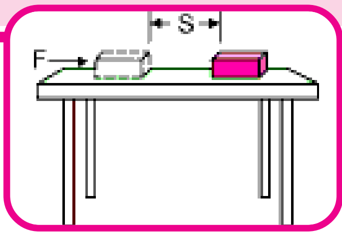
Chapter 9

WORK AND ENERGY



In previous few chapters you have learnt about various ways of describing the motion of objects and causes of motion. In performing our day - to - day activities we use various words like work, energy, and power which are closely related to each other and sometimes we use these words without paying much attention.. In this chapter you will examine these concepts more carefully.

People carry out various tasks in daily life. For example, lifting of weights, carrying of weights, sweeping / cleaning of house, cooking of food, and watering of plants in the garden etc are some of the day to day activities.

Similarly you might have also observed that people employ machines in their homes to carry out different tasks like blowing of air by fan, pumping of water by electric motor, heating of water by electric heater etc.

Washing machines, vacuum cleaners are used for cleaning of clothes, and cleaning the house respectively.

- How are these works being done?
- What do you need to do these works?

Both human beings or machines need energy to do work. Generally this energy is supplied to human beings through food they take in and for machines through the electricity supplied to them.

In all the examples mentioned above, we notice that a person or a machine doing work spends some energy to do work. For example to lift your school bag you spend some energy. Similarly an electric fan uses some electric energy for blowing air.

- Where does the energy spent go ultimately?
- Is there any transfer of energy while work is being done?
- Can we do any work without transfer of energy?

Think about various works you observed and try to indentify the force employed for doing the work and the object on which the work was done. Discuss with your friends about possibility of energy transfer during work.

Work

In our daily life, we use the term 'work' in various situations. The word 'work' takes on different meanings depending on the situation. For example the statements like ' I am working in a factory' , 'The Ramayana is a great work of Valmiki' 'The machine is in working condition' 'There are large number of worked out problems in this book' ' Let us work out a plan for next year' etc have different meanings. There is a difference between the way we use the term 'work' in our day to day life and the way we use it Science.

Let us examine these situations.

i) Priyanka is preparing for examinations. She spends lot of time in studies. She reads books, draws diagrams, organizes her thoughts, collects question papers, attends special classes, discusses problems with her friends and performs experiments etc.

In our common view 'she is working hard' but if we go by scientific definition of work the above mentioned activities are not considered as work.

ii) Rangaiah is working hard to push the huge rock. Let us say the rock does not move despite all efforts by him. He gets completely exhausted and tired. According to our common view he worked hard but as per science he has not done any work on the rock.

iii) Let us assume you climb up the staircase and reach the second floor of a building. You spend some energy to do this. In our common understanding you are not doing any work but as per science you have done a lot of work to reach the second floor of the building.

In our daily life we consider any useful physical or mental labor as 'work'

For example we consider cooking of food, washing of clothes, sweeping, doing home work, reading, writing etc. as works. But according to scientific definition of work all of these activities are not considered as work, only a few of them are considered as work.

- What is work?
- Why is there difference between general view of work and scientific view of work?

Scientific meaning of the work

To understand the way we view work and scientific meaning of work let us observe the following examples.

Example-1

Fig - 1

A man is lifting cement bags from the ground and keeping them one by one in a lorry.

Example-2

Fig - 2

A girl is pulling a toy car on the ground and the trolley moves a distance.

Example-3

A boy is trying to push a huge rock lying in a play ground.

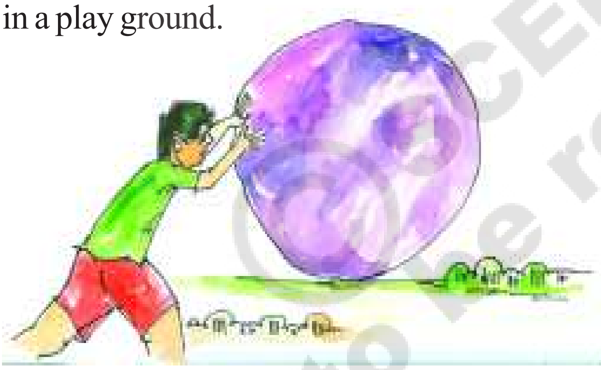


Fig - 3

Example-4

A porter is waiting on the platform of a railway station with luggage on his head.

Fig - 4

- Are all the people mentioned in the above examples doing work?
- How do you define work?

To know the meaning of work according to science analyse the above examples as per the table in the following activity 1.

Activity-1

Let us understand the meaning of work as per science

Copy the table given below in your note book.

Discuss with your friends whether work is being done in each of the examples mentioned above. What could be your reason to say that work has been done? Write your reasons in the following table.

After careful comparison of all the above mentioned examples, you can understand that in each case the person involved in action/ doing work, spends some energy to perform the actions mentioned in the examples. In some cases there is a change in the position of the object on which work has been done, For instance in example -1 the position of the bag is changed from ground to the height of the lorry, and similarly the toycar moved through a distance by changing its position.

In some other cases though the person is doing the work and spends energy, there is no change in the position of the object on which work has been done. Like in

Table - 1

Situation	Whether work has been done or not ? (Yes/No)	Who is doing the work (Name the force)	Object on which work has been done.	Reason to say that work has been done	The changes you notice in objects on which work has been done
Example – 1	Yes	Man, Muscular force	Cement bag	The person is lifting the bag from ground to lorry using muscular force	The cement bag moved from the ground to the height of the lorry
Example – 2					
Example – 3					
Example – 4					

example -3, the boy who is trying to push the huge rock by applying force on it spends lot of energy though there is no change in the position of the rock. Similarly in example - 4 the porter standing on the railway platform with luggage on his head spends a lot of energy against the gravitational force acting on the luggage though there is no change in the position of luggage.

