7. What is meant by the latent heat of fusion and latent heat of vaporization of a substance?
8. What is meant by evaporation ? On what factors the evaporation of a liquid depends. Explain how cooling is produced by evaporation. Diffrenciate between boiling and evaporation.

## NUMERICAL QUESTIONS

1. Perform the temperature conversions (a) **Temperature difference in the body.** The surface temperature of the body is normally about 7 °C lower than the internal temperature. Express this temperature difference in kelvins and in Fahrenheit degrees. (b) **Blood storage.** Blood stored at 4.0 °C lasts safely for about 3 weeks, whereas blood stored at -160 °C lasts for 5 years. Express both temperatures on the Fahrenheit and Kelvin scales.
2. Consider a metre-stick composed of platinum (the coefficient of linear expansion for platinum is $\alpha = 8.8 \times 10^{-6}\ K^{-1}$). By what amount does the length of this metre-stick change if the temperature increases by 1.0 K?
3. A railway line made of iron is 1200 km long and is laid at 25 °C. By how much will it contract in winter when the temperature falls to 15 °C? By how much will it expand when the temperature rises to 40 °C in summer? (the coefficient of linear expansion for iron is $\alpha = 12 \times 10^{-6}\ K^{-1}$).
4. The volume of a brass ball is 800 $cm^3$ at 20 °C. Find out the new volume of the ball if the temperature is raised to 52 °C. The coefficient of volumetric expansion of brass is $57 \times 10^{-6}\ K^{-1}$.
5. What is the specific heat of a metal substance if 135 kJ of heat is needed to raise 4.1 kg of the metal from 18.0 °C to 37.2 °C?
6. How much heat is needed to melt 23.50 kg of silver that is initially at 25 °C? (Specific Heat of silver is $c = 230\ J\ kg^{-1}\ K^{-1}$ Latent heat of fusion for silver is $L_f = 8.82 \times 10^4$).

## WEB LINK

http://www.thermopedia.com/



# Unit 9 TRANSFER OF HEAT

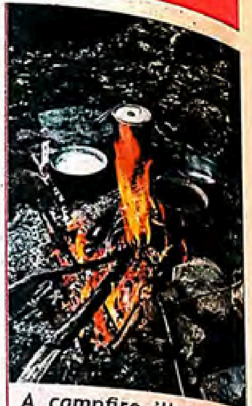
**CHECK LIST**

**After studying this unit you should be able to:**

- ✓ recall that thermal energy is transferred from a region of higher temperature to region of lower temperature.
- ✓ describe in terms of molecules and electrons, how heat transfer occurs in solids.
- ✓ state the factors affecting the transfer of heat through solid conductors and hence, define the term "Thermal Conductivity".
- ✓ solve problems based on thermal conductivity of solid conductors.
- ✓ write examples of good and bad conductors of heat and describe their uses.
- ✓ explain the convection currents in fluids due to difference in density.
- ✓ state some examples of heat transfer by convection in everyday life.
- ✓ explain insulation reduces energy transfer by conduction.
- ✓ describe the process of radiation from all objects.
- ✓ explain that energy transfer of a body by radiation does not require a material medium and rate of energy transfer is affected by:
  - Colour and texture of the surface
  - Surface temperature
  - Surface area

Heat (Q) is the thermal energy that can be transferred between two systems by temperature difference. When two bodies are at different temperatures, thermal energy transfers from the one with higher temperature to the one with lower temperature.

Heat transfer has an enormous range of application, even our survival, and comfort, depends on keeping our bodies at a constant temperature. To keep a building or a house at a comfortable temperature in winter and in summer, if it is to be done economically and efficiently, requires a knowledge of how heat travels.



*A campfire illustrates the three main modes of thermal energy transfer: conduction, convection, and radiation.*

## 9.1 CONDUCTION OF HEAT

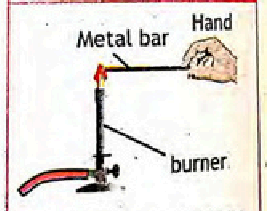
The handle of a metal spoon held in a hot tea soon gets warm. Heat passes along the spoon by conduction.

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

### 9.1.1 Mechanism of Heat Conduction

The mode of heat transfer by conduction can be examined with the help of a simple activity. Take an iron bar. Hold one end of the bar in the flame of a burner. After a few seconds, you will find that the other end is too hot to hold as shown in figure 9.1. How does the heat flow from the hotter to the colder end of the bar? What is the mechanism of heat transfer from one location to another?

Figure 9.1




Heat Transfer Activity

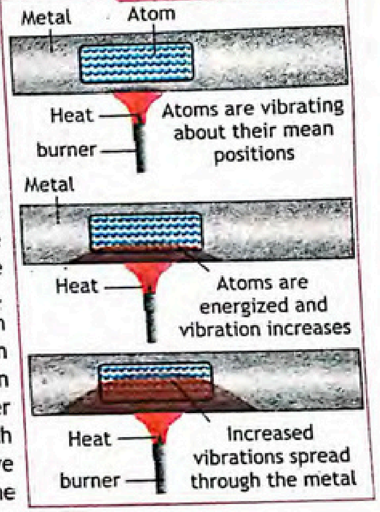
The mechanism of heat conduction can be explained by the behaviour of atoms within the material. The solid iron rod is made of closely packed iron atoms. According to kinetic molecular description of matter the greater the temperature the more is the kinetic energy of atoms or molecules. The atoms in the hotter part of the rod vibrate more violently (thus possess more kinetic energy) than those in the colder part.





Initially, before the rod is inserted into the flame, the iron atoms are vibrating about their equilibrium positions. As the flame heats the rod, the iron atoms near the flame begin to vibrate with greater speeds and wider distance. These wildly vibrating atoms collide with their neighboring atoms and transfer some of their energy to these atoms. Which in turn pass thermal energy to their own neighbors and so on as shown in figure 9.2. Iron is a metal and contains a large number of electrons that are free to move through the metal called free electrons. These free electrons also play a big part in the conduction of heat. For example, when one end of the iron 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 occurs which result in the transfer of energy. In light of this discussion we can define the conduction of heat as that **process by which heat energy is transferred from particle to particle.**

Figure 9.2 HEAT TRANSFER BY CONDUCTION




### 9.1.2 GOOD AND BAD THERMAL CONDUCTORS

Some materials allow heat to pass through them easily. They are called heat conductors or good conductors. Those that do not allow heat to flow through them easily are called heat insulators or bad conductors.

**ACTIVITY 9.1 COMPARISON OF CONDUCTING ABILITY OF DIFFERENT METALS**

A simple demonstration of the different conducting powers of various metals is shown in Figure. Match sticks are fixed to one end of each rod using a melted wax. The other ends of the rods are heated by a burner. When the temperatures of the far ends reach the melting point of wax, the matchsticks drop off. The match stick on copper falls first, showing it is the best conductor, followed by aluminium, brass and then iron.

