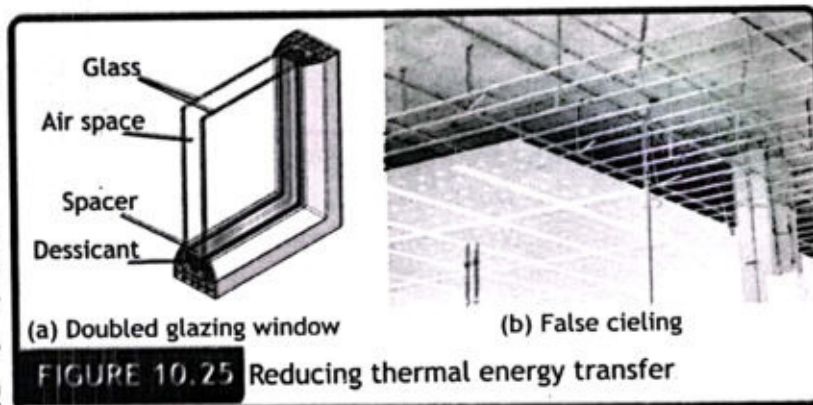
Also the freezer is placed above the hot compressor, which is usually located near the bottom of the refrigerator.



D. Maintaining Liquid Temperature: Wrapping an insulator around a hot object or around a hot/cold liquid containing object can reduce the flow of heat. This property of insulators helps to maintain the temperature of liquids. This property of insulators is used in thermos flasks (also called vacuum flask) as shown in figure 10.24. Thermos flasks have double walled construction with vacuum between its inner and outer walls. With vacuum in the double walls, conduction of heat of the liquid through the outer wall is not possible. Transfer of heat is also not possible through the vacuum. Convection requires movement of air for heat flow, so convection currents cannot produce. Some heat is lost due to radiation. To minimize heat loss due to radiation, inner walls of the flasks are silvered. This reflects a significant portion of the radiant heat back towards the liquid inside, minimizing heat loss. Some of the heat can flow out due to conduction from the material of the flask and from the lid. Therefore, interior of the thermos flasks are now made up of stainless steel which has low conductivity and lids are made up of plastic which usually trap air for better insulation.



E. Reducing Thermal Energy Transfer in Buildings: We can maintain comfort improve energy efficiency and reducing heating and cooling costs by proper thermal insulation in our homes and other buildings. Thermal insulation in winters, slows down the heat loss from warm interior to colder outside environment and it reduces the need of heating systems. In summer, it slows down the heat gain from the hot outside environment to the cooler interior, keeping the building cooler and reducing the need for air conditioning. Thermal insulation can be achieved in many ways. To reduce the conduction and convection, use double wall glazing windows with vacuum or air between its walls as shown in figure 10.25 (a), use foam etc in the gaps on the walls or doors. False ceiling which traps the air acts as insulation between the roof and the ground as shown in figure 10.25 (b), using thick curtains etc. Proper orientation of the home and shading during the summer reduce the heat entering the home. Proper ventilation also help to reduce temperature inside the home during summer.



F. Measuring Temperature with Infrared thermometers: In this chapter, we have studied that all objects emit heat radiations in the form of infrared radiation. These are not visible but we can sense them because they carry heat. Heat coming from the Sun, heaters or hot plates etc have infrared radiations in large amount. It is this heat that the infrared thermometers detect to measure the temperature of objects.

When it is unsafe or impracticable to make direct physical touch, infrared thermometers are used. For example, during the Corona Pañdemic, infrared thermometers were routinely used. They are also used to determine the temperatures of highly hot surfaces, such as those found in furnaces, industries, food storage facilities, and hazardous places, such as those containing radioactive materials etc. Infrared thermometers can be utilized as:

1. Carefully read the instructions on the device manual.
2. Power on infrared thermometer and adjust its scale (degree Celsius or degree Fahrenheit).
3. Point the thermometer sensor to the target surface. Hold the thermometer steadily at a suitable distance mentioned in the manual as shown in figure 10.26.
4. Press and hold the trigger (a button) until the reading on the display screen stabilizes.
5. Once you hear a beep or see a stable reading on the display screen, release the trigger and note down the temperature.



