UNIT 05

Work, Energy and Power

Q1. Define and explain work. 09105001

WORK
- Definition of Work.
- Mathematical Form of Work.
- Cases of Work
- Unit of Work

YouTube **Online Lecture**

Ans: Work:

Force and distance are two essential elements of work. When a constant force acting on a body moves it through some distance, we say that the force has done work.

Definition:

Work is defined as the product of magnitude of force and the distance covered in the direction of force.

Explanation:

Consider a block of wood lying on a table (Fig 5.1). If we exert a force F on the block to move it through a distance S in the direction of force, then the work W done by the force is:

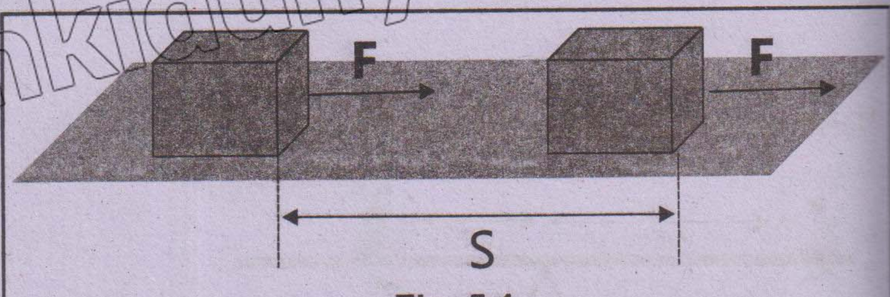


Fig. 5.1

Work = Magnitude of force × Distance

Or $W = F \times S$ .... (5.1)

Cases of Work:

i. From above expression it is clear that if some force is acting on a body but there is no displacement, then no work is done. For example, a man is pushing hard a wall but the wall remains fixed in its place. In this case, the man is doing no work.

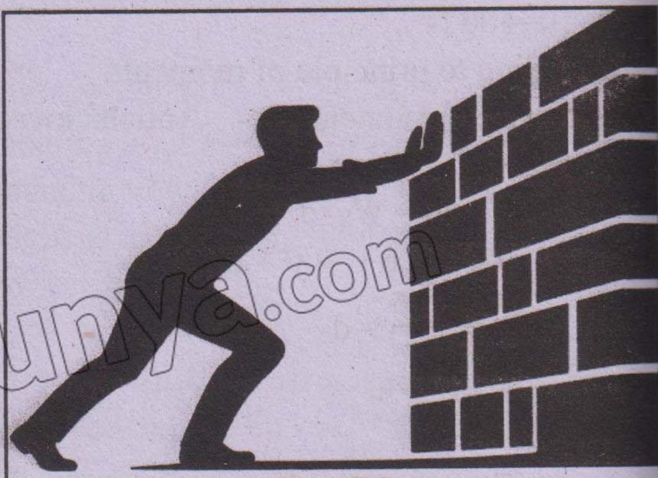


Fig. 5.2

ii. Similarly, if a force acting on the body is zero and the body is moving with uniform velocity, work will be zero.

As $F = 0$ so $W = 0 \times S = 0$

iii. If a force is acting on a body making an angle θ with the direction of motion. In this case, work is done due to the component of force which is acting along the direction of motion (Fig 5.3). Resolving the force F into its components, we have the component $F\cos\theta$ that acts in the direction of motion. Therefore,

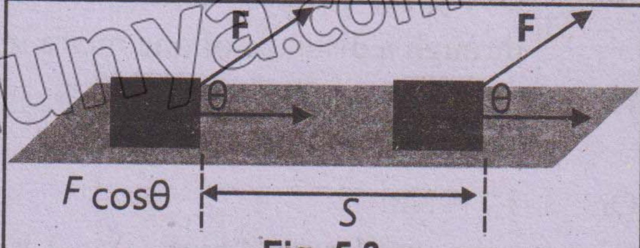


Fig. 5.3

$$W = (F\cos\theta)\,S$$

Or $$W = FS\cos\theta \quad \ldots\ldots\ldots (5.2)$$

Special cases:

i. If θ is zero, $\cos 0^\circ = 1$, then $W = FS\,(1) = FS$

This is the case when force and distance covered are in the same direction.

ii. If $\theta = 90^\circ$, then $\cos 90^\circ = 0$ which means the force has zero component in the direction of motion. Thus, $W = FS\,(0) = 0$

This is the case when force is perpendicular to the displacement. Look at (Fig. 5.4). It suggests that if a person carries a bag to some distance, this work is zero, because the force applied to hold the load is upward which is perpendicular to the displacement.

Fig. 5.4

Work done is a scaler quantity:

The work done to push an object is the same whether the object moves North to South or East to west, provided the magnitude of force and the distance moved are not changed. Work does not convey any directional information, so it is a scaler quantity.

Q.2. How work done is found by constant force applied graphically? Explain.

09105002

Ans: **<u>Calculation of Work Done by Graph:</u>**

When a constant force F acts through a distance S, the event can be plotted on a force-distance graph as shown in fig. 5.5. If the force and distance covered are in the same direction, the work done is F×S.

Clearly the shaded area in the figure is also F×S. Hence the area under a force distance curve can be taken to represent the work done by that force.

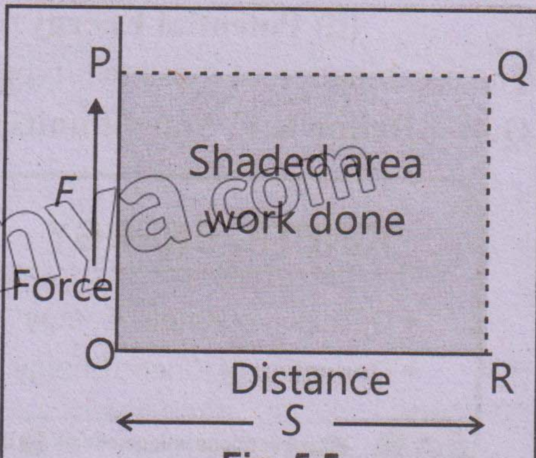


Fig. 5.5

Units of Work:

The SI unit of work is joule (J).

One joule work is done when a force of one newton acting on a body moves it through a distance of one metre in its own direction.

From Eq. (5.1)

$$1\ J = 1\ N \times 1\ m$$

Or $$1\ J = Nm$$

Bigger units are also used like $1\ kJ = 10^3 J$ and $1 MJ = 10^6 J$

Q.3. Define and Explain concept of energy. 09105003

Ans: <u>Energy:</u>

Our body cannot move unless we have energy from food. A car would not run without the energy it obtains from burning fuel. Machines in the factories cannot run without consuming energy supplied by electricity. Any change in motion requires energy. When we say that a certain body has energy, we mean that it has ability of doing work.

Definition:

Energy can be defined as the ability of a body to do work.

Explanation:

When someone does work, energy of the body has to be spent. In fact, energy is transferred from one system to another. For example, when you do work pushing a swing, chemical energy in your body is transferred to the swing and appears as energy of the motion of the swing.

Nature of quantity:

Like work, energy is scaler quantity. Its SI unit is joule (J).
When one joule work is done on a body, the amount of energy spent is one joule.

Forms of Energy:

There are many forms of energy. Electrical energy, chemical energy, nuclear energy, heat energy and light energy are some well-known forms which we shall study later on.

Basic form of Energy:

There are two basic forms of energy:

(i) Kinetic Energy

(ii) Potential Energy

The combination of these two types of energies is called mechanical energy.

Q.4. Define K.E. State it units. Derive an expression for same. 09105004

Ans: Definition:

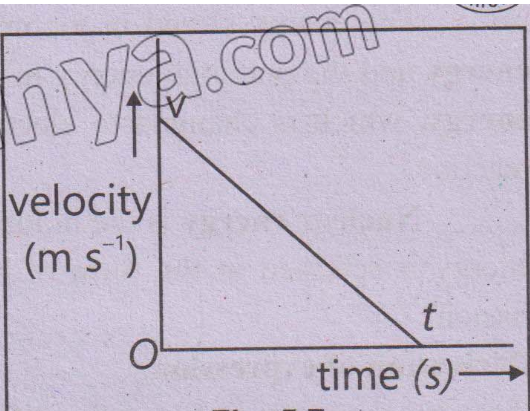


Fig. 5.7

The kinetic energy of a body is the energy that a body possesses by virtue of its motion.

