6 HEAT AND ENERGY

Syllabus :

(i) *Concepts of heat and temperature.*

Scope – Heat as energy; SI unit, joule, 1 cal = 4·186 J exactly.

(ii) *Anomalous expansion of water.*

Scope – Anomalous expansion of water, graphs showing variation of volume and density of water with temperature in the 0 to 10°C range. Hope's experiment and consequences of anomalous expansion.

(iii) *Energy flow and its importance.*

Scope – Understanding the flow of energy as linear and linking it with the laws of thermodynamics — 'energy is neither created nor destroyed' and 'no energy transfer is 100% efficient'.

(iv) *Energy sources. Renewable versus non-renewable sources (elementary ideas with example), energy degradation.*

Scope – Solar, wind, water and nuclear energy (only qualitative discussion of steps to produce electricity).

Renewable energy : Bio gas, solar energy, wind energy, energy from falling of water, run-of-the river schemes, energy from waste, tidal energy, etc. Issues of economic viability and ability to meet demands.

Non-renewable energy : Coal, oil, natural gas, inequitable use of energy in urban and rural areas, use of hydroelectrical power for light and tube-wells.

Energy degradation : Meaning and examples..

(v) *Green house effect and global warming.*

Scope – Meaning and impact on the life on earth; projections for the future; what needs to be done.

(A) HEAT AND TEMPERATURE; ANOMALOUS EXPANSION

6.1 CONCEPT OF HEAT (HEAT AS ENERGY)

It is our common experience that on rubbing our palms, they get heated ; on passing electric current in a metallic wire, the wire gets heated; on burning coal, we get heat; on pumping air in a bicycle tube, the barrel of pump gets heated. In all these cases, heat is produced either by doing work or by providing energy in some form other than heat. On rubbing palms and on pumping air in a bicycle tube, heat is produced by doing work *i.e.*, from mechanical energy, while on passing current in a metallic wire, heat is obtained from electrical energy and on burning coal, heat is obtained from chemical energy. Thus *heat is also a form of energy.*

Each body is made up of molecules. The molecules are in random motion and each molecule exerts a force of attraction on other molecules. Thus molecules possess energy and the heat energy of a body is the internal energy* of its molecules. A hot body has more internal energy than an identical cold body. When a hot body is kept in contact with a cold body, the cold body warms up and the hot body cools down *i.e.*, the internal energy of cold body increases and that of the hot body decreases. Thus energy is transferred from the hot body to the cold body when they are placed in contact. The energy which flows from hot body to the cold body is called the *heat energy* or simply the *heat.*

On touching, a body appears hot to us when heat energy flows from that body to our hand, while it appears cool to us when heat energy flows from our hand to the body.

Example **:** If we touch warm water, we feel hot because heat energy from warm water passes to our hand. Similarly, if we touch a cube of ice, we feel cool because heat energy from our hand passes to the cube of ice.

Thus we can define heat as follows :

> *Heat is the internal energy of molecules constituting the body. It flows from a hot body to a cold body.*

* *Total internal energy is equal to the sum of internal kinetic energy due to molecular motion and internal potential energy due to molecular attractive forces.*

Unit of heat

The unit of heat is same as that of energy. The S.I. unit of heat is joule (abbreviated as J) and its C.G.S. unit is erg, where

$$1 \text{ J} = 10^7 \text{ erg} \quad ...(6.1)$$

Other units of heat are calorie (cal) and kilocalorie (kcal), where

$$1 \text{ kilocalorie} = 1000 \text{ calories} \quad ...(6.2)$$

The units calorie and joule are related as :

$$1 \text{ cal} = 4{\cdot}186 \text{ J (or nearly } 4{\cdot}2 \text{ J)} \quad ...(6.3)$$

6.2 CONCEPT OF TEMPERATURE

When a hot body is kept in contact with a cold body, it is noticed that after some time, the hot body becomes less hot and the cold body becomes less cold. Obviously, this is because of the *flow of heat from hot body to the cold body*. The body which imparts heat is said to be at a higher temperature than the body which receives heat. Thus, *temperature determines the direction of flow of heat.*

When a body receives heat energy, the particles constituting the body start vibrating more vigorously and its temperature rises provided its physical state or dimensions remain unchanged.

Thus temperature is defined as below.

> *Temperature is a quantity which tells the thermal state of a body (i.e., the degree of hotness or coldness of the body). It determines the direction of flow of heat when two bodies at different temperatures are placed in contact.*

If there is no transfer of heat between the two bodies placed in contact, they are said to be at the same temperature, but it does not mean that they have equal amount of heat in them. In fact, temperature alone does not tell us the quantity of heat energy contained in a body. Experimentally, we find that by imparting same quantity of heat energy to different bodies, they get heated to different temperatures. *The amount of heat energy contained by a body depends on its mass, temperature and the material of the body.*

Unit of temperature

The S.I. unit of temperature is kelvin (symbol K). The other most common unit of temperature is degree celsius (symbol °C) and degree fahrenheit (symbol °F).

The temperature on Celsius scale and Kelvin scale are related as :

$$\text{T K} = 273 + t \text{ °C} \quad ...(6.4)^*$$

Thus, *by adding 273 to the temperature in degree celsius, we get the temperature in Kelvin.* Actually a degree on both the Kelvin and Celsius scales is equal.

The ice point is 0°C on Celsius scale, 32°F on Fahrenheit scale and 273 K on the Kelvin scale. The steam point is 100°C on Celsius scale, 212°F on Fahrenheit scale and 373 K on the Kelvin scale. Thus there are 100 equal degrees between the ice point and steam point on both the Celsius and Kelvin scales, but 180 equal divisions on the Fahrenheit scale. Thus 1 degree on Celsius scale is $\frac{9}{5}$ degree on Fahrenheit scale.

* More precisely T K = 273·15 + t °C

Difference between heat and temperature

Heat	Temperature
1. Heat is a form of energy obtained due to random motion of molecules in a substance	1. Temperature is a quantity which determines the direction of flow of heat on keeping the two bodies at different temperatures in contact.
2. The S.I. unit of heat is joule (J)	2. The S.I. unit of temperature is kelvin (K).
3. The amount of heat contained in a body depends on mass, temperature and material of body.	3. The temperature of a body depends on the average kinetic energy of its molecules due to their random motion.
4. Heat is measured by the principle of calorimetry.	4. Temperature is measured by a thermometer.
5. Two bodies having same quantity of heat may differ in their temperature.	5. Two bodies at same temperature may differ in the quantities of heat contained in them.
6. When two bodies are placed in contact, the total amount of heat is equal to the sum of heat of the individual bodies.	6. When two bodies at different temperatures are placed in contact, the resultant temperature is a temperature in between the two temperatures.

The zero of the Kelvin scale is called *absolute zero* and it is at a temperature when molecular motion ceases. It is at –273°C *i.e.* 0 K = –273°C.

The temperature on Celsius and Fahrenheit scales are related as : $\frac{C}{5} = \frac{F-32}{9}$ ....(6.5)

6.3 THERMAL EXPANSION

Almost all substances (solids, liquids and gases) expand on heating and contract on cooling.

> *The expansion of a substance on heating is called the thermal expansion of that substance.*

A solid has a definite shape, so when a solid is heated, it expands in all directions *i.e.,* the length, area and volume, all increase on heating. The increase in length is called the *linear expansion*, the increase in area is called the *superficial expansion* and the increase in volume is called the *cubical expansion*. The liquids and gases do not have a definite shape, so they have only the cubical (or volume) expansion. On heating, *liquids expand more than the solids,* and *gases expand much more than the liquids.*

Some substances such as water from 0°C to 4°C, silver iodide from 80°C to 141°C and silica below –80°C contract on heating and expand on cooling. The expansion of a substance on cooling in a certain range of temperature is called the *anomalous expansion* of that substance. Here we shall study the anomalous expansion of water.

6.4 ANOMALOUS EXPANSION OF WATER

If we take some water at 0°C and start heating it, we find that it contracts (instead of expanding) in the temperature range from 0°C to 4°C. On heating it further above 4°C, it expands. Similarly, if water initially at a temperature above 4°C is cooled, it contracts till the temperature of water reaches 4°C. On further cooling it below 4°C to 0°C, it expands. This unusual expansion of water on cooling it in the temperature range 4°C to 0°C, is called *anomalous expansion of water*. Thus,

> ***The expansion of water when it is cooled from 4°C to 0°C, is known as anomalous expansion of water.***

Fig. 6.1 shows the variation in volume of 1 g of water with temperature in the range

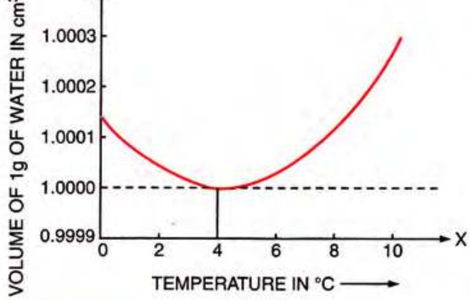


Fig. 6.1 Variation in volume of water in range of temperature 0°C to 10°C

from 0°C to 10°C. The volume of water first *decreases* on heating it from 0°C to 4°C and then *increases* on further heating it from 4°C to 10°C. *The volume of water is thus minimum at* 4°C. For 1 g of water, the volume at 4°C is 1·0000 cm^3.