In our common perception of work all the forces acting on bodies applied by persons mentioned in examples 1 to 4 are doing work but according to science only the forces applied by persons mentioned in examples 1 and 2 are doing the work.

According to the scientific concept of the work, two conditions need to be satisfied in order to say that work has been done.

1. A force should act on the object.
2. The object must be displaced or there must be change in the position of the object.

Let us define the term 'work'

Definition of work in science

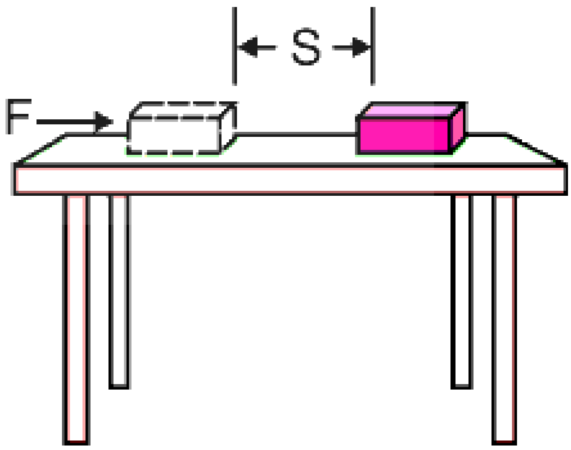


Fig - 5

Let us consider the following

example:

Suppose that a constant force (F) acts on an object and object is moved through a distance (s) along the direction of the force (F) as shown in figure 5

In science we define work to be equal to the product of the force (F) and the distance (s) moved along the direction of the force.

Work done = Force x Displacement.

$$W = F\,s$$

This formula for work is used in only translatory motion of the object.

Work has only magnitude, no direction. So work is a scalar.

We measure force (F) in Newtons (N) and distance (s) in meters (m). In equation W=F s, if F=1 and N=1 then the work done by the force will be '1 N-m'. Hence the unit of work is 'Newton-meter' (N-m) or 'Joule' (J)

Thus 1 Joule (J) is the amount of work done on an object when a force of 1 Newton displaces it by 1m along the line of action of the force.

Look at the equation W = F s

- What would be the work done when the force on the object is zero?
- What would be the work done when the displacement of the object is zero?
- Can you give some examples, where the displacement of the object is zero?

Think and discuss

- A wooden chair is dragged on the level floor and brought to the same place. Let the distance covered be **'s'** and frictional force acted on the chair by the floor be **'f'** . What is the work done by the frictional force ?

Example 1

A boy pushes a book kept on a table by applying a force of 4.5 N. Find the work done by the force if the book is displaced through 30 cm along the direction of push.

Solution

Force applied on the book (F) = 4.5 N

Displacement (s) = 30 cm = (30/100) m

= 0.3m

Work done, W = F s

= 4.5 x 0.3

= 1.35 J

Example 2

Calculate the work done by a student in lifting a 0.5 kg book from the ground and keeping it on a shelf of 1.5 m height. ($g=9.8\ m/s^2$)

Solution

The mass of the book = 0.5 kg

The force of gravity acting on the book is equal to 'mg'

That is mg = 0.5 x 9.8

= 4.9 N

The student has to apply a force equal to that of force of gravity acting on the book in order to lift it.

Thus force applied by the student on the book, F = 4.9 N

Displacement in the direction of force,

$s = 1.5m$

Work done, $W = F s$

$= 4.9 \times 1.5$

$= 7.35$ J

In the situation mentioned in figure 5 the displacement of the object is in the direction of the force. But there are certain cases where the displacement of the object may be in a direction opposite to the force acting on it.

For example if a ball is thrown up (Fig – 6), the motion is in upward direction, where as the force due to earth's gravity is in downward direction.

- What happens to the speed of the ball while it moves up?
- What is the speed at its maximum height?

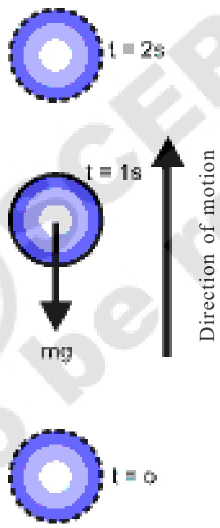


Fig - 6 Positions of ball at various instants while moving up

- What happens to the speed of the ball during its downward motion?

Similarly the ball moving on plain ground (Fig-7) will get stopped after some time due to frictional force acting on it in opposite direction.

Fig - 7

If the force acting on an object and displacement are in opposite directions then the work done by the force is taken as negative.

$$W = -F s$$

If work has positive value, the body on which the work has been done would gain energy.

If work has negative value, the body on which the work has been done loses energy

Think and discuss

Lift an object up from the ground. Work done by the force exerted by you on the object moves it in upward direction. Thus the force applied is in the direction of displacement. However there exists a force of gravitation on the object at the same time

- Which one of these forces is doing positive work?
- Which one is doing negative work?
- Give reasons.

Example - 3

A box is pushed through a distance of 4m across a floor offering 100N resistance. How much work is done by the resisting force?

Solution

The force of friction acting on the box,

$F = 100N$

The displacement of the box, $s = 4m$

The force and displacement are in

opposite directions. Hence work done on the box is negative.