FIGURE 10.26 Infrared thermometer

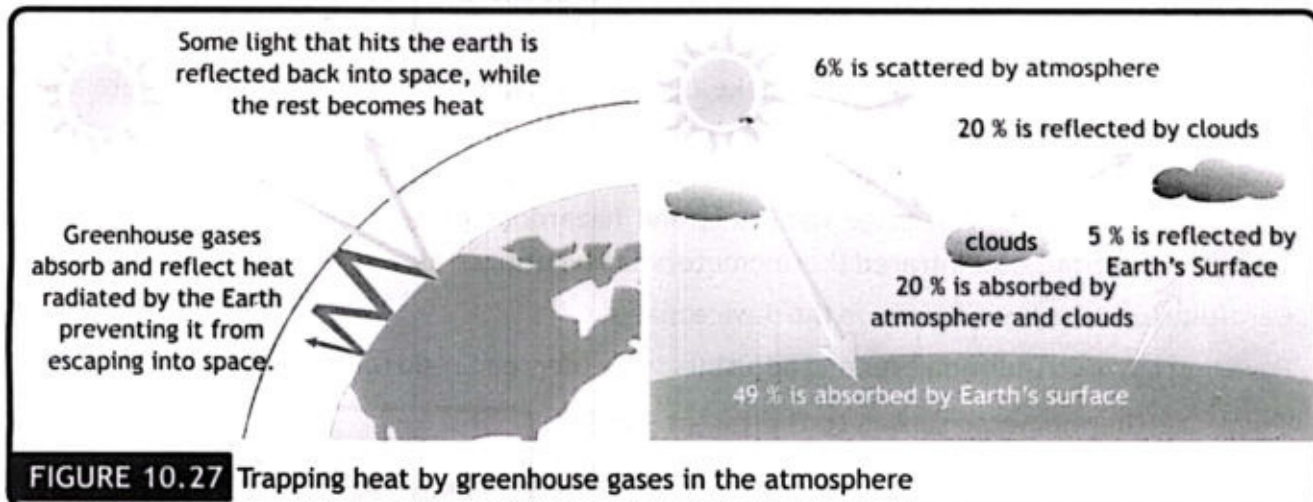
The following precautions should be maintained while using infrared thermometer.

1. Each infrared thermometer has a distance-to-spot (D:S) ratio. This ratio tells you the diameter of the target area (whose temperature is to be measured) relative to the distance from the target. For example, a D:S ratio of 12:1 means that for every 12 units of distance from the object, the thermometer will measure a spot with a diameter of 1 unit. So, if you hold the thermometer 12 inches away from the surface, it will measure temperature of the circle roughly 1 inch in diameter.
2. Avoid taking measurement of the small objects, moving objects, wet objects, reflective surfaces and rough surfaces.
3. Keep comparing its accuracy, off and on, with the mercury thermometer.

10.4 GREEN HOUSE EFFECT AND GLOBAL WARMING

Just like all objects, Earth also absorbs and emits radiations. Earth absorbs theses high energy radiations and emits low energy radiations back in the atmosphere. But water vapours, carbon dioxide, methane and other greenhouse gases forming atmosphere absorb these heat radiations emitted by the Earth and re-emit back to the Earth. Due to this, Earth warms which is necessary

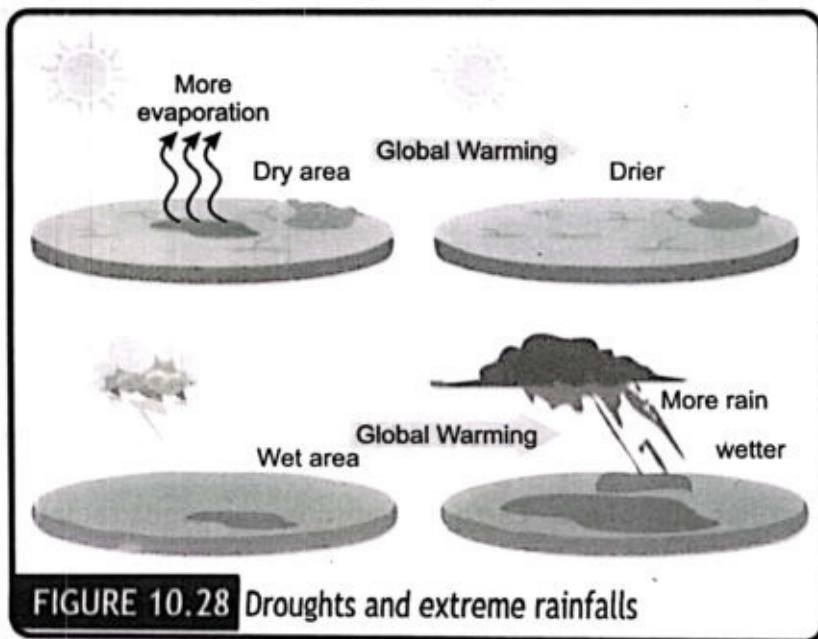
for life to sustain on it. This is called greenhouse effect. If Earth had no atmosphere, it would have emitted all the absorbed radiations and its temperature would have drop to -180°C at night (equal to temperature of Moon at night). At such low temperature, life would not have existed at the Earth.



Human activities like burning of fossil fuels (coal, wood, oil and natural gas), large number of vehicles on roads generating smoke, many industrial and agricultural activities (producing methane and nitrogen oxide) and deforestations (which reduces the number of trees that can absorb carbon dioxide) have increased the concentration of greenhouse gases in the atmosphere.

Due to this amount of thermal radiation, trapped by the greenhouse gases, have increased. This has increased the Earth's average temperature. This gradual increase in the temperature of Earth's atmosphere and oceans is called **global warming**. This higher temperature is affecting our ecosystem, weather pattern (e.g. duration of season is changing) and human health. Due to global warming, we are facing effects like flooding, hurricanes, extreme rainfall, droughts etc. Let's discuss their causes:

A. Flooding: This increased temperature of the Earth is causing fast melting of glacier, which is increasing the sea levels. Rising sea levels is a threat to coastal area life as it is increasing flooding and erosion of land.



