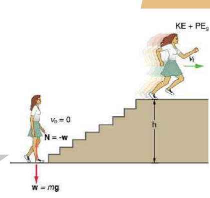
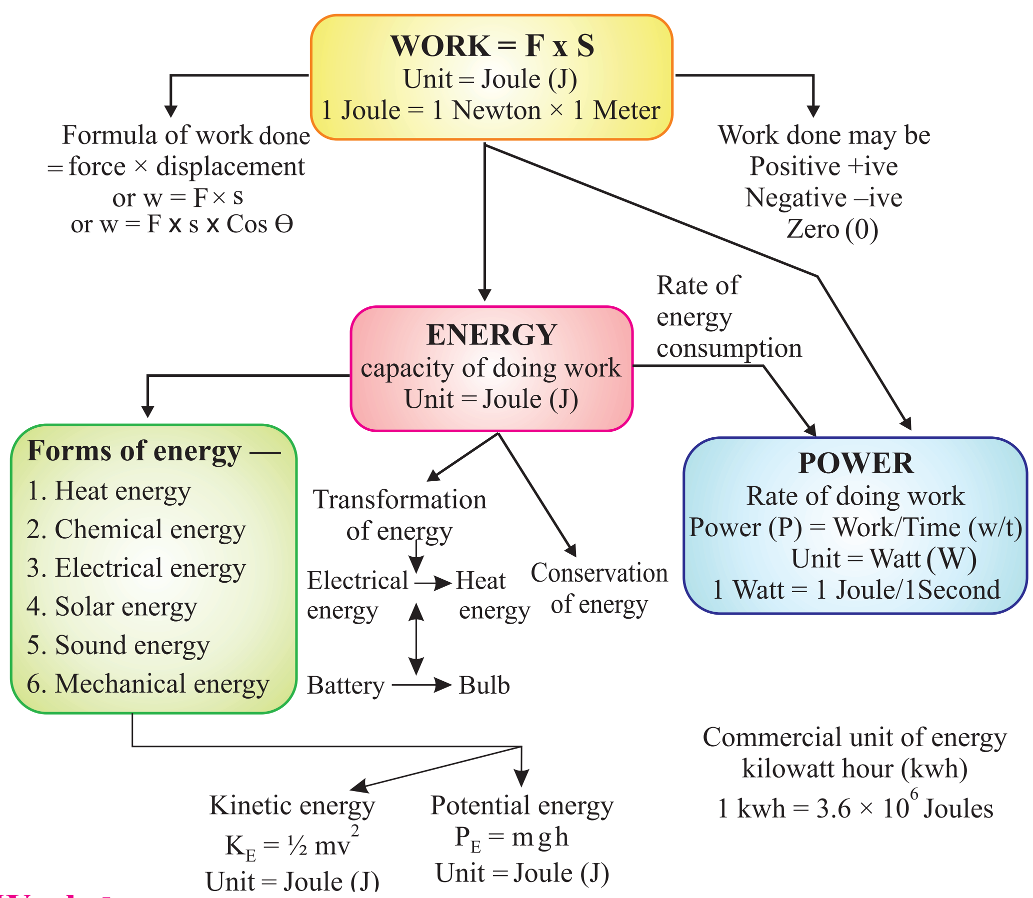


Chapter - 10

Work And Energy

CONCEPT MAPPING



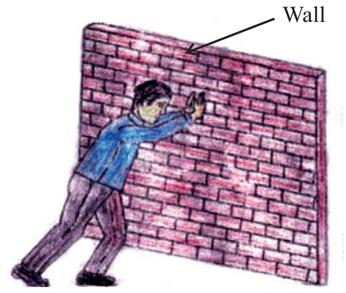
Work done :

For doing work, energy is required.