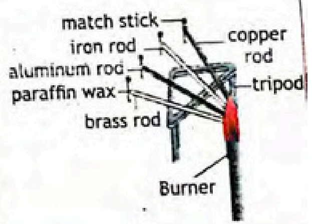
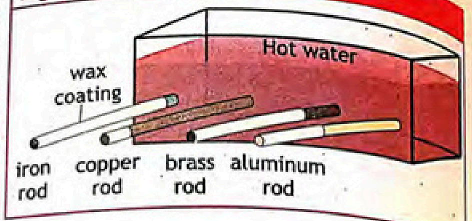


Figure 9.3 CONDUCTION

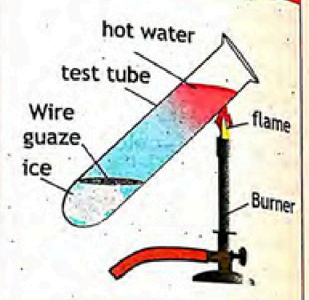



Metals are the best heat conductors. Materials such as wood, rubber, plastic, paper and fiber glass are poor conductors of heat. You can sometimes tell how well something conducts just by touching it.

A similar activity for comparing the conducting abilities of different metals is shown in the figure. The ends of long rods of the same size but made of different metals are soldered into a tank. Initially, coat each rod with a layer of wax. Pour some boiling water into the tank.

Wait for about ten minutes or so. Wax melts to different lengths along the different rods. A greater length of wax melts on the copper rod. This shows that copper is a good conductor amongst these materials.

Activity 9.2 WATER




**Water is a bad conductor of heat:** The water at the top of the test tube can be boiled without making the ice melt.

Conduction occurs in all the three states of matter solids, liquids and gases. Solids conduct better than liquids. Gases are the worst conductors. As discussed earlier metallic solids are best thermal conductors. Besides the closely connected atoms; metals have free electrons. Non-metallic solids are poor conductors of heat because they do not have free electrons.

Most of the liquids are poor conductors of heat. Compared with solids, the inter-molecular distances in liquids are relatively larger and conductive collisions do not occur as often as in solids. Water is a poor conductor of heat. The poor conductivity is illustrated by the activity 9.2. Gases are the poorest of all heat conductors. In gases the separation between particles is very large. Air has about one-twentieth of the thermal conductive ability of water. Many materials such as wood, cloth, fiberglass and plastic foam etc are poor conductors because they contain tiny pockets of trapped air.





## 9.1.3 PRACTICAL APPLICATIONS OF CONDUCTION OF HEAT

The good, as well as, bad thermal conductors have many useful applications in our daily life.

A. 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.

B. Plastic foam:

Plastic foam and fiberglass insulators are used in the walls and ceilings of our homes to keep them cool in summer and warm in winter seasons. These materials are good insulators because they contain tiny pockets of trapped air.

C. Wire gauze:

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

D. Pot holders and table mats:

Pot holders and table mats for hot pans are made of poor conductors such as cloth and wood. The use of poor conductors avoid burning of hands.

E. Woolen clothes:

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

F. 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 thermal insulation and minimize the loss of heat from the inside due to conduction.

G. 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 out side heat into the box, thus keeping the ice from melting.

H. Soldering:

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

## 9.2 THERMAL CONDUCTIVITY

The thermal conductivity of a substance is a measure of the ability of the substance to conduct heat energy. The rate of flow of heat through a medium depends on a number of factors.

For example consider a rod of length 'L', area of cross-section 'A'. Let the hot face of the slab be at temperature $T_h$ and the colder face be at temperature $T_c$, which means $T_h > T_c$. The rate of heat flow (Q/t) across the slab depends on the following factors.

i) The difference of temperatures $T_h - T_c$ between two the two faces of the slab. The greater the temperature difference, the greater is the heat transferred per unit time across the slab.

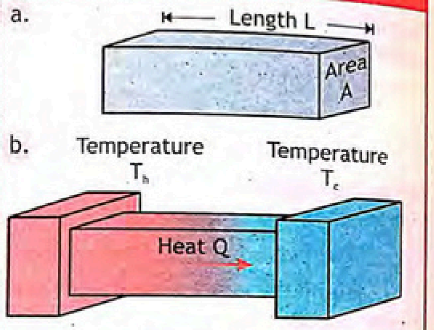
ii) Length of rod 'L' more the length, the less is the rate of flow of heat through it.

iii) The cross-section area ( A ). Larger cross-sectional area will allow a greater rate of heat flow.

iv) The nature or material of the slab. Mathematically,

$$\frac{Q}{t} = k \times A \times \frac{T_h - T_c}{L} \quad \text{—— 9.1}$$

**Figure 9.4 CONDUCTIVITY**




a. A bar with cross-sectional area A and length L.
b. The bar is placed between two thermal reservoirs with temperatures $T_h$ and $T_c$.

**TABLE 9.1: THERMAL CONDUCTIVITIES OF COMMON SUBSTANCES**

| Substance | Thermal conductivity $J\,m^{-1}K^{-1}s^{-1}$ |
|---|---|
| Silver | 420 |
| Copper | 390 |
| Gold | 318 |
| Aluminum | 220 |
| brass | 105 |
| Steel iron | 80 |
| lead | 35 |
| Steel (stainless) | 14 |
| Ice | 2.2 |
| Concrete brick | 0.84 |
| Glass (average) | 0.8 |
| Water | 0.6 |
| Wood | 0.08-0.16 |
| Cotton | 0.08 |
| Cork | 0.042 |
| Wool | 0.04 |
| Plastic foam | 0.033 |
| Air | 0.023 |
| Styrofoam | 0.010 |







Where k is the thermal conductivity of the material of the bar. Thermal conductivity depends on the nature of the material. Such that

$$k = \frac{Q \times L}{A \times t \times (T_h - T_c)} \quad \text{—— 9.2}$$

As a special case, if L = 1 m, A = 1 $m^2$, $T_h - T_c$ = 1 °C or 1K and t = 1s, then from Equation 9.2 we obtain k = Q. Thus the thermal conductivity k of a substance is defined as **the quantity of heat which flows through one square metre of area of the substance in one second when a temperature difference of one kelvin is maintained across a thickness of one meter.** The SI units of thermal conductivity are $W\,m^{-1}K^{-1}$ or $J\,m^{-1}K^{-1}s^{-1}$. Some typical values of thermal conductivity are listed in Table 9.1.

**Example 9.1 STYROFOAM ICE BOX**

A Styrofoam (k = 0.010 W/mK) ice box has a total area of 0.950 $m^2$ and walls with an average thickness of 2.50 cm. The box contains ice, water, and canned beverages at 0°C. The inside of the box is kept cold by melting ice. What is the rate of energy transfer in J/s if the ice box is kept at 35.0°C?

