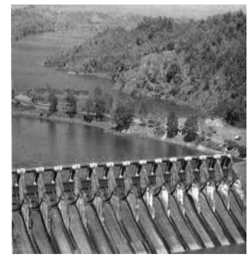
Chapter foru

WORK, POWER AND ENERGY



[By work we mean to do something in our everyday life. But in physics it refers to a specific concept. In the beginning of this chapter we will present this concept. The most important topic in science is energy. From our experience we see that the world becomes inactive without energy. We get energy in different forms. Such as kinetic energy for motion, potential energy for object in higher position from the ground, the energy of spring at contract condition or expanding condition, heat energy of hot body, electrical energy of charged body etc. The energy is transforming from one form to another gradually although the total energy of the universe remains unchanged and constant. In this chapter we will discuss about the transformation of energy and the law of conservation of energy, one of the important laws of science.]

By the end of this chapter we will be able to -

1. Explain the relation between work and energy.
2. Establish the relation among work, force and displacement.
3. Explain kinetic and potential energy.
4. Explain the transformation of energy in its source.
5. Analyze the contribution of the source of energy regarding economic, social and environmental influence.
6. Explain the relation between transformation of energy and conservation of energy.
7. Explain transformation of energy and how its uses hamper the balance of environment.
8. Explain the effective use of energy in developing activities.
9. Be conscious about the effective and safe use of energy.
10. Explain the mass-energy relation.
11. Establish the relation between transmission of energy and power.
12. Measure the efficiency.

4.1 Work:

Work means to do something in our everyday life but in science doing anything is not work. In science the term work represents a definite concept. A gateman guards a house all day long sitting at a place and can say he has done his work. A boat was floating with the current of a river or canal and Mr. Karim was pulling it back. He might say he has done work to hold the boat otherwise the current of the river could pull it away. These are recognized as work in our daily life but these are not work in the point of view of science. Rather had the gateman guarded the house walking instead of sitting or had the boat floated with the current of the river, work could have been done. The concept of work in science is different from that of daily life. In fact in science work is done when displacement is associated with force. So, if a force acts on a body and causes its displacement only then work is said to be done. We see many examples of work around us in our daily life. For example, bull pulls the plough; a laborer pushes forward a push cart, someone throws iron sphere is sports competition etc.

Let us consider the following examples:

a) Ratan is standing still with a packet of book in his hand.
b) Mita is pushing her physics book from one end to another of a table.
c) Niru is lifting a heavy bag through stairs.
d) Rimi is pushing the wall strongly.

As work is said to be done only when a force is acted on a body and displaces it, so in the above examples (b) and (c) work is done but in the example (a) and (d) no work is done. We can apply force to shift a body from one place to another. We can change the shape of any body by applying force. In these cases work is done.

If a construction laborer wants to get to the second floor of a building with ten bricks, he has to do more work than that of lifting a single brick to the same place as he has to use more force. He has to do more work if he wants to lift those brick on the third floor. Therefore, the amount of work depends on the applied force and the distance. Work is measured by the product of applied force on a body and its displacement along the direction of force. Therefore,

Work = Force × Distance travelled along the direction of force

If a force F is applied on a body and the body travels a distance s along the direction of force (fig: 4.1) then the work done (W) will be,

$W = Fs$… … … (4.1)

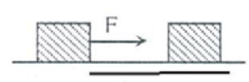


Figure: 4.1

Work has no direction. It is a scalar quantity.

Dimension of Work:

Dimension of work will be the dimension of force × dimension of displacement or, Work = Force × displacement

$$= \text{mass} \times \text{acceleration} \times \text{displacement}$$

$$= \text{mass} \times \frac{\text{displacement}}{(\text{time})^2} \times \text{displacement}$$

$$= \text{mass} \times \frac{(\text{displacement})^2}{(\text{time})^2}$$

or, $W = \dfrac{ML^2}{T^2}$

$\therefore [W] = [ML^2T^{-2}]$

Unit of work: The unit of work is obtained by multiplying the unit of force with unit of distance. Since the unit of force is Newton (N) and the unit of distance is meter (m) then the unit of work will be newton-meter (Nm) which is called joule. Joule is expressed by J. If a force of 1N is applied on a body and the body gets a displacement of 1m along the direction of force then the work done is said to be 1joule (1J), i.e. 1J = 1Nm.

If the displacement takes place along the direction of force then work done is said to be work done by the force.

If a duster falls on a floor from a table the work is done here by the force of gravity.

If the displacement of a body takes place opposite to the direction of force then the work done is called work done against force.

If a duster is lifted on the top of a table from the floor then the work is done against the force of gravity. This is because the displacement takes place opposite to the direction of the force of gravity.

Mathematical example 4.1: A man of mass 70kg climbs on a mountain of height 200m. How much work will he do?

Given,
Mass of man, m = 70kg
Force, F = weight of the man = mg
$= 70\text{kg} \times 9.8\ \text{ms}^{-2}$
$= 686\text{N}$
Displacement, S = 200m
Work, W =?