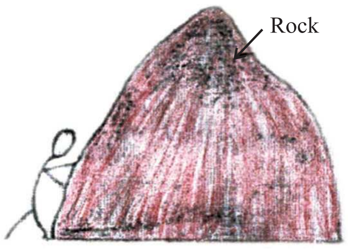
- In animals, energy is supplied by the food they eat.
- In machine, energy is supplied by fuel.

Not much work inspite of working hard : Reading, writing, drawing, thinking, and analysing are all energy consuming. But in scientific manner, no work is done in above cases.

- *Example :* A man is completely exhausted in trying to push a rock (wall), but work done is zero as the wall is remain stationary.
- A man standing still with heavy suitcase may be tired soon but he does no work in this situation as he is stationary.



When a force is applied on the wall, the wall does not move. So work is not done



When a force is applied on the rock, the rock does not move. So work is not done

Work is said to be done when :

(i) a moving object bring to rest.

(ii) an object at rest starts moving.

(iii) velocity of an object changes.

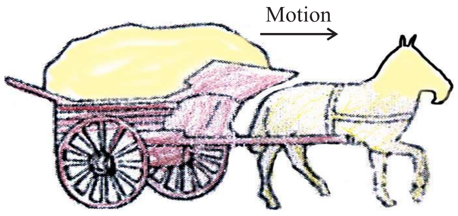
(iv) shape of an object changes.

Scientific Conception of Work is done when force is applied on a body and when that force produces motion under its influence.

Condition of Work done

(i) Force should be applied on the body.

(ii) Body should be displaced.



Force is applied by the horse and cart start moving.

Examples : Work is done when :

(i) A cyclist is pedalling the cycle.

(ii) A man is lifting load in upward or downward direction.

Work is not done when :

(i) A coolie carrying some load on his head stands stationary.

(ii) A man is applying force on a big rock, that does not move at all.

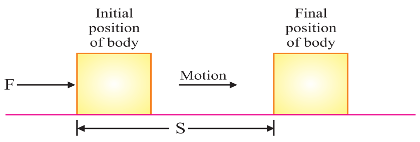
Work Done by a Fixed Force

Work done in moving a body is equal to the product of force and displacement of body in the direction of force.

Work = Force × Displacement

W = F × S

Work is a scalar quantity.



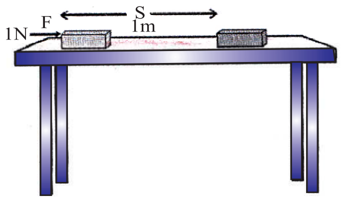
Unit of Work

Unit of work is **Newton metre or Joule.**

When a force of 1 Newton moves a body through a distance of 1 metre in its own direction, then the work done is known as 1 Joule.

1 Joule = 1 Newton × 1 metre

1 J = 1 Nm



1J = 1N × 1 m

Whenever work is done against gravity, the amount of work done is equal to the product of weight of the body and the vertical distance through which the body is lifted.

W = Weight of body x vertical distance.

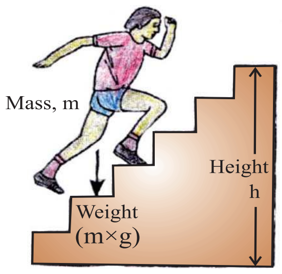
W = m x g x h

m - mass of the body

g - acceleration due to gravity

h - height through which the body is lifted.

Note : Here, force required to lift the body is equal to its weight.



During climbing work is done against gravity

The amount of work done depends on the following factors :

(i) Magnitude of force : Greater the force, greater is the amount of work & vice-versa.

(ii) Displacement : Greater the displacement, greater is the amount of work & vice-versa.

Negative, Positive and Zero Work

Work done by a force can be positive, negative or zero.