That is, $W = -F s$

$= -100 \times 4$

$= -400$ J

Example 4

A ball of mass 0.5 kg thrown upwards reaches a maximum height of 5m. Calculate the work done by the force of gravity during this vertical displacement considering the value of $g = 10 m/s^2$.

Solution

Force of gravity acting on the ball, $F = mg = 0.5 \times 10 = 5N$

Displacement of the ball, $s = 5m$

The force and displacement are in opposite directions. Hence work done by the force of gravity on the ball is negative.

$W = -F s$

$= -5 \times 5$

$= -25$ J

Idea of Energy

The word Energy is very often used in our daily in various occasions like ' He is more energetic' I am so tired and lost my energy', Today I am feeling more energetic than yester day' etc.

- What is energy?
- How can we decide that an object possess energy or not?

Let us consider the following cases

Case -1

A metal ball kept in a ceramic plate is raised to a certain height from the plate and allowed to fall on it.

- What will happen to the plate? Why?

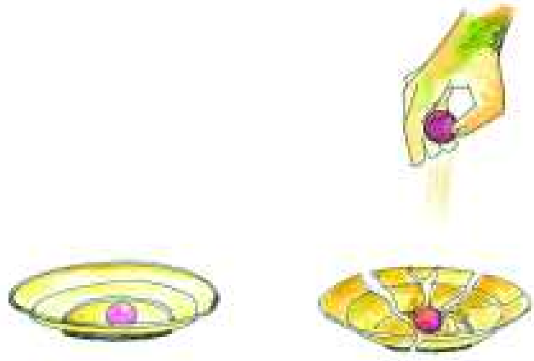


Fig - 8

Case -2

A toy car is placed on floor without winding the key attached to it and the same toy car placed on the floor after winding the key attached to it.

Fig - 9 : A Toy Car

- What changes do you notice? Why?

In case -1 you might have noticed that the metal ball does no work when it rests on the surface of the plate but is able to do some work when it is raised to a height .

Similarly in case -2 you may notice that the toy is at rest before winding the key but the same toy gets energy to move when the key attached to it is wound up.

Children may not be able to lift 25 kg rice bag but elders can do that.

- What could be the reason?

You may observe many such situations where the capacity to do work changes from person to person.

Similarly the capacity of doing work by an object on another object depends on position and state of the object which is doing work. Thus an object acquires energy through different means and is able to do work.

Energy transfer and the work

We learned in previous paragraphs, that we need energy to do any work and a person doing work spends some energy while doing the work i.e. the person doing the work loses some energy.

- Where does this energy go?
- Is there any energy transfer between the object doing the work and the object on which work has been done?
- Can any force do work without energy transfer?

In science, we consider work has been done only when there is a change in the position of the object. The object is able to change its position due to the energy transferred to it by the force doing the work. Thus whenever work is done on an object its energy either increases or decreases.

For example if we push a wooden block which is kept on a table, it starts moving due to the work done on it and as a result it gains kinetic energy.

Activity-2

Understanding the increase and decrease in energy of an object

Take a hard spring and keep it on the table as shown in the figure 10.

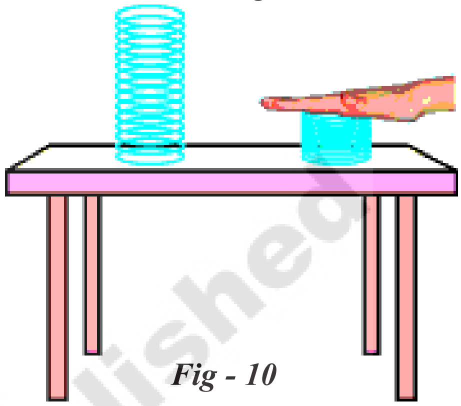


Fig - 10

Now compress the spring with your palm and release it after few seconds. Observe the changes in its position, state and size after compressing the spring and releasing it. You will notice that when spring is being compressed there is a change in its size. When it is released it gains some energy and may even jump from the table. The work done by your palm on the spring increases its energy and makes it to jump away from the table.

Thus we can conclude that the object which does work loses energy and the object on which work has been done gains energy. If negative work is done on an object, its energy decreases. For example, when a ball moves on the ground the force of friction does negative work on the ball (because it acts in a direction opposite to the motion of the ball). This negative work done on the ball decreases its kinetic energy and makes it comes to rest after some time.

Think and discuss

- What would happen if nature does not allow the transfer of energy? Disscuss with few examples.

Sources of energy

Life would be impossible without energy. We need energy in different forms like muscular energy, thermal energy, light energy, electrical energy etc., to do our day to day activities. The demand for energy is ever increasing.

- Where do we get energy from?

The Sun is the biggest natural and primary source of energy for us. Many other secondary sources are derived from the Sun. We can also get energy from the interior of the earth and from tides of the sea.

- Can you think of other sources of energy?

Activity-3

List the energy sources

A few sources of energy are mentioned above. There are many other sources of energy.

List them and identify which of them are sources of energy due to Sun. Discuss with your friends how these sources are considered as sources of energy due to the Sun.

- Are there sources of energy which are not dependent on the Sun?

Forms of energy

Energy can exists in several forms like mechanical energy, light energy, thermal energy, sound energy, electrical energy, magnetic energy etc..

Apart from these, electric batteries, cooking gas, coal, and petroleum etc. have chemical energy stored in them. Even matter itself is a concentrated form of energy and sometimes can be converted into other forms like nuclear energy, heat energy etc.