Fig. 6.2 shows the variation in density of water with temperature in the range from 0°C to 10°C. When water is heated from 0°C, the density of water first *increases* from 0°C to 4°C and then *decreases* above 4°C to 10°C. On the other hand, on cooling water from 10°C, the density of water first *increases* up to 4°C and then *decreases* when it is cooled further below 4°C to 0°C. Thus *the density of water is maximum at* 4°C which is equal to 1 g cm^{-3} (or 1000 kg m^{-3}).

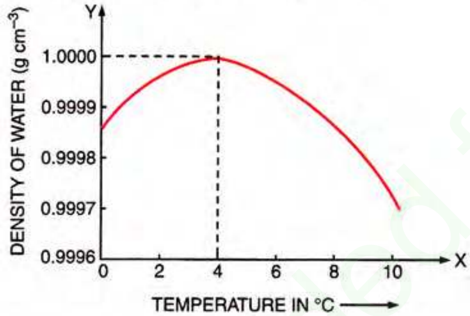


Fig. 6.2 Variation in density of water with temperature in range 0°C to 10°C

6.5 HOPE'S EXPERIMENT TO DEMONSTRATE THE ANOMALOUS EXPANSION OF WATER

In 1805, the scientist T.C. Hope devised a simple arrangement, known as Hope's apparatus for demonstrating the anomalous expansion of water. Fig 6.3 shows the Hope's apparatus.

The apparatus consists of a tall metallic cylinder provided with two side openings *P* near the top and *Q* near the bottom, fitted with thermometers T_1 and T_2 respectively. The central

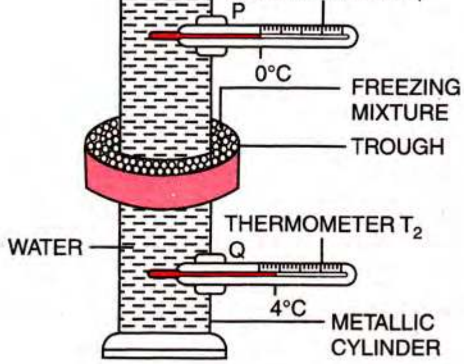


Fig. 6.3 Hope's apparatus

part of the cylinder is surrounded by a cylindrical trough containing a freezing mixture of ice and salt. The cylinder is filled with pure water at room temperature. The temperature recorded by both the thermometers is observed at a regular interval of time.

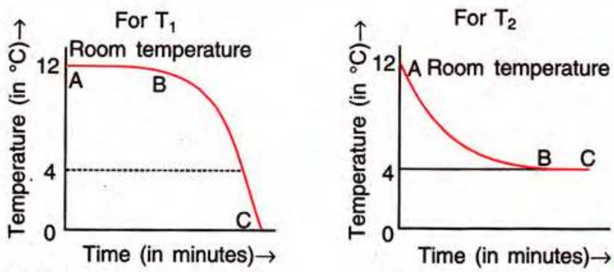
Observations : (i) Initially both the thermometers T_1 and T_2 show same temperature, (*i.e.*, room temperature).

(ii) First the temperature recorded by lower thermometer T_2 starts decreasing and finally it becomes steady at 4°C, while the temperature recorded in upper thermometer T_1 remains almost unchanged during this time.

(iii) While the temperature recorded by lower thermometer T_2 remains constant at 4°C, the upper thermometer T_1 shows a continuous fall in temperature up to 0°C and then it also becomes steady.

Thus finally the temperature recorded by upper thermometer T_1 is 0°C and that by lower thermometer T_2 is 4°C.

Fig. 6.4 shows the variation in temperature recorded by thermometers T_1 and T_2 with time.



(a) Temperature-time graph for thermometer T_1

(b) Temperature-time graph for thermometer T_2

Fig. 6.4 Variation in temperature with time recorded by the thermometers T_1 and T_2

at room temperature (say 12°C) which is indicated by the point *A* in the graphs. As the freezing mixture cools water in the central portion of the cylinder, water contracts and its density *increases*. Consequently the cooled water sinks to the bottom and warm water from the bottom rises up to take its place. Thus by convection, water of the lower part cools, so the reading of the lower thermometer T_2 falls rapidly. The reading of upper thermometer T_1 does not change because the temperature of water in the upper part does not change. This continues till temperature of entire water below the central portion reaches at 4°C. This is shown by the part *AB* in graphs (a) and (b). Now the reading of lower thermometer T_2 becomes steady. On further cooling below 4°C, due to anomalous expansion, water of the central portion now expands, so its density *decreases* and hence it rises up. To take its place, water from top descends down and by convection, water above the central portion cools. So the reading of upper thermometer T_1 now falls rapidly till 0°C and water near the top freezes to form ice at 0°C. Now the thermometer T_1 shows the steady temperature 0°C. This is shown by the part *BC* in graphs (a) and (b). At this stage, the *lower thermometer T_2 shows the temperature 4°C at which water has the maximum density while the upper thermometer T_1 shows the temperature of water and ice at 0°C.*

6.6 CONSEQUENCES OF ANOMALOUS EXPANSION OF WATER

(i) *The anomalous expansion of water helps in preserving the aquatic life during the very cold weather*

In cold weather (or winter), when the atmospheric temperature starts falling well below 0°C, water at the surface of a pond (or lake) initially at temperature above 4°C, begins to radiate heat to the atmosphere, so the temperature of water starts falling upto 4°C. When temperature of water at the surface falls, water contracts, so its density increases and therefore, it sinks to the bottom. This continues till temperature of entire water reaches to 4°C. Now, further cooling of top layers below 4°C results in expansion of water and so its density decreases. As a result, water does not sink

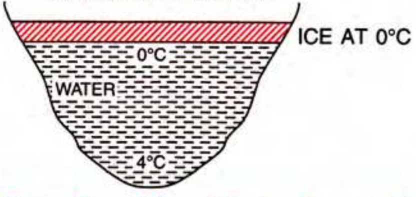


Fig. 6.5 Formation of ice at the top in a pond

further, but it remains on the surface. When the temperature of atmosphere falls below 0°C, water on the surface rejects heat to the atmosphere and gradually freezes into ice, but water well below the ice layer remains at 4°C. The water layer just below the ice in contact with it will be at 0°C. Fig. 6.5 shows the formation of ice at the surface of pond (or lake). Since ice is a *poor conductor of heat*, so ice now prevents the flow of heat from water of pond (or lake) to the atmosphere. Thus temperature of water in contact with ice is at 0°C, while the temperature of water layers below the ice gradually increases to 4°C. As a result, fish and other aquatic creatures remain alive in water of the pond (or lake), though water on the surface has frozen into ice. Nature thus protects the aquatic life during the winter season.

(ii) *The anomalous expansion of water is responsible for the burst of water pipe lines, and destruction of crop during the very cold nights*

In winter nights, as the atmospheric temperature starts falling below 4°C, water in pipe lines expands and it exerts large pressure on the pipes, causing them to burst. Plants also die for the same reason as their capillaries burst when water expands below 4°C.

To protect the plants, the field is filled with water.

EXERCISE 6(A)

1. What is heat ? Write its S.I. unit.
2. Two bodies at different temperatures are placed in contact. State the direction in which heat will flow. **Ans.** From the body at high temperature to the body at low temperature.
3. Name the S.I. unit of heat and how is it related to the unit calorie ?

   Ans. joule (J), 1 J = 0·24 cal (nearly)
4. Define temperature and write its S.I. unit.
5. Why does a piece of ice when touched with hand, appear cool ? Explain.

   Ans. On touching ice, heat passes from our hand to the ice.
6. Distinguish between heat and temperature.
7. What do you understand by thermal expansion of a substance ?
8. Name *two* substances which expand on heating.

   Ans. Brass, Iron
9. Name *two* substances which contract on heating.

   Ans. Water from 0°C to 4°C, silver iodide from 80°C to 141°C.
10. What do you mean by anomalous expansion of water ?

    Ans. Expansion of water on cooling it from 4°C to 0°C.
11. At what temperature the density of water is maximum ? State its value.

    Ans. At 4°C, 1000 kg m^{-3}
12. State the volume changes observed when a given mass of water is heated from 0°C to 10°C. Sketch a temperature-volume graph to show the behaviour.
13. Draw a graph to show the variation in density of water with temperature in the temperature range from 0°C to 10°C.
14. A given mass of water is cooled from 10°C to 0°C. State the volume changes observed. Represent these changes on a temperature-volume graph.
15. Describe an experiment to show that water has maximum density at 4°C. What important consequences follow from this peculiar property of water ? Discuss the importance of this phenomenon in nature.
16. Deep pond of water has its top layer frozen during winter. State the expected temperature of water layer (i) just in contact with ice, (ii) at the bottom of pond. **Ans.** (i) 0°C (ii) 4°C
17. Draw a diagram showing the temperature of various layers of water in an ice covered pond.
18. Explain the following :

    (a) Water pipes in colder countries often burst in winter.

    (b) In winter, water tank (or ocean) starts freezing from the surface and not from the bottom.

atmospheric temperature is well below 0°C.

(d) A hollow glass sphere which floats with its entire volume submerged in water at 4°C, sinks when water is heated above 4°C.

(e) A glass bottle completely filled with water and tightly closed at room temperature, is likely to burst when kept in the freezer of a refrigerator.