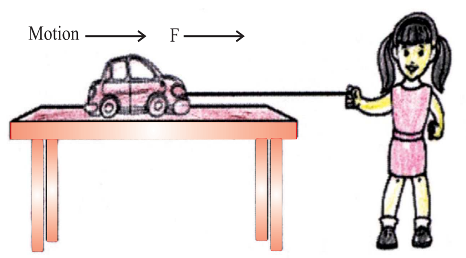
(i) Work done is **positive** when a force acts in the direction of motion of the body. ($\theta = 0^o$) (Θ is the angle between the applied force and direction of object)

θ = angle between direction of force applied & the motion of body.

Example : A child pulls a toy car with a string horizontally on the ground. Here work done is positive.

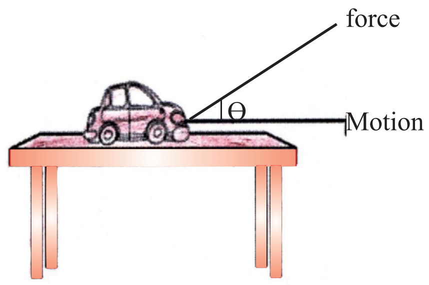
Case I

W = F × S



Case II

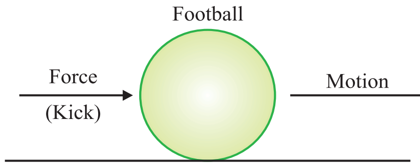
Work done = F x s x cos Θ



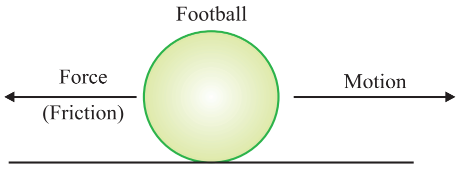
Positive work done

(ii) Work done is **negative** when a force acts opposite to the direction of motion of the body. ($\theta = 180^o$)

Example : When we kick a football lying on the ground, the force of our kick moves the football. Here direction of force applied & motion of football is same so work done is positive. But the football moving on the ground slows down gradually and ultimately stops. This is because a force due to friction (of ground) acts on the football. This force of friction acts in a direction opposite to the direction of motion of football. So, in this case, the work done by the force of friction on the football is negative (and) it decrease the speed of the football.



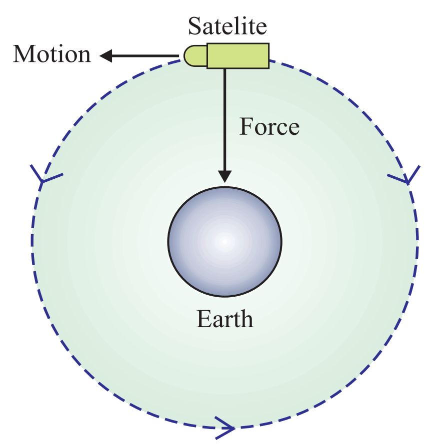
Positive work



Negative work

(iii) Work done is **zero** when a force acts at right angles to the direction of motion. ($\theta = 90^o$)

Example : The moon moves around the earth in circular path. Here force of gravitation acts on the moon at right angles to the direction of motion of the moon. So work done is zero.



Zero work

- -ve (negative) sign indicates that work is done against gravity.

Note that if work is done against the direction of motion (gravity), then it is taken –ve.

Example. *A coolie lifts a luggage of 15 kg from the ground and put it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.*

Solution : Mass of luggage (m) = 15 kg

Displacement (S) = 1.5 m

So, Work done, W = F × S

= mg × S [F= mg]

= 15 × 10 × 1.5 [g = 10 m/s^2]

[g = force of gravity]

= 225.0 kg m/s^2

= 225 Nm = 225 J

Hence, work done = 225 J.

Energy

(i) The sun is the biggest source of energy.

(ii) Most of the energy sources are derived from the Sun.

(iii) Some energy is received from nucleus of atoms, interior of the earth and the tides.

Definition : The capacity of doing work is known as energy.

The amount of energy possessed by a body is equal to the amount of work it can do. Working body loses energy, body on which work is done gains energy.