We know,
W = Fs
$= 686\text{N} \times 200\text{m}$
$= 1.372 \times 10^5$ J
Ans: 1.372×10^5 J

4.2 Energy

Nothing can move or work without energy. We need energy for our survival. The amount of work we do everyday depends on our energy level. We get energy from the food we take. Plants need energy for growth. Engine also needs energy for its functioning. Some engines use electricity and some need fuel for energy. Energy is stored in fuel.

What do we mean by energy? The energy of a body means its ability to work. So the body which is able to work has energy in it and the body that does not have energy in it cannot work.

When we say a body has energy in it we mean the body can apply force on other and can work. Again the amount of work done on a body is equal to the energy we use.

The energy of a body refers to its ability to work. Here work means the transformation of energy from one form to another. It means that the total amount of work that a body can do is its energy. The amount of work a body can do is the measure of its energy. So, the amount of work done is the amount of energy used.

Therefore, Work done = Energy used

Energy has no direction. So it is a scalar quantity.

The unit of energy and work is the same and it is joule (J).

Different forms of energy

We need different types energy for doing different kinds of work. For example we need heat to boil water. We get light energy from an electric bulb. There is sound energy in the music we hear. We need muscular energy to shift or to lift any object. Electrical energy is necessary to operate an electrical device. We get chemical energy by chemical reaction in the electric cell. A piece of paper flies due to energy of air. Nuclear energy is released when the atoms are accumulated or broken.

The universe is in motion as there is energy. If no energy existed the universe would be motionless. As there is light energy we can see and hear because of sound energy. We can move for mechanical energy. Fan rotates and factory runs with the help of electric energy. Energy exists in the universe in different forms.

Generally we observe the following forms of energy. Such as, mechanical energy, heat energy, sound energy, light energy, magnetic energy, electrical energy, chemical energy, nuclear energy and solar energy.

The most common form of energy is mechanical energy. The energy that is stored in a body due to its position or motion is called mechanical energy. In this lesson we will discuss two forms of mechanical energy-kinetic energy is produced due to motion and potential energy is produced due to the position of object.

Kinetic Energy: We sometimes notice that cricket ball hits the stamp and strikes it down. If anything hard hits the glass of window the glass breaks down. If we throw stones at mango or jujube it may fall down.

From the above example we can see energy exists in the body in motion. The capacity of doing work acquired by a moving body due to its motion is called kinetic energy.

> **Do it yourself:** Keep a pen on a table or a desk in front of you. Put a light object before the pen. Hit the pen by your finger towards the object.

Why does the object displace from its initial position? This is because the hit makes the pen move and the pen obtains the ability to work that is kinetic energy is produced in it. So it could displace the object.

Creating velocity in a body in rest or increasing the velocity of a moving object means to produce acceleration in it. For this force has to be applied. As a result work will be done on the body. For this the body will obtain the ability to work and this work will be stored in the object as kinetic energy. This is why all moving objects are in possession of kinetic energy. The body will be able to perform this amount of work before it rests.

Let a force F be applied on a body of mass m at rest. The body attains a velocity v. Suppose the body moves a distance s in the direction of the force. The work done to produce this velocity of the body is its kinetic energy.

Therefore,

Kinetic energy = Work done

= Force × displacement

$= F \times s$

or, $E_k = mas$; $[\text{ as, } F = ma]$

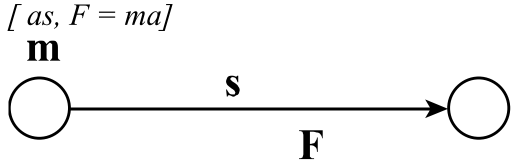


Fig: 4.2

But, $v^2 = u^2 + 2as$

or, $as = \frac{v^2}{2}$; [since, initial velocity, $u = 0$]

$\therefore E_k = \frac{1}{2} mv^2$ … … … (4.2)

$\therefore$ Kinetic energy $= \frac{1}{2} \times$ mass $\times$ (velocity)^2

Kinetic energy depends on the mass of object. The more is the mass the higher is the kinetic energy. With the same velocity a light tennis ball and a heavy cricket ball are thrown at you. The hit will be more by the cricket ball than that of tennis ball.

Kinetic energy also depends on the velocity of objects. The more is the velocity the higher will be the kinetic energy. The damage will be less if a truck hits a wall with less velocity but the damage will be more in case of higher velocity.

Mathematical Example 4.2: The kinetic energy of a runner of mass 70 kg is 1715 J. What is his velocity?

We know,

$E_k = \frac{1}{2} mv^2$

or, $v^2 = \frac{2E_k}{m}$

$\therefore v = \sqrt{\left(\frac{2E_k}{m}\right)}$

$= \sqrt{\left(\frac{2 \times 1715 \text{ J}}{70 \text{ kg}}\right)}$

$= 7 \text{ ms}^{-1}$

Ans: 7 ms^{-1}

Here,
Mass, m = 70 kg
Kinetic energy, $E_k = 1715$ J
Velocity, v =?

Potential Energy:

If a piece of stone or brick falls on a body from the roof of a building it may flatten or break the body. When the stone or brick was in rest on the roof potential energy was stored in it but the potential energy works when it falls down. The energy was stored in the stone because it was above the ground.