Multiple choice type :

1. Calorie is the unit of :
   (a) heat (b) work
   (c) temperature (d) food
   Ans. (a) heat

(a) 0·24 cal (b) 4·18 cal
(c) 1 cal (d) 1 kcal
Ans. (a) 0·24 cal

3. S.I. unit of temperature is :
   (a) cal (b) joule
   (c) celsius (d) kelvin
   Ans. (d) kelvin

4. Water is cooled from 4°C to 0°C. It will :
   (a) contract
   (b) expand
   (c) first contract, then expand
   (d) first expand, then contract. **Ans.** (b) expand

5. Density of water is maximum at :
   (a) 0°C (b) 100°C
   (c) 4°C (d) 15°C **Ans.** (c) 4°C

(B) ENERGY FLOW AND ITS IMPORTANCE

6.7 ENERGY FLOW IN AN ECOSYSTEM

A unit composed of biotic components (*i.e.*, producers, consumers and decomposers) and abiotic components (*i.e.*, light, heat, rain, humidity, inorganic and organic substances) is called an *ecosystem*.

The existence of living beings such as plants and animals depends on the flow of energy in them. Energy is needed for all the biotic activities. The most significant source of energy for all ecosystems is the *sun*.

The energy received on the earth from the sun is utilised in different ways. Nearly 56-60% part of the incident energy is absorbed by the atmosphere, nearly 10% is utilised in heating of water and land, and only 8% falls on plants. Plants absorb most of the energy falling on them. Out of the absorbed energy, plants use only 0·02% in photosynthesis for producing their food. They are called the *producers*.

Food chain : In ecosystem, photosynthetic plants and bacteria act as *producers*. The food synthesized by producers is utilised by *primary consumers* (such as krill). The primary consumers are eaten by the *secondary consumers* (such as small fish) and in turn they are consumed by the *tertiary consumers* (such as large fish). The tertiary consumers may be eaten by man. The man may be the *last consumer* in this chain of energy transfer when he eats the fish. This simple food chain is shown in Fig. 6.6.

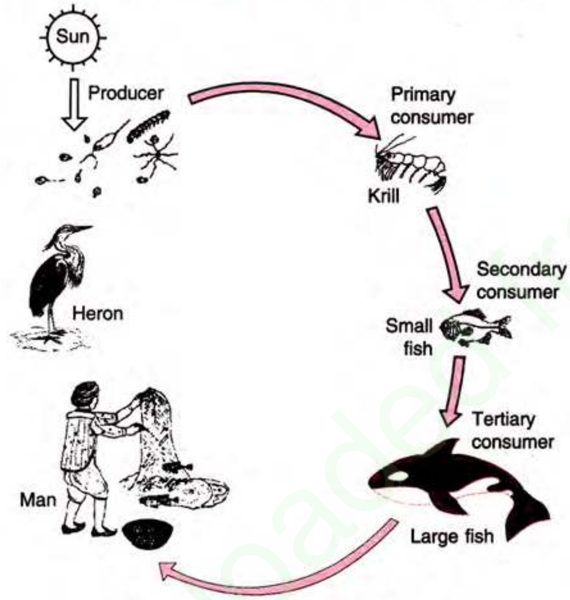


Fig. 6.6 The simple food chain

Energy flow : Fig. 6.7 shows the energy flow in the ecosystem. The *producers* (photosynthetic plants) synthesize organic substances by the process of photosynthesis (*i.e.*, they bind the simple compounds with the help of solar energy into the complex organic substances). The chemical energy so stored in plants is called the *gross primary production*. The producers themselves first use the synthesized organic substances in the process of respiration in which some energy is used in oxidation of organic substances. The rest of the energy, called the *net primary production*, is stored for the growth, development and important metabolic processes. In Fig. 6.7, the gross primary production by the producers is 20,810 cal energy, out of which 11,977 cal energy is used in the respiration and the net primary production is 8,833 cal energy.

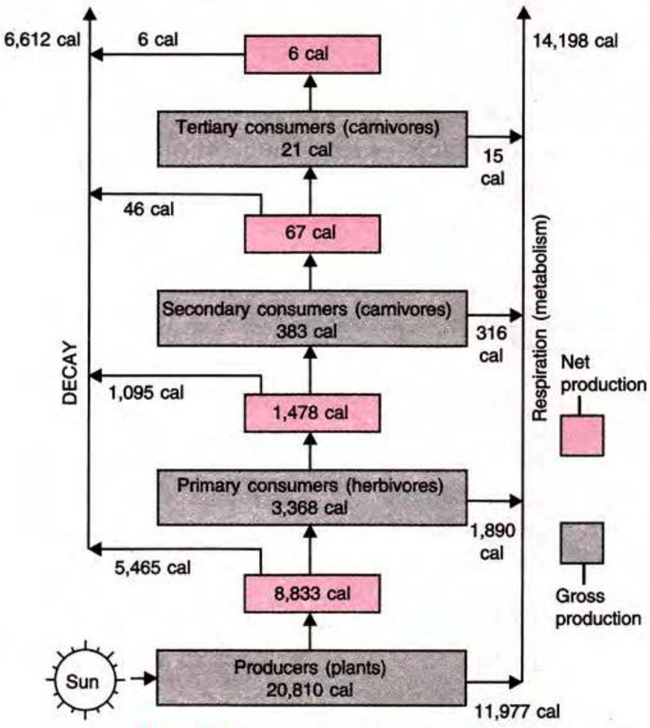


Fig. 6.7 Energy flow in ecosystems

Next the *primary consumers* (herbivores) obtain their food from the producers, so they obtain only a small part of energy from the producers and the rest is wasted in decay of producers. A small part of the energy obtained by the primary consumers is utilized in respiration through which they perform metabolic processes of their body and the remaining part is stored in them as food. In Fig. 6.7, the primary consumers obtain only 3,368 cal energy from the producers and rest of the energy 5,465 cal is wasted in their decay. Then out of 3,368 cal energy which the primary consumers obtain from the producers, 1,890 cal energy is used up in respiration and 1,478 cal energy is stored as food.

Afterwards, a small part of the energy stored as food in the primary consumers is obtained by the *secondary consumers* (carnivores). They again make use of a part of the energy in respiration and rest is stored in them as food. In Fig. 6.7, the secondary consumers obtain only 383 cal energy from the primary consumers and rest of the energy 1,095 cal is wasted in their decay. The secondary consumers utilise 316 cal energy in respiration and rest of the energy 67 cal is stored in them as food.

By repeating the sequence, the *tertiary consumers* (carnivores) obtain energy as food from the secondary consumers and utilise a small part of it in respiration and remaining energy is wasted in their decay and decomposition. In Fig. 6.7, the tertiary consumers obtain only 21 cal energy from the secondary consumers and rest of the energy (*i.e.*, 46 cal) is wasted in their decay. Out of the 21 cal energy obtained by the tertiary consumers, 15 cal energy is used in respiration and 6 cal energy is wasted in their decay.

The energy flow in ecosystems is thus linear i.e., it moves in a fixed direction. At the end, the energy reaches to the degraded (or unuseful) state.

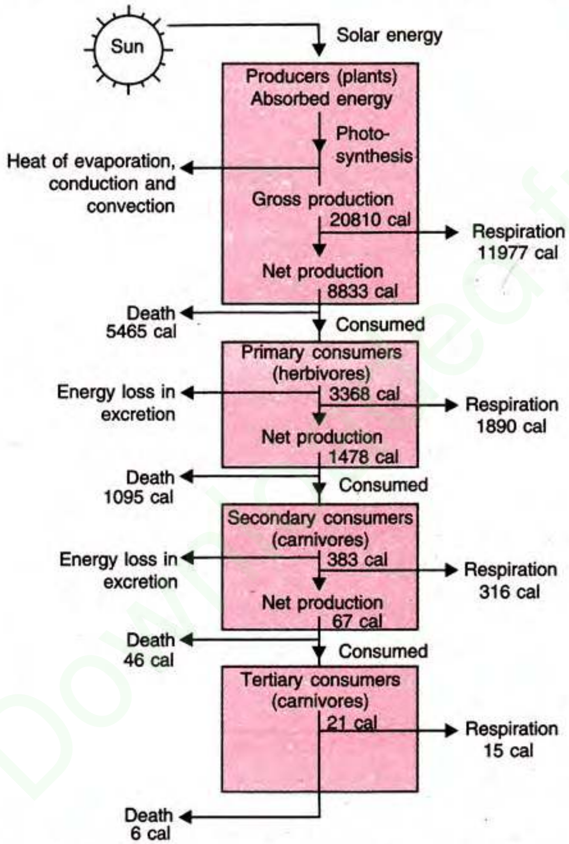


Fig. 6.8 Energy flow in ecosystem in form of a food chain

cyclic.

The energy flow in the ecosystem can also be understood in form of a food chain shown in Fig. 6.8.

6.8 APPLICATION OF LAWS OF THERMODYNAMICS IN ENERGY FLOW

The flow of energy in the process of entrance, transformation and diffusion in ecosystem is governed by the laws of thermodynamics.