Energy is a scalar quantity.

Unit : The SI unit of energy is Joule (J) and its bigger unit is kilo joule (kJ).

$$1 \text{ kJ} = 1000 \text{ J}$$

The energy required to do 1 Joule of work is called 1 Joule energy.

Forms of Energy

Main forms of energy are :

(i) Kinetic energy
(ii) Potential energy
(iii) Heat energy
(iv) Chemical energy
(v) Electrical energy
(vi) Light energy
(vii) Sound energy
(viii) Nuclear energy

- Sum of kinetic energy & potential energy of a body is called mechanical energy.

Mechanical energy

The energy possessed by a body on account of its motion or position is called mechanical energy.

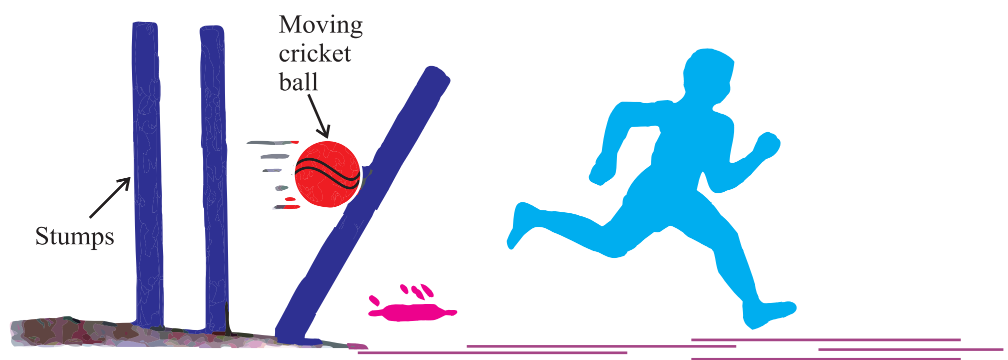
Kinetic Energy

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

Examples of kinetic energy :

- A moving cricket ball
- Running water
- A moving bullet, stone
- Flowing wind
- A moving car, arrow
- A running athelete
- A rolling stone

- Flying aircraft



Kinetic energy

Kinetic energy is directly proportional to mass and the square of velocity.

Formula for Kinetic Energy

The kinetic energy of a moving body is measured by the amount of work it can do before coming to rest. If an object of mass 'm' moving with uniform velocity 'u', it is displaced through a distance 's', Constant force 'F' acts on it in the direction of displacement velocity changes from 'u' to 'v'. Then acceleration is 'a'.

Work done, $W = F \times s$ ...(i)

and $F = ma$ ...(ii)

According to third equation of motion, relationship between u, v, s and a is as follows :

$$v^2 - u^2 = 2as$$

So, $$s = \frac{v^2 - u^2}{2a}$$ ...(iii)

Now putting the value of F and s from (ii) and (iii) in equation (i),

$$W = ma \times \frac{v^2 - u^2}{2a}$$

$$= \frac{m}{2} \times v^2 - u^2 = \frac{1}{2} m\left(v^2 - u^2\right)$$

If $u = 0$ (when body starts moving from rest)

$$W = ½mv^2$$

Or $$E_K = ½mv^2$$

Example. *An object of mass 15 kg is moving with uniform velocity of 4 m/sec. What is the kinetic energy possessed by it ?*

Solution : Mass of the object, m = 15 kg

Velocity of the object, v = 4 m/s

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

$= \frac{1}{2} \times 15 \text{ kg} \times 4 \text{ ms}^{-1} \times 4 \text{ ms}^{-1}$