**SOLUTION**

**GIVEN:**

Area A = 0.950 $m^2$

Length L = 2.50 cm = 0.0250 m;

Temperature difference $T_h - T_c$ = 35 °C - 0 °C = 35 °C = 35 K

thermal conductivity of Styrofoam k = 0.010 $Wm^{-1}K^{-1}$

**REQUIRED:**

rate of heat transfer Q/t = ?

The rate of energy transfer is given as

$$\frac{Q}{t} = k \times A \times \frac{T_h - T_c}{L}$$

putting values $\frac{Q}{t} = 0.010\frac{W}{\cancel{m}K} \times 0.950\,\cancel{m}^2 \times \frac{35K}{0.0250\,\cancel{m}}$

therefore $\frac{Q}{t} = 13.3\,W = 13.3\frac{J}{s}$ — Answer

**Assignment 9.1** CONCRETE WALL 0.20m THICK

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

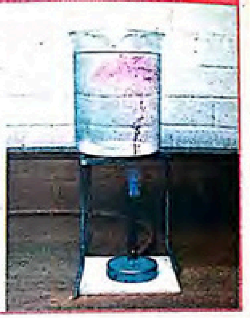
## 9.3 CONVECTION OF HEAT

We can warm our hands by holding them over an open flame. In this case, the air directly above the flame is heated and expands. Heat is transferred by the movement of heated particles.

The transfer of heat from one place to another by the bulk motion of fluids is called convection. Convection occurs only in fluids (liquids and gases). Convection cannot occur in solids as the atoms in a solid are located in fixed positions and cannot change place. For the same reason convection occur very easily in gases.

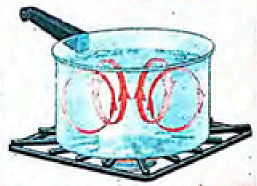
**Activity 9.3** CONVECTION OF HEAT

Convection currents shown in water by dropping a few crystals of potassium permanganate down a tube to the bottom of a beaker of water. When the tube is removed and the beaker heated just below the crystals by a small flame, purple streaks of water rise upwards.



To understand convection, take some water in a beaker and drop in it few crystals of potassium permanganate. Heat gently the water. See how the coloured water moves. You will observe that streaks of purple coloured water begin to rise and cold water from the sides takes its place. The water will go on circulating and becomes hotter and hotter. In this way each part of water is heated in turn. The currents set up in the process are known as **convection currents**.

**Figure 9.5**



*Convection currents are set up when a pot of water is heated.*

### 9.3.1 MECHANISM OF HEAT CONVECTION

The heated portion of water at the bottom of the 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







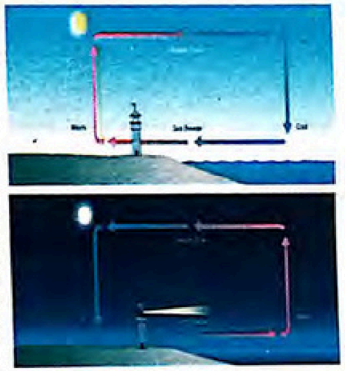
to the point of heating in its turn absorbs heat energy, expands and is pushed upward. Thus a continuous circulatory flow is established from the bottom to the top of the water. Black marks often appear on the wall or ceiling above a lamp. They are caused by dust being carried upwards in air convection currents produced by the hot lamp or radiator.

### 9.3.2 PRACTICAL APPLICATIONS OF HEAT CONVECTION

The following are few practical applications of heat convection.

A. **Heating Water:**

If it were not for convection currents, it will be very difficult to boil water. The lower layers of water in a electric kettle are warmed first. These 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.



B. **Sea breeze:**

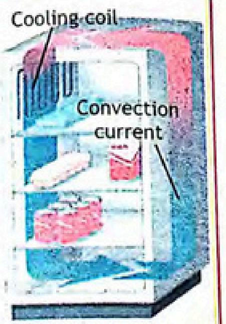
Convection causes coastal breeze. During the day the land heats up more quickly than the sea. The hot air over the land rises and the cold air from the sea blows to replace it. Thus there is a sea breeze during the day. At night, the reverse happens. The land cools more quickly than the sea. The hot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

C. **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 aeroplanes are able to rise by riding on the thermals.

**D. Refrigerator:**

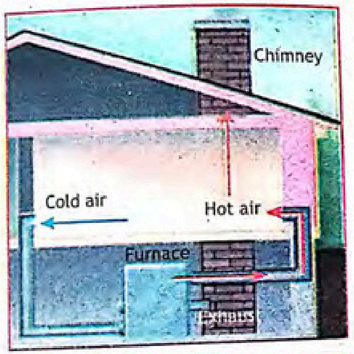
In a refrigerator, convection is used to circulate cold air around the food. Air is cooled by the freezer compartment at the top of the refrigerator. As it sinks, it is replaced by warmer air rising from the below. The circulating air carries heat energy away from all the food in the fridge.




*Air cooled by the cooling coil sinks to the bottom of the refrigerat-or*

**E. Ventilation:**

Convection currents are used in ventilation. Your classroom or the rooms in your 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 in to 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.




**TID-BIT**

When you light a candle, it heats the air near the flame as it burns. Because hot air is less dense—and hence more buoyant—than cool air, a circulation pattern is established with hot air rising and being replaced from below by cool, oxygenated air. Thus, convection is necessary for a candle to continue burning. When the burning candle in this jar is dropped, it suddenly finds itself in free fall—an essentially "weightless" environment where buoyancy has no effect. As a result, convection ceases and the flame is quickly extinguished as it consumes all the oxygen in its immediate vicinity.





**POINT TO PONDER**

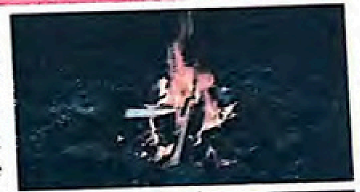
Blow warm air onto your hand from your wide-open mouth. Now reduce the opening between your lips so that the air expands as you blow. Do you notice a difference in the air temperature? Why?

**POINT TO PONDER**

You can hold your fingers beside the candle flame without harm, but not above the flame. Why? Hot air travels upward by air convection. Since air is a poor conductor, very little heat travels sideways to your fingers.

## 9.4 RADIATION OF HEAT

When we sit next to an open campfire, the heat from the fire does not reach us by conduction because air is a bad conductor of heat. It does not reach us by convection because hot air rises up. In this case, the heat reaches us by radiation of heat. The hot fire radiates heat rays just as light rays. When these rays fall on anything they make that object hotter.