What will happen when the two ends of a spring is stretched and tied to two objects and then released? The objects will move fast and collide with each other. The stretched spring was at rest but potential energy was there in it. If it is released it may work. The energy was stored in the stretched spring because it was strained.

The ability of a body to do work when its normal position or configuration is changed to some other position or configuration is called potential energy.

Expanded Activities: Take a pulley and place a rope on it. Tie a heavy object A with its one end and a light object B with the other end. Such that, A remains above the ground but B remains on the ground [Fig: 4.3]. Remove your hand.

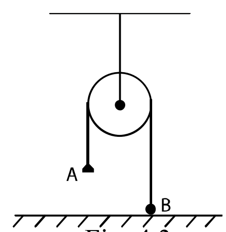


Fig: 4.3

What did you see? The object A goes down and object B goes up. The potential energy was stored in the object A as it was above the ground from its normal position and gained ability to work. It can work till it reaches the ground that is it can raise the object B.

Experiment: Take a spring and tie its one end with a strong support and a block to its other end. Place them on a smooth surface. Now apply force on the block and contract the spring and keep another object in front of the block [Fig: 4.4] then remove your hand.

Why did the object move fast? Spring could work while regaining its original configuration and was able to displace the other body. This ability of spring to work for the change of its normal configuration is its potential energy. If some work is done against the force at the time of changing from normal position or configuration to some other position or configuration then the body obtains the capacity of doing work that is same amount of energy is stored in it. This principle is applicable within the sphere of influence of conservative force such as electric force, magnetic force, spring force etc. This sphere of influence is called the field of that force such as gravitational field, electric field etc. We work against the force of gravity when we lift anything higher from the ground. As a result the object obtains some amount of potential energy. It can perform the same amount of work when it falls on the ground.

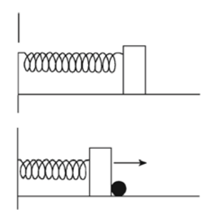


Fig: 4.4

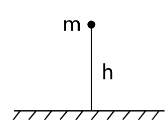


Fig: 4.5

If a body of mass m is raised to a height h (fig:4.5) above the surface of the earth, the work done in such a process is a measure of potential energy stored in the body. In this case, the work done is the product of the applied gravitational force i.e. the weight of the body and the vertical height.

$\therefore$ Potential energy = weight of the body × vertical height

$$= mgh$$

$$\therefore E_p = mgh \qquad (4.3)$$

i.e. potential energy = mass of the body × acceleration due to gravity × vertical height Potential energy depends on the vertical height of the object from the surface of the earth. The more is the height, the higher will be the potential energy. Potential energy also depends on the mass of the object. The more the mass the more will be the potential energy of the object.

To use the potential energy stored in a body it is necessary to transform it into other form of energy. For example, a piece of stone is not dangerous as long as it is on the roof and its potential energy transforms into kinetic energy i.e. it starts to fall.

Mathematical Example 4.3: What will be the potential energy of a body of mass 6kg if it is raised to a height of 20m above the surface of the earth? $g = 9.8 \text{ ms}^{-2}$.

Here,
Mass of the body, m = 6 kg
Height, h = 20m
$g = 9.8 \text{ ms}^{-2}$
Potential Energy, E_p = ?

We know,

$$E_p = mgh$$

$$= 6\text{kg} \times 9.8 \text{ ms}^{-2} \times 20\text{m}$$

$$= 1176 \text{ J}$$

Ans: 1176 J

4.3 Prime Sources of Energy

The modern mechanized civilization cannot proceed a moment without energy. Work is available at the expense of energy. Uninterrupted energy supply is essential for the survival of all living creatures. The demand of energy is increasing day by day with the development of life style. For this increasing demand of energy man is looking for newer sources of energy. We need to have clear idea about the sources of energy to save the living beings and to continue the supply of energy. We know that the sun is the only source of all energy. Moreover, the nuclear energy in the nucleus and the energy from the hot melted substances are considered to be the sources of energy. All the existing energy of the world is directly or indirectly comes from the sun or are produced using the radiation of the sun.

Chemical Energy/Fuel Energy:

Man in the ancient time was dependent wholly on the energy of their muscles. Afterwards, they learnt to tame the wild animals and use their energy in different work. They used to carry their goods and cultivate land with the help of animals. The initial stage of civilization was to produce heat energy from burning wood and leaves and mechanical energy from current of water and flow of wind. The economic development of human being begins from the use of machine energy. Industrial revolution and invention of steam engine reduced men’s dependence on muscle energy of human and animals. Man kept operating different machines with the help of steam energy. Fuel is necessary to produce this steam energy. So we consider different kinds of fuels to be the sources of energy.

The most common sources of energy are coal, mineral oil and natural gas. Coal, mineral oil and natural gas from underground are used as fuel directly or by refining them slightly.

Coal:

Coal is best known to us as one of the sources of energy. It is an organic substance. Once upon a time there were numerous plants and trees. Due to different natural calamities and natural consequences the leaves of the trees and their stems were buried underneath the earth and began to coagulate. As a result of chemical changes, the leaves of the trees and stems were transformed into coal. Combustion of coal gives us heat directly. This is a well known fuel. Many essential substances can be produced from coal apart from using it as a fuel. Some of the coal products are coal gas, tar, benzene, ammonia, toluene etc. Coal is used to cook food and to drive the steam engines. In modern age, the main use of coal is in thermal power plants. The main fuel in a thermal power station is coal.