$= 120 \text{ J}$

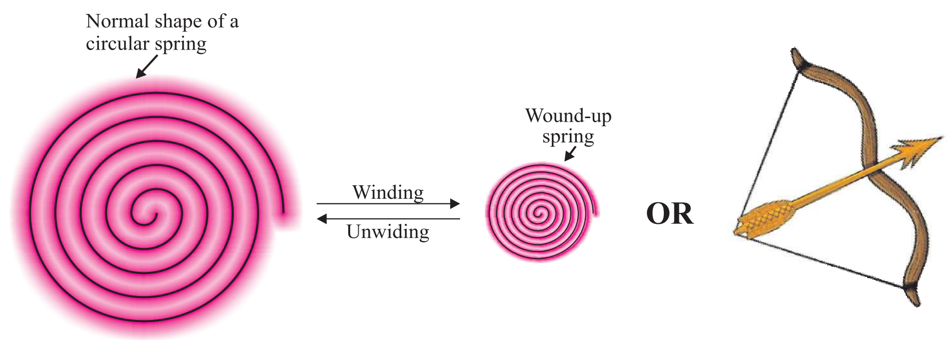
The kinetic energy of the object is 120 J.

Potential Energy

The energy of a body due to its position or change in shape is known as potential energy.

Examples :

- **(i) Water kept in dam :** It can rotate turbine to generate electricity due to its position above the ground.
- **(ii) Wound up spring of a toy car :** It possess potential energy which is released during unwinding of spring. So toy car moves.
- **(iii) Bent string of bow :** Potential energy due to change of its shape (deformation) released in the form of kinetic energy while shooting an arrow.



Factors affecting Potential Energy

(i) Mass : P. E. $\propto m$

More the mass of body, greater is the potential energy and vice-versa.

(ii) Height above the ground :

P. E. $\propto h$ (does not depend on the path it follows)

Greater the height above the ground, greater is the P.E. and vice-versa.

(iii) Change in shape : Greater the stretching, twisting or bending, more is the potential energy.

Potential Energy of an Object on a Height

If a body of mass 'm' is raised to a height 'h' above the surface of the earth, the gravitational pull of the earth ($m \times g$) acts in downward direction. To lift the body, we have to do work against the force of gravity.

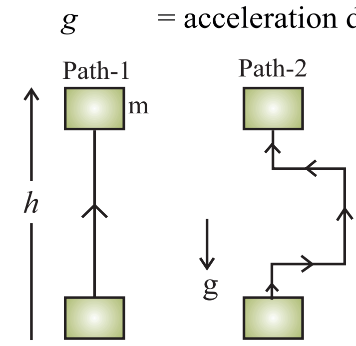
Thus, Work done, W = Force × Displacement

Or W $= m \times g \times h = mgh$

This work is stored in the body as potential energy (gravitational potential energy).

Thus, Potential energy, $E_P = m \times g \times h$

where g = acceleration due to gravity.



Ep = M×g×h = Ep = mgh

Example. *If a body of mass 10 kg is raised to a height of 6 m above the earth, calculate its potential energy.*

Solution : Potential energy of the body = mgh

Mass of body = 10 kg

Height above the earth = 6 m

Acceleration due to gravity = 10 m/s^2

So, $E_P = 10 \times 10 \times 6$

$= 600$ J

Thus, potential energy of the body is 600 Joules.

Transformation of Energy

The change of one form of energy to another form of energy is known as transformation of energy.

Example :

(i) A stone on a certain height has entire potential energy. But when it starts moving downward, potential energy of stone goes on decreasing as height goes on decreasing but its kinetic energy goes on increasing as velocity of stone goes on increasing. At the time stone reaches the ground, potential energy becomes zero and kinetic energy is maximum.

Thus, its entire potential energy is transformed into kinetic energy.

(ii) At hydroelectric power house, the potential energy of water is transformed into kinetic energy and then into electrical energy by dynamo.

(iii) At thermal power house, chemical energy of coal is changed into heat energy, which is futher converted into kinetic energy and electrical energy.

(iv) Plants use solar energy to make chemical energy in food by the process of photosynthesis.