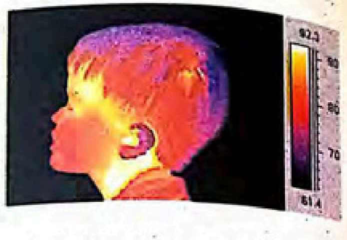


Sun heat reaches us after passing through millions of kilometers in empty space. Sun heat also warms up anything on which it falls. Neither conduction nor convection can take place in vacuum as no material is present for the transfer of heat through conduction or convection. Sun heat reaches us by radiation of heat. Based on the above observations, we define radiation of heat as **The heat transfer from a hotter place to a colder place with or without having a material medium in between is called radiation of heat.**

Unlike conduction and convection transfer of heat by radiation, does not necessarily require a material medium.

### 9.4.1 MECHANISM OF RADIATION OF HEAT

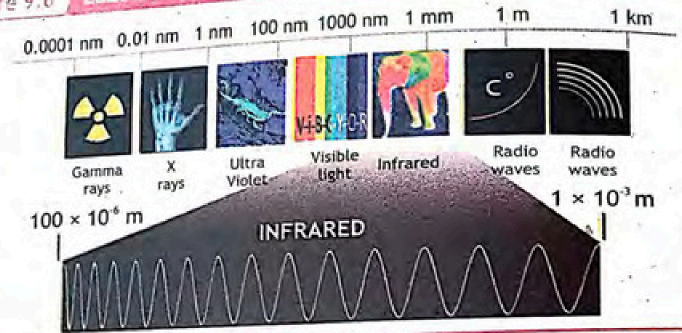
The mechanism of radiation is energy transfer by electromagnetic waves. Electromagnetic radiation comes from accelerating electric charges. On a molecular level, that's what happens as objects warm up – their molecules vibrate harder and harder, causing acceleration of electric charges which emits those radiation. 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 (radiation) 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 (which is a little unlikely because you can't physically get to a temperature of absolute zero, with no molecular movement). For example a scoop of ice cream has temperature of about 237 K, 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 the spectrum. However, that light is visible to infrared scopes, as you've probably seen in the movies or on television.

Figure 9.6 ELECTROMAGNETIC SPECTRUM

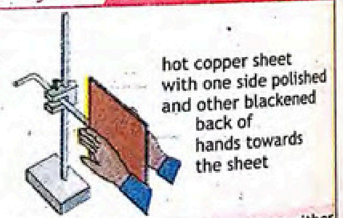



## 9.4.2 GOOD AND BAD EMITTERS AND ABSORBERS

Some surfaces are better absorbers of radiation than others, a black colour absorbs most and white reflects most. A dull black kettle absorbs heat better than a silver kettle. Standing in the sun, a black car warms up more quickly than car of any other colour.

Some surfaces are better at emitting radiation than others when heated or allowed to cool. A black saucepan cools down quickly than any other. Hot water in a kettle covered with soot cools faster than a

**Activity 9.4 RADIATION OF HEAT**




If you hold the backs of your hands on either side of a hot copper sheet that has one side polished and the other side blackened as shown in figure, it will be found that the dull black surface is a better emitter of radiation than the shiny one.





similar kettle having shining surface.

**In general a good absorber is a good radiator and a poor absorber is a poor radiator.**

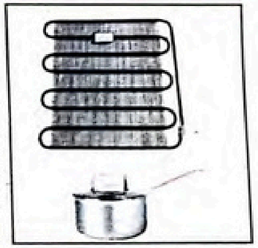
The rate of energy transfer by radiation is affected by:

- o Colour and texture of the surface
- o Surface temperature
- o Surface area

White clothes are worn in hot climates because white is a good reflector and a poor absorber. Black or dark coloured clothes are worn in cold climates, because dark is a poor reflector and a good absorber.

## 9.4.3 PRACTICAL APPLICATIONS OF RADIATION OF HEAT

The following are few examples of radiation of heat.



### A. 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.

### B. Texture of the surface:

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

### C. Satellite Protective Coating:

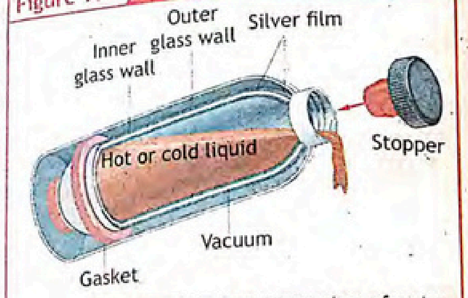
The highly reflective metal foil covering this satellite (the Hubble Space Telescope) minimizes temperature changes.

D. **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 slivering is to reflect all radiant heat trying to enter or leave the vessel. The space between the walls is highly evacuated (vacuum is created) to prevent convection. The glass, being a poor conductor minimizes conduction of heat as well. 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.

Figure 9.7 THERMOS FLASK




A thermos bottle minimizes energy transfer due to convection, conduction, and radiation.

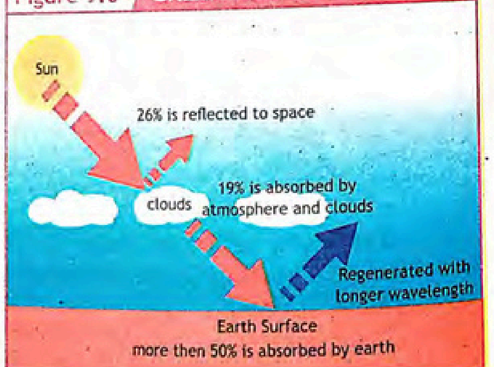
## 9.5 GREENHOUSE EFFECT AND GLOBAL WARMING

**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.** The strength of the greenhouse effect - will depend on the atmosphere's temperature and on the amount of greenhouse gases that the atmosphere contains.

### 9.5.1 MECHANISM OF GREEN HOUSE 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% is reflected to space by the atmosphere and clouds and 19% is absorbed by the atmosphere and clouds. Most of the remaining energy is absorbed at the surface of Earth.

Figure 9.8 GREEN HOUSE EFFECT




Because the Earth's surface





is colder than the photosphere of the Sun, it radiates at wavelengths 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 a higher equilibrium temperature than if the atmosphere were absent.

### 9.5.2 IMPORTANCE OF GREENHOUSE EFFECT

Green house effect is important for the survival of life on earth. On Earth, an atmosphere containing naturally occurring amounts of greenhouse gases (water vapour, carbon dioxide $CO_2$, methane $CH_4$, and ozone $O_3$) causes air temperature near the surface to be about 33 °C (59 °F) warmer than it would be in their absence. Without the Earth's atmosphere, the Earth's average temperature would be well below the freezing temperature of water.

Human activity has increased the amount of greenhouse gases in the atmosphere leading to 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 the burning of fossil fuels is not absorbed by 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.