Explanation:

To find out how much kinetic energy a moving body possesses, an opposite force can be applied on the body to stop its motion. Then the work done by the force will be equal to the kinetic energy of the body i.e. Kinetic energy (E_k) = Work done (W)

Suppose a body of mass m is moving with velocity v. An opposing force F is acting on the body through a distance S brings it to rest. Then,

E_k = work done = F×S

As from Newton's Law F = ma and $S = v_{av} \times time = (\frac{v+0}{2})t = \frac{v}{2} \times t$

Hence, $E_k = ma \times \frac{vt}{2} = \frac{1}{2} ma \times vt$

Using velocity-time graph, (Fig 5.7) the acceleration 'a' is given by its slope.

Hence, $a = \frac{v}{t}$, the slope is negative as the velocity and force are in opposite direction. (We take its magnitude positive.)

Thus $$E_k = \frac{1}{2} m(\frac{v}{t})vt$$

Or $$E_k = \frac{1}{2} m v^2 \quad \text{.........} (5.3)$$

Q.5. Define and Explain Potential Energy. Derive an Expression for gravitational P.E. **09105005**

Ans: <u>Potential Energy:</u>

Definition:

Potential energy is defined as the energy that a body possesses by virtue of its position or deformation.

Explanation:

In the previous section, we have seen that the work done on a body is used to increase its kinetic energy. Sometimes, the work done on a body does not increase its kinetic energy, rather it is stored in the body as **potential energy.**

Forms of Potential Energy:

There are many forms of potential energy. As mentioned above, the energy possessed by an object by virtue of its position relative to the Earth is known as **gravitational potential energy.**

The energy stored in a compressed or stretched spring is called **elastic potential energy** and the potential energy in the chemicals of a battery is called **chemical potential energy,** which is changed to electrical energy by chemical oil or gas through chemical reaction.

Nuclear energy is the hidden energy in the nuclei of atoms. When they are broken, energy is released in the form of heat and some other radiations. This is called nuclear fission.

Derivation of expression:

If the block shown in Fig. 5.8 is lifted to a height h above the ground, then the block would have potential energy in that raised position. Therefore, it has the ability to that work whenever it is allowed to fall. The potential energy is measured by work done on the block. Thus, **potential energy** E_p is given by

E_p = Work done to put the block in elevated position

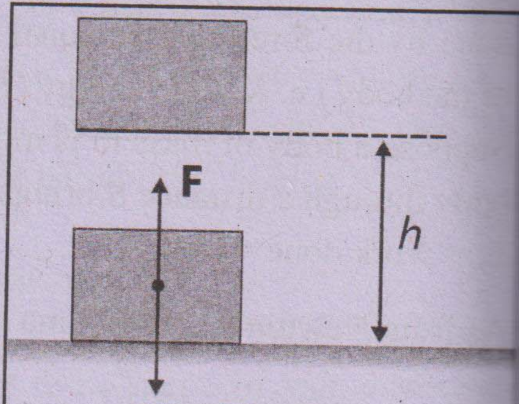


Fig. 5.8

The applied force necessary to lift the block with constant velocity is equal to weight w of the block and since w = mg, therefore, potential energy of the block at height h becomes,

$$E_p = wh$$

Or

$$E_p = mgh \quad \ldots\ldots\ldots\ldots (5.4)$$

Example:

The most obvious example of gravitational potential energy is a waterfall (Fig. 5.9), water at the top of the fall has potential energy. When the water falls to the bottom, it can be used to run turbines to produce electricity and thus can do work. (remains constant)

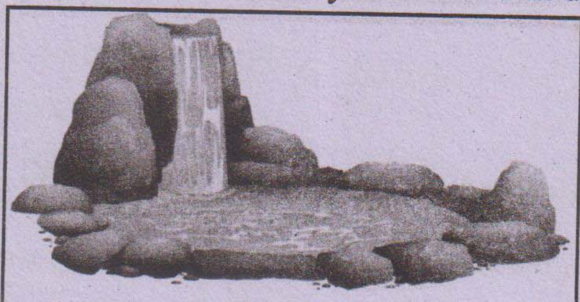


Fig. 5.9

Q.6. State the law of conservation of energy. Explain it with the help of an example of a body falling from certain height in terms of its potential energy and kinetic energy.

09105006

Ans: <u>Conservation of energy:</u>

The study of various forms of energy and the transformation of one kind of energy into another has led to a very important principle known as the principle of conservation of energy. Formally, it is stated as:

Statement:

Energy cannot be created or destroyed. It may be transformed from one form to another, but the total amount of energy never changes.

Explanation:

During energy transfer process, some energy seems to be lost and not accounted for in calculation. This loss of energy is due to work done against friction of the moving parts in the process. This energy appears as heat and is dissipated in the environment. This energy does not remain available for doing some useful work and may be called waste energy.

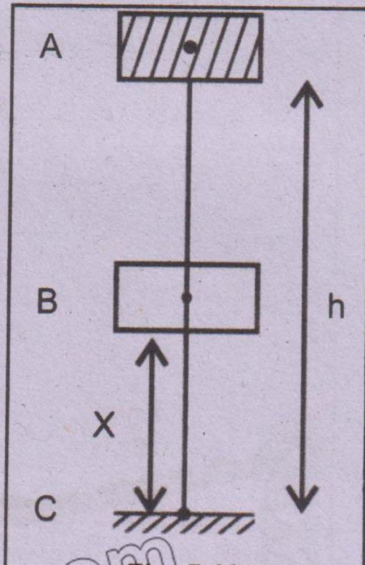


Fig. 5.10

A process of energy conversion and conservation can be described with the given example.

Let a body of mass m be at rest at a point A above the height h from the ground (Fig 5.10). Its total energy is P.E is mgh,

$$E_p = mgh$$

and $$E_k = 0$$

Then the body is allowed to drop to point B at a height 'x' from the ground. The body lose potential energy and gains kinetic energy as it gets speed while falling down. Assuming air resistance negligible.

$$E_p = mg(h - x)$$

The loss of potential energy will appear as the gain in kinetic energy, hence, at point B

$$E_k = mgx$$

Total energy at B $$E_k = mg(h - x) + mgx = mgh$$

Just before hitting the ground at point C, the whole of potential energy is changed into kinetic energy. Thus,

$$E_p = 0 \quad \text{and} \quad E_k = mgh$$

Thus, total energy remains the same as mgh. On hitting the ground, this energy is dissipated as heat and sound in the environment.

Q.7. Describe very briefly different sources of energy. 09105007

Ans: (i) Fossil Fuel Energy:

Fossil fuel energy comes out from burning of oil, coal and natural gas. These materials are known as fossil fuels.

Explanation:

The burning of these fuels gives out heat which is used to generate steam that runs the turbines to produce electricity. A block diagram of the process going on in electricity generation by fossil fuels is give in Fig. 5.11.