The main problem of a coal fueled power station is that it emits sulphur smog which causes acid rain. Though this acid is very weak, it kills the fishes of pond, cannel and lake, destroys forest and damages the sculptures of stone.

Mineral Oil:

Petroleum or mineral oil is one of the principal sources of energy. It is widely used as a fuel in the present world. It is being used right from a rural cottage to the most modern transport system. Petrol, pitch that is used to pave roads, kerosene and chemical fertilizers are all petroleum products. There is nothing like petrol to be used as fuel. On the other hand, many kinds of artificial fabrics can be developed from petroleum. These are terry line, polyester, cashmilon etc. Moreover, various types of cosmetics are produced from petroleum. But it is basically used as a fuel. Petroleum products are used to produce electric and mechanical energy. Petroleum is a Latin word. It is a combination of two minor words: Petro and Olium. In Latin language ‘petro’ means stone and ‘olium’ means oil. So, petroleum means oil of stones i.e. oil stored inside stones. In tertiary age i.e. almost five to six crores of years ago the trees and the animals fell buried in the different layers of sedimentary rock on the bottom of the sea. Due to different chemical changes these were transformed into mineral oil. Most of the solid regions of the present world were a part of the bottom region of the sea in prehistoric age.

Natural Gas:

Natural gas is a well known source of energy. Specially, the use of natural gas in Bangladesh is wider. Use of natural gas is very high in all advanced countries. It is also used in different industries as fuel. In Bangladesh it is widely used for domestic requirement basically for cooking purposes. It is also used in fertilizer factories. Heat energy is produced by the combustion of gas and electric energy is produced from heat energy in a thermal power station.

Natural gas is obtained from underneath the earth. Digging very deep well the gas may be taken out from underneath the earth. Tremendous temperature and pressure inside the earth is the root cause of the creation of the gas. Natural gas is also available in petroleum well. The principal element in a natural gas is the methane gas. These are called fossil energy.

The three sources of energy discussed above are reducing very fast due to the men's increasing demand of energy. The physical condition of the world is such that these sources-coal, mineral oil, natural gas cannot be recreated, these are called nonrenewable energy. So men are looking for alternate sources of energy of which solar energy, energy from water flow, energy from tide and ebb, geothermal energy, wind energy, biomass etc are the main sources. These sources are directly or indirectly dependent on the sun. As long as earth receives sunlight the energy supply from these sources is possible. These are called renewable sources.

Solar Energy:

The energy that we obtain from the sun is called Solar Energy. It is known to all that the sun is the source of all energy. The origin of all forms of energy is from the solar energy in one way or the other. For an example, the fossil fuel such as coal, mineral, oil, and natural gas is actually a store of solar energy for a long time.

From ancient times man is using sunlight directly to dry things. At present man is adopting various means to use the solar energy round the clock. Ignition can be done by concentrating sun's rays- with the help of a convex lens. Solar cooker consists of a metallic bowl on which the solar rays are reflected. The cooker can be used in cooking purposes.

> **Do it yourself:** Take a concave mirror with a focal length of 15cm or 20cm. Hold the mirror facing the sun. Take a piece of paper and concentrate the sunlight with the help of the mirror on it. Hold the mirror till the paper ignites.

The solar rays are used to keep the dwelling houses warm in cold countries. Solar energy is used for drying purposes of crops, fish, vegetables etc. Dried fish can be preserved for many days. More examples of solar energy are- solar water heater, solar cooker etc.

Solar cell has been made by using modern technology. The characteristics of a solar cell are that the cell produces electricity instantly while solar rays fall upon it. There are various uses of solar cell.

1. This cell is used to supply electricity in artificial satellites. For this reason the artificial satellites move along their orbits for a long time.
2. Solar energy is being used to operate different electronic devices like pocket calculator, pocket radio and electronic watch.
3. Currently electrical energy is produced from solar energy in the rural area, houses or offices to meet up the need of electricity.

The advantage of solar energy is that it does not pollute the environment. There is almost no possibility of danger in using this energy. There is also no possibility of sudden exhaustion of solar energy. This is why it is likely to be used as a prospective fuel instead of fossil fuel.

Hydroelectricity (Transformation of mechanical energy):

Water is one of the renewable sources of energy. Energy can be produced by means of water current and tide and ebb. There are different forms of energy in the water current such as, kinetic and potential energy. Electricity produced by means of water current is known as hydroelectricity. Different countries of the world make use of potential energy for producing electricity in hydroelectric projects. The method of producing hydroelectricity using the water current is simple. The current of water is used to rotate a turbine. A co-ordination of mechanical and magnetic energy is possible from the rotation of turbines.

Electricity produced by mechanical energy created by water current in co-ordination of magnetic energy is called hydroelectricity.