The 'greenhouse effect' of the atmosphere is named by analogy to greenhouses (a structure with walls and roof made chiefly of transparent material, such as glass) which become warmer in sunlight. However, a greenhouse is not primarily warmed by the 'greenhouse effect', because 'greenhouse effect' works by preventing absorbed heat from leaving the structure through radiative transfer, while in 'green house' warming is produced mainly by reducing convection of air. Similar effect is also observed in car parked in the hot sun with its windows closed, there is some greenhouse effect but the warming is chiefly achieved through reduction in convection.

## KEY POINTS

Heat transfer: The process, in which heat travels from one place to another place because of difference of temperature, is called transfer of heat.

Conduction of heat: The particle to particle mode of heat transfer by collisions or indirect interaction is called conduction of heat.

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

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

Convection currents: The currents set up in the process are known as convection currents.

Radiation of heat: The heat and energy transfer from a hotter place to a colder place with or without having a material medium in between is called radiation of heat.

Radiant energy: The energy emitted from a hotter place and carried through radiation is called radiant energy.

## PROJECTS

### GROUP - A

HEAT CONDUCTOR SURFACES: Choose a variety of surfaces for your ice to melt on. Compare metal, plastic, glass, and paper to see which makes a better conductor of heat. Explain your finding in form of research and present your findings in classroom.

### GROUP - B

OIL AND GHEE HEAT CONDUCTION: Investigate heat transfer in any cooking process. Does cooking oil or ghee added during cooking increase the heat transfer? Do we require materials that are good conductors of heat transfer for cooking? Demonstrate your results in class in form of a presentation.





### GROUP - C

INSULATING MATERIALS: Visit the market and find out the materials available for home roof and wall insulation. State the advantages of different materials over the other. Make your own suggestive material that is both good insulator and cost effective. Defend your material in front of class.

### GROUP - D

GLOBAL WARMING: Write an essay on how important for us to keep the temperature of earth. What are the consequences of global warming and how we can safely overcome it.

### GROUP - E

COLOR TEMPERATURE: Research books and internet to find how are the temperature measured using the color of hot objects? Write a column for school magazine.

# EXERCISE

## MULTIPLE CHOICE QUESTIONS

Choose the best possible answer:

1. Which of the following is the best heat conductor?
   A. aluminum. B. tin C. iron D. copper
2. Identical cubes of the following materials are kept in a room at the same temperature. Which will feel coldest by touching them?
   A. Wood B. Glass C. Iron D. Styrofoam
3. The transfer of heat by convection is smallest in
   A. solids B. liquids C. gases D. none
4. One way that heat is transferred from place to place inside the human body is by the flow of blood. Which one of the following heat transfer processes best describes this action of the blood?
   A. convection B. conduction C. radiation D. none
5. The best absorber of radiation is a body whose surface is
   A. White B. Grey C. Dull black D. Highly polished

5. The mode of transfer of heat which does not require material medium is called
   A. convection B. conduction C. radiation D. none
6. Which of the following has the highest thermal conductivity
   A. water B. wood C. wool D. air
7. The temperature at which a body is not radiating any heat is
   A. 0 °C B. 0 °F C. 0 K D. all of these
8. The electrons that are free to move through the metal called
   A. lose electrons B. free electrons
   C. conduction electrons D. holes

## CONCEPTUAL QUESTIONS

**Give a brief response to the following questions.**

1. Why white clothes are preferred wearing in summer? Explain briefly.
2. Why is the freezer compartment kept at the top of a refrigerator? Explain briefly.
3. A black car standing in the sun warms up more quickly than any other. Why?
4. Why a tile floor feels colder to bare feet than a carpeted floor?
5. How woolen sweaters keep us warmer in winter?
6. In certain places, birds can fly for hours without flapping their wings. Explain.
7. 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 from all three transfer methods and keep the bottle's contents your coffee hot?
8. 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.
9. Some pot handles remain cool during cooking while others become unpleasantly hot. What determines which handles remain cool and which become hot?
10. When sunlight warms the land beside a cool body of water, a breeze begins to blow from the water toward the land. Explain.





## COMPREHENSIVE QUESTIONS

**Give an extended response to the following questions.**

1. Explain conduction of heat and its mechanism. Describe any three of its practical applications.
2. Explain thermal conductivity of a substance and its mathematical description.
3. Explain convection of heat and its mechanism. Explain any three of its practical applications.
4. Explain radiation of heat and its mechanism. Describe any three of its practical applications.
5. Discuss the greenhouse effect. Explain its importance and global warming concern.

## NUMERICAL QUESTIONS

1. A person's body is covered with 1.6 $m^2$ of wool clothing. The thickness of the wool is $2.0 \times 10^3$ m. The temperature at the outside surface of the wool is 11° C, and the skin temperature is 36° C. How much heat per second does the person lose due to conduction? Thermal conductivity of wool is k = 0.04 $W\,m^{-1}\,K^{-1}$.
2. The external wall of a brick house has an area of 16 $m^2$ and thickness 0.3 m. The temperatures inside and outside the house are respectively 20 °C and 0 °C. Calculate the rate of heat loss through the wall. Thermal conductivity of brick is k = 0.84 $W\,m^{-1}\,K^{-1}$.. [533 W]
3. Window glass has thermal conductivity of 0.8 $W\,m^{-1}\,K^{-1}$. Calculate the rate at which heat is conducted through a window of area 2.0 $m^2$ and thickness 4.0 mm. The temperature inside an air-conditioned room is 20 °C. The outdoors temperature is 35°C.

# ANSWERS

## CHAPTER - 1

| Assignment | Answer |
|---|---|
| 1.1 | $5.98 \times 10^{24}$ kg |
| 1.2 | $6.048 \times 10^{5}$ s |
| 1.3 | $2.14 \times 10^{-5}$ kg, 21.4 milligrams |
| 1.4 | $5.7\times10^{-2}$ m, $57\times10^{-3}$ m, 57 mm |
| 1.5 | $4.89 \times 10^{8}$ mm |
| 1.6 | A. Vernier Caliper |
| 1.7 | 200 $cm^3$, $2.0\times10^{-4}$ $m^3$ or 0.0002 $m^3$ |

| Extension Exercise | Answer |
|---|---|
| 1.1 | Earth moves around sun in elliptical orbit therefore the distance varies |
| 1.2 | No, we must take 365.25 days to account for leap tear |
| 1.3 | By road the distance is longer, aeroplane moves by the straight distance |

| Numerical Problems | Answer |
|---|---|
| 1 | a. 1.0 ag, b. 3.00 Em, c. 194.6 Gm |
| 2 | 0.1 nm, $10^{5}$ fm, $10^{10}$ Angstrom |
| 3 | (a) $2.99792458 \times 10^{8}$ m $s^{-1}$ (b) (i) $2.997\,9 \times 10^{8}$ m $s^{-1}$ (ii) $3.00 \times 10^{8}$ m $s^{-1}$) |
| 4 | $7\times10^{-9}$ m, $9.6\times10^{7}$ W, $4.3\times10^{-11}$ F, $2\times10^{-3}$ m |
| 5 | $5\times10^{-12}$ kg, $1.39 \times10^{9}$ m |