POINT TO PONDER



Climate models predict that by 2050, global fires could increase by 19% compared to 2015. Why is this happening?

There are three main reasons for increase in global fires:

- 1. Hotter, Drier Conditions:** A key factor is rising temperatures. A warmer climate means more evaporation, leading to drier soil and vegetation. This creates more flammable fuel for fires to spread quickly.
- 2. Longer Fire Seasons:** As temperatures rise, the window for hot and dry weather - prime fire season - gets longer. This extends the period when wildfires are most likely to ignite and spread.
- 3. Changes in Precipitation Patterns:** Rainfall patterns are also predicted to shift due to climate change. Some areas may experience less rain, further exacerbating drought conditions and increasing fire risk.



B. Hurricanes: Global warming heats up the oceans, giving hurricanes more energy. This makes them stronger with faster winds and heavier rain. Warm air can hold more moisture, so hurricanes can drop even more rain.

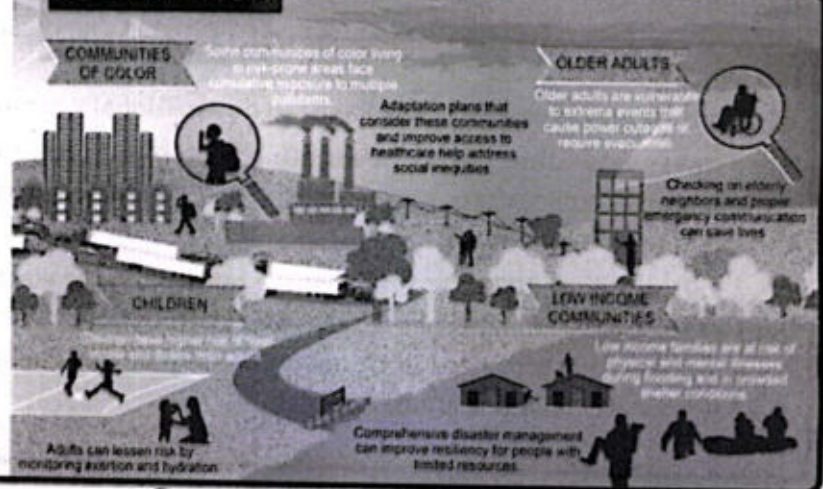
C. Rainfall: Rising temperature due to global warming have increased evaporation, causing greater moisture in the atmosphere and resulting in more intense rainfall in the area that already experience significant rainfall.

D. Droughts: Due to greater evaporation rate, water in soil and plants is decreasing. It is causing the land to get drier and making it harder for plants to acquire enough water to grow healthily.

E. Wildfires: Increased temperatures due to global warming are drying out more trees, vegetation, and bushes, increasing the amount of fuel available for fires. If a fire starts due to lightning or human activity, it can quickly spread over a large area, becoming uncontrollable. This results in huge amounts of smoke, significantly decreasing air quality.

The image shows communities at higher risk to health issues related to climate change and Possible remedies. Dark text shows steps that can be made to reduce the dangers that those communities face, while white text highlights such risks.

INFORMATION



MINI LAB

**Activity: Carbon Footprint of Daily Transportation**

Carbon Footprint: A carbon footprint measures greenhouse gas emissions from activities like fossil fuel burning, deforestation, and industrial processes. It can be reduced by unplugging devices, using energy-efficient technologies, and adopting renewable energy sources.

Ecological Footprint: The ecological footprint measures the resources needed to support a lifestyle, including land, water, and waste absorption. A larger footprint means higher environmental impact, so reducing it helps protect the planet.

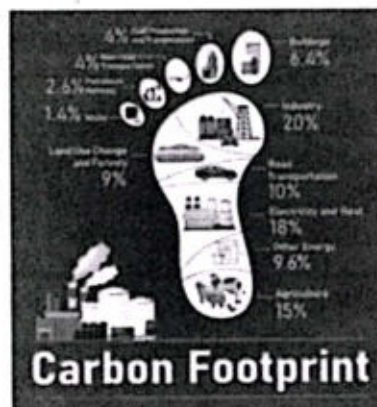
Activity: We can estimate carbon footprints using simple calculations. For example, a car emits approximately 0.2 kg of CO₂ per kilometre travelled. If a student travels 5 km to school every day by car, he can calculate his daily carbon emissions from transportation as:

$$\text{Daily CO}_2 \text{ emission} = 5 \text{ km} \times 0.2 \text{ kg CO}_2/\text{km} = 1 \text{ kg CO}_2/\text{day}$$

Then, calculate for a week (assuming 5 days per week of school):

$$\text{Weekly CO}_2 \text{ emission} = 1 \text{ kg/day} \times 5 \text{ days} = 5 \text{ kg CO}_2/\text{week}$$

Class Activity: All students of the class are asked to calculate the carbon footprint of their own daily transportation and compare results with classmate. Discuss actions to lower your carbon footprint?