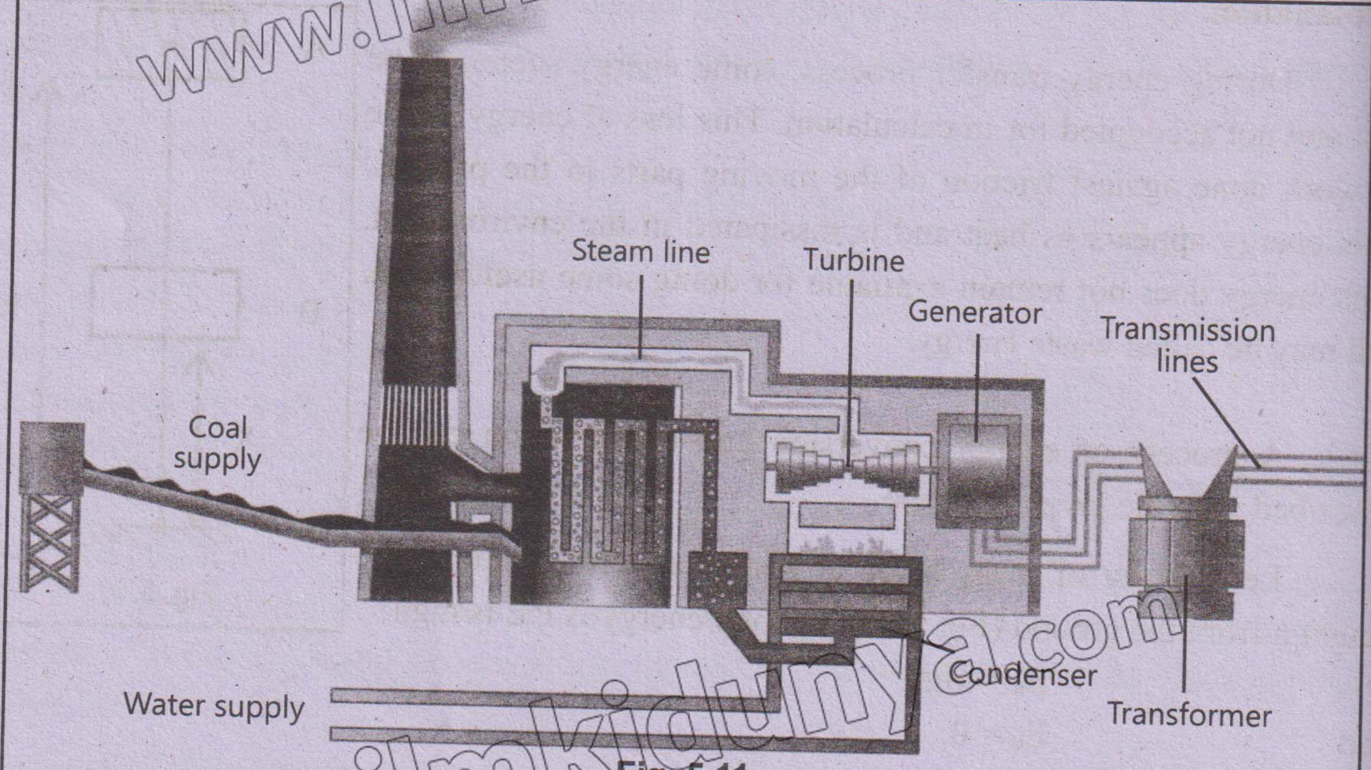


Fig. 5.11

(ii) Hydraulic Generation:

Hydraulic generation is the electricity generated from the power of falling water.

Explanation:

Water in a high lake or reservoir possesses gravitational potential energy stored in it. When water is allowed to fall from height, the potential energy is changed into kinetic energy (Fig. 5.12). Tunnels are made for water to flow from the reservoir to a lower place. Such a construction is known as dam.

The kinetic energy of running water rotates the turbine which in turn runs the electric generator.

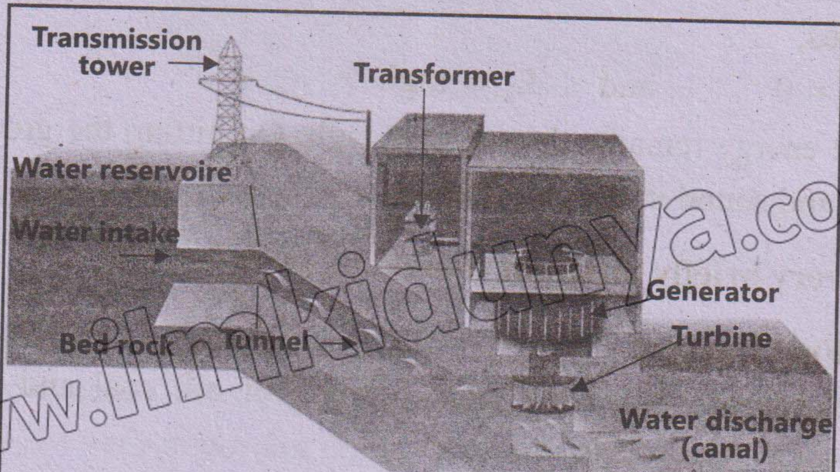


Fig. 5.12

(iii) Solar Energy:

Sun is the biggest source of energy. The energy obtained from sunlight is referred to as solar energy.

Explanation:

Solar energy can be used in two ways either it can be used for heating system or can be converted to electricity.

i. In one way, solar panels absorb heat of the Sun. They consist of large metal plates which are painted black (Fig. 5.13). Heat can be used for warming houses or running water heating system. If solar radiation is concentrated to a small surface area by using large reflectors or lenses, reasonably high temperature can be achieved.

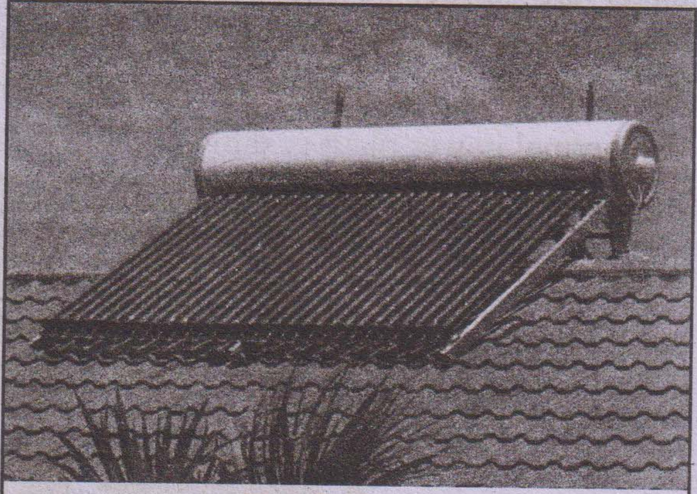


Fig. 5.13

Solar panels installed on the roof

At this high temperature, water can boil to produce steam that can run the turbine of an electric generator. In this way, electricity can be produced.

ii. In the second method, sunlight is directly transformed to electricity through the use of solar cells. Solar cells are also known as photo voltaic cells. The voltage produced by a single voltaic cell is very low. In order to get sufficient high voltage for practical use, a large number of such cells are connected in series to form a solar cell panel as shown in Fig. 5.14

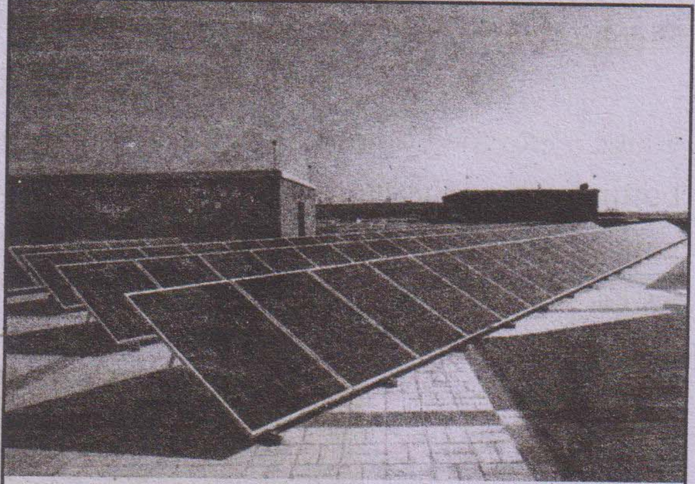


Fig. 5.14

Solar cells panels

Solar calculators are also available which work by using the electrical energy provided by solar cells. Large solar panels are also used to power satellites.

(iv) Nuclear Energy:

Nuclear energy is released in the form of heat when an atomic nucleus breaks. Nuclear power stations make use of nuclear fuels such as uranium and plutonium.

Explanation:

These materials release huge amount of energy as the nuclei of their atoms break during nuclear fission. The process is done in a nuclear reactor. Heat produced by the fuel is used to make steam that runs the turbines of electric generators. Pakistan also runs nuclear power stations at Karachi and Chashma.

(v) Geothermal Energy:

In some parts of the world, hot rocks are present in the semi molten form deep under the surface of the Earth. They are heated by energy released due to decay of radioactive elements. The temperature of these rocks is about 250ºC. This energy is known as geothermal energy which can be extracted to run electric generators. A typical geothermal power plant is shown in Fig. 5.15.