## CHAPTER - 2

| Assignment | Answer |
|---|---|
| 2.1 | 10.43 m/s |
| 2.2 | 9 $ms^{-1}$, 0 $ms^{-1}$ |
| 2.3 | 0.66 $m/s^2$ |
| 2.4 | 280 m |
| 2.5 | 5 m/s |
| 2.6 | - 18.5 m/s |
| 2.7 | 81.6 m round off to 80 m, 4.08 s round off to 4 s |

| Extension Exercise | Answer |
|---|---|
| 2.1 | Speed of snail varies |
| 2.2 | WEST |
| 2.3 | 41.8 m/s = 150.48 km/h which is high speed |
| 2.4 | longer runway is required for landing due to smaller deceleration |

| Numerical Problems | Answer |
|---|---|
| 1 | 400 $m/s^2$ E |
| 2 | 10 m |
| 3 | 896 m/s |
| 4 | NO, 44.4 m, she will be 24.3 m past the light |
| 5 | 66 m, 17 m/s |
| 6 | 31.3 m/s |



## CHAPTER -3

| Assignment | ANSWER |
|---|---|
| 3.1 | 5.83 $m/s^2$, 1.46 $m/s^2$ |
| 3.2 | 150 kg, $1.5 \times 10^{3}$N, mass does not change it is same as 150 kg both on earth and moon |
| 3.3 | 3.49 kgm/s |
| 3.4 | 6000 N, 45000 N |
| 3.5 | 0.6 m/s |
| 3.6 | 4.5 m/s |
| 3.7 | 5 N |
| 3.8 | 9.2 $m/s^{-2}$ , 21 N |
| 3.9 | 11 kg |
| 3.10 | 1112 kg |

| Extension Exercise | Answer |
|---|---|
| 3.1 | 62.5 $m/s^2$, 2.5 $m/s^2$ |
| 3.2 | No, recoil of gun will be greater than speed of bullet |
| 3.3 | 0 $m/s^2$, 9800 N |

| Numerical Problems | Answer |
|---|---|
| 1 | 3560 N or $3.55 \times 10^{3}$ N |
| 2 | 1000 N |
| 3 | $-2.7 \times 10^{3}$ N, $-1.5 \times 10^{4}$ N and $-2.6 \times 10^{5}$ N |
| 4 | 0.46, 0.40 |
| 5 | 2.8 $m/s^2$ , 42 N |
| 6 | $8.44 \times 10^{4}$ N |
| 7 | 3000 N |
| 8 | 8000 N |

## CHAPTER - 4

| Assignment | ANSWER |
|---|---|
| 4.1 | 30 N |
| 4.2 | 86 N, 8.7° |
| 4.3 | 200 N |
| 4.4 | 2 kg |

| Extension Exercise | ANSWER |
|---|---|
| 4.1 | No |
| 4.2 | 40.8 kg, 61.2 kg |

| Numerical Problems | Answer |
|---|---|
| 1 | 13 N, 7.5 N |
| 2 | 160 N |
| 3 | 1.5 m |
| 4 | 0.6 m |
| 5 | 24 N |
| 6 | 294,000 Nm, 176,000 Nm |

## CHAPTER - 5

| Assignment | Answer |
|---|---|
| 5.1 | $2 \times 10^{20}$ N |
| 5.2 | $7.3 \times 10^{22}$ kg |
| 5.3 | 105 N, 1.62 $m/s^2$ |
| 5.4 | 7.33 $m/s^2$ , 0.22 $m/s^2$ |
| 5.5 | 6890 m/s |

| Extension Exercise | Answer |
|---|---|
| 5.1 | Only Confirmation is required |

| Numerical Problems | Answer |
|---|---|
| 1 | $4.1 \times 10^{18}$ N |
| 2 | 3.68 $m/s^2$ or 3.68 N/kg |
| 3 | 1.352 $m/s^2$ |
| 4 | $2.6 \times 10^{6}$ m |
| 5 | $7.76 \times 10^{3}$ m/s |
| 6 | $1.02 \times 10^{3}$ m/s |
| 7 | 547 km |

## CHAPTER - 6

| Assignment | Answer |
|---|---|
| 6.1 | $2.2 \times 10^{3}$ J |
| 6.2 | 2400 J |
| 6.3 | 490 J |
| 6.4 | $9 \times 10^{13}$ J |
| 6.5 | 150 kJ |

| Extension Exercise | Answer |
|---|---|
| 6.1 | 2.8 m/s |
| 6.2 | Variable |

| Numerical Problems | Answer |
|---|---|
| 1 | a. 6 J, b. $9.6 \times 10^{2}$ J |
| 2 | $3 \times 10^{4}$ m/s |
| 3 | a. 0J, b. $3.7 \times 10^{4}$ J |
| 4 | 7500 W |
| 5 | $1.06 \times 10^{5}$ W |
| 6 | 22 s |
| 7 | $5.4 \times 10^{6}$ J |

## CHAPTER - 7

| Assignment | Answer |
|---|---|
| 7.1 | 3600 kg/m$^{3}$ |
| 7.2 | 100 Pa or 100 N/m$^{2}$ |
| 7.3 | $10^{6}$ Pa |
| 7.4 | 3 kg/m$^{3}$ |
| 7.5 | $3 \times 10^{5}$ N/m$^{2}$ |

| Extension Exercise | Answer |
|---|---|
| 7.1 | 400 kPa |

| Numerical Problems | Answer |
|---|---|
| 1 | 1250 Pa and 7500 Pa |
| 2 | 10.. m |
| 3 | $2.7 \times 10^{3}$ N |
| 4 | $1.11 \times 10^{8}$ Pa |
| 5 | (a) 5 N (b) 5 N<br>(c) 0.5 kg (d) $5 \times 10^{-4}$ m$^{3}$<br>and (e) 5882 kg m$^{-3}$ |
| 6 | 150 N/m |
| 7 | 1 cm |

## CHAPTER - 8

| Assignment | Answer |
|---|---|
| 8.1 | – 23 °C |
| 8.2 | 2.3 × 10– 5 ° C$^{-1}$ |
| 8.3 | 0.522 cm$^{3}$ |
| 8.4 | 262 Liter |
| 8.5 | 235.2 J/kg K |
| 8.6 | $7.1 \times 10^{6}$ J |

| Numerical Problems | ANSWER |
|---|---|
| 1 | a. 7 K, 13 °F<br>b. -256 °F, 115 K |
| 2 | $8.8 \times 10^{-6}$ m |
| 3 | 144 m, 216 m |
| 4 | 1.228 cm$^{3}$ |
| 5 | 1700 J/kgK |
| 6 | $7.1 \times 10^{6}$ J |