F. Winter Storms: Winter storms are events like snow, sleet and freezing rains with strong winds. Due to increased moisture in atmosphere results in heavier snowfall in winters.

We have to take steps to fight the effects of this global warming. We have to stop deforestation and increase forestation on the globe which are natural carbon dioxide absorbing source. This can reduce the about of carbon dioxide in the atmosphere. We have to find such energy efficient sources which releases no or minimum greenhouse gases. Beside this, we have to adapt with this global warming conditions as well. Make resilient infrastructure which could sustain the extreme weather events.

INFORMATION

Recent Heat waves and Floods in Pakistan due to Global Warming

Heat-waves May- June 2022: Devastating heatwave gripped Pakistan and India with temperatures exceeding 51°C (123.8°F). Scientists linked this event to global warming.

Devastating Floods 2022: Severe monsoon rains and rapid glacial melt, both influenced by climate change, caused disastrous floods in the whole country, especially provinces Sindh, major areas of Khyber Pakhtunkhwa and Balochistan, and some areas of Punjab.



10.5 FLOW OF HEAT IN GEOTHERMAL ACTIVITIES

The structure of the earth is divided into three parts; core, mantle, and crust as shown in figure 10.29. The **core** is the central part of the earth. It is the hottest part. Its temperature is about 6000°C . It is mainly composed of iron and nickel. The core is so hot due to different factors, involving left-over heat during the formation of the earth, radioactive decay of elements like uranium and thorium inside the core, and extra pressure applied by the earth's gravity. The inner core is the portion of the core that is solid. The core's solid form is maintained by the extreme

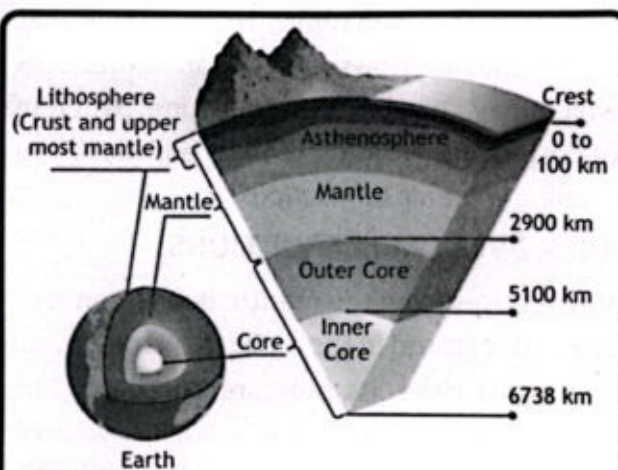


FIGURE 10.29 Earth's structure

pressure. The molten portion of the core is referred to as "the outer core". It is molten because the core's pressure has dropped. Temperature of the outer core is about 4000°C . The mantle lies between core and crust. It is the thickest part. It floats on the outer core. It is composed of the silicate minerals mainly containing iron and magnesium. It is solid but shows plasticity (permanent change in shape of solid material) under high pressure due to gravity. The crust is the outer part of the earth's structure. It is composed of silicate materials. It is divided into continental crust and oceanic crust. The **lithosphere** is the layer between the crust and the upper mantle. The **asthenosphere** lies just beneath the lithosphere and plays a critical role in plate tectonics. **Magma** is molten or partially molten rock located beneath the Earth's crust. It forms from the partial melting of the mantle and crust due to various geological processes.

10.5.1 FLOW OF MAGMA BENEATH THE EARTH

There is extremely high temperature around $2,000^{\circ}\text{C}$ to $6,000^{\circ}\text{C}$ between core to crest. This intense heat within the mantle can cause some solid rock to partially melt, forming magma. This molten material i.e. magma is less dense than the surrounding solid rock. Heat is transferred from core to mantle through conduction as there is temperature difference between core and mantle. In