According to the first law of thermodynamics, *the energy can be transformed from one form to the other form, but it can neither be created nor destroyed.* When certain amount of one form of form of energy is created as shown in Fig. 6.7

According to the second law of thermodynamics, when energy is put to work, *a part of it is always converted in unuseful form as heat mainly, due to friction and radiation.* In all such cases the total sum of useful and unuseful energy remains constant. In Fig. 6.7, the energy used in respiration and in decay (or death) appears as unuseful heat energy because this energy does not reach to the consumer of next stage. So just like a machine, in ecosystem also the energy transfer is not 100% efficient, a portion of the transferred energy always goes to unuseful form in accordance with the second law of thermodynamics.

EXERCISE 6(B)

1. What is an ecosystem ? Name its *two* components.
2. What is the source of energy for all ecosystems ?
3. State the importance of green plants in an ecosystem.
4. Differentiate between the producers and consumers.
5. State the functions of decomposers in an ecosystem.
6. What is a food chain ?
7. Draw a simple diagram showing a food chain.
8. Describe the energy flow in an ecosystem.
9. State the law which governs the energy flow in an ecosystem.
10. Show that the energy flow in an ecosystem is linear.
11. Draw a simple diagram showing the energy flow in a food chain.
12. Draw a diagram to show that the energy flow in an ecosystem is governed by the law of conservation of energy.

Multiple choice type :

1. Food chain begins with :
   (a) respiration (b) photosynthesis
   (c) decomposition (d) decay.
   Ans. (b) photosynthesis.
2. The source of energy in an ecosystem is :
   (a) sun (b) decayed bodies
   (c) green plants (d) sugar.
   Ans. (a) sun.
3. Energy enters in a food chain through :
   (a) primary consumers
   (b) secondary consumers
   (c) tertiary consumers
   (d) producers.
   Ans. (d) producers.
4. The place of human being in food chain in an ecosystem is as a :
   (a) producer (b) consumer
   (c) decomposer (d) both (a) & (b).
   Ans. (b) consumer.

6.9 SOURCES OF ENERGY

We require energy in every activity of our life. For example, energy is required to cook food, to light homes, to run gadgets, to move vehicles, to run T.V., cinema, radio, etc. We need energy for production in factories and also for crops in fields. To meet most of these requirements, the energy needed is in form of heat and electricity. For example, we need heat energy for cooking food and this heat energy is obtained by burning the fuels such as coal, wood, kerosene or cooking gas. We need electricity to run electric motors, fans, etc. and it is obtained from coal, hydro-energy or nuclear energy.

Characteristics of a source of energy : *A source of energy should be such that it can provide an adequate amount of useful energy at a steady rate over a long period of time. It should be safe and convenient to use, economical and easy to store and transport.*

Classification of sources of energy : From the point of *view of availability*, the energy sources are divided into the following *two* groups:

(1) renewable or non-conventional sources of energy, and

(2) non-renewable or conventional sources of energy.

6.10 RENEWABLE OR THE NON-CONVENTIONAL SOURCES OF ENERGY

A natural source providing us energy continuously is called a renewable (or non-conventional) source of energy. Sun is the main source of energy for us on the earth. The energy harnessed from the natural sources like wind, flowing water, tides, ocean waves and biogas is directly or indirectly derived from the energy of the sun. We can use these sources as long as the earth continues to receive heat and light from the sun. Apart from these sources, geo-thermal energy and nuclear energy are the other sources of energy which can provide us energy over a long period of time. These sources of energy can be used again and again and will never get exhausted.

Although the wood, obtained from trees, is also considered a renewable source of energy, but trees usually take more than 15 years to grow fully, therefore, renewal of wood as source of energy takes a long time. Further, *cutting of trees on a large scale causes depletion of forests which results in global warming and environmental imbalance. Hence use of wood as a source of energy must be avoided.*

Thus, the main sources of renewable energy are : (i) Sun (ii) Wind (iii) Flowing water (Hydro) (iv) Bio mass and bio fuels from waste (v) Tides (vi) Oceans (vii) Geo-thermal spots and (viii) Nuclear fuel.

(i) Sun as source of energy : Sun is the main source of various types of energy. *The energy obtained from sun is called the solar energy.* In the interior of the sun, nuclear fusion reactions generate huge amount of energy which is radiated out continuously in all directions in space. Since the sun is very far from the earth, we receive only a very small fraction of the total solar energy.

The solar energy that reaches earth is neither uniform nor equal at all places. It changes daily even at one place. It also varies during a day. The average solar energy reaching the upper atmosphere of earth per second on an area of 1 metre^2 is called the *solar constant* and it is estimated to be nearly 1·34 kW m^{-2}. The solar energy reaching the earth is absorbed by land, plants and water bodies like rivers, lakes and oceans. The solar energy absorbed by land and water bodies cause winds, storms, rains, snow falls and sea waves, etc. while the solar energy absorbed by plants is utilized by them in preparing their food by the process of photosynthesis.

(ii) Wind as source of energy : The large mass of moving air is called wind. Due to motion, it has kinetic energy. *The kinetic energy of wind is called the wind energy.*

energy. The sun rays falling on earth heat different areas of earth unequally. Due to (i) unequal heating of different areas of earth, (ii) rotation of earth and (iii) local convection currents, we have different wind cycles.

From the very early days, we have been using energy possessed by wind for various purposes such as in removing husk from grains, in propelling sail boats in rivers and seas, in moving vehicles for transportation and in windmills to draw water from the ground and to grind grains.

(iii) Flowing water as a source of energy: *The kinetic energy possessed by the flowing water is called the hydro energy.*

Hydro energy too comes indirectly from the sun. The solar energy is responsible for water cycle in nature. Water in oceans, rivers, lakes, etc. absorbs solar energy and it then evaporates to form clouds. The clouds move due to air currents and ultimately water comes back on earth in the form of rain and snow.

Man has been utilizing for centuries the energy of flowing water in rivers for rotating the wheels of water mill used to drive the flour mill in remote hilly areas and for transporting heavy logs of wood from forests in hilly areas to the downstream areas in planes.

(iv) Bio mass as source of energy : The wastes and dead parts of living beings like plants, trees and animals, is called *bio mass.* They contain carbon compounds. *The chemical energy stored in the bio mass is called the bio energy*. Thus, bio energy also comes from solar energy. Bio mass such as wood, cattle dung, crop residues and agriculture wastes like bagasse have been traditionally used as fuel to produce heat energy for domestic as well as commercial purposes.

Bio mass is also used to produce bio gas by its decomposition in the absence of oxygen. The main constituent of bio gas is methane (65%) and rest is a mixture of carbon dioxide, hydrogen and hydrogen sulphide. Bio gas is used as a fuel to run engines and for generating plants : (1) the floating gas holder type and (2) the fixed dome type. They are also called **Gobar gas plants** because the main bio mass used in these plants is called *slurry* which is the mixture of animal dung (or gobar) in water.

(v) Tides as source of energy : The rise of ocean water near the coast is called *high tide* and fall of ocean water is called *low tide*. This rise and fall of tidal waves occur twice a day in oceans. *The energy possessed by rising and falling water in tides is known as tidal energy.*

Tidal energy is harnessed for producing electricity by constructing a dam across a narrow opening to the sea. But this is not a major source of energy because of the following *two* reasons :

(1) The rise and fall of sea water during tides is not enough to generate electricity on a large scale.

(2) There are very few sites which are suitable for building the tidal dams.

(vi) Oceans as source of energy : Water in oceans possesses energy in *two* forms : (a) ocean thermal energy and (b) oceanic (or sea) waves energy.

(a) Ocean thermal energy : Water at the surface of an ocean gets heated by absorbing the heat of sun, while water at its deeper levels remains cold. Thus, there is a difference in temperature of water at the surface and at deeper levels of an ocean. This difference in temperature is found to be up to 20°C. *The energy available due to the difference in temperature of water at the surface and at deeper levels of ocean is called the ocean thermal energy (OTE).* Obviously, this energy also comes indirectly from the sun.

Ocean thermal energy is harnessed for producing electricity by a device called *ocean thermal energy conversion power plant* (OCTEC power plant).

(b) Oceanic (or sea) waves energy : Due to the wind blowing on the surface of oceans, waves move at high speed on its surface which are called the oceanic waves (or sea waves). Due to their high speed, they carry tremendous amount of kinetic energy with them. Thus, *the kinetic energy possessed by such fast moving oceanic (or sea) waves is called the oceanic (or sea) waves energy.* This energy also comes indirectly from the sun.

Sea waves energy can also be harnessed to produce electricity, but so far it has not become possible to produce electricity from sea waves energy on a large scale. However, models have been made to generate electricity from oceanic waves.

(vii) Geo thermal spots as source of energy : At some places, rocks below the surface of earth are very hot. Such places are known as *hot spots. The heat energy possessed by rocks inside the earth is called the geo thermal energy.*

Geo thermal energy is harnessed to produce electricity. The rocks present at hot spots, heat the underground water and turn it into steam, which gets compressed at high pressure between the rocks. By drilling holes into the earth up to the hot spots, steam is extracted through pipes which is utilized to rotate the turbine connected to the armature of an electric generator to produce electricity.

In India, there are very few places where geothermal energy is harnessed to produce electricity. One such place is in Madhya Pradesh. However, in USA and Newzealand, there are a number of geo thermal energy based power plants.