Making a model: Make a model of a hydroelectric station that uses the energy of falling water to turn a turbine to operate a dynamo to produce hydroelectricity. [Fig: 4.6]

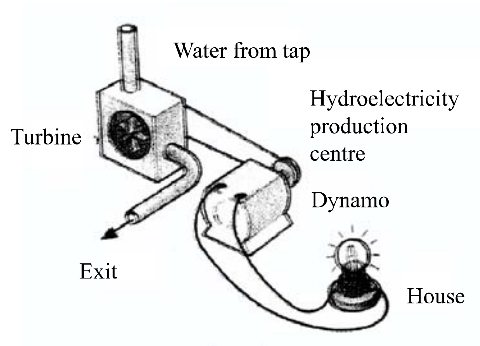


Figure: 4.6

Potential energy is used to produce electricity in the Kaptai electricity production station of our country.

Man is trying to use the energy of tide and ebb of river or ocean for a long time. The operation of different machines using the energy of tide and ebb has been invented a long time ago.

In France electric energy production projects are being successfully implemented using the energy of tide and ebb. Other countries of the world are also trying to set up tidal energy projects to produce electricity.

Wind Energy

Wind flows due to the difference of temperature in the earth surface. Kinetic energy due to the air flow can be transferred into electric energy. The machine that transforms energy is called Windmill. People in the ancient time used to lift water from well, sail ship using the wind blow. Still today people sail in the boat using air energy. Nowadays electric energy is produced using windmill with the help of technology.

Geo-Thermal Energy

The heat in the earth can be used as the source of energy. The heat in the deep of earth is so high that it can melt pieces of rocks. This melted rock is called Magma. This Magma sometimes rises up and remains stored just below the surface of the ground due to geological changes. These types of places are known as hot spot. When the water under the ground comes in contact with the hot spot it turns into steam which remains stored in the ground. This steam could be let out passing a pipe through a hole on the hot spot with the help of high pressure. Electricity can be produced rotating a turbine with the help of this steam. There is such kind of power station in Newzealand.

Biomass Energy

A small fraction of solar energy is transformed into chemical energy by the green plants in the process of photosynthesis and remains stored as biomass in different parts of the trees. Biomass refers to all those organic materials that can transform into energy. Man along with other animals takes biomass as food and keeps their activities of life active by transforming biomass into energy. Biomass can be considered as a multiple source of energy. The organic substances that can be used as the source of energy are – plants and trees, dry wood, waste of wood, crops, husk of rice, herbs, waste of birds and animals, garbage etc. Biomass is mainly composed of Carbon and Hydrogen. One of the renewable sources of energy is biomass.

Biogas can be produced easily from biomass. We can use this gas as the alternate to natural gas and use for cooking even for the production of electricity. The production of biogas is very simple. If we keep cow dung and water in 1:2 ratio in a closed pot for dumping, biogas will be produced. This gas comes out through a tube. This gas is used for cooking. For the cooking and lighting bulbs for a family of 4/5 persons the requirement of gas can be supplied from the cow dung of only 2/3 cows.

Nuclear energy

Electricity can be produced by using the energy produced in nuclear reaction. The nuclear reaction from which the obtained energy is used to produce electricity is called nuclear fission. Here, uranium is made to react with a neutron of particular amount of energy. This reaction takes place in a nuclear reactor.

In nuclear reaction usually matter that is mass is transformed into energy. But in nuclear reaction only a small fraction of energy of the total mass is transformed into energy. If mass is transformed and E amount of energy is obtained, then,

$E = mc^2$

Here m is the mass transformed into energy.

c is the speed of light that is equal to $3 \times 10^8 \text{ ms}^{-1}$.

From experiment it is known that in a fission reaction, that is, if a neutron of definite energy strikes a uranium nucleus, then almost

200 Mev = 200×10^6 ev = $200 \times 10^6 \times 1.6 \times 10^{-19}$ J = 3.2×10^{-11} J energy is released.

Since nuclear fission is a chain reaction, hence in a moment crores of reactions take place and huge amount of energy is released.

Calculate: If a substance of 1kg mass is converted completely into energy, then how many kilowatt energy will be produced? 1 kilowatt-hour (1 kWh) = 3.6×10^6 J

The energy obtained from this reaction can be transferred to another container as the internal energy of carbon dioxide, by pumping continuously at high pressure in a controlled way. This heated gas moves around a special steam boiler and heats the steam inside which can rotate a turbine and produce electricity. The amount of energy obtained from a ton of uranium by a nuclear reaction will be equal to the amount of energy obtained from burning ten lac tons of coal.

But there are some problems of nuclear power plants. The waste of nuclear fuel is extremely radioactive and so it has to be preserved for thousands of years to make it safe. Moreover, in a nuclear reactor high temperature and pressure is produced. So it has to be made of such a material that can tolerate the high temperature and pressure. Any nuclear accident is very dangerous which we can realize from the accidents of Chernobyl in Soviet Union (at present Ukraine) and Fukushima in Japan. In nuclear power production less greenhouse gas is released in the environment.