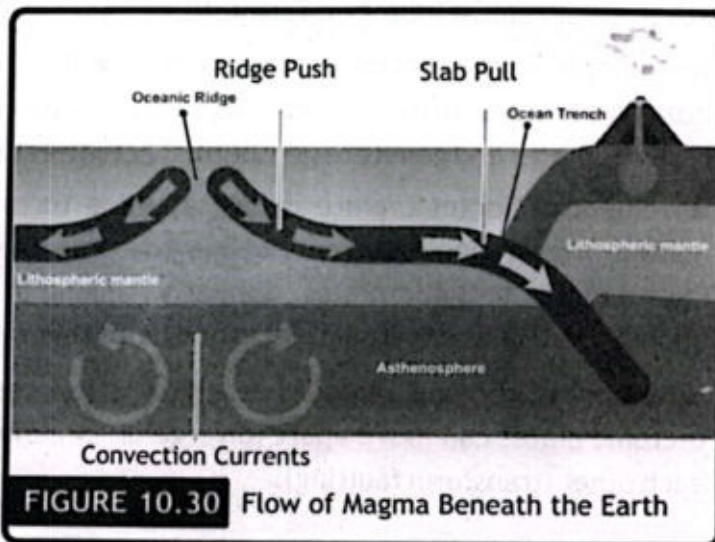


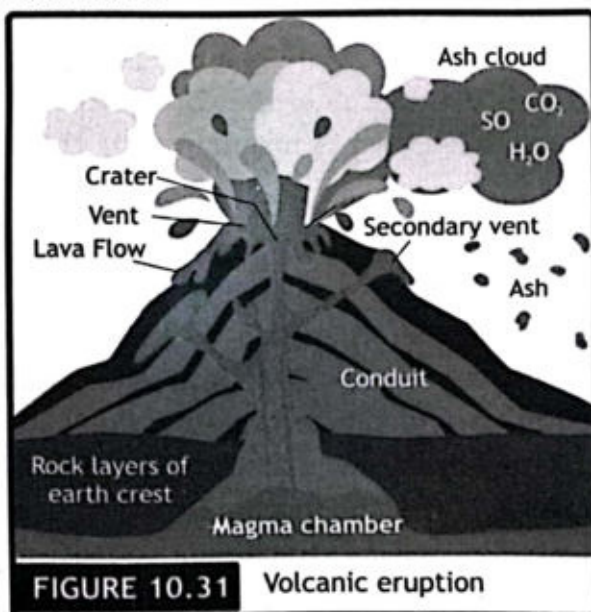
FIGURE 10.30 Flow of Magma Beneath the Earth

the mantle, magma gets heat, becomes less dense and rises up i.e. it transfers heat through convection. Hot magma rises up and cold magma sinks. This process develops convectional current as shown in figure 10.30. In this way, magma flows from bottom of mantle towards crust. Hotter magma flows easily than colder one. When magma flows, it melts the rocks on the way which may change its composition. When magma cools down, it solidifies and forms rocks deep underground. If magma finds a path to the surface through vents or fissures, it erupts as lava, shaping volcanic landscapes.

10.5.2 VOLCANIC ERUPTIONS

Magma rises from the mantle due to convectional currents and pressure difference in mantle and crust. It is stored in the crust at the place, called magma chamber.

As magma rises, its pressure decrease. This allows the dissolved gases such water vapor, carbon dioxide, and other volatiles to release and it increases the internal pressure of the magma chamber. When this pressure exceeds the strength of the covering rock, magma fractures it and creates pathways (main and secondary vents) for itself to reach the crust. This leads to a forceful volcanic eruption through crater (main opening), driven by high-pressure gases and magma as shown in figure 10.31. The hot magma that flows out during an eruption is called lava. Volcanic eruption depends upon factors like magma composition, temperature, amount of gas and interaction with water etc.



10.5.3 MOVEMENT OF TECTONIC PLATES

Tectonic plates are very large, rigid parts of the Earth's crust and upper most mantle. These plates float on the molten mantle (semi-fluid asthenosphere). These tectonic plates interact with other tectonic plates and generate geothermal activities like earthquakes, volcanic eruptions etc.

Movement of Tectonic plate is basically due to the process of magma convection current in mantle. Convectional currents of magma drag the plates along with it and cause horizontal movement in tectonic plates. Similarly, sinking of dense and cold magma due to convection applies a pull on the tectonic plates and helps them to move as shown in figure 10.32.

Movement of tectonic plates is very slowly, few centimeters per year. Due to their movement, tectonic plates can move apart (diverge or spreading), come together (converge), or slide past each other (transform faulting).

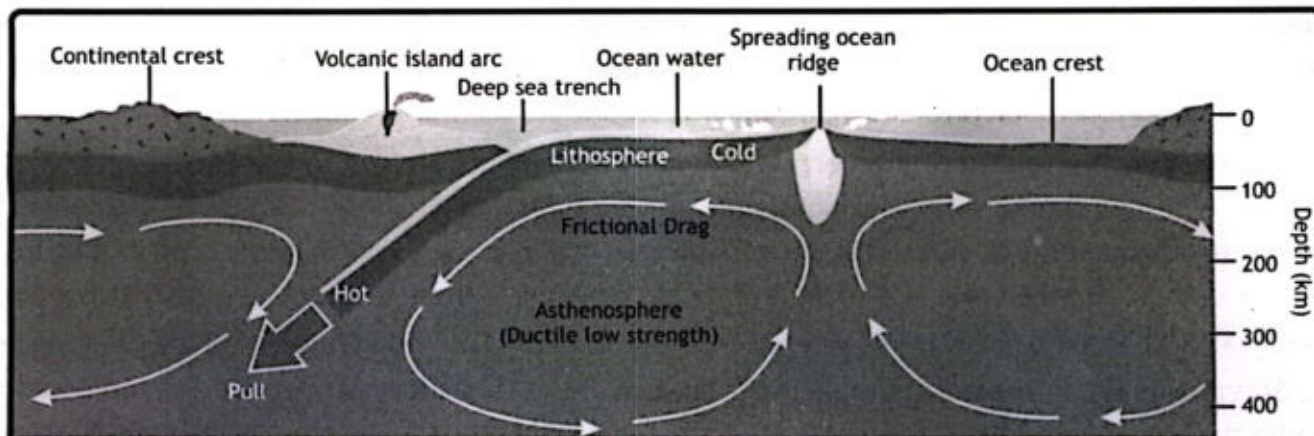


FIGURE 10.32 Movement of tectonic plates caused by the motion of magma

INFORMATION

There are seven major tectonic plates:

1. Pacific Plate
2. North American Plate
3. South American Plate
4. Eurasian Plate
5. African Plate
6. Indo-Australian Plate (It is considered as two separate tectonic plates i.e. Indian plate and Australian plate)
7. Antarctic Plate



Apart from these there are eight minor plates (Arabian plate, Caribbean plate, Indian plate etc.) and many micro plates (Riviera Plate, Somali Plate etc.) as well.