## CHAPTER - 9

| Assignment | Answer |
|---|---|
| 9.1 | $2.6 \times 10^{6}$ J |

| Numerical Problems | Answer |
|---|---|
| 1 | $8.0 \times 10^{2}$ W |
| 2 | $6.1 \times 10^{4}$ J |
| 3 | 533 W |
| 4 | 6.0 W$\times 10^{3}$ W |





# Glossary

**Absolute Zero:** The lowest temperature (-273°C) that any substance can reach. At this temperature the molecules or atoms of the substance contain no heat energy.
**Acceleration:** The rate of change of velocity.
**Acceleration Due To Gravity:** The acceleration of a freely falling body within a gravitational field close to the surface of earth its value is 10ms$^{-2}$.
**Artificial Satellite:** Objects moving in fixed circular orbit around the earth.
**Atmospheric Pressure:** The pressure exerted on a body by the atmosphere due to the weight of the atmosphere. At the surface of the earth atmospheric pressure is 100 KPa / m$^{2}$.
**Base Quantity:** Such quantity, which can be expressed independently without the reference of any other quantity.
**Base Units:** The units in system international which are seven in number.
**Buoyant Force:** The force acting on an object due to buoyant of a liquid.
**Centre Of Gravity:** The point of body where its weight acts.
**Centripetal Acceleration:** Acceleration produced by the centripetal force.
**Centripetal Force:** The force, which keeps an object to move in a circular path.
**Circular Motion:** Motion of a body along a circular path.
**Co-Efficient of Volume Expansion:** Change in unit volume caused by unit Kelvin change in temperature.
**Co-Efficient of Linear Expansion:** Change in unit length caused by unit Kelvin change in temperature.
**Component of a Vector:** Such vectors when added given the resultant vector.
**Conduction:** Transfer of heat due to interaction of electrons or molecules.
**Convention:** Transfer of heat due to the movement of molecules from one place to another.
**Couple:** When two equal and unlike parallel forces act at different points of a body, then they constitute a couple.
**Derived Quantity:** Such quantity which is expressed with reference to base quantities.
**Displacement:** The shortest distance between two points.
**Dynamics:** Study of motion of bodies under action of force.
**Efficiency:** Ratio of output and input.
**Effort Arm:** The intermediate distance between fulcrum and effort.
**Effort moment:** Product of effort and effort arm.
**Effort:** Force applied on the machine.
**Elastic Potential Energy:** Energy of a compressed or stretched spring.
**Elasticity Modulus:** Ratios of stress and strain.
**Elasticity:** The property of the solids because of which they restore there original shape when external force ceases to act.
**Energy:** Ability of a body to do work.
**Equilibrium:** A body whose acceleration is

zero.
**Force:** The agent that changes or tends to change the state of a body.
**Friction:** The force of resistance against the relative motion between two surfaces.
**Fulcrum:** The point around which lever revolves.
**Fossil Fuels:** Fuels formed over millions of year by the partial decay of the remains of living things.
**Gravitational Force:** Mutual force of attraction between the objects.
**Gravitational Potential Energy:** energy of a body due to its position in the gravitational field.
**Gravitational Field Strength:** The gravitational force exerted on a 1 Kg mass placed within any gravitational field.
**Heat:** The form of energy, which is transferred from one place to another because of difference of temperature.
**Horizontal Component:** The component of a vector F which is along horizontal or x-direction.
**Hydraulic Systems:** System that transfer forces from place to place using fluids.
**Inertia:** The characteristic of a body due to which it resists against any change in its state.
**Insulators:** Materials that prevent, or significantly inhibit, the flow of heat through them:
**Joule:** The unit of work in system international.
**Kinematics:** Study of motion of bodies without taking into consideration the mass and forces.
**Kinetic Energy:** Energy of a body due to motion.
**Kinetic Friction:** Friction during motion.
**Latent Heat of Fusion:** The quantity of heat required to change the state of one kilogram of a liquid to vapour or gaseous state during which its temperature remains constant.
**Lever:** A strong bar revolving around some point.
**Light Year:** The unit of distance for celestial bodies is equal to $9.46 \times 10^{15}$ m.
Like Parallel Forces: Forces acting along parallel lines in the same direction.
**Limiting friction:** The maximum value of static friction.
**Linear Motion:** The motion of body along a straight line.
**Load Arm:** The intermediate distance between fulcrum and load.
**Load Moment:** Product of load effort arm.
Load: Resistance or lifted up weight.
**Mass:** That characteristics of a body, which determiners the acceleration produced by the application of a force.
**Mechanical Advantage:** Ratio of load and effort.
**Mechanics:** The branch of physics which deals with the study of motion of bodies is known as mechanics.
**Momentum:** The product of mass and velocity of a body.
**Neutral Equilibrium:** The condition of a body, in which its centre of gravity neither rises not becomes lower of its original position after disturbance.
**Newton:** The unit of force. 1 Newton is the force that gives a 1 Kg mass an acceleration of $1ms^{-2}$.
Non – Renewable Source: A source of energy that is used up faster than it can be replaced.
**Orbit Velocity:** A critical velocity of a satellite in order to keep on moving around the earth at a specific height.
**Output:** A work, which the machine does.
**Physics:** That branch of science, which explains the properties of matter and energy.
**Power:** Rate of doing work.
**Proportionality Constant:** Such a number, which connects two quantities to convert them in the form of an equation.
**Radiation:** Transfer of heat by infra red radiation requiring no medium for the transmission.



**Random Motion:** Motion without any consideration of time and direction.
**Rectangular Components:** The components of a vector which are mutually perpendicular to each other.
**Resolution of a Vector:** Division of a vector into its components.
**Resultant Vector:** Such a vector, which shows the combined effect of two or more vectors.
**Rolling Friction:** The friction produced during the motion of one body over the other with the help of wheels.
**Scalar Quantities:** Only magnitude is necessary for their representation.
**Scientific Methods:** Logical applications of arguments that explain a certain phenomenon.
**Scientific Notion:** The numbers written as power or prefix of ten in which there is only one non zero number before decimal.
**Significant Figures:** In a measurement, the correctly known digits and the first doubtful digit.
**Simple Machine:** A thing, which help in doing work more easily.
**Sliding Friction:** The friction between two surfaces sliding against each other.
**Specific Heat Capacity:** The quantity of heat, which changes the temperature of one kilogram mass by one kelvin.
**Speed:** Distance covered by a body in certain time.
**Stable Equilibrium:** The condition of a body in which it comes to its original condition after being disturbed.
**Static Fraction:** The force of friction arising due to applied external fore before motion.
**Strain:** The change in the shape of an object under the action of an external force.
**Stress:** Force acting on unit area of an object.
**Surface Tension:** The force acting along the surface of a liquid.
**Tension:** The force acting along string.
Thermometry: Art of measurement of temperature.
**Torque:** The capacity of a force to revolve a body.
**Trigonometric Ratios:** The rations of the sides of a right – angled triangle.