Energy inside a human body

The human body is a complicated system in which a variety of energy exchange takes place. The main source of energy for human body is food. Energy is used up when the muscles are stretched and heart pumps blood and so on.

Work done by the force inside the body in performing various activities reduces the energy of the body. We feel tired in such situations.

- Do you know why a person gets tired standing at place for long time?

Though the person standing is not doing any work externally, a lot of work is being done inside the body.

The muscles of the body become stretched when he stands for long time and heart has to pump more blood to muscles. This leads to loss of energy inside the body and hence he gets tired.

Kinetic energy

Activity-4

Understanding the energy of moving objects

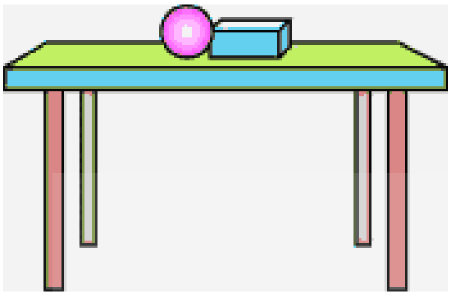


Fig – 11 (a)

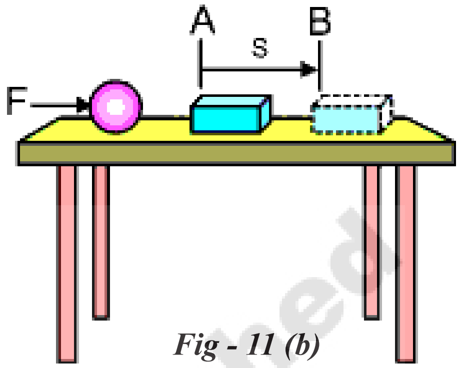


Fig - 11 (b)

Consider a metal ball and a hollow plastic block which are kept on a table side by side as shown in the figure 11 (a). Now suppose that the ball is separated from the block and brought to one end of the table as shown in the figure 11 (b) and pushed to roll on the table with speed 'v'.

- What will happen to block?
- What changes do you notice in the position and state of the ball and block when the ball is allowed to roll on the table?

You may notice that when the ball is pushed , it starts moving with speed of 'v' and hits the plastic block and displaces it from point A to B as shown in figure 11 (b). Thus a moving ball is more energetic than the ball at rest because the moving ball is able to do the work on plastic block to push it forward, whereas the same ball cannot do any work when it is at rest. In other words, a body possess more energy when it is moving than when it is at rest.

Repeat this activity by pushing the metal ball with more force so as to increase its speed and observe the change in position of the plastic block on the table. You may notice that the increase in the speed of the ball increases its capacity of doing work on the block.

Thus we can conclude that a moving object can do work. An object moving faster can do more work than an identical object moving relatively slow.

The energy possessed by an object due to its motion is called kinetic energy.

The Kinetic energy of an object increases with its speed.

We come across many situations in our daily life where objects with kinetic energy do work on other objects. For example when a fast moving cricket ball hits the wickets, it makes the wickets to tumble but if the swinging bat in the hands of a batsman hits the ball it reaches the boundary.

Similarly a fast moving bullet pieces the target, blowing wind moves the blades of the wind mill. Objects like a falling coconut, a speeding car, a rolling stone, a flying aircraft, flowing water and running athlete etc, also possess kinetic energy.

- How can we find out as to how much energy is possessed by a moving body?

Numerical expression for kinetic energy

We know that the kinetic energy of a body at rest is zero, but the kinetic energy of a body moving with certain velocity is equal to the work done on it to make it acquire that velocity from rest.

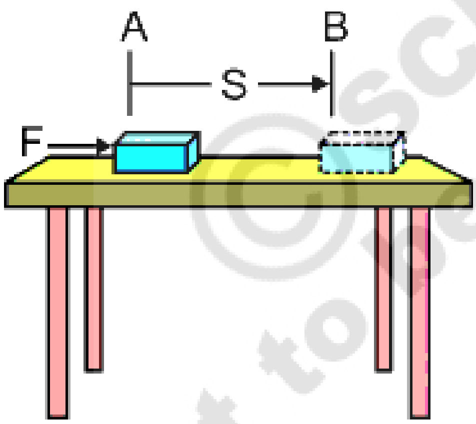


Fig – 12

Let us assume that an object of mass (m) is at rest on a smooth horizontal plane as shown in figure 12. Let it be displaced through a distance 's' from the point A to B by a force (F) acting upon it in the direction of the displacement. In the horizontal direction the net force F_{net} is equal to the applied force F.

The work done on the object by the net force

$$W = F_{net}\, s = F\, s \quad \text{—— (1)}$$

Let the work done on the object cause a change in its velocity from 'u' to 'v' and the acceleration produced be 'a'.

In the chapter **motion** we studied about equations of uniform accelerated motion. The relation between initial velocity u, final velocity v, acceleration 'a' and displacement 's' is given by

$$v^2 - u^2 = 2\,a\,s \quad \text{or} \quad s = (v^2 - u^2) / 2\,a \quad \text{——(2)}$$

We know by Newton's second law of motion

$$F_{net} = ma \quad \text{———— (3)}$$

From equations (1), (2) and (3)

$$W = ma \times (v^2 - u^2) / 2a$$

$$W = \tfrac{1}{2}\, m\, (v^2 - u^2)$$

This is called work - energy theorem.