10.5.4 EARTH'S CORE MAINTAINING ITS TEMPERATURE

Scientists believe that Earth's formation involved accretion, where gravity pulls matter together to create celestial bodies. After the Sun formed, gravity combined dust, rocks, ice, and gases to form massive objects like Earth. According to the Giant Impact Hypothesis, a planet named Theia collided with Earth about 4.4 billion years ago, resulting in the destruction of Theia. The partial melting of Earth and the scattering debris into space. The early atmosphere was mainly hydrogen and helium, and as the crust solidified, volcanic eruptions and asteroid impacts introduced water, water vapour, ammonia, and carbon dioxide. Over time, Earth evolved to support life. Today, the Earth's core remains extremely hot, around 6000 °C. Let's discuss different factors due to which Earth's core is maintaining its temperature.

A. Residual Heat from Formation: During the formation of the Earth (accretion process), large

number of massive objects, e.g. planetesimal objects, asteroids and other massive objects collided with it. The kinetic energy from these collisions was converted into heat, large amount this heat energy has been retained in the Earth's core.

B. Radioactive Decay: There are certain radioactive elements present in the Earth's core like uranium-238 and thorium-232 and potassium-40. During decay of these radioactive elements, large amount of energy is released in the form of heat. This process is continuously contributing to the temperature of the core. Due to decay process, amount of these radioactive elements is also decreasing, that's why rate of heat generation from radioactivity has decreased slightly.

C. Gravitational Compression: During the formation of the Earth, its materials were compressed under the force of gravity. This increased the pressure and hence, temperature in the core. In this way, gravitational compression becomes a constant source of heat to the core.

D. Crust as Insulator: The Earth's outer layers act as a thick layer of insulation. This slows down the rate at which heat escapes from the core into space. So, crust helps maintain the high temperature of the core for a longer period.

Mechanisms that generate heat are gradually slowing down, allowing heat to escape from the Earth. However, this process is so slow that the core has managed to maintain its temperature for the past 4 billion years.

SUMMARY

- **Heat Capacity** is the amount of heat required to raise the temperature of any amount of substance by 1°C or 1 K .
- **Specific Heat Capacity** is the amount of heat required to raise the temperature of one gram of a substance by 1°C or 1 K .
- **Conduction** is the mode of transfer of heat due to direct contact of medium particles, which do not change their positions. It occurs in solids because of difference in temperatures.
- **Convection** is the mode of transfer of heat due to the motion of particles. It occurs in liquids and gases because of the density difference between different regions.
- **Radiation** is the mode of transfer of heat due to electromagnetic waves. It does not require material medium for its motion.
- **Land Breeze** is the breeze that blows from the land. It normally occurs during the night and early morning.
- **Sea Breeze** is the breeze that blows from the massive water bodies. It normally occurs during the summer and spring season.
- **Greenhouse Effect** is the process through which heat is trapped near Earth's surface by substances known as greenhouse gases.

- **Global Warming** is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning.
- **Cyclones** are large revolving tropical storms caused by winds blowing around a central area of low atmospheric pressure.
- **Hurricane** is a tropical system with winds that have reached a constant speed of 74 miles per hour or more.
- **Heat Wave** is a period of abnormally hot weather generally lasting more than two days and can occur with or without high humidity.
- **Flooding** is an overflow of water onto normally dry land.
- **Drought** is a prolonged dry period (deficiency of precipitation) in the natural climate cycle that can occur anywhere in the world.
- **Accretion** is a process in which particles of matter, such as dust and gas, gradually come together due to gravitational attraction to form large objects, like planets, moons etc.
- **Debris** refer to the fragments rock, dust and other material that were scattered into space as a result of collision between Theia and Earth.
- **Geothermal Activity** is a group of natural heat transfer processes, caused by the presence of excess heat in the subsurface of the affected area, occurring on Earth's surface.

EXERCISE



MULTIPLE CHOICE QUESTIONS

Q1. Choose the best possible option in the following questions.