Law of Conservation of Energy

- Whenever energy changes from one form to another form, the total amount of energy remains constant.
- "Energy can neither be created nor be destroyed."
- Although some energy may be wasted during conversion, but the total energy of the system remains the same.

Conservation of Energy during Free Fall of a Body

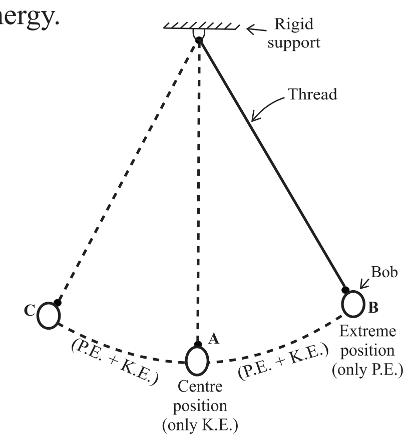
- A ball of mass 'm' at a height 'h' has potential energy = mgh.
- As ball falls downwards, height 'h' decreases, so the potential energy also decreases.
- Kinetic energy at 'h' is zero but it is increasing during falling of ball.
- The sum of potential energy & kinetic energy of the ball remains the same at every point during its fall.

$$\tfrac{1}{2}mv^2 + mgh = \text{Constant}$$

Kinetic energy + Potential energy = Constant

	Ball		P.E. of Ball	K.E. of Ball	Total Energy of Ball (P.E. + K.E.)
Ball at rest		A	20J	0J	20 + 0 = 20J
Falling ball		B	15J	5J	15 + 5 = 20J
Falling ball		C	10J	10J	10 + 10 = 20J
Falling ball		D	5J	15J	5 + 15 = 20J
Just before hitting the ground		E	0J	20J	0 + 20 = 20J

Conservation of energy in a simple Pendulum A swinging pendulum shows an example of conservation of energy.



A swinging (or oscillating) simple pendulum

A simple pendulum consists of small metal ball (called bob) suspended by a long thread from a rigid support, such that the bob is free to swing back and forth when displaced.
Its energy is continuously transformed (or converted) from potential energy to kinetic energy and vice-versa.
The total energy of the swinging pendulum at any instant remains the same (or conserved).
The body which does work loses energy and the body on which work is done gains energy.

Rate of Doing Work = Power

"Power is defined as the rate of energy consumption." or Rate of doing work.

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \quad \text{Or} \quad P = \frac{W}{t}$$

where P = Power

W = Work done

t = Time taken

Unit of Power

SI unit of Power is Watt (W) = 1 Joule/second.

$$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ second}} \quad \text{Or} \quad 1 \text{ W} = \frac{1 \text{ J}}{1 \text{ s}}$$

Power is one Watt when one Joule work is done in one second.

$$\text{Average Power} = \frac{\text{Total work done or total energy used}}{\text{Total time taken}}$$

Power of Electrical Gadget

The power of an electrical appliance tells us the rate at which electrical energy is consumed by it. Here, when work is done, an equal amount of energy in consumed.

Bigger unit of Power : Bigger unit of power is called Kilowatt or KW.

1 Kilowatt (KW) = 1000 Watt = 1000 W or 1000 J/s

Example. *A body does 20 Joules of work in 5 seconds. What is its power ?*

Solution : $$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

Work done = 20 Joules

Time taken = 5 sec.

$$P = \frac{20 \text{ J}}{5 \text{ s}}$$

So, Power = 4 J/s = 4 W

Thus, power of the body is 4 Watts.

QUESTIONS

OBJECTIVE TYPE QUESTIONS

I. Objective Type Questions.

(i) If Ramesh has done the same amount of work in less time as compared to Rohan then

(a) Ramesh has more power (b) Rohan has more power

(c) both have equal power (d) None of these

(ii) A flying kite possesses

(a) only potential energy (b) Only kinetic energy

(c) both P.E. and K.E. (d) neither P.E. nor K.E.