As we have assumed that object is at rest, its initial velocity u = o, then

$$W = \tfrac{1}{2}\, m\, v^2$$

Thus the work done on the object is equal to $\tfrac{1}{2}\, m\, v^2$

We know that kinetic Energy of a body moving with certain velocity is equal to work done on the object to acquire that velocity from rest.

Thus the kinetic Energy (K.E.) possessed by an object of mass 'm' and moving with velocity 'v' is equal to $\tfrac{1}{2}\, m\, v^2$

$$K.E. = \tfrac{1}{2}\, m\, v^2$$

Think and discuss

- Why is it easier to stop a lightly loaded truck than heavier one that has equal speed.
- Does the Kinetic energy of a car change more when it goes from 10 m/s to 20 m/s or when it goes from 20 m/s to 30 m/s.?
- A person starts from rest and begins to run. The runner puts a certain momentum into himself. What is the momentum of ground? And the runner puts a certain amount of kinetic energy into himself. What is the kinetic energy of the ground.?

Example 5

Find the kinetic energy of a ball of 250 g mass, moving at a velocity of 40 cm /s.

Solution

Mass of the ball, m = 250g = 0.25 kg

Speed of the ball, v = 40 cm / s =0.4 m /s

Kinetic Energy,

K.E. = $\frac{1}{2}(0.25) \times (0.4)^2 = 0.02$ J

Example 6

The mass of a cyclist together with the bicycle is 90 kg. Calculate the work done by cyclist if the speed increases from 6km /h to 12 km / h.

Solution

Mass of cyclist together with bike,

m = 90 kg.

Initial velocity, u = 6km/h = 6x(5/18)

= 5/3 m/s

Final velocity, v = 12 km /h = 12x(5/18)

= 10/3 m/s

Initial kinetic energy

$K.E_{(i)} = \frac{1}{2} mu^2$

$= \frac{1}{2}(90)(5/3)^2$

$= \frac{1}{2}(90)(5/3)(5/3)$

= 125 J

Final kinetic energy,

$K.E_{(f)} = \frac{1}{2} m v^2$

$= \frac{1}{2}(90)(10/3)^2$

$= \frac{1}{2}(90)(10/3)(10/3)$

= 500 J

The work done by the cyclist = Change in kinetic energy = $K.E_{(f)} - K.E_{(i)}$

= 500 J – 125 J = 375 J.

Potential energy

Activity-5

Understanding potential energy

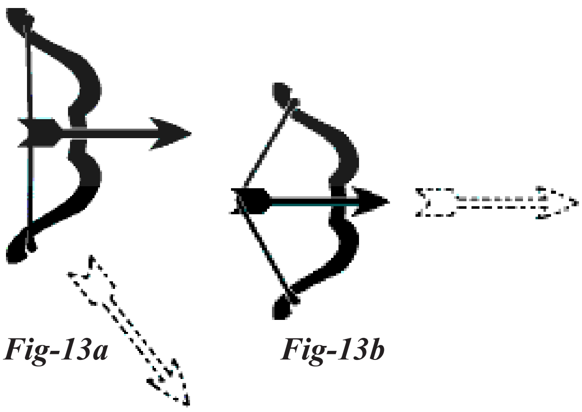


Fig-13a *Fig-13b*

Take a bamboo stick and make a bow as shown in the figure 13 (a). Place an arrow made of a light stick on it with one end supported by the string of the bow as shown in figure13 (a) and stretch the string gently and release the arrow.

- What do you notice?

Now place the arrow on the bow with one end supported by the string and stretch the string applying more force and release the arrow as shown in figure13 (b)

- What differences do you notice in these two instances with respect to motion of arrow?
- Is there any change in the shape of the bow when the string is stretched by applying more force?

You may notice that in the first instance, figure13(a), when you release the arrow it gets separated from the bow and falls down on ground. But in second instance, figure13(b), you will notice the arrow flies with great speed into the air.

From this activity we can conclude that the bow in normal shape is not able to push the arrow but when we stretch the string, it acquires energy to throw the arrow into air with a great speed. The energy acquired by the bow due to change in its shape is known as its potential energy.

Where does the bow get this energy from?

Why is it not able to throw off the arrow in the first case?

Can we increase the potential energy of the bow?

Discuss with friends about changes you need to make to the bow for increasing its potential energy .

In the first instance of above activity, you have gently stretched the string of the bow. Thus the work done by the force on the bow is negligible and energy transferred to the bow due to this work is also negligible. Hence the bow is not able to push the arrow.

In the second instance, you have applied more force on the string to stretch it. Thus the work done by you on bow changed its shape and it acquires large amount of energy. This energy is stored as potential energy in the bow which is responsible for throwing the arrow into air with a great speed.

In our daily life we come across many such situations where the work done on an object is stored as potential energy in it and used to do various other works.

For example the work done in winding the key of toy car is stored as potential energy in it and forces the car to move on the ground when released.

Do the following activities for the better understanding of potential energy.

Activity-6

Observing the energy in stretched rubber band

Take a rubber band hold it at one end and pull it from the other end and then release the rubber band at one of the ends.

What happens?

Activity-7

Observing the energy in an object at some height

Take a heavy ball. Drop it on a thick bed of wet sand from different heights from 25cm to 1.5 m. Observe the depression created by the ball on the bed of sand. Compare depths of these depressions.

- What do you notice?
- Is there any relation to the depth of depression and the height from which ball was dropped?

In above activity we can observe that objects also acquire energy sometimes due to change in position.

Let us consider the following example

We use a hammer to drive nails into a plank. If a hammer is placed just on the tip of a nail, it hardly moves into the plank.