- Why is water used in radiators of automobile as coolant?
A. It is easily available
B. It is low cost or free
C. It has large specific heat
D. It has oxygen
- Which of the following situations is the best example of conduction?
A. A metal spoon becomes hot when placed in boiling water
B. Warm air rising near a heater
C. Sunlight warming the surface of the Earth
D. A microwave oven heating food
- Which combination of heat transfer methods would be dominant when you place your hand near, but not touching, a fire?
A. Conduction and radiation
B. Convection and conduction
C. Radiation and convection
D. Conduction and insulation
- What is symbol and what is unit for the heat capacity of an object?
A. $J^{\circ}C^{-1}$
B. $J\ kg^{-1}\ K^{-1}$
C. $J\ kg\ K^{-1}$
D. $J\ kg^{-1}\ K$
- If the same amount of heat energy is supplied to equal masses of water and copper, why does the temperature of copper increase faster?
A. Copper has a lower specific heat capacity
B. Water is a poor conductor of heat
C. Convection in water dissipates heat energy quickly
D. Radiation from water is stronger
- The transfer of heat that takes place because of density difference in fluids is
A. Conduction
B. Radiation
C. Convection
D. Insulation
- Which of the following statements best explains why the Earth experiences more heat from the Sun than the Moon, despite being almost the same distance away?
A. Earth is better conductor than the moon
B. The Earth has greenhouse gases
C. The Moon reflects most of the Sun's radiation
D. Moon traps heat effectively
- Dull black colour on a surface is the best absorber of radiation, which of the followings is the best radiator?
A. Dull black surface
B. Shining silver surface
C. Red Coloured Surface
D. White surface

9. How does the enhanced greenhouse effect contribute to global warming?
 - A. It increases the Earth's ability to reflect solar radiation
 - B. It traps more heat in the Earth's atmosphere, raising global temperatures
 - C. It blocks ultraviolet rays from entering the atmosphere
 - D. It increases the Earth's rotation speed, causing heat buildup
10. What is the primary driving force behind the movement of tectonic plates?
 - A. Gravitational pull of the Moon
 - B. Solar radiation
 - C. Mantle convection currents
 - D. Magnetic field of the Earth
11. Which layer of the Earth is composed of partially molten rock that can flow slowly?
 - A. Lithosphere
 - B. Asthenosphere
 - C. Mesosphere
 - D. Outer core
12. Which of the following extreme weather events is most directly associated with rising sea levels?
 - A. Tornadoes
 - B. Wildfires
 - C. Hurricanes
 - D. Earthquakes

CONSTRUCTED RESPONSE QUESTIONS

QII. Follow the directions to respond to the following questions.

1. This AI-generated image illustrates global warming caused by the greenhouse effect and its impact on climate change. It shows how rising temperatures due to the greenhouse effect led to more frequent and intense heatwaves and hurricanes.

It shows how rising temperatures due to the greenhouse effect led to more frequent and intense heatwaves and hurricanes. Answer the following questions, considering the concepts mentioned above:

- a. How do increased temperatures lead to more frequent heatwaves in cities?
- b. How might the intensity of future hurricanes change if global temperatures continue to rise?
- c. Explain what the glass roof of a greenhouse and carbon dioxide in Earth's atmosphere have in common in terms of heat and temperature.



2. This table shows the temperature of 10 g of water and 10 g of iron after being in direct sunlight for up to 60 minutes.

Time (minutes)	0	15	30	45	60
Temperature of water (°C)	25	26.2	27.5	28.8	30
Temperature of iron (°C)	25	35	45	55	65

- Create line graphs of temperature (on the y-axis) and time (on the x-axis) for both water and iron on a graph sheet. Be sure to label the substances.
- Based on the data in the table, which heats up quickly: water or metal?
- Which do you think will cool more slowly: water or iron? Elaborate your answer.
- When you boil water in an iron pot on the stove, which heats up faster: the iron pot or the water? Provide a reason for your response.

SHORT RESPONSE QUESTIONS

QIII. Give a short response to the following questions.

- Why should we wear dark-coloured clothes in winter and white-coloured clothes in summer?
- In a house, geysers or water boilers are fitted on the ground floor, and still, we get warm water on the top floor without using a pump. How is it possible?
- Where will you get more heat from the wood fire, 1 meter above the woods or 1 meter from the front of the woods?
- Why do crowded city areas feel hotter compared to the outskirts on a hot summer day? State the reasons for this difference.
- Why is the metallic handle of a door colder than the wood of the same door when touched?
- How do trees help reduce the effects of climate change, and what could happen if forests are depleted?
- How does gravity contribute to the Earth's core temperature?
- Why do certain gases in the atmosphere trap more heat than others?
- What are the potential environmental impacts of extraction of geothermal energy?
- How does the specific heat capacity of different materials affect their use in cookware?

11. Water at 20°C is sent deep underground into heated layers, where it turns into a mix of steam and hot water at 100°C . As the steam and hot water cool back down to 20°C , why does 1 kg of steam release more energy than 1 kg of hot water?

LONG RESPONSE QUESTIONS

QIV. Give a detailed response to the following questions.