The Social Effects and Advantages of Renewable Energy

Uses of renewable energy have a far-reaching effect on our social life. In comparison with the demand of our country the storage of coal, petroleum and natural gas is very poor. So, we have to import mineral oil and coal from abroad to meet up the demand of energy by spending a lot of valuable foreign currency. But utilizing the renewable energy sources that we have in our country especially if we can encourage the people to produce and use biogas, we will be able to change the infrastructure of rural area. We can focus our attention to electricity production using windmill. If we can make the use of solar energy available through research, we will be able to meet up all our demands of energy from this unlimited source.

The main advantage of using of renewable energy is that there is no possibility of diminishing of energy. Moreover it will be possible to protect our country from environment pollution.

4.4 Transformation of energy

Energy is being transformed continuously from one form to another. Various incidents are taking place in this universe due to transformation of energy. Though energy is transforming from one form to more than one form, the total amount of energy in this universe remains unchanged.

Transformation of energy is required for man, computer or any other machine to work or to make any change or to process anything. One form of energy can be used to produce another different form of energy. Actually, one form of energy is simultaneously transforming into another form which is known as the transformation of energy. What happens when anyone plays guitar? The muscle energy of the artist transforms into mechanical energy on the vibrating string which transforms into sound energy as a melodious music and travels to our ears. When wood is burned chemical energy is released and transforms into heat and light energy. A chemical reaction takes place in an electric cell and the chemical energy of these reactions transforms into electric energy which is used for various purposes.

When a definite amount of energy of a particular form is transformed how much energy is obtained? It can be known from the law of conservation of energy.

When such a transformation takes place there is no net loss of energy. The energy lost by one body is exactly equal to the energy gained by another body.

In fact, we can neither create energy nor destroy it. In other words the total energy of the universe does neither increase nor decrease. The amount of energy that existed in the universe at the moment of its creation exists till today. This known as conservation of energy.

Principle of Conservation of Energy:

Energy can be transformed form one form to another or more forms. The total energy of the universe is constant and unchangeable.

Transformation of energy:

We have mentioned earlier about different forms of energy. All of them are related to one another. In other words, it is possible to transform one form of energy into another. This is known as transformation of energy. In fact, almost every natural phenomenon can be considered as a transformation of energy. Several examples of energy transformation are described below.

1. Transformation of mechanical Energy:

Rubbing of hands produces heat. In this case mechanical energy is converted into heat energy. If we low air in an empty pen cap, mechanical energy is converted into sound energy. When water is on a hill or a mountain, potential energy is stored in it. When this water flows down through a spring or river then the potential energy is transformed into kinetic energy. This flow of water can rotate a wheel to produce electricity. In this way mechanical energy can be transformed into electrical energy.

2. Transformation of heat Energy:

In steam engine heat is used to produce steam for driving train etc. Here heat energy is converted into mechanical energy. Heat energy is converted into light energy by conducting electric current through the filament of a bulb. If the junction of two different metallic substances is heated, the heat energy is converted into electric energy.

3. Transformation of light energy:

If we touch the chimney of a lantern we feel it to be hot. Here the light energy is converted into heat energy. Action of light on a photovoltaic cell converts light energy into electric energy. Due to the action of light on a photographic film light energy is transformed into chemical energy.

4. Transformation of chemical energy:

Food and fuel, such as oil, gas, coal and wood are the sources of chemical energy. The energy of food is released in our body by chemical reaction and we can work when this energy is transformed into other forms of energy. When fuel is burnt in an engine or boiler, transformation of energy takes place. In an electric cell chemical energy is transformed into electrical energy. In the filament of an electric bulb, electrical energy is transformed into light and heat energy.

5. Transformation of electrical energy:

In electric motor electric energy is transformed into mechanical energy. In instruments like heater, electric iron etc. electric energy is converted into heat energy. In electric bulbs electric energy is converted into light energy. The receiver of a telephone or radio converts electrical energy into sound energy. In a storage cell electric energy is converted into chemical energy. In electromagnets electric energy is converted into magnetic energy.

6. Transformation of Nuclear energy:

In nuclear submarine nuclear energy is transformed into mechanical energy. Devastating action of atom bomb is nothing but the transformation of nuclear energy. Nowadays, transformation of nuclear energy into other forms of energy especially electrical energy in a nuclear reactor mostly satisfies the demand of energy.

We can understand from the electric power station that the way energy is transformed from one form to another and we get light and heat energy in our houses. By burning coal and natural gas in a power station, we can obtain chemical and heat energy. Heat energy is converted into mechanical energy with the help of turbine which rotates the coil of electric generator. In this process electrical energy is produced. Electric bulb and heater of houses and factories transform electrical into light and heat energy.

Again, which energy is transformed into what type of energy when we pierce a nail into wood by hammering it? The chemical energy of our boy is used to lift the hammer upward which is stored as potential energy due to the higher position of it. When it moves down the potential energy stored is transformed into kinetic energy. This kinetic energy is used to pierce the nail into wood. At the same time sound energy and heat energy in nail, wood and in hammer is produced.

During the transformation energy may not be created or destroyed but reduced. Such as, we cannot make use of all the heat energy as we can use light or electric energy.