But if the hammer is raised to a certain height and then allowed to fall on the nail, we observe that the nail is pushed some distance into the plank.

Thus the energy of hammer is increased when it is raised to a certain height. This energy is due to the special position (height) of the hammer.

The energy possessed by an object because of its position or shape is called its potential energy

Potential energy of an object at height (or) Gravitational potential energy

An object increases its energy when it is raised through a height. This is because of the work done on object against gravity acting on it. The energy of such object is known as gravitational potential energy.

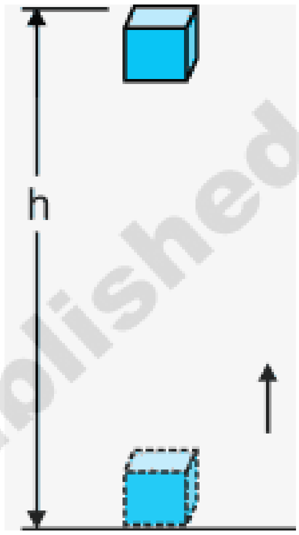


Fig-14

The gravitational potential energy of an object at a point above the ground is defined as the work done in raising it from the ground to that point against gravity.

Consider an object of mass m raised to height h from the ground. A force is required to do this. The minimum force required to raise the object is equal to the weight of the object (mg). The object gains energy equal to the work done on it. Let the work done on the object against gravity be ‘W’.

That is Work done,

$$W = \text{force} \times \text{displacement}$$
$$= mg \times h$$
$$= mgh.$$

Since the work done on the object is equal to ' mgh' an energy equal to 'mgh' units is gained by the object, This is the potential energy of the object at a height 'h'.

P.E. = mgh.

Think and discuss

- Does the international space station have gravitational potential energy ?

Example 7

A block of 2 kg is lifted up through 2m from the ground. Calculate the potential energy of the block at that point. [Take g=9.8m/s^2]

Solution

Mass of the block, m = 2 kg

Height raised, h = 2 m

Acceleration due to gravity, g = 9.8 m/s^2

Potential Energy of the block,

P.E. = m g h

= (2) (9.8) (2)

= 39.2 J

Example 8

A book of mss 1 kg is raised through a height 'h'. If the potential energy increased by 49 J, find the height raised.

Solution

The increase in potential energy = mgh

That is, mgh = 49 J

(1)(9.8)h = 49 J

The height raised, h = (49) / (1x 9.8)

= 5m

Mechanical energy

The sum of the kinetic energy and the potential energy of an object is called its mechanical energy.

Consider the following example

The kinetic energy of an aeroplane at rest is zero. Its potential energy when it is on ground is also considered as zero. Thus its mechanical energy is zero while it rests on the ground. When the same aeroplane flies it has kinetic energy as well as potential energy, the sum these energies gives the total mechanical energy of the aeroplane in flight.

Conversion of energy

We find in nature a number of instances of conversion of energy from one form to another form. Sun is the big source of energy in nature. The solar energy from the Sun is converted into various forms like light energy, heat energy, wind energy etc.

Apart from this, we observe various instances of energy conversions in day to day activities, like conversion of electrical energy into heat energy by Iron box, chemical energy into light energy by a torch etc.

Activity-8

Listing the energy conversions in nature and in day to day life

Discuss various ways of energy conversions in nature as well as in our day to day activities and make a separate list of situations for natural conversions of energy and energy conversions in day-to-day life and write them in table-2, table-3.

Table -2: Energy conversions taking place in nature

S.No.	Situation of energy conversion in Nature
1	Heat energy from the Sun used for preparing food by plants gets converted into chemical energy.
2	
3	
4	

Table -3 Energy conversions taking place in day to day activities.

S.No.	Situation of energy conversion	Gadgets/appliances used for energy conversion
1	Conversion of electrical energy into mechanical energy	Electric fan
2		
3		
4		

Discuss about the following questions with your friends

- How do green plants produce food?
- How are fuels like coal and petroleum formed?
- What kind of energy conversions sustain the water cycle in nature?

We see other energy conversions in nature, for example snow deposited at altitudes melts and the water so formed flows down to seas. In the process, its potential energy is converted into kinetic energy. We convert the kinetic energy of water to electrical energy in hydroelectric power plants.

Dead plants buried deep below the earth's surface for millions of years get converted to fuels like petroleum and coal, which have chemical energy stored in them.

The food we eat comes from plant sources or an animal source which takes plant parts as their food.

When we eat food, several chemical processes take place and the chemical energy stored in food gets converted in to various forms needed by the body. For example when we walk, run, exercise etc., the energy from food is used for kinetic energy.

Activity - 9

Conservation of mechanical energy

Take a long thread say 50-60cm long and attach a small heavy object like a metal ball at one end, tie other to a nail fixed to the wall as shown in the figure 15.

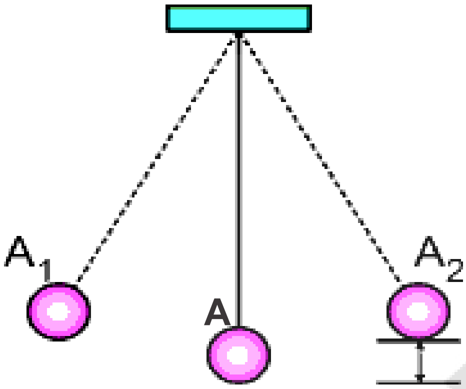


Fig-15

Now pull the object or bob of the pendulum to one side to the position A_1 (Fig-15) and release it.