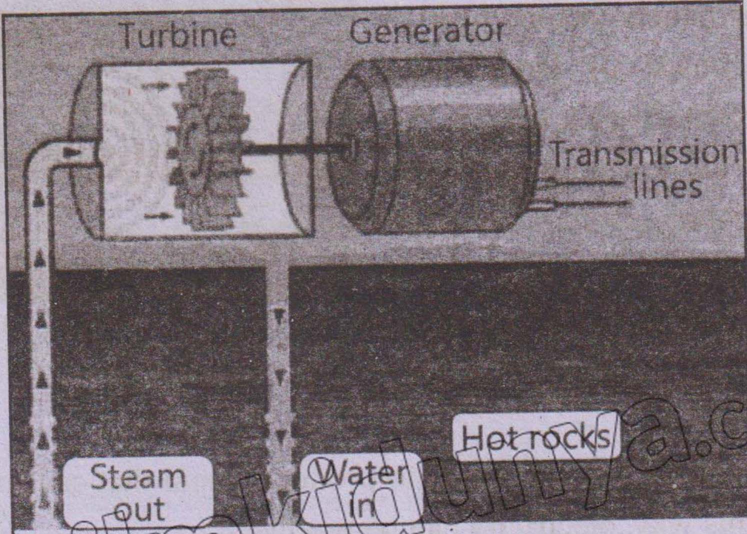


Fig. 5.15

Mechanism:

To make use of the heat of the rocks, two holes are drilled up to the rocks. Cold water is pumped down through one of the holes. It is heated up by the hot rocks and starts boiling. Steam is produced that comes out through the other hole. The steam runs the generator which produces electricity. Where there is water already present over the hot rocks, it comes out of the surface of the Earth in the form of hot springs and geysers. Such a geyser is shown in fig. 5.16.

Fig. 5.16

(vi) Wind Energy:

For thousands of year, people have been using windmills to draw water from the well or to grind grains into flour. The modern windmill used to run generators that produce electricity. Wind generator make electricity. Wind generators make electricity in the same way as steam generators in power stations. For large scale power generation, a 'wind farm' with a hundred or more windmills is needed. A windmills farm is shown in Fig. 5.17.

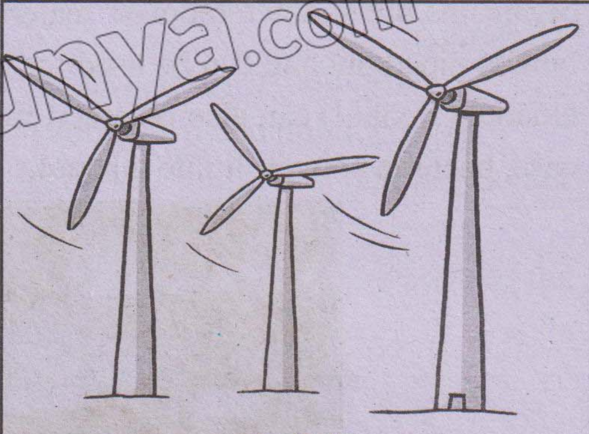


Fig. 5.17

(vii) Energy form Tides:

The gravitational force for the moon gives rise to tides in the seas. The tide raises the water level near the sea shore twice a day. The rise and fall of water can utilized to turn on turbine for electricity generation. The water at high tides can be trapped at a suitable location, a basin, by building a dam. The water is then released in a controlled way at low tide to drive the turbines for producing electricity. At next high tide, the dam is filled again and the incoming water also drives turbines.

(viii) Energy from Waves in Sea:

The tides and winds blowing over the surface of the sea produce strong water waves. Their energy can be used to generate electricity. The method to harness wave energy is to use large floats which move up and down with the waves. One such device invented by Prof. Salter is known as Salter's duck (Fig.5.18). It consists of two parts.

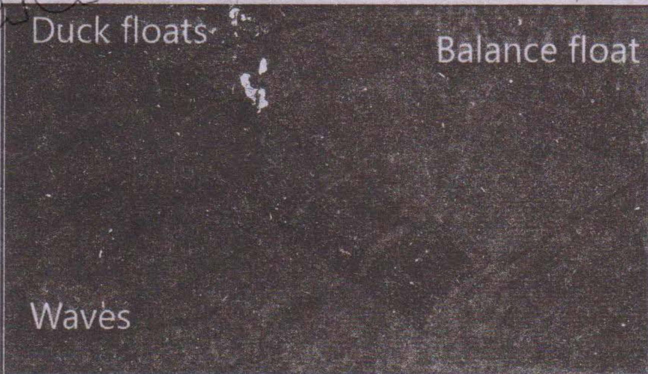


Fig. 5.18

(i) Duck Float **(ii) Balanced Float**

The energy of the water waves causes duck float to move relative to the balance float. The relative motion of the duck float is used to drive the electricity generator.

(ix) Biofuel Energy:

It is that energy which is obtained from the biomass. Biomass consists of organic materials such s plants, waste foods, animals dung, sewage, etc. Sewage is that dirt which is left over after staining dirty water. The material can itself be used as fuel or can be converted into other types of fuels Direct combustion is a method in which biomass, commonly known as solid waste, is burnt to boil water and produce steam. The steam can be sued to generate electricity. In another process, the rotting of biomass in a closed tank called a 'digester' produces methane rich biogas (Fig 5.19). In this process, microorganisms break down biomass material in the absence of oxygen. Biogas produced in the tank is piped out and can be used for heating and cooking like natural gas. Biofuel such as ethanol (alcohol) can also obtained from the biomass. It is a replacement of petrol. In this case, bacteria convert it into ethanol.

Fig. 5.19

Q.8. Differentiate between Renewable and Non-Renewable sources of energy with examples. 09105008

Ans: <u>Renewable Sources:</u>

The resources of energy which are replaced by new ones after their use are called renewable energy sources. On the other hand, non-renewable sources are those which are depleted with the continuous use. Once they run out. They are not easily replaced by new ones. Sources such as **hydroelectricity, solar energy, wind energy, tidal energy, wave energy and geothermal energy** are renewable. These are replaced by new ones. For examples, snow fall and rain fall are continuous processes. Therefore, water supply to the reservoirs of dams for generation of hydroelectric power will never end up. Likewise, solar energy will remain available forever. Same is the case with wind and tidal energy. These are not going to run out in future.

Non- Renewable Sources:

Non-renewable sources include **fossil fuels** and **nuclear energy**. The remnants of plants and animals buried under the Earth took millions of years to change into fossil fuels. These fuels are in limited quantity. Once they are used up, it will take further millions of years to form new ones. Similarly, fuel for the nuclear energy are also limited.

As the need for energy is increasing day by day, there is need to develop other non-traditional renewable energy sources.

Q.9. Define Advantages and Disadvantages of method of energy production. 09105009

Ans: The Advantages and Disadvantages of methods of Energy production:

(i) The production of hydroelectric power is more economical and pollution free.

(ii) The solar power, wind, tidal and wave power need more initial cost but they do not produce pollution and are also economical as well.

(iii) On the other hand, power generation by fossil fuels and nuclear fuel adds to the pollution of environment. Burning of fossil fuels produces smoke, carbon dioxide gas and heat (Fig. 5.20). They enhance direct pollution to atmosphere.

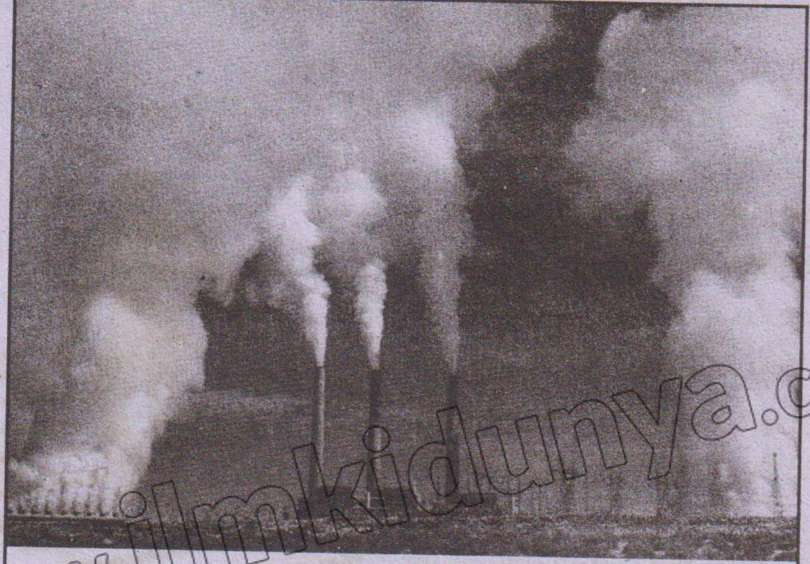


Fig. 5.20

(iv) Wind-mills are very noisy. Some people think that wind turbines spoil the beauty of landscape.

(v) Nuclear power generators are also run by steam produced by nuclear heat energy. Heat itself is a form of pollution. Moreover, there is always danger of leakage of the radioactive radiation which is harmful to living bodies. People living around nuclear plants are always at risk. The disposal of nuclear waste is energy ends up as thermal energy that goes to the environment. Thus, thermal pollution is increasing day by day causing global warming.