$$\sin\theta = \frac{\text{Perpendicular}}{\text{Hypotenuse}}$$

$$\cos\theta = \frac{\text{Base}}{\text{Hypotenuse}}$$

$$\tan\theta = \frac{\text{Perpendicular}}{\text{Base}}$$

**Uniform Acceleration:** Equal change in velocity in equal intervals of time.
Uniform Speed: Equal distances covered by a body in equal intervals of time.
**Uniform Velocity:** Equal change in displacement in equal interval of time.
**Unlike Parallel Forces:** Forces acting along parallel forces but in opposite directions.
**Unstable Equilibrium:** The condition of a body in which it does not come to its original condition after disturbance.
**Vector Quantities:** Magnitude and direction both are necessary for their representation.
**Velocity:** Rate of change of displacement with time.
**Vertical Component:** The component of a vector F which is along vertical of Y – direction.
**Vibratory Motion:** The to and fro motion of body about a fixed point.
**Viscosity:** the fractional force between the layers of a fluid in flow.
**Watt:** The unit of power in system international.
**Weight:** The force with which the earth pulls a body toward itself.
**Work:** The product of force and the displacement in the direction of force.
**Young's Modulus:** Ratio of tensile stress to tensile strain.

# INDEX







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Randall D. Knight
ESSENTIAL UNIVERSITY PHYSICS (SECOND EDITION)
Richard Wolfson

## SUGGESTION FOR TEACHERS

Dear teachers, this book mainly focus on friendly and joyful learning material. An effort is made to make the book rich in tasks like assignments, projects, conceptual questions, activities, tidbit, tips, interesting information and point of ponder.

**Topics:** An effort is made to make students think themselves as scientists. Students' participation must be encouraged in the learning process; allow them to discuss and give them a choice to incorporate their interest. Involve students with tidbits, activities and points of ponder and share with them interesting information and tips in your classroom.

**Assignments:** Each topic that covers some mathematical work is assisted with relevant example and followed by an assignment task for students to workout. Some examples are even added with **extension exercise** for higher order thinking.

**Projects:** After each chapter you will find projects for group work by students. Divide your class in 5 groups (A, B, C, D and E) and assign tasks to them, after three to four days arrange a special class for the students to share their projects with the rest of the class.

**Exercise:** When the student groups are assigned different projects in the being time try to cover exercise having Multiple Choice Questions (MCQs), Conceptual Questions (CQs), Comprehensive Questions and Numerical Problems.

APPENDIX

## USEFUL PHYSICAL DATA

| Quantity | Value |
|---|---|
| Speed of light in vacuum | $2.997\,924\,58 \times 10^8$ m/s |
| Acceleration due to earth's gravity | $9.80$ m/s$^2$ = $32.2$ ft /s$^2$ |
| Universal gravitational constant | $6.674 \times 10^{-11}$ Nm$^2$/kg$^2$ |
| Atmospheric pressure at sea level | $1.013 \times 10^5$ Pa |
| Mass of Earth | $5.98 \times 10^{24}$ Kg |
| Mass of Moon | $7.35 \times 10^{22}$ Kg |
| Mass of Sun | $1.99 \times 10^{30}$ Kg |



## FREQUENTLY USED MATHEMATICAL SYMBOLS

| Symbol | Meaning |
|---|---|
| $=$ | Is equal to |
| $\neq$ | Is not equal to |
| $\leq$ | Is less than or equal to |
| $\geq$ | Is greater than or equal to |
| $\alpha$ | is proportional to |
| $\Delta$ | the difference between two variables (e.g., $\Delta T$ is the final temperature minus the initial temperature) |

## BASIC MATHEMATICAL FORMULAS

| Quantity | Formula |
|---|---|
| Area of a circle | $\pi r^2$ |
| Circumference of a circle | $2\pi r$ |
| Surface area of a sphere | $4\pi r^2$ |
| Volume of a sphere | $^4/_3\,\pi r^3$ |
| Pythagorean theorem | $h^2 = h_o^2 + h_a^2$ |
| Sine of an angle | $sin\theta = h_o/h$ |
| Cosine of an angle | $cos\theta = h_a/h$ |
| Tangent of an angle | $tan\theta = h_o/h_a$ |

## LABORATORY INSTRUCTIONS FOR STUDENTS :

Experiments in National curriculum are designed to illustrate important concept described in class. You are expected to come prepared when you arrive to laboratory to perform an experiment. The instructor at laboratory is not to perform an experiment he will be there to answer your questions, aid you in the use of equipment, discuss the physics behind the experiment and guide you in completing your analysis and write-up.

All write up should be finished in the laboratory session and handed over to the instructor for sign. Remember the neatness, organization and explanations of your measurements and calculations represent the quality of your work.

In your lab ask the instructor to provide you the materials required for practical work. Arrange them on table and examine their condition; if equipment is out of order try to replace. Apparatus requiring frequent adjustment must be placed within easy reach.

The apparatus provided for the laboratory experiment are often expensive and delicate. If a piece of apparatus is broken report to the instructor immediately.

Try to record original data and let all the group member participate in the experiment.

After completing an experiment the experimental setup must be disassembled, and turn off all the sources of water electricity and gas.

**Safety:** The most important thing in the laboratory is your safety and that of others. The danger increases if you have less knowledge of the equipment and procedures. If you have a question about safety you should direct it immediately to the instructor. The students in the physics lab are expected to exercise common sense judgment when working with laboratory equipment.

Name

Lion

## THE GREEK ALPHABET

| Name | Capital Letters | Small Letters | Name | Capital Letters | Small Letters |
|---|---|---|---|---|---|
| Alpha | Α | α | Nu | Ν | ν |
| Beta | Β | β | Xi | Ξ | ξ |
| Gamma | Γ | γ | Omicron | Ο | ο |
| Delta | Δ | δ | Pi | Π | π |
| Epsilon | Ε | ε | Rho | Ρ | ρ |
| Zeta | Ζ | ζ | Sigma | Σ | σ |
| Eta | Η | η | Tau | Τ | τ |
| Theta | Θ | θ | Upsilon | Υ | υ |
| Iota | Ι | ι | Phi | Φ | φ |
| Kappa | Κ | κ | Chi | Χ | χ |
| Lambda | Λ | λ | Psi | Ψ | ψ |
| Mu | Μ | μ | Omega | Ω | ω |



Page

مومن تو آپس میں بھائی بھائی ہیں۔

تو اپنے دو بھائیوں میں صلح کرا دیا کرو۔

اور اللہ سے ڈرتے رہو۔

تا کہ تم پر رحمت کی جائے۔

(سورۃ الحجرات: ۱۰)