What do you notice?

You may notice that, the bob swings towards opposite side and reaches the point A_2. It repeats this motion over and over again.

- The potential energy of the bob is minimum at A and reaches maximum at A_1 because the height of the bob is maximum at that position.
- When the bob is released from this point (A_1), its potential energy decreases and kinetic energy starts increasing slowly.
- When the bob reaches the position A its kinetic energy reaches maximum and potential energy becomes minimum.
- As the bob proceeds from A to A_1 its potential energy increases slowly and becomes maximum at A_2

If we neglect small loss of energy due to air resistance , the sum of potential energy and kinetic energy remains constant at any point on the path of motion during the oscillation of the pendulum.

Thus the total mechanical energy in the system of pendulum remains constant. This is called conservation of mechanical energy.

Similarly energy can neither be created nor destroyed. It can only be changed from one form to another.

This is called law of conservation of energy.

When a ball is dropped from a height its gravitational potential energy decreases, but as the ball comes into motion, its kinetic energy increases. Thus a free-fall body possesses both potential energy as well as kinetic energy during its fall to the ground.

Does the conservation of energy apply for the system of free-fall body? How?

Let us find

Activity-10

Calculating the total energy of freefall at different heights

An object of mass 20 kg is dropped from a height of 4m. Compute the potential and kinetic energy in each case given in the following table and write the values in respective column of the table. (Take g = 10 ms^{-2}.)

Table-4

Height at which object located in meters (m)	Velocity of object at different height [in m/s]	Potential energy $E_p = mgh$ [in Joules (J)]	Kinetic energy $E_k = mv^2/2$ [in Joules (J)]	Total energy $(E_p + E_k)$ [in Joules (J)]
4.0	0			
3.55	3			
3.0	$\sqrt{20}$			
2.35	$\sqrt{33}$			
0.8	8			

- What do you say about total energy of system of freely falling body?
- Is the mechanical energy conserved in the system?

Think and discuss

- Someone wanting to sell you a super ball claims that it will bounce to a height greater than the height from which it is dropped. Would you buy this ball ? If yes explain, if not explain.
- A ball, intially at the top of the inclined hill, is allowed to roll down. At the bottom its speed is 4 m/s. Next the ball is again rolled down the hill, but this time it does not start from rest. It has an initial speed of 3 m/s. How fast is it going when it gets to the bottom ?

Power

In our day to day life we observe many situtation where same activity is being completed in different time intervals. For example a hefty rickshaw puller is able to reach the destination in less time when compared other thinner rickshaw puller. Sometimes we notice that a grinder in our home takes more time to grind 1kg of ‘ dal’ when compared to the grinder in neighbours house.

- Do all of us do the work at the same rate?
- Is the energy spent by the force doing work same every time?
- Do the machines consume or transfer energy at same rate every time while doing a particular work?

Let us consider the following example.

Raheem wanted to do some repairs in the first floor of his building. He brought 100 bricks as advised by the mason. A labourer was asked to shift these bricks from ground floor to first floor. The labourer completed the work of shifting bricks to first floor in one hour and asked Rs 150/- for the work.

Next day the mason asked Raheem to bring 100 bricks more to complete the repair work. Raheem brought another 100 bricks and assigned the work of shifting bricks to some another labourer. He completed the work and demanded Rs 300/- for completing the assigned work. Raheem said that he paid Rs 150/- to the labourer yester day. But the labourer argued that he worked more hours hence he is eligible for more money.

- Whose argument is correct?
- Is work done in two cases same?
- Why is there a change in rate of doing work?

In the above example the amount of work done is same in both cases. But the time taken to complete the work is different. This means that rate of doing work is different.

A stronger person like in the first case of above mentioned example may do certain work in relatively less time compared to other person, similarly a powerful machine can do a work assigned to it in relatively less time when compared with another machine.

We talk about the power of machines like motorbikes, motorcar, water pumping motors etc., the speed at which these machines do the work is the basis for their classification. Power is a measure of the speed of the work done, that is how fast or how slow work is done.

Power is defined as the rate of doing work or rate of transfer of energy.

If an agent does a work W in time t, then power is given by

Power = Work / time

P = W/t

The unit of power is 'watt' and denoted by symbol 'W'

1 watt is the power of an agent, which does work at the rate of 1 joule per second.

We express larger rate of energy transfer in kilowatts (kW)

1 kilowatt (kW)	1000 watts (W)
1kW	1000 J. s^{-1}

Think and discuss

- The work done by a force F_1 is larger than the work done by another force F_2. Is it neccesary that power delivered by F_1 is also larger than that of F_2 ? Why ?

Example 9

A person performs 420 J of work in 5 minutes. Calculate the power delivered by him.

Solution

Work done by the person, W = 420 J

Time taken to complete the work,

t = 5 min = 5 x 60s = 300s

Power delivered, P = W / t

= 420/300 = 1.4 W

Example 10

A woman does 250 J of work in 10 seconds and a boy does 100 J of work in 4 seconds. Who delivers more power?

Solution

Power, P = W / t

Power delivered by woman=250/10=25W

Power delivered by boy = 100/4 = 25W

Both woman and boy deliver same power. That is, rate of doing the work by woman and boy are equal.

Key words

Work, Energy, Transfer of energy, Sources of energy, Conservation of energy, Kinetic energy, Potential energy, Mechanical energy, Gravitational potential.