(viii) Nuclear fuel as source of energy : When uranium nucleus is bombarded with a slow neutron, it splits into two nearly equal light nuclei and a large amount of energy is released. This phenomenon is called *nuclear fission*. Similarly, when two light nuclei combine to form a heavy nucleus at a very high temperature ($\approx 10^7$ K) and high pressure, a tremendous amount of energy is released. This phenomenon is called *nuclear fusion*. In both these processes, the origin of energy is the loss in mass *i.e.*, the sum of masses of the products of reaction is less than the sum of masses of reactants and this loss in mass is converted into energy E according to the Einstein's mass-energy equivalence relation $E = mc^2$, where c ($=3 \times 10^8$ m s^{-1}) is the speed of light and m is the loss in mass. This energy is known as nuclear energy.

In fission reaction of one uranium nucleus, nearly 200 MeV energy is released and *two* or *three* neutrons are also emitted. If number of uranium nuclei present are more, each neutron emitted in the fission reaction of a uranium nucleus causes fission in the new uranium nuclei and thus a chain of nuclear fission reactions occurs, which once started continues till the entire uranium is exhausted. As a result of such an *uncontrolled* chain reaction, more and more energy is produced which may cause an explosion. An *atom bomb* is based on this principle. But to utilize the energy produced in the process of fission for constructive use (such as to produce electricity), the chain reaction is *controlled* by absorbing some neutrons with the help of cadmium rods. This is done in a *nuclear reactor.*

So far it has not become possible to harness energy by the process of nuclear fusion.

6.11 NON-RENEWABLE OR THE CONVENTIONAL SOURCES OF ENERGY

The sources of energy which have accumulated in nature over a very long period and cannot be quickly replaced when exhausted, are called the non-renewable or conventional sources of energy. Coal, petroleum and natural gas known as fossil fuels are non-renewable sources. They are formed by the decomposition of the remains of plants and animals buried under the earth, millions of years ago. Thus, the formation of fossil fuels have occurred over millions of years due to certain very slow changes under special circumstances. If they are being used extensively, their known reserves will soon deplete and once exhausted, they cannot be regenerated soon.

The common non-renewable sources of energy are : (i) *coal,* (ii) *petroleum* and (iii) *natural gas.*

made up of complex compounds of carbon, hydrogen and oxygen along with some free carbon and compounds of nitrogen and sulphur. It is found in deep mines under the surface of earth. In India, coal mines are found in Jharkhand, West Bengal, Orissa and Chattishgarh. Since coal is found in abundance in our country, it is the most common source of energy for us.

(ii) Petroleum : *Petroleum is a dark coloured viscous liquid* also called crude oil. It is a non-renewable source of energy which is found under the earth's crust trapped in rocks. It is called petroleum because petroleum means rock oil. *It is a complex mixture of many hydrocarbons with water, salt, earth particles and other compounds of carbon, oxygen, nitrogen and sulphur.* It is lighter than water and does not mix with it. Petroleum is obtained by drilling oil wells into the earth's crust at its reservoirs. In India, the reservoirs of petroleum have been found in Assam and Mumbai.

The crude petroleum extracted from wells is not suitable to be used as a fuel in its natural form. It has to be purified (or refined) to obtain different useful components. *The process of separating useful components from crude petroleum is called refining which is done by fractional distillation in big oil refineries set up for this purpose.*

The petroleum gas obtained as a by-product from the fractional distillation of petroleum contains mainly the butane and a small amount of propane and ethane. These gases burn readily and produce a lot of heat. Hence the petroleum gas can be used as a good fuel.

Butane, propane and ethane are in gaseous states at ordinary pressure, but they can be easily liquefied under pressure. *The petroleum gas liquefied under pressure is called the liquefied petroleum gas (or LPG)* which is used in domestic gas stoves as fuel for heating purposes. It is stored in gas cylinders after mixing a strong smelling substance called ethyl mercaptan (C_2H_5SH) so that the gas leakage, if any, from the cylinder can easily be detected.

non-renewable source of energy which is found deep under the earth's crust either alone or above the petroleum reservoirs. It is also obtained by digging wells into the earth. From some wells we can extract only the natural gas, while from others both the natural gas and petroleum. In India, there are a number of natural gas fields such as in Tripura, Jaisalmer, off shore area of Mumbai and in the Krishna-Godavari delta. The main component of natural gas is methane (up to 95%) along with small quantities of ethane and propane. It easily burns to produce heat.

Distinction between the renewable and the non-renwable sources of energy

Renewable sources	Non-renewable sources
1. These are the sources from which energy can be obtained continuously over a long period of time.	1. These are the sources from which energy can not be continuously obtained over a long period of time.
2. They are the non-conventional sources.	2. They are the conventional sources.
3. These are the natural sources which will not get exhausted.	3. These are the natural sources which will get exhausted with the time.
4. These sources can be regenerated.	4. These sources can not be regenerated.
Examples : Sun, wind, flowing water (hydro), bio mass (waste), tides, oceans, geo thermal spots and nuclear fuel.	*Examples* : Coal, petroleum and natural gas.

6.12 JUDICIOUS USE OF ENERGY

It is not possible to harness energy sufficent for our requirement from the non-conventional sources, so we have to make use of the conventional sources also. But the conventional sources of energy (*i.e.*, fossil fuels) are limited and non-renewable, so the constant use of them will create an energy crisis in the coming future. Therefore the following measures must be taken for the judicious use of energy.

(1) The fossil fuels such as coal, petroleum, etc. should be used only for limited

purposes when no other alternative source of energy is available.

(2) Wastage of energy should be avoided.

(3) Cutting of trees must be banned and more and more trees should be planted.

(4) Efforts must be made to make use of energy in community (or groups).

(5) The use of energy in urban areas is much more than in the rural areas. In rural areas, the use of renewable sources of energy is easier than in urban areas. In rural areas, we can use bio gas, wind energy, hydro energy for running lights and tube wells.

(6) Such techniques should be developed by which in near future, we may make use of the renewable sources such as solar energy, wind energy, hydro energy, bio energy, ocean energy, etc. as much as possible to meet our requirements.

(7) Efforts must be made to obtain nuclear energy by the controlled nuclear fusion of deuterium nuclei present in heavy water available in sea. This will then become an endless source of energy.

In our daily life both in urban and rural area, we need energy mostly in form of electricity, so we shall now study the methods of producing electricity from the renewable sources of energy.

6.13 PRODUCTION OF ELECTRICITY FROM SOLAR ENERGY

The sun is the most vast and direct source of energy. To obtain electricity from the solar energy, *two* devices are used : a solar cell and a solar power plant. *The device which converts solar energy directly into the electricity is called a* ***solar cell.*** On the other hand, *a solar heating device used to generate electricity from solar energy, is called a* ***solar power plant.***

(i) Solar cell : About a hundred years ago, it was discovered that when sunlight falls on a thin layer of selenium, an electric current is produced. Since only 0·6% of the solar energy incident on selenium could convert into electric energy, so no serious efforts were then made to produce electricity from solar energy. The first solar cell was made in 1954 which had an efficiency of only 1%. But nowadays solar cells have been made with an efficiency of up to 30%.

The solar cells are usually made from semiconductors like silicon and gallium. A semiconductor has conductivity less than that of a metal, but more than that of an insulator. At ordinary temperature, a semiconductor has a very low conductivity, but its conductivity increases either with the rise in temperature or when some impurities are added in it. If sunlight is made incident on an impurity added semiconductor, a potential difference is produced between its surfaces. This forms a solar cell. Due to this potential difference, a current flows in the circuit connected between the opposite faces of the semiconductor. Such a single solar cell of area 4 cm^2 produces a potential difference of nearly 0·4 volt to 0·5 volt due to which a current of nearly 60 milli-ampere can be obtained. To increase the efficiency, a large number of such cells are arranged over a large area so that they could collect a large amount of solar energy to produce sufficient electricity. Such an arrangement of solar cells is called a *solar panel.*

A solar panel gives electricity so long as sunlight is falling on it. Therefore a solar panel cannot produce electricity at night. To overcome this difficulty, the storage battery (or secondary cell) is charged by a solar panel during the day time and it can then be used at night to provide electricity. The solar panels are used to supply electricity in the artificial satellites and for

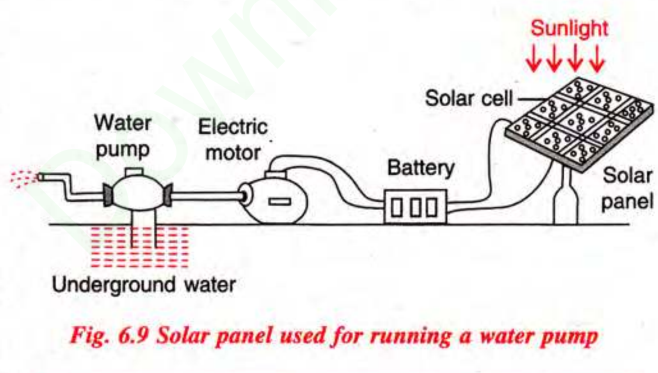


Fig. 6.9 Solar panel used for running a water pump

running water pumps, street lighting, radio and television sets in remote, inaccessible and isolated areas where conventional sources of energy are not available. Small solar cells are used in watches and calculators. Fig. 6.9 shows a solar panel used for running a water pump.

Advantages of using solar panels :

1. They do not require any maintenance.
2. They last over a long period of time.
3. Their running cost is almost nil.
4. They are most suitable for the remote, inaccessible, and isolated places where electric power lines cannot be laid.
5. They do not cause any pollution in the environment.