Q.10. Define and Explain Power and its unit. 09105010

Ans: Definition:

Power is defined as the time rate of doing work.

Mathematically,

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

If W is the work done in time t, then

$$P = \frac{W}{t} \quad \ldots\ldots(5.5)$$

Power of any agency can also be defined as energy transferred per unit time.

Units of Power:

Since both work and time are scalar quantities, so according to Eq. (5.5) power is also a scalar quantity. The SI unit of power is watt (W).

One watt is the work done at the rate of one joule per second.

$$1\ \text{W} = \frac{1\text{J}}{1\text{s}} \quad \text{or} \quad 1\text{Js}^{-1}$$

Bigger Units of power are:

$$1\ \text{kW} = 10^3\,\text{W}$$

$$1\text{MW} = 10^6\,\text{W}$$

In British engineering system, the unit of power used is horse-power (hp). The horse power is defined as

$$1\ \text{hp} = 746\ \text{W}$$

Explanation:

In many cases, the time to do work is as important as the amount of work done. Suppose you walk up to a height 'h' through upstairs (Fig. 5.21). You do work, because you are lifting your body up the stairs. If you run up, you can reach the same height in a shorter time interval.

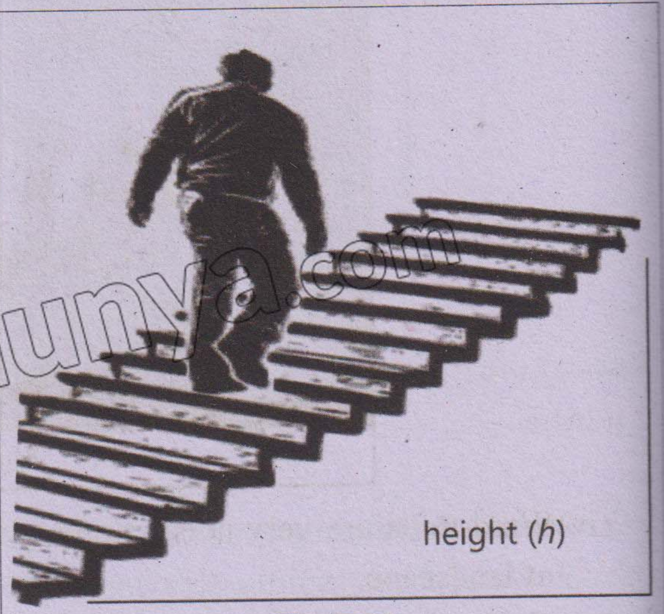


Fig. 5.21

The work done is the same in either case, because the net result is that you lifted up the same weight w to the same height h. But you know that if you run up the stairs, you would be more tired than you walked up slowly. In fact, there is a difference in the rate at which work is done. We say that you expend more energy when you go up the stairs rapidly than when you go slowly.

The concept of power can also be explained with another example of an electric motor or a water pump. A bigger motor draws more water during the same interval of time as compared to a smaller one. It is said that the power of bigger motor is greater than that of smaller one.

Q.11. Explain what is meant by efficiency of a machine? How is it calculated? Why efficiency of a machine is less than 100%? **09105011**

Ans: Definition:

The efficiency of a system is defined as:

The ratio of useful output energy and the total input energy is called the efficiency of a working system.

Or
$$\text{Efficiency}\ (\eta) = \frac{\text{Useful output energy}}{\text{Total input energy}}$$

%age efficiency:

Efficiency is often multiplied by 100 to give percentage efficiency. Thus,

$$\text{Percentage Efficiency} = \frac{\text{Useful output energy}}{\text{Total input energy}} \times 100$$

It can also be given as:

$$\text{Percentage Efficiency} = \frac{\text{Useful power output}}{\text{Total power input}} \times 100 \quad \text{.....(5.6)}$$

Efficiency is less than 100%:

It is found that the energy output is always less than the energy input. During any conversion of energy, some energy is wasted in the form of heat. NO device has yet been invented that may convert all the input energy into required output. That is why a system cannot have an efficiency of 100 %. As the energy loses are inevitable in the working of a machine, hence, an ideal or perpetual machine cannot be constructed.

Efficiency:

- The efficiency of a working system tells us what part of the energy can be converted into the required useful form of energy and what part wasted out of the energy available.
- The available energy for conversion is usually called the input energy and the energy converted into the required form is known as the output energy

Q.12. What is meant by Perpetual Energy Machine? Explain Briefly. 09105012

Ans It is a hypothetical machine that can do work indefinitely, without any external source of energy. A perpetual machine would have to generate more energy than it consumes, effectively producing energy from nothing, which is impossible. In any real mechanical system, some energy is always lost as heat due to friction between moving parts and air resistance etc. Thus, making it impossible for a machine to keep moving without an external source of energy. Infact, it is a consequence of the principle of conservation of energy that I perpetual energy machine is not workable.

Examples

Example 5.1 09105013

A person does 200 J of work in pushing a carton through a distance of 5 metres. How much force is applied by him?

Solution:

Work done W = 200 J

Distance S = 5m

Force F =?

From eq. $W = F \times S$ or $F = \frac{W}{S}$

Putting the values, we get

$$F = \frac{200J}{5m} = 40\text{ N}$$

Hence, force applied by person is 40 N.

Example 5.2 09105014

Find the work done by a 65 N force in pulling the suitcase (Fig. 5.6) for distance of 20 metres.

Solution

Force F = 65 N

Distance covered S = 20 m

Angle from the figure $\theta = 30^o$

Work W done = ?

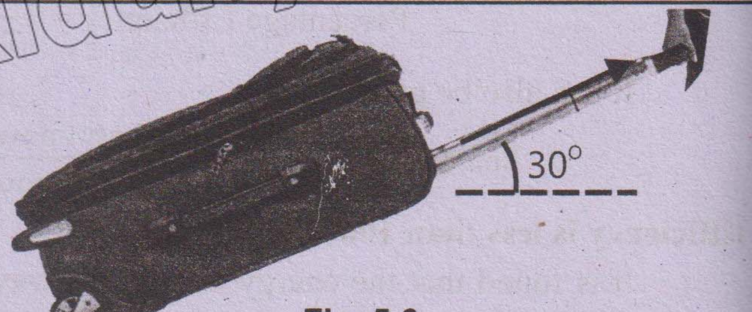


Fig. 5.6

Using eq.,

$$W = FS \cos 30^o$$

$$W = 65\ N \times 20\ m \times 0.866$$

$$W = 1125.8\ Nm$$

$$W = 1125.8\ J$$

Thus, the work done is 1125.8 J.

Example 5.3 09105015

A truck of mass 3000 kg is moving on a road with uniform velocity of 54 km h^{-1}. Determine its kinetic energy.

Given data:

Mass of the truck m = 3000kg

Velocity $v = 54\ kmh^{-1} = 15\ ms^{-1}$

To Find:

Kinetic Energy E_k = ?

Solution:

Putting the values,

$$E_k = \frac{1}{2} m v^2 = \frac{1}{2} \times 3000kg \times (15)^2\ m^2s^{-2}$$

$$E_k = 337500\ J = 337.5\ kJ$$

Thus, E_k is 337.6 kJ.

Example 5.4 09105016

A ball of mass 180g was thrown vertically upward to a height of 12 m. Find the potential energy gained by the ball.

Given data:

Mass of ball m = 180g = 0.18 kg

Height h = 12m

To find:

P.E gained E_p =?

Solution:

$g = 10\ ms^{-2}$

From eq. (5.4) $E_p = mgh$

Putting the values

$E_p = 0.18\ kg\ \times 10ms^{-2}\ \times 12m = 21.6\ J$

Hence, potential energy is 21.6 J.

Example 5.5 09105017

A 1000 kg car moving with an acceleration of 4 ms^{-2} covers a distance of 50 m in 4 seconds. What is the power generated by its engine?

Solution:

Mass of car $m = 1000kg$

Acceleration $a = 4\ ms^{-2}$

Distance $S = 50m$

Time taken $t = 5\ s$

Power $P = ?$

First, we shal determine the force applied by Newton's second law.

$$F = ma = 1000\ kg \times 4ms^{-2} = 4000N$$

From Eq. Work, $W = FS$

Or $W = 4000\ N \times 50\ m = 2.0 \times 10^5 J$

From Eq. $P = \frac{W}{t}$

Putting the values of W and t, we have

$$P = 2.0 \times \frac{10^5 J}{5s} = 4\ \times 10^4\ kW$$

$$P = 40\ kW$$

Thus, the power is 40 kW.