What we have learnt

- Two conditions need to be satisfied in order to say that work has taken place. One is, a force should act on the object and another is, the object must be displaced or there must be change in the position of the object.
- The work done by a force acting on an object is equal to the magnitude of force (F) multiplied by the distance moved (s). This formula for work is used in only translatory motion of the object.
- Work has only magnitude, no direction. So work is a scalar.
- If the force acting on an object and displacement are in opposite directions then the work done by the force is taken as negative.
- If work has positive value, the body on which work has been done would gain energy. If work has negative value, the body on which work has been done loses energy.
- Capability of doing work by an object or energy possessed by an object depends on position and state of the object which is doing work.
- Whenever work has been done on an object its energy either increases or decreases.
- Sun is the biggest natural source of energy to us. Many other sources are derived from it.
- The energy possessed by an object due to its motion is called kinetic energy.
- The energy possessed by an object because of its position or shape is called its potential energy.
- The sum of the kinetic energy and the potential energy of an object is called its mechanical energy.
- Energy can neither be created nor destroyed. It can only be changed from one form to another. This is called law of conservation of energy.
- Power is defined as the rate of doing work or rate of transfer of energy.

Improve your learning

1. Define work and write its units. (AS_1)
2. Give few examples where displacement of an object is in the direction opposite to the force acting on the object. (AS_1)
3. Identify the wrong statement among the following. Rewrite them by making necessary corrections. (AS_1)
   a) Work and energy have different units.
   b) When an aeroplane takes off, the work done by its weight is positive.
   c) The potential energy of spring increases when it is extended and decreases when it is compressed.
   d) If the work done by external forces on a system is negative then the energy of the system decreases.
   e) When a body is falling freely from a height, its kinetic energy remains constant.
   f) The unit of power is watt.

4 What is mechanical energy? (AS_1)

5 State the principle of conservation of energy. (AS_1)

6 When you lift a box from the floor and put it on an almirah the potential energy of the box increases but there is no change in its kinetic energy. Is it violation of conservation of energy? Explain. (AS_7)

7 One person says that potential energy of a particular book kept in an almrah is 20 J and other says it is 30J . Is one of them necessarily wrong? Give reasons. (AS_2 ,AS_1)

8 In which of the following cases is the work done positive or zero or negative? (AS_1)

   a) Work done by the porter on a suitcase in lifting it from the platform on to his head.
   b) Work done by the force of gravity on suitcase as the suitcase falls from porter's head.
   c) Work done by the porter standing on platform with suitcase on his head.
   d) Work done by force of gravity on a ball thrown up vertically up into the sky.
   e) Work done by force applied by hands of a man swimming in a pond.

9. What is potential energy? Derive an equation for gravitational potential energy of a body of mass 'm' at a height 'h'. (AS_1)

10. When an apple falls from a tree what happens to its gravitational potential energy just as it reaches the ground? After it strikes the ground? (AS_7)

11. Let us assume that you have lifted a suitcase and kept it on a table. On which of the following does the work done by you depend or not depend? Why? (AS_2 , AS_1)

a) The path taken by the suitcase. b) The time taken by you in doing so.

c) The weight of the suitcase. d) Your weight.

12. When you push your bicycle up an incline, the potential energy of the bicycle and yourself increase. Where does this energy come from? (AS_7)

13. Why does a person standing for a long time get tired when he does not appear to be doing any work. (AS_7)

14. What is kinetic energy? Derive an equation for the kinetic energy of a body of mass 'm' moving at a speed 'v'. (AS_1)

15. A free-fall object eventually stops on reaching the ground. What happens to its kinetic energy? (AS_1)

16. A man carrying a bag of total mass 25kg climbs up to a height of 10m in 50 seconds. Calculate the power delivered by him on the bag. (AS_1) (Ans : 49J)

17. A 10 kg ball is dropped from a height of 10m. Find (a) the initial potential energy of the ball , (b) the kinetic energy just before it reaches the ground, and (c) the speed just before it reaches the ground. (AS_1) (Ans: 980J, 980J, 14m/s)

18. Calculate the work done by a person in lifting a load of 20 kg from the ground and placing it 1m high on a table. (AS_1)

19. Find the mass of a body which has 5J of kinetic energy while moving at a speed of 2m/s. (AS_1)

20. A cycle together with its rider weighs 100kg. How much work is needed to set it moving at 3 m/s. (AS_1)

21. When the speed of a ball is doubled its kinetic energy (AS_1)

(a) Remains same (b) gets doubled

(c) Becomes half (d) becomes 4 times

22. Two bodies of unequal masses are dropped from the top of building. Which of the following is equal for both bodies at any instance? (AS_1, AS_2)

(a) Speed (b) force of gravity

(c) potential energy (d) kinetic energy

23. A man with a box on his head is climbing up a ladder. The work done by the man on the box is (AS_1)

(a) Positive (b) Negative

(c) Zero (d) Undefined.

24. A porter with a suitcase on his head is climbing up steps with uniform speed. The work done by the "weight of the suitcase" on the suitcase is (AS_1)

(a) Positive (b) Negative

(c) Zero (d) Undefined

25. How will the increasing energy needs and conservation of energy influence international peace, co-operation and security? Discuss. (AS_7)

26. How do you appreciats role of energy conversion occuring naturally in maintaining ecological balance of nature. (AS_6)

27. Collect picturs showing various situation where potential energy possessed by object depends an its shape and position. Prepare a scrap book. (AS_4)

28. Draw a digrame to show conservation of mechanical energy in cafe of free falling body. (AS_5)