Disadvantages of using solar panels :

1. The initial cost of a solar panel is sufficiently high.
2. The efficiency of conversion of solar energy to electricity is low.
3. A solar panel produces d.c. electricity which cannot be directly used for many household purposes.

(ii) Solar power plant : A solar power plant is a device in which heat energy of sun is used to generate electricity. The sun rays after reflection from a large concave reflector get concentrated at its focus. The rays have sufficient heat energy which can boil water, if it is placed at the focus of the reflector. This principle is used in a solar power plant.

A solar power plant consists of a number of big concave reflectors, at the focus of which there are black painted water pipes. The reflectors concentrate the heat energy of sun rays on the pipes due to which water inside the pipes starts boiling and produces steam. The steam thus produced is used to rotate a steam turbine which drives a generator producing electricity. Such a solar power plant of capacity 50 kW has been installed at Gurgaon in Haryana.

6.14 PRODUCTION OF ELECTRICITY FROM WIND ENERGY

Nowadays wind energy is used in a wind generator to produce electricity by making use of a windmill (or wind turbine) to drive a wind generator.

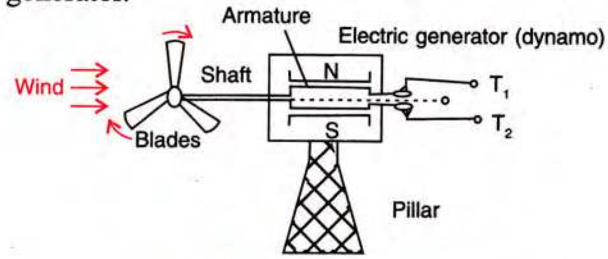


Fig. 6.10 Wind generator

Fig. 6.10 shows a wind generator in which a small electric generator (or dynamo) is placed at the top of a pillar. The armature of the dynamo is connected to the shaft attached with the blades of a wind mill. When the blowing wind strikes the blades of the wind mill (or turbine), the kinetic energy of wind changes into the rotational kinetic energy of the blades. The rotation of blades of the turbine rotates the armature of the dynamo in the magnetic field between the pole pieces N and S of a strong magnet, thus an alternating e.m.f. is produced between the terminals T_1 and T_2.

The electric power generated by a single wind mill generator is small. So to generate a sufficient amount of electric power, a large number of such wind generators are arranged over a big area called a *wind farm*, and then the electric power generated by each generator is combined together for supply to the consumers. At present in India, we are generating more than 1025 MW electric power by this technique in coastal areas of Gujarat and Tamil Nadu. It is planned to produce electric power up to 20,000 MW in our country by the use of wind energy.

Advantages of using the wind energy : (i) It does not cause any kind of pollution. (ii) It is an everlasting (*i.e.*, renewable) source.

Limitations of using the wind energy : (i) The wind farms can be established only at places near the coastal areas where wind blows around the year steadily with a speed not less than 15 km h^{-1}. (ii) A large area of land is needed for the establishment of a wind farm. (iii) The establishment of a wind farm is expensive.

6.15 PRODUCTION OF ELECTRICITY FROM WATER (*or hydro*) ENERGY

The most important use of hydro energy is to convert it into the electrical energy by using a turbine. The electricity so obtained is called the *hydroelectric power*.

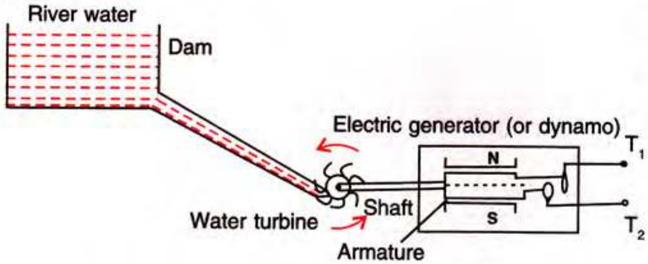


Fig. 6.11 Hydroelectric plant

Fig. 6.11 shows the principle of a hydroelectric power plant. The flowing water of river is collected in a dam at high altitude. The water stored in the dam has the potential energy. When water from dam falls on the water turbine, the potential energy of the water stored in dam changes into its kinetic energy and this kinetic energy of water is transferred to the blades of turbine as the rotational kinetic energy. As the turbine rotates, it rotates the armature of the generator (or dynamo) in the magnetic field between the pole pieces N and S of a strong magnet, due to which an alternating e.m.f. is produced between the terminals T_1 and T_2. Such a mini hydroelectric power plant can be constructed on the rivers in hilly areas across a small dam of height nearly 10 m. At present in India we are generating hydro-electricity which is only 23% of the total electricity generated by us. However, it is planned to produce nearly 4×10^{11} kWh electrical energy from the hydro energy.

Advantages of using the hydro energy : (i) It does not produce any environmental pollution. (ii) It is a renewable source of energy. (iii) The dams constructed over rivers help us in irrigation and control of floods in rivers.

Limitations of using hydro energy : (i) The flowing water is not available every where. (ii) Due to the construction of dams over the rivers, plants and animals of that place get destroyed or killed. (iii) The ecological balance in the downstream areas of rivers gets disturbed.

6.16 PRODUCTION OF ELECTRICITY FROM NUCLEAR ENERGY

It is possible to produce electricity from the nuclear energy by the controlled chain reaction of nuclear fission of a radioactive substance like uranium-235 (or plutonium-239). The set up used is called the *nuclear power plant*.

Fig. 6.12 shows the arrangment of a nuclear power plant in which the main part is the nuclear reactor. In a nuclear reactor, the chain reaction of nuclear fission of uranium-235 (or plutonium-239) is controlled by the cadmium rods. The heat energy released in the process, is absorbed by the coolant which then passes through the coils of a heat exchanger containing water. The water in heat exchanger gets heated and converts into steam. The steam is used to rotate the turbine

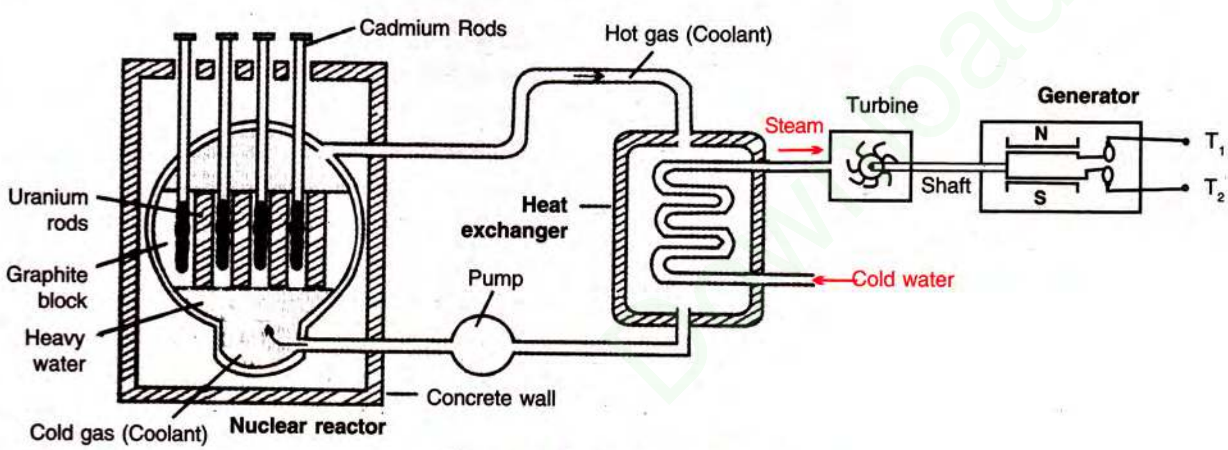


Fig. 6.12 Nuclear power plant

which in turn rotates the armature of a generator in a magnetic field and thus electricity is produced.

In India, we have *four* nuclear power plants : (i) at Tarapur in Maharashtra, (ii) at Rana Pratap Sagar near Kota in Rajasthan, (iii) at Kalpakkam in Tamil Nadu and (iv) at Narora in Uttar Pradesh, where electricity is generated by the use of nuclear energy. At present only about 3% of the total electrical power generated in India is obtained from the nuclear power plants.

Advantages of using the nuclear energy : (i) A very small amount of nuclear fuel (such as uranium-235) can produce a tremendous amount of energy. (ii) Once the nuclear fuel is loaded into a nuclear power plant, it continues to release energy over a long period.

Limitation of use of nuclear energy : (i) It is not a clean source of energy because very harmful nuclear radiations are produced in the process which are highly energetic and penetrating. These radiations cause ionisation and are very harmful to the human body, so a high standard of protection is needed for the persons working in the power plant and also for the environment. (ii) The waste obtained from the nuclear power plants causes a high degree of environmental pollution.

6.17 ENERGY DEGRADATION

In our daily life we require to transform one form of energy to the other required form of energy. By the law of conservation of energy, the given form of energy must be completely converted into the desired useful form without any loss of it. In practice, it has been observed that in transformation of energy from one form to the other desired form, the *entire energy* does not change into the desired form, but a part of it changes either to some other undesirable form (usually heat due to friction) or is lost to the surroundings due to radiation which is not useful. This conversion of energy to the undesirable (or non-useful) form is called the *dissipation of energy*. Since this part of energy is not available to us for any productive purpose, so we call this as the *degraded form of energy*. With more and more use of energy, the degraded form of energy will gradually increase, while the energy available for productive purpose will gradually decrease (since total energy remains constant).