Example 5.6 09105018

A block weighing 120 N is dragged up a slope with a force of 100N to lift it up a height of 10m. If the slope is 20 m long, calculate the efficiency of the system.

Solution:

Weight of block $W = 120\ N$

Force applied $F = 100\ N$

Distance $S = 20\ m$

Height $h = 10\ m$

% Efficiency $=?$

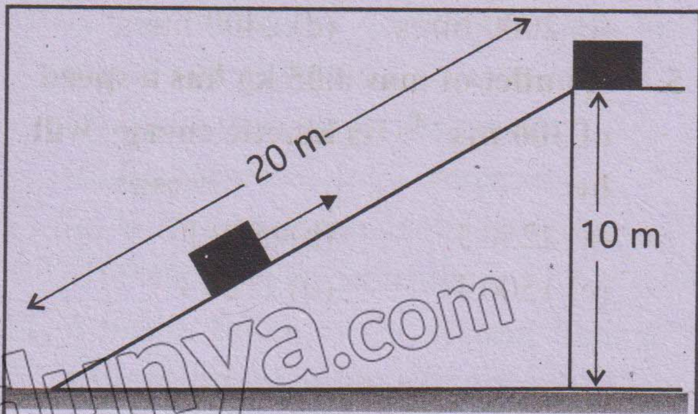


Fig. 5.22

Work done to lift the block up is:

$$W = F \times S = 100\ N \times 20\ m = 2000\ J$$

Now, total input energy = work done on the block = 2000 J

Useful output energy = Gravitational potential energy gained = wh

$= 120\ N \times 10\ m = 1200\ J$

$$\text{Percentage efficiency} = \frac{\text{Useful output energy}}{\text{Total input energy}} \times 100$$

$$= \frac{1200\ J}{2000\ J} \times 100 = 60\%$$

Hence, the percentage efficiency of the system is 60%.

Exercise

(A) Multiple Choice Questions (Exercise)

1. **Work done is maximum when the angle between the force F and the displacement d is:** 09105019
   (a) 0^o (b) 30^o
   (c) 60^o (d) 90^o

2. **A joule can also be written as:** 09105020
   (a) $kgms^{-2}$ (b) $kgms^{-1}$
   (c) kgm^2s^{-3} (d) kgm^2s^{-2}

3. **The SI unit of power is:** 09105021
   (a) Joule (b) newton
   (c) watt (d) second

4. **The power of a water pump is 2 kW. The amount of water it can raise in one minute to a height of 5 meter is:** 09105022
   (a) 1000 litres (b) 1200 litres
   (c) 2000 litres (d) 2400 litres

5. **A bullet of mas 0.05 kg has a speed of 300 ms^{-1}. Its kinetic energy will be:** 09105023
   (a) 2250 J (b) 4500 J
   (c) 1500 J (d) 1125 J

6. **If a car doubles its speed, its kinetic energy will be:** 09105024
   (a) the same
   (b) doubled
   (c) increased to three times
   (d) increased to four times

7. **The energy possessed by a body by virtue of its position is:** 09105025
   (a) kinetic energy
   (b) potential energy
   (c) chemical energy
   (d) solar energy

8. **The magnitude of momentum of an object is doubled, the kinetic energy of the object will:** 09105026
   (a) double
   (b) increase to four times
   (c) reduce to one-half
   (d) remain the same

9. **Which of the following is not renewable energy source?** 09105027
   (a) Hydroelectric energy
   (b) Fossil fuels
   (c) Wind energy
   (d) Solar energy

Answer Key

1.	(a)	2.	(d)	3.	(c)	4.	(d)	5.	(a)
6.	(d)	7.	(b)	8.	(b)	9.	(b)		

SLO based Additional MCQs

Work

1. The unit of work or energy joule (J) is equal to __________. 09105028

(a) horsepower
(b) watt metre
(c) newton metre
(d) newton second

Kinetic Energy

2. A car, an elephant and a cricket ball have same kinetic energies. Which of these have greater speed? 09105029

(a) car
(b) Elephant
(c) Cricket ball
(d) all have same speed

3. A heavy and a lighter object have same momentum. The object with greater kinetic energy is: 09105030

(a) lighter
(b) heavy
(c) same kinetic energy
(d) either (a) or (b)

Potential Energy

4. A ball weighing 50 N is lifted to a height of 5 metre. The potential energy stored in it is: 09105031

(a) 250 J (b) 25 J
(c) 45 J (d) 55 J

5. A weight lifter of power 1960 watt lifts a load of mass 'M' from the ground to a height of 2m in 3 second. 'M' is: 09105032

(a) 100 kg
(b) 200 kg
(c) 300 kg
(d) 400 kg

Power

6. What is the power utilized when 100 J of work is done in 5 s: 09105033

(a) 10 W (b) 20 W
(c) 105 W (d) 500 W

7. The SI unit of power: 09105034

(a) Joule (b) watt
(c) newton (d) erg

8. One unit of horsepower is equivalent to: 09105035

(a) 756 W (b) 716 W
(c) 736 W (d) 746 W

Law of Conservation of Energy

9. A 4 kg body is thrown vertically upward from the ground with a velocity of 5 ms^{-1}. If friction is neglected its kinetic energy just before hitting the ground is: 09105036

(a) 25 J (b) 50 J
(c) 75 J (d) 100 J

10. A ball is thrown downward with an initial velocity, its: 09105037

(a) E_K increases& E_p decreases
(b) E_K decreases & E_p increases
(c) Both E_K& E_p increases
(d) Both E_K& E_p decreases

11. A box is taken to the second floor of a building by doing some work. This work converts to: 09105038

(a) kinetic energy
(b) potential energy
(c) heat energy
(d) sound energy

Geothermal Energy

12. The type of energy derived from heated ground water is: 09105039

(a) tidal energy

(b) geothermal energy

(c) hydroelectric energy

(d) nuclear energy

Renewable Source of Energy

13. Which one is renewable source of: 09105040

(a) Coal (b) Natural gas

(c) Sunlight (d) Uranium

Efficiency

14. A practical engine cannot have an efficiency equal to: 09105041

(a) 0

(b) 0.5

(c) 0.8

(d) 1

Cases of Work

15. A force is acting on body but causes no displacement. The work done on the body is: 09105042

(a) positive (b) negative

(c)zero (d) infinite

Answer Key

1.	(c)	2.	(c)	3.	(a)	4.	(b)	5.	(c)
6.	(b)	7.	(b)	8.	(d)	9.	(b)	10.	(a)
11.	(b)	12.	(b)	13.	(c)	14.	(d)	15	(c)

(B) Short Questions (Exercise)

5.1 What is work done on an object that remains at rest when a force is applied on it? 09105043

Ans: $W = FS$

As $S = 0$, for body at rest

So $W = F \times 0$

$W = 0$

Hence, work done on object that remains at rest when a force is applied is zero.

5.2 A slow- moving car may have more kinetic energy than a fast-moving motorcycle. How is this possible? 09105044

Ans: The K.E of moving body is given by the expression

$$K.E = \frac{1}{2}mv^2$$

It means that K.E of body moving with same velocity depends upon mass of the body. Greater is the mass, more is K.E and vice-versa.

Hence, K.E of car is greater as compared to motor cycle due to larger mass of car.

5.3 A force F_1 does 5 J of work in 10s. Another force F_2 does 3 J of work in 5s. Which force delivers greater power? 09105045

Ans: The power is calculated by formula:

$$P = \frac{w}{t}$$

So, power of both forces are:

$$P_1 = \frac{w_1}{t_1} = \frac{5}{10} = 0.5\text{watt}$$

$$P_2 = \frac{w_2}{t_2} = \frac{3}{5} = 0.6\text{watt}$$

Hence force F_2, will deliver greater power as clear from the above relations.

5.4 A woman runs up a flight of stairs. The gain in her gravitational potential energy is 4500 J. If she runs up the same stairs with twice the same speed, what will be her gain in potential energy? 09105046

Ans: The potential energy of an object is given by expression:

$$P.E = mgh$$

This expression shows potential energy is independent of speed of object, so if a women runs up the same stairs with double velocity, then there will be no change in gain her potential energy.