4.5 Power

We all are familiar with the word power. In our daily life power is usually related to taking decision and implementation. In science the word "power" is related to the devices motor, pump, and engine etc. i.e. any device that can work. Sometimes we want to solve any task quickly. Suppose we want to fill a water tank on the roof of a multistoried building taking water from its reservoir at the ground floor or from a pond. It takes a lot of time if we want to fill the tank carrying water with a bucket. It takes less time to fill the tank with the help of a motor or a pump. Sometimes a work is done quickly or slowly. Power is the measure of a source by which how fast or how slow a source can work is measured. Suppose two friends-Roni and Oni live on the fifth floor of a building. The mass of the two friends is the same. Coming to the lift at the ground floor they found the lift not working. They had to use the stairs to go up the building. Roni took 40 seconds and Oni took 80 seconds to reach the 5^{th} floor. We say Roni has more power than Oni. Though both of them has done same amount of work to reach the same height Roni has more power because he has done the work faster. Power is the rate of doing work or transformation of energy. Power of a person or a source is measured by the amount of work done per unit time.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

If as person or a device can do W amount of work or transform energy at time t then the power P will be,

$$P = \frac{W}{t} \qquad (4.4)$$

Power has no direction. So it is a scalar quantity.

Dimension: The dimension of power is the dimension of $\frac{\text{Work}}{\text{Time}}$.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force x Displacement}}{\text{Time}} = \frac{\text{Mass x Acceleration x Displacement}}{\text{Time}}$$

$$= \frac{\text{Mass x Displacement x Displacement}}{\text{Time x Time}^2} = \frac{\text{Mass x Displacement}^2}{\text{Time}^3}$$

$$\therefore [P] = \frac{ML^2}{T^3} = [ML^2T^{-3}]$$

Unit: We can get the unit of power by dividing the unit of work with that of time. Since the unit of work is joule (J) and the unit of time is second (s), the unit of power will be Joule/second (J/s). It is called Watt. Watt is denoted by W.

If one joule work is done in one second or the rate of transformation of energy is called one watt.

$1W = \frac{1J}{1S} = 1\ Js^{-1}$

Since watt is very smaller, its thousand times larger unit kilo-watt is used.

1 kilo-watt = 1000 watt

You have probably heard the word "Horse Power". This unit of power was used earlier. Still today this unit is sometimes used to mean the power of a motor or a car.

1 Horse Power = 746 watt

Have you heard the word "kilowatt-hour"? What does it mean? Actually it is the unit of work or energy. We usually pay the bill of electricity of houses, factories etc measured in this unit. One kilowatt-hour means the energy that a machine with a power of one kilowatt uses in one hour. 60 watt mark on a bulb means that it transforms 60 Joules electrical energy to light and heat energy in one second.

200 megawatt power of an electrical power station means that it supplies 200000000 joules energy in one second. We are using this energy in houses, factories and offices.

Mathematical Example 4.4: A person of mass 70 kg can stair up 30 steps of 25 cm height each in 15 s. What is his power?

($g = 9.8\ ms^{-2}$)

Here,

Mass of the person, m = 70 kg

Force = Weight of the person = mg

$= 70\ kg \times 9.8\ ms^{-2}$

$= 686\ N$

Displacement, $S = 35 \times 25\ cm$

$= 750\ cm$

$= 7.5\ m$

Time, t=15s

Power, P = ?

We know,

$$P = \frac{Work}{Time} = \frac{Fs}{t}$$

$$= \frac{686\ N \times 7.5\ m}{15\ s}$$

$$= 343\ W$$

Ans: 343 W

Do it: Count the number of steps of the stairs to reach the roof of your school or house or any other building. Measure the height of the roof in meter. Measure your mass with the help of a weight measuring machine in kilogram. Multiply your mass with 9.8 and then you will find your weight in newton. Then run to the top of the roof. Measure the total time of reaching the roof with the help of a stop watch.

Your work done will be, your weight × total height

Your power will be, your total work done ÷ total time i.e., $\frac{\text{Work done}}{\text{Total Time}}$.

Perform these activities with your friends and compare your power with them. Who is the most powerful student in your class?

4.6 Efficiency:

We fulfill our daily needs with the help of transformation of energy. For example we run an engine by transforming chemical energy stored in petrol into kinetic energy. According to the principle of conservation of energy, we should obtain the amount of energy which is given to the engine. But it is seen that the energy gained is always less than the energy given to. This is because some energy is lost due to the work done against the frictional force of the engine. The amount of energy obtained from the engine is called effective energy. In this case the equation of energy is,

Given energy = Effective energy + the energy lost in other ways

The efficiency of an engine means that how much of the given energy is obtained as effective energy. So, the efficiency means the ratio of effective energy and the total given energy. Usually the efficiency is expressed in percentage.

$\therefore$ efficiency, $\eta = \frac{\text{Effective energy}}{\text{Total input energy}} \times 100\%$

Energy transformation takes place in different steps in a normal electricity production centre. This transformation continues from coal, oil, natural gas or Uranium up to the production of electricity. It is seen that up to 70% of this energy is lost as heat energy.

At last only the 30% of input energy is transformed into useable electrical energy. So, we can say the efficiency of the electricity production centre is 30%.

Mathematical Example 4.5: An electric motor is used to lift a body of weight 10N at a height 5m. It uses electrical energy of 65J.

a) What is the energy lost by the motor?

b) Find the efficiency of the motor.