1. Explain the concept of specific heat capacity in matter. Discuss various applications of water based on its high specific heat capacity.
2. What is conduction, and how is it explained by the kinetic theory of solids? What makes metals better conductors than other solid substances.
3. Analyze how heat is transferred through convection. Provide at least three practical examples of how convection is used in daily life.
4. Analyze the process of heat transfer through radiation, explaining why it is the fastest method of heat transfer. What factors influence the rate of heat transfer by radiation?
5. Analyze the role of greenhouse gases in global warming. How does global warming contribute to the increased severity of hurricanes, heat waves, flooding, and droughts?
6. Why Earth's core has extreme high temperature even after 4 billion years? Explain in detail.
7. How are tectonic plates formed, and what factors cause them to move? Explain these causes in detail and discuss the effects of plate movements.

NUMERICAL RESPONSE QUESTIONS

QV. Solve the questions given below.

1. Convert specific heat of water $4180 \text{ J kg}^{-1} \text{ K}^{-1}$ into units of $\text{Jg}^{-1} \text{ }^{\circ}\text{C}^{-1}$.
(Ans. $4.18 \text{ Jg}^{-1} \text{ }^{\circ}\text{C}^{-1}$)
2. Calculate amount of heat given to 25 kg of water to increase its temperature by 50°C .
(Ans. 5.25 MJ)
- 3.. A half kg block of an unknown metal is heated from 30°C to 80°C , requiring 19 kJ of heat energy. (a) Calculate the specific heat capacity of the metal. (b) If the same metal block is heated from 80°C to 125°C , how much additional heat energy would be needed?
(Ans. $760 \text{ J kg}^{-1} \text{ K}^{-1}$, 17.1 kJ)
4. Calculate the change in temperature of 5 litre of water if it absorbs 8.4 MJ of heat energy? (Use Specific heat of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$)
(Ans. 400°C)

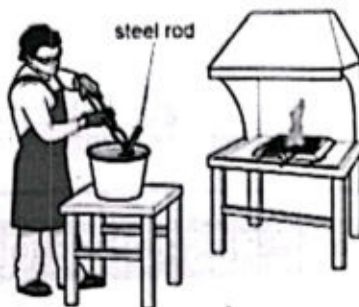
5. In a container, 100 g of water at 80°C is mixed with 200 g of water at 20°C . What will be the final temperature of the mixture, assuming no heat loss to the surroundings (and container)? (Use specific heat capacity of water is $4200\text{ J kg}^{-1}\text{ K}^{-1}$ or $4.2\text{ J g}^{-1}\text{ K}^{-1}$).

(Ans. 40°C)

6. A 200 g piece of an unknown solid cylinder is heated to 110°C and then placed into a calorimeter containing 200 g of water at 20°C . The calorimeter has a mass of 60 g and specific heat capacity of $0.9\text{ J/g}^{\circ}\text{C}$. The final temperature of the system (solid, water, and calorimeter) is 35°C . Assume no heat is lost to the surroundings. Calculate the specific heat capacity of the solid.

(Ans. $890\text{ J kg}^{-1}\text{ K}^{-1}$ or $0.89\text{ Jg}^{-1}\text{K}^{-1}$)

6. A hot steel rod is cooled by plunging it into cold water, as shown in Fig. The steel rod has a mass of 3 kg and is initially at a temperature of 450°C . It cools to 50°C when placed in the water. The specific heat capacity of steel is $460\text{ J kg}^{-1}\text{ }^{\circ}\text{C}^{-1}$. Calculate the thermal energy (heat) lost by the steel rod as it cools to 50°C .



(Ans. 552 kJ)

STUDENT LEARNING OUTCOMES

The students will:

- ✓ [SLO: P-10-C-04] Use the terms for the changes in state between solids, liquids and gasses.
- ✓ [SLO: P-10-C-05] Explain thermal expansion in terms of kinetic theory.
- ✓ [SLO: P-10-C-06] Analyze the applications and consequences of thermal expansion in real life.
- ✓ [SLO: P-10-C-07] Analyze melting, solidification, boiling and condensation in terms of energy transfer without a change in temperature.
- ✓ [SLO: P-10-C-08] State the melting and boiling temperatures for water at standard atmospheric pressure.
- ✓ [SLO: P-10-C-09] Describe qualitatively the thermal expansion of solids.
- ✓ [SLO: P-10-C-10] Explain the thermal expansion of liquids.
- ✓ [SLO: P-10-C-11] Analyse the pressure and the changes in pressure of a gas in terms of particles.
- ✓ [SLO: P-10-C-12] Differentiate between boiling and evaporation.
- ✓ [SLO: P-10-C-22] Describe evaporation in terms of particles.
- ✓ [SLO: P-10-C-23] Analyze how temperature, humidity, surface area and air movement over a surface affect evaporation.
- ✓ [SLO: P-10-C-24] Explain how evaporation causes cooling.
- ✓ [SLO: P-10-C-25] Describe the use of cooling caused by evaporation in the refrigeration process without using harmful CFCs.
- ✓ [SLO: P-10-C-26] Explain latent heat.
- ✓ [SLO: P-10-C-27] Justify experiments to determine latent heat of fusion and latent heat of vaporization of ice and water.
- ✓ [SLO: P-10-C-28] State that certain materials, when cooled to near absolute zero, can exhibit superconductivity.
- ✓ [SLO: P-10-C-29] Describe superconductivity.