5.5 Define work and its SI units.

Ans: See Q No. 1 09105047

5.6 What is the potential energy of a body of mass m when it is raised through a height h? 09105048

Ans: See Q No. 5.

5.7 Find an expression for the kinetic energy of a moving body. 09105049

Ans: See QNo. 4.

5.8 Define efficiency of a working system. Why a system cannot have 100% efficiency? 09105050

Ans: See QNo. 11.

5.9 What is power? Define the unit used for it. 09105051

Ans: See Q No. 10.

5.10 Differentiate between renewable and non-renewable energy sources. 09105052

Ans: See Q No. 8.

SLO based Additional Short Questions

Energy

5.1 How does a stretched bow store energy and transfer it to the arrow? 09105053

Ans: A stretched bow stores potential energy in the form of elastic potential energy when the bowstring is pulled back. When the string is released, this stored potential energy is converted into kinetic energy, transferring to the arrow and propelling it forward. Some bows can store enough energy to shoot an arrow as far as 1 km away.

5.2 According to Einstein's theory of relativity, how are matter and energy related? 09105054

Ans: According to Einstein's theory of relativity matter and energy are interchangeable under certain conditions. The loss of some mass in nuclear reactions can transform into energy and similarly energy can be converted into material particles. This leads to the conservation of mass and energy rather than the conservation of each separately.

Sources of Energy

5.3 What are the benefits of geothermal energy? 09105055

Ans: One of the main benefits of geothermal energy is its low cost for heating. It is significantly cheaper than burning oil to power electric heaters. For example, in Iceland, more than 85% of people use geothermal energy to warm their homes, and the cost of heating is only one-third of the cost of using oil. Geothermal energy is also used in countries like Japan, Russia, Italy, New Zealand, and the USA.

5.4 What were the effects of the 1986 Chernobyl nuclear accident? 09105056

Ans: The radioactive fallout from the 1986 Chernobyl nuclear accident in Russia affected people, livestock, and crops. Although only 31 people died from direct exposure, about 600,000 people were significantly exposed to the fallout.

5.5 What are the economic social and environmental impacts of various energy sources? 09105057

Answer: Fossil fuels are expensive and cause pollution that harms human health. Hydroelectric energy is the cheapest and pollution free but it may cause water logging by raising the water table. Solar wind and tidal energy are pollution free though they have high initial costs. Nuclear energy is cheaper and can easily meet growing energy demands.

Efficiency

5.6 What is an ideal machine? 09105058

Ans: An ideal machine is a machine with its output equal to input and efficiency of 100%.

(C) Constructed Response Questions

5.1 Can the kinetic energy of a body ever be negative? 09105059

Ans: The expression of K.E is given by:

$$K.E = \frac{1}{2}mv^2$$

K.E can never be negative because it is calculated by squaring velocity, resulting in a positive value.

5.2 Which one has the greater kinetic energy; an object travelling with a velocity v or an object twice as heavy travelling with a velocity of ½ v? 09105060

Ans: Kinetic energy (KE) is given by:

$KE = (1/2)mv^2$

For the first object:

$KE_1 = (1/2)\, m_1 v_1^2$

For the second object:

$$= \frac{1}{2}(2m_1)\left(\frac{v_1}{2}\right)^2$$

$$v_2 = \frac{v_1}{2}$$

$$KE_2 = \frac{1}{2}(2m_1)\left(\frac{v_1}{2}\right)^2$$

$= (1/2)\, m_1 v_1^2$

Both objects have the same kinetic energy.

5.3 A car is moving along a curved road at constant speed. Does its kinetic energy change? 09105061

Ans: The formula for K.E is:

$$K.E = \frac{1}{2}mv^2$$

A car is moving on a curved road at constant speed has no change in it speed. So, it K.E will remain same.

5.4 Comment on the statement. "An object has one joule of potential energy." 09105062

Ans: The object is at rest and has the potential to do work but it is not currently doing any work. It means that an object having 1 J of potential energy can perform 1 J of work.

5.5 While driving on a motorway, tyre of a vehicle sometimes bursts. What may be its cause? 09105063

Ans: Tyre bursts on motorways are often caused by overheating, under inflation, tyre wear, road debris, excessive speed, and overloading.

5.6 While playing cricket on a street, the ball smashes a window pane. Describe the energy changes in this event. 09105064

Ans: The kinetic energy of cricket ball is transferred into sound energy, thermal energy, potential energy and deformation energy as it smashes the windowpanes.

5.7 A man rowing boat upstream is at rest with respect to the shore. Is he doing work? 09105065

Ans: $w = F s\cos\theta = F \times 0\cos\theta = 0$

When the man is at rest with respect to the shore of upstream, he is not doing any work because work can be calculated by formula.

$w = FS$

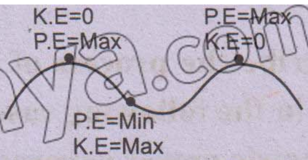
$w = F \times 0 = 0$

5.8 A cyclist goes downhill from the top of a steep hill without pedaling and takes it to the top of the next hill. 09105066

i. Draw a diagram of what happened.

ii. Analyse this event in terms of potential and kinetic energy. Label your diagram using these terms.

Ans:



Initial State (Top of First Hill)

- Potential Energy (PE) is maximum due to the cyclist's height.
- Kinetic Energy (KE) is zero since the cyclist is not moving.

Downhill Motion

- As the cyclist rolls downhill, PE decreases.
- KE increases as the cyclist gains speed.

Bottom of the Hill

- PE is minimum (near zero).
- KE is maximum due to the cyclist's speed.

Upward Motion (Next Hill)

- As the cyclist climbs the next hill, KE decreases.
- PE increases as the cyclist gains height.

Final State (Top of Next Hill)

- PE is maximum again.
- KE is zero since the cyclist stops at the top.

In this process, the total mechanical energy (PE + KE) remains conserved, but the forms of energy are converted from PE to KE and back to PE again.

5.9 Is timber or wood renewable source of heat energy? Comment. 09105067

Ans: Wood is a renewable energy source as trees can be replanted and regrown, maintaining a sustainable.

(D) Comprehensive Questions

5.1 What is meant by kinetic energy? State its unit. Describe how it is determined. 09105068

Ans: See Q No.4

5.2 State the law of conservation of energy. Explain it with the help of an determined. 09105069

Ans: See Q No.6

5.3 Differentiate between renewable and non-renewable sources of energy. Give three examples for each. 09105070

Ans: See Q No.8

5.4 Explain what is meant by efficiency of a machine. How it is calculated? Why there is a limit for the efficiency of a machine? 09105071

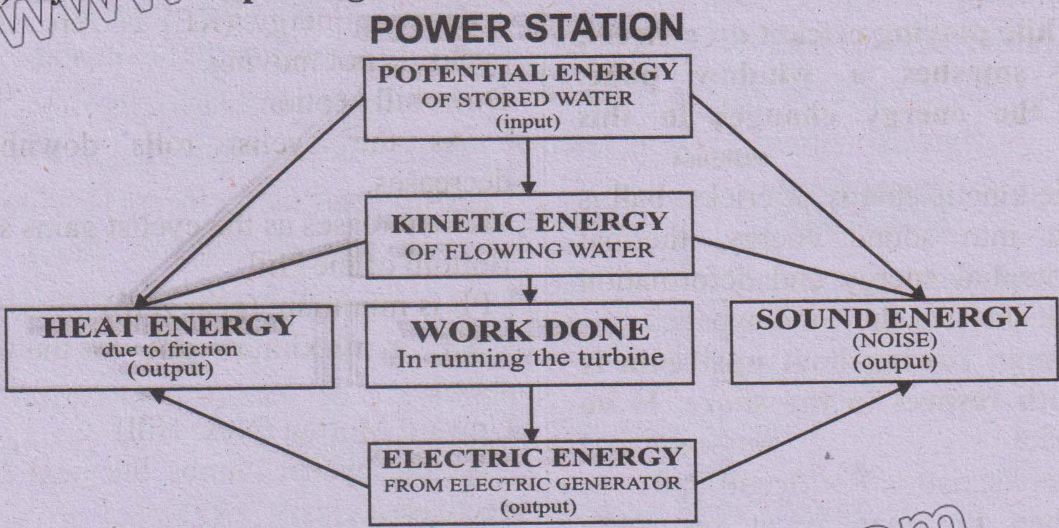
Ans: See Q No.11

5.5 Describe the process of electricity generation by drawing a block diagram of the process in the following cases. 09105072