The gradual decrease of useful energy due to radiation loss, friction, etc. is called the degradation of energy.

Examples :

(i) When we light a bulb using electricity, less than 25% of the electrical energy converts into the light energy. The remaining part of electrical energy changes into the heat in the filament and the other invisible radiations. This energy is ultimately imparted to the atmosphere in the form of vibrational kinetic energy of air molecules. The energy in this form is not useful to us.

(ii) When we run a vehicle, only a part of energy obtained from its fuel is used up in running the vehicle, major part of it is wasted in heating the moving parts of machine, in doing work against friction between the ground and its tyres and in the form of sound.

(iii) When we cook food over a fire, the major part of heat energy obtained from the fuel is radiated out in the atmosphere. This radiated energy is of no use to us. It is thus the degraded form of energy.

(iv) When electrical appliances are run by electricity, an appreciable part of electrical energy is wasted in the form of heat energy.

(v) In transmission of electricity from the power generating station, a lot of electrical energy is wasted in the form of heat energy in the line wires used for transmission.

(vi) All machines have efficiency less than 1, which implies that only a fraction of input energy is used for doing useful work and rest of the input energy is wasted or goes to the degraded form.

From the above examples, we conclude that in all processes of transfer of available form of energy to the useful form, a good fraction of energy changes to the non-productive or degraded form.

1. State *two* characteristics which a source of energy must have.
2. Name the *two* groups in which various sources of energy are classified. State on what basis are they classified.
3. What is meant by the renewable and non-renewable sources of energy ? State *two* differences between them, giving *two* examples of each.
4. Select the renewable and non-renewable sources of energy from the following :
   (a) Coal (b) Wood (c) Water
   (d) Diesel (e) Wind (f) Oil

   Ans. Renewable — (b), (c) and (e)
   Non-renewable — (a), (d) and (f)
5. Why is the use of wood as a fuel not advisable although wood is a renewable source of energy ?
6. Name *five* renewable and *three* non-renewable sources of energy.
7. What is (i) tidal, (ii) ocean and (iii) geo thermal energy ? Explain in brief.
8. What is the main source of energy for earth ?

   Ans. Sun
9. What is solar energy ? How is the solar energy used to generate electricity in a solar power plant ?
10. What is a solar cell ? State *two* uses of solar cells. State whether a solar cell produces a.c. or d.c. Give *one* disadvantage of using a solar cell.
11. State *two* advantages and *two* limitations of producing electricity from solar energy.
12. What is wind energy ? How is wind energy used to produce electricity? How much electric power is generated in India using the wind energy ?
13. State *two* advantages and *two* limitations of using wind energy for generating electricity.
14. What is hydro energy ? Explain the principle of generating electricity from hydro energy. How much hydro electric power is generated in India ?
15. State *two* advantages and *two* disadvantages of producing hydro electricity.
16. What is nuclear energy ? Name the process used for producing electricity using the nuclear energy.
17. What percentage of total electrical power generated in India is obtained from nuclear power plants ? Name *two* places in India where electricity is generated from nuclear power plants.
18. State *two* advantages and *two* disadvantages of using nuclear energy for producing electricity.
19. State the energy transformation in the following :
    (i) electricity is obtained from solar energy.
    (ii) electricity is obtained from wind energy.
    (iii) electricity is obtained from hydro energy.
    (iv) electricity is obtained from nuclear energy.
20. State *four* ways for the judicious use of energy.
21. What do you mean by degradation of energy ? Explain it by taking *two* examples of your daily life.
22. The conversion of part of energy into an unuseful form of energy is called ....

    Ans. Degradation of energy

Multiple choice type

1. The ultimate source of energy is :
   (a) wood (b) wind
   (c) water (d) sun. **Ans.** (d) sun
2. Renewable source of energy is :
   (a) coal (b) fossil fuels
   (c) natural gas (d) sun. **Ans.** (d) sun

(D) GREEN HOUSE EFFECT AND GLOBAL WARMING

6.18 GREEN HOUSE EFFECT

In 1824, Joseph Fourier discovered the green house effect. *It is the process of warming of planet's surface and its lower atmosphere by absorption of infrared radiations of long wavelength emitted out from the surface of planet.*

The solar radiations coming from sun have high energy radiations such as gamma rays, X-rays, ultra-violet rays and low energy radiations such as visible light, infrared radiation and radio waves. Our earth's atmosphere is transparent only for visible light and *infrared radiation of short wavelength.* Gamma rays, X-rays, ultraviolet rays are absorbed by the ozone layer surrounding the earth while infrared radiation of long wavelength and radio waves are reflected back into the space by the uppermost layer of earth's atmosphere *i.e.*, ionosphere and the polar ice-caps.

The solar radiations which travel through the atmosphere of the earth, are absorbed by the clouds, earth's surface and sea water due to which earth's surface gets heated up. Now earth's surface radiates infrared radiations of *long wavelength.* For these radiations, the earth's atmosphere is opaque, so they are reflected back by the clouds and are absorbed by the gases present above the earth's surface Thus the clouds and gases prevent the long wavelength infrared radiation from escaping into the space, and keeps the earth's surface warm. Fig. 6.13 shows the green house effect.

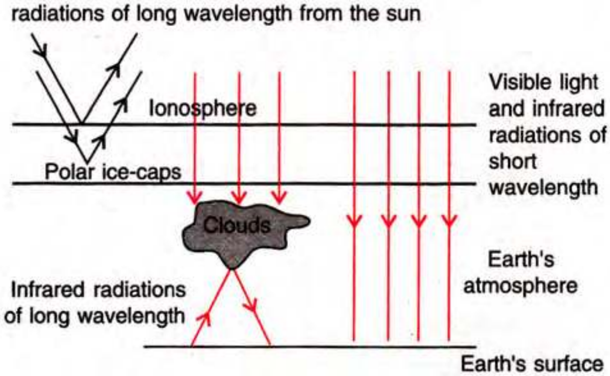


Fig. 6.13 Green house effect

The gases which are the good absorber of long wavelength infrared radiation are called the *green house gases.* They are : carbon dioxide, water vapours, methane and chlorofluorocarbons. These gases contribute in trapping the heat energy within the atmosphere. *The naturally occuring green house gases have an average warming effect of nearly* 33°C *so that the average temperature on earth's surface is about* 15·5°C *(or* 60°F*).* In absence of the green house gases in atmosphere, entire heat energy radiated from the earth's surface and objects on it, would escape out into the space and then the average temperature on earth would be −18°C (or 0°F) instead of being 15·5°C (or 60°F). On the other hand, if there is an increase in proportion of green house gases in atmosphere, the average temperature on earth will rise and it will be above 15·5°C (or 60°F).

Future projections : In the recent decades, it has been observed that the effective temperature of earth's surface has risen by 0·74 ± 0·18°C per decade for the last 50 years since 1900. The rate of increase is 2·5°C per decade (nearly three times since 1970) and since 2000, it is much more. So it is expected that by the end of this century, the earth's temperature will rise up to 64°C. The reason for this is the increase in the proportion of the green house gases present in the earth's atmosphere. Due to their increase, more heat radiations radiated from the earth's surface are trapped in its atompshere. It is believed that the human activities are responsible for the increase in the green house gas namely the carbon dioxide in the earth's atmosphere. The main human activities responsible for increase of the carbon dioxide gas are given below:

(i) The burning of fuels, deforestation, transportation and industrial production (particularly cement factories).

(ii) Increase of population (human beings emit nearly 32 giga tonnes of carbon dioxide each year).

(iii) Imbalance of carbon dioxide cycle (the ocean does not absorb full amount of carbon dioxide and the vegetables are not able to change all the carbon dioxide into oxygen).

The increase in the concentration of carbon dioxide due to above human activities is responsible for 60% increase in green house effect. Apart from this, rice cultivation, animal husbandry, natural gas exploration, burning of bio-mass in clearing of forests and leakage in natural gas pipe line has doubled the concentration of methane which is also responsible for the increase in green house effect.

Thus, the increase in green house gases in the atmosphere enhances the green house effect and this causes the *global warming.*

GLOBAL WARMING

Global warming means the increase in average effective temperature near the earth's surface due to an increase in the amount of green house gases in its atmosphere.

Our earth gets heated up due to absorption of visible and short wavelength infrared radiations received from the sun. The green house gases, namely the carbon dioxide, water vapours, methane and chlorofluorocarbons, trap the infrared radiations of long wavelength emitted from the earth's surface and thus keep the earth's surface warm at an average temperature of 15·5°C. It has been observed in recent decades that over a period of 50 years in the 20th century, the average temperature of earth's atmosphere has risen at a rate of $0{\cdot}74 \pm 0{\cdot}18$°C per decade. Now the rate of increase of temperature of earth's atmosphere is much more and it is expected that the earth's average temperature will reach to 64°C by the year 2100. *An increase in average temperature of the earth implies an increase in the amount of green house gases present in its atmosphere so that they could trap more heat radiated from the earth's surface*. It is believed that the human activities such as burning of fossil fuels, industrial growth, clearing of forests, use of automobiles *etc*., have played a significant role in increasing the green house gases (particularly carbon dioxide) in the earth atmosphere.