Ans:

a) Here, energy used = work done

= Force x displacement

= Weight x height

= 10N x 5m

= 50J

$\therefore$ The energy lost = Energy supplied – energy used

= 65J – 50J

= 15J

b) Efficiency, $\eta = \frac{\text{Effective energy}}{\text{Total input energy}}$ x 100%

$= \frac{50\text{J}}{65\text{J}}$ x 100%

= 76.92%

Investigation 4.1:
Determination of power of a student running up through a stair.

Objective:
Determination of power and the comparison of applied power at different times with the power of other.

Apparatus:
Stop watch

Working procedure:

1. Fix a building (three to six storied building is better) that may be your school building or residence or any other building.
2. Count the number of steps of the stair to reach the roof.
3. Measure the height of a step by a scale and multiply it by the number of steps and find the total height of the roof.
4. Determine your mass by a weight measuring machine.
5. Reach the top of the roof as fast as possible.
6. Measure the time to reach the roof with the stop watch.
7. Now reach the roof of the building running slowly, walking fast, walking normally and walking slowly and measure the time respectively.
8. Find your power in every case according to the table below.

Table of observation

Your mass, m= ….. kg

Height of the roof, h =…..m

Acceleration due to gravity, g = 9.8 ms^{-2}

Readings	Nature of running	Time required to reach the roof, t (s)	Power= $\frac{mgh}{t}$ (W)
1	Running fast		
2	Running slowly		
3	Walking fast		
4	Walking normally		
5	Walking slowly		

9. Why your powers are different at different times? Explain
10. Obtained in the same way compare your power with the power of your friends.
11. Write down the names of five students of your class having the highest and lowest power.

Investigation 4.2
Production of biogas from bio-mass.

Objective: Demonstration of the uses of renewable energy.

Apparatus and materials: Cow-dung, husk of rice, dust of wood, big bottle of plastic or glass (or conical flux if available in lab) , cork, tube etc.

Working procedure:

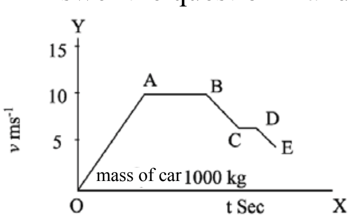
1. Mix cow-dung, husg , wood dust and water in the bottle in proportion 1:2
2. Now close the mouth of the bottle or flux with the tube attached cork.
3. Close the mouth of the tube by a cork also.
4. Put the bottle or flux at the corner of a house.
5. After two or three days open the cork of the bottle and observe if gas is emitting or not.
6. If gas emits hold a fire stick at the mouth of the bottle.
7. Gas will burn.

Exercise

Multiple choice questions:

1. Which is the unit of work?
   a) Joule b) Newton
   c) Kelvin d) Watt
2. What type of energy is stored when a body is stretched?
   a) Kinetic energy b) Potential Energy
   c) Heat Energy d) Chemical Energy
3. A body of mass m is kept at 20 m, 30 m, 40 m and 50 m height respectively. At which position its potential energy is maximum?
   a) 20 m b) 30 m
   c) 40 m d) 50 m

   Answer the question 4 and 5 according to the following graph.



4. At which part of the graph velocity increases in proportion to time?
   a) part OA b) part AB
   c) part CD d) part DE

5. What is the maximum kinetic energy?
   a) 1.25×10^5 J b) 5×10^4 J
   c) 1.25×10^4 J d) 6.2×10^3 J
6. From the law of conservation of energy it is found-
   i) Energy cannot be created or destroyed. The total energy of the universe is constant and unchangeable.
   ii) Non renewable energy will be finished quickly, so renewable energy has to be used
   iii) We have to use energy effectively and reduce system loss in order to save energy.

Which one is correct?
   a) i b) ii c) iii d) i. ii and iii

Creative Question:

1. A boy of mass 40kg and a young man of mass 60kg start running from the ground floor and reach the roof at the same time. Both of them ran with the same velocity of 30m/min.
   a) What is power?
   b) What do you mean by the work 50J?
   c) Find the kinetic energy of the young man.
   d) Explain with mathematical logic whether the power of both are equal or not.

General Question:

1. A match stick is rubbed with its box with a force of 5N. The stick is dragged 5cm.
   a) What is the energy used in rubbing?
   b) What is the power needed if it takes 0.5s to drag the stick?
2. The reservoir of a hydro-electric project is 800m high from the sea level and the power station is 250m high. The water of reservoir rotates a turbine coming through the pipe. There is 20×10^8 liter water in the reservoir. If the mass of 1 liter water is 1kg find the potential energy stored in the water of the reservoir.
3. A boy of 40kg can reach the roof by the stairs in 12s. The number of steps of the stairs is 20 and height of each step is 20cm.
   a) What is the weight of the boy?
   b) What is the height the boy reached on?
   c) What is the work done to reach the roof?
   d) What is the power he used to reach the roof?
4. It is more advantageous to produce nuclear energy than the power station that uses fuel because no green house gas is produced.
   a) What are the other advantages of using nuclear energy?
   b) What are the disadvantages of using nuclear energy?