(iii) The workdone on an object does not depend upon the

(a) Displacement (b) force applied

(c) angle between force (d) initial velocity of the object

(iv) If a force F applied on a body gives its velocity V, its power will be.

(a) Fv (b) F/v

(c) Fv^2 (d) F/v^2

(v) Two particles of masses 1g and 4g have equal kinetic energies. what is the ratio between their velocity?

(a) 1:4 (b) 1:8

(c) 1:2 (d) 1:16

(vi) Moon revolves around the earth due to gravitational force (F) of earth on moon. The work done by the gravitational force is (r=radius of circular orbit of moon).

(a) $F.2\pi r$ (b) $F.\pi r$

(c) Zero (d) negative work

II. Fill in the blanks :

(i) A 20 Kg. mass object is being lifted through a height of __________m when 784 J of work is done on it.

(ii) In a heat engine, heat energy is converted into ___________

(iii) If the velocity of a body is tripled, then the K.E. of the body becomes _________ times that its initial values.

(iv) If a proton and an electron are brought towards each other, the _________ will decrease.

VERY SHORT ANSWERS QUESTIONS

1. When we say the work is done?
2. Define 1 Joule of work.
3. Give an example in which a force does positive work.
4. Give an example in which a force does negative work.
5. Define the term energy of a body.
6. Write the units of : (a) Work, (b) Energy. (c) Power
7. Define power
8. Define 1 Watt energy
9. Define 1 Kilo Watt hour.
10. What are various energy transformations, that occurs when you hit a cricket ball?

SHORT ANSWERS QUESTIONS

1. What is conservation of energy ? Explain with an example.
2. What do you understand by kinetic energy ? Write its formula.
3. On what factors does the kinetic energy of a body depends ?
4. What happens to potential energy of a body when its height is doubled ?
5. How many joules are there in 1 Kilowatt hour ?

LONG ANSWERS QUESTIONS

1. What are the quantities on which the amount of work done depend ? How are they related to work ?
2. A load of 100 kg is pulled up to 5 m. Calculate the work done. ($g = 10\ m/s^2$) (Ans. 5000 J)
3. A body of mass m is moving with a velocity 5 ms^{-1}. Its kinetic energy is 25 J. If its velocity is doubled, what is its kinetic energy ? (Ans. 100 J)
4. A boy weighing 50 kg climbs up a vertical height of 100 m. Calculate the amount of work done by him. How much potential energy he gains ? (Given $g = 9.8\ m/s^2$) (Ans. 4.9×10^4 J)
5. Five electric fans of 120 watts each are used for 4 hours. Calculate the electrical energy consumed in kilowatt hours. (Ans. 2.4 KWh)
6. The power of an electric heater is 1500 Watt. How much energy it consumes in 10 hours ? [Ans. 15 KWh (units)]
7. a) Justify law of conservation of energy with the help of a suitable activity or example.
   b) Give 3 examples where kinetic energy changed to potential energy?

III Assertion and reasoning Questions

Directions : In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Mark the correct choice as :

(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).

(b) Both assertion (A) and reason (R) are true but reason (R) is not correct explanation of assertion (A).

(c) Assertion (A) is true but reason (R) is false.

(d) Assertion (A) is false but reason (R) is true.

Q1. Assertion - As a ball falls downwards, potential energy keeps decreasing but kinetic energy keeps increasing.

Reason - Energy can neither be created nor be destroyed.

Ans. option (a)Law of conservation of energy implies that the sum of potential energy and kinetic energy of the ball remains same at every point during its fall.

Q2. Assertion - Work done by the gravitational force of a revolving satellite, around the Earth, in a circular motion is zero.

Reason - Force of gravitation acts on the satellite, opposite to the direction of motion of the satellite.

Ans . option (c) Force of gravitation acts on the satellite at right angles to the direction of motion of the satellite, therefore work done is zero therefore Assertion (A) is true but Reason (R) is false.