Cause of global warming : The cause of global warming is the increase in concentration of green house gases present in the atmosphere of earth due to human activities. The increase in different green house gases is as follows :

(i) The concentration of carbon dioxide has increased up to 25% due to industrial growth, combustion of fossil fuels, clearing of forests etc.

(ii) The concentration of methane has doubled due to agricultural sources such as rice cultivation and animal husbandry, natural gas exploration, burning of biomass, clearing of forests and leakage in natural gas pipe lines.

(iii) The concentration of chlorofluorocarbons has increased at a rate of 5% per year.

Thus increase in green house gases in atmosphere enhances the green house effect and hence causes global warming.

Impacts of global warming on life on the earth :

The increase in proportion of green house gases in the atmosphere has the following impacts on the life on earth :

(1) The variable changes in the climate in different parts of the world which has created difficulties and forced the people and animals to migrate from one place to the other.

(2) The change in blooming season of different plants.

(3) The change in regional climate which has an immediate effect on simple organisms and plants.

(4) The change in the world's ecology.

(5) The increase in the heat stroke deaths.

Future predictions : With the present rate of increase of green house effect and global warming, it is predicted that the average temperature of earth's surface will become 64°C by the end of the year 2100. Although it is not possible to make very accurate predictions on its impact for the future, but still looking at the changes in some natural phenomenon which we are facing now, following predictions can be made.

(1) Dislocation and disappearance of plant and animal species : At the present rate of increase of green house effect, it is expected that nearly 30% of the plant and animal species will vanish by the year 2050 and up to 70% by the end of the year 2100. This will disrupt ecosystem. The animals from the equatorial region will shift to higher latitude in search of ice and cold region. The absorption of carbon dioxide by ocean will cause acidification due to which marine species will migrate.

(2) Warming of ocean : The temperature of ocean water will increase due to which many species in the ocean will either die or they will disappear, while various other species which prefer warm water will increase tremendously.

(3) Melting of glacier : Due to global warming, the frozen tundra in Siberia has started melting. Greenland has experienced 32 glacial earth quakes in one year. The Arctic snow cover is expected to be ice-free by the end of September 2037. The global average sea level has risen at a rate of 3·1 mm per year. This rate of rise is expected to increase in future. It is also expected that the amount of oxygen dissolved in ocean will decrease which will have adverse effect on the marine life.

(4) Shift in farming region : In the near future, warming of nearly 3°C will result in poor yield in farms in low latitude regions and will increase the rise of malnutrition. The crop yield is expected to increase in middle and high latitude regions. Therefore farmers will have to shift their farming region from low latitude to high latitude.

(5) Increase in new diseases and heat related deaths : Due to global warming, many new diseases will emerge because bacteria can survive better in increased temperature and they can multiply faster. It will extend the distribution of mosquitoes due to increase in humidity levels and their frequent growth in warmer atmosphere. This will result in increase of many new diseases. Apart from it, the deaths due to heat stroke will also increase.

(6) Change in regional climate : It is expected that the warming over land will increase and it will be maximum at high northern latitudes while minimum over the southern ocean. The frequency of hot extremes, heat waves and heavy precipitation will also increase.

(7) Variable changes in the climate : The variable changes in the climate will result in increase in the number of people suffering from death diseases and injuries from floods, storms and droughts.

(8) Increase in cost of air conditioning : Due to warming effect, the cost of air conditioning will increase as it will consume more electric energy.

(9) Change in sea level : Due to melting of ice, the area of sea ice around both the poles is shrinking. It is expected that in the next 50 years, the ice at both the poles will melt completely and therefore the sea level will rise. Buildings and roads in the coastal areas will get flooded and they could suffer damage from hurricans and tropical storms.

6.20 WAYS TO MINIMISE THE IMPACT OF GLOBAL WARMING

To minimise the impact of global warming, following *three* main measures must be taken : (1) Technological measures, (2) Economic measures and (3) Policy measures. These measures are inter-related and must be taken simultaneously.

(1) Technological measures

The economic growth and population growth, each increases consumption of fuel and hence both are responsible for the release of green house gases. We need to check them and use the following *three* technological measures :

(a) Use of renewable sources of energy to generate electricity in place of generating electricity from the fossil fuels based power plants, (b) Change of transportation vehicles, and (c) Use of bio-char stoves for cooking.

(a) Use of renewable sources of energy for generation of electricity in place of electricity from the fossil fuel based power plants : The fossil fuel based power plants are the main source of generation of the green house gases. They produce nearly 21·3% of the total green house gases. Therefore alternate energy sources such as wind energy, solar energy, tidal energy, geo thermal energy, etc. must be used to generate electricity in place of fossil fuel based power plants. *The fossil fuel based power plants must be banned.*

(b) Change of transportation vehicles : Vehicles such as lorry, truck etc. that are presently in use for transportation are run by the internal combustion engine and they contribute nearly 14% of the total green house gas emission. Such vehicles must be switched to battery operated vehicles which will reduce carbon dioxide emission drastically. For charging the battery, electricity generated from renewable sources must be used. Further the vehicles must be used at their full capacity and the size of vehicles must be reduced.

(c) Use of bio-char stoves for cooking : In developing countries, bio-mass is mostly used for cooking which also contributes significantly in the increase of green house gases. For burning the bio-mass, new technology must be used to burn it in absence of air in a specially constructed stove known as *bio-char stove*. It will release the smokeless combustible gases methane and hydrogen, leaving a charcoal residue which can be buried in soil.

(2) Economic measures

The industrial growth and deforestation for population growth have caused the increase in green house effect. To check them, following *two* economic measures are needed : *(a) Reforestation and sustainable use of land, and (b) Industries to pay carbon tax.*

(a) Reforestation and sustainable use of land : In developing countries, the pressure of population and industrial growth has resulted in unsustainable agricultural practices which are responsible for 90% of deforestation. These countries must be asked to reforest and maintain forest habitats. Their loss must be verified by satellite imaging before compensating them by the international agencies.

(b) Industries to pay carbon tax : Since industries emit carbon dioxide to a good extent, so to check them, they must be asked to pay carbon tax. This tax can be calculated on the basis of carbon emission from the industry, number of employee hour and turn over of the industry. This will encourage the industry to use the energy efficient offices and to avoid the travelling of its employees by having tele-conferencing.

(3) Policy measures

To check global warming, Government must take the following *two* policy measures : *(a) Educating children to live sustainable life style, and (b) Controlling population through family planning, welfare reforms and the empowerment of women.*

(a) Educating children to live sustainable life style : We need to educate children that genuine happiness lies in a less competitive and more cooperative society. Consuming more and buying more must not be the aim of life. For a sustainable life, we must make full use of what we have. The materialistic gain gives a temporary pleasure.

(b) Controlling population through family planning, welfare reforms and the empowerment of women : The world population is expected to increase from 7·1 billion in the year 2012 to 9·15 billion by the year 2050 with most of the growth taking place in the developing countries. This needs to be controlled. Population growth can be controlled through various measures such as (i) free and easy access to family planning, (ii) welfare provisions to encourage smaller families, and (iii) the empowerment of women through education and freedom to choose their future career (because the educated women are more conscious about family planning due to their career commitments).

Recently in 'the 21st yearly 2015 United Nations Climate Change conference CUP21/CMP11' held in Paris from November 30 to December 12, 2015 each nation has expressed a deep concern on the present rate of increase of green house gases and it is committed to limit the global warming to below 2·0°C compared to pre-industrial level by the year 2100 for which a goal of zero carbon emission is to be achieved between 2030 to 2050.

EXERCISE 6(D)

1. What do you mean by green house effect ?
2. Name *three* green house gases.
3. Which of the following solar radiations pass through the atmosphere of the earth :
   X-rays, ultraviolet rays, visible light rays, infrared radiation.
   Ans. Visible light rays and infrared radiation
4. Name the radiation which are absorbed by the green house gases.
   Ans. Infrared radiation of long wavelength
5. What results in the increase of carbon dioxide contents of earth's atmosphere ?
6. What would have been the temperature of earth's atmosphere in absence of green house gases in it ?

temperature of earth's atmosphere.

8. What do you mean by global warming ?
9. What causes the rise in atmospheric temperature ?
10. State the cause of increase of green house effect.
11. What will be the effect of global warming at the poles ?
12. State the effect of global warming in coastal regions.
13. How will global warming affect the sea level.
14. How will global warming affect the agriculture ?
15. State *two* ways to minimise the impact of global warming.
16. What is carbon tax ? Who will pay it ?

Multiple choice type :

1. The green house gas is :

(a) oxygen (b) nitrogen
(c) chlorine (d) carbon dioxide.

Ans. (d) carbon dioxide

atmosphere will cause :

(a) decrease in temperature
(b) increase in temperature
(c) no change in temperature
(d) increase in humidity.

Ans. (b) increase in temperature

3. Without green house effect, the average temperature of earth's surface would have been :

(a) –18°C (b) 33°C
(c) 0°C (d) 15°C

Ans. (a) –18°C

4. The global warming has resulted in :

(a) the increase in yield of crops
(b) the decrease in sea levels
(c) the decrease in human deaths
(d) the increase in sea levels.

Ans. (d) the increase in sea levels.