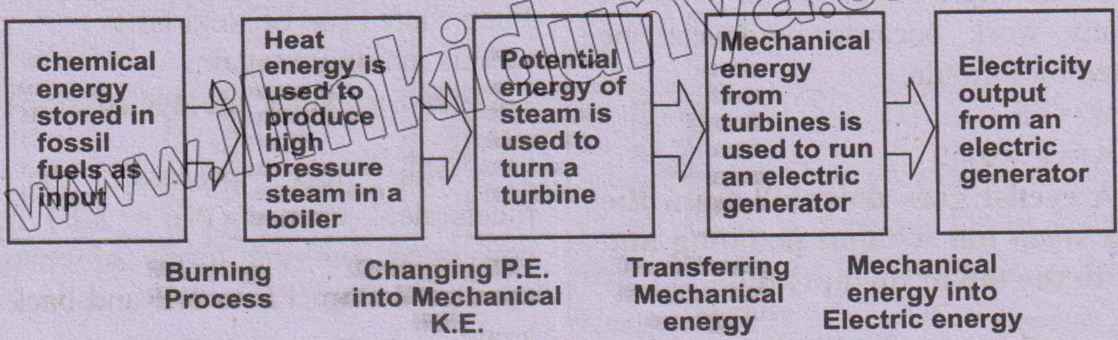
(i) Hydroelectric power generations

(ii) Fossil fuels

Ans: (i) Hydroelectric power generations



(ii) Electricity from fossil fuels:



Several energy conversion processes are involved in producing electricity.

(E) Numerical Problems

5.1 A force of 20 N acting at angle of 60° to the horizontal is used to pull a box through a distance of 3 m across a floor. How much work is done? 09105073

Solution:

Given Data:

Force F = 20 N

Angle θ = 60°

Distance S = 3 m

To Find:

Work w =?

As we know that

$$W = FS\cos\theta$$

Putting values, we have

$$W = 20\times3\times\cos60^\circ$$

$$W = 20\times3\times\frac{1}{2} = 30\text{J}$$

Result:

Thus work done by a force is 30 J.

5.2 A body moves a distance of 5 metres in a straight line under the action of a force of 8 N. IF the work done is 20 joules, find the angle which

the force makes with the direction of motion of the body. 09105074

Solution:

Given data:

Force F = 20 N

Distance S = 5m

Work done w = 20 J

To find:

Angle θ= ?

As we know that

$W = FS\cos\theta$

Put the values, we have

$20 = 8 \times 5 \times \cos\theta$

$20 = 40\cos\theta$

$\cos\theta = \frac{20}{40}$

$\theta = \cos^{-1}(\frac{1}{2})$

$\theta = 60^0$

Result:

Thus, the angle made by force with direction of motion is 60^0.

5.3 An engine raises 100kg of water through a height of 80 m in 25 s. What is the power of the engine? 09105075

Solution:

Given data:

Mass m = 100 kg

Height h = 80 m

Time t = 25 s

$g = 10ms^{-2}$

To find:

Power =?

We know that

$$p = \frac{work}{time}$$

$$p = \frac{mgh}{t}$$

$$= \frac{100\times 9.8\times 80}{25}$$

P = 3200 w

Result:

Thus, power of engine is 3200 watts.

5.4 A body of mass 20 kg is at rest. A 40 N force acts on it for 5 seconds. What is the kinetic energy of the body at the end of this time? 09105076

Solution:

Given data:

Mass m = 20 kg

Force F = 40 N

Time t = 5 s

To Find:

Kinetic energy E_K =?

We know that

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

First we find velocity by using

$$v_f = v_i + at$$

For velocity first calculate 'a' by

Equation F = ma

40= 20a

Or $a = \frac{40}{20} = 2m/s^2$

So, $v_f = v_i + at$

As $v_i = 0$ for body started from rest

$$v_f = 0+(2)(5)$$

$$v_f = 10m/s$$

$$E_K = \frac{1}{2}\times 20\times (10)^2$$

$$E_K = 1000J$$

Result:

Thus, kinetic energy of body at the end of time is 1000 Joule.

5.5 A ball of mass 160 g is thrown vertically upward. The ball reaches a height of 20m. Find the potential energy gained by the ball at this height.

09105077

Solution:

Given data:

Mass m = 160 g $= \frac{160}{1000} = 0.16kg$

Acceleration due to gravity g = 10 m/s^2

Height h = 20 m

To find:

Potential energy E_P =?

We know that

$E_P = mgh$

Put the values, we have

$E_P = 0.16 \times 10 \times 20 = 32J$

Result:

Thus, potential energy gained by the ball at the given height is 32 J.

5.6 A 0.14 kg ball is thrown vertically upward with an initial velocity of $35ms^{-1}$. Find the maximum height reached by the ball. 09105078

Solution:

Given data:

Mass m = 0.14 kg

Initial velocity $v_i = 35m/s$

Acceleration due to gravity $g = -10m/s^2$

Final velocity at maximum height $v_f = 0$

To Find:

Maximum height h =?

We know that

$v_f^2 - v_i^2 = 2gh$

$(0)^2 - (35)^2 = -2 \times 10 \times h$

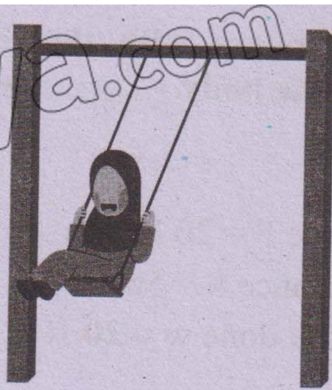
$35 \times 35 = 20h$

$h = \frac{1225}{20} = 61.25m$

Result:

Thus. The maximum height reached by the ball is 61.25m.

5.7 A girl is swinging on a swing. At the lowest point of her swing, she is 1.2 m from the ground, and at the highest point she is 2.0 m from the ground. What is her maximum velocity and where? 09105079



Solution:

To find the maximum velocity, we need to calculate the change in potential energy (PE) and then convert it to kinetic energy (KE).

Let's denote the height at the lowest point as

$$h_1 = 1.2 \text{ m}$$

and the height at the highest point as $h_2 = 2\ m$.

The change in potential energy (ΔPE) is given by:

$$\Delta E_P = m \times g \times (h_2 - h_1)$$

where m is the mass of the girl (which we don't need to know) and g is the acceleration due to gravity (approximately 9.8 m/s^2).

Since we want to find the maximum velocity, we'll assume that all the potential energy at the highest point is converted to kinetic energy at the lowest point.

$\Delta E_P = K_E$

$m \times g \times (h2 - h1) = (1/2) \times m \times v^2$

Now, we can cancel out the mass (m) and rearrange the equation to solve for velocity (v):

$v^2 = 2 \times g \times (h2 - h1)$

$v^2 = 2 \times 9.8\ m/s^2 \times (2\ m - 1.2\ m)$

$v^2 = 2 \times 9.8\ m/s^2 \times 0.8\ m$

$v^2 = 15.68\ m^2/s^2$

$v \approx \sqrt{15.68}\ m^2/s^2$

$v \approx 3.96\ m/s$

So, the maximum velocity is approximately 3.96 m/s.

5.8 A person pushes a lawn mower with a force of 50 N making an anlgeof 45°, through a distance of 20m how much work is done? 09105080

Given data:

Force F = 50 N

Angle θ = 45°

Distance S = 20m

To find:

Work done =?

Solution:

We know that

$w = FS \cos\theta$

putt the values

$w = 50 \times 20 \times 0.707$

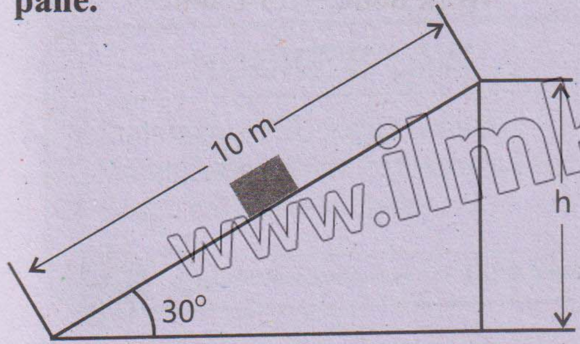
$w = 707$ J

Result: Thus, work done by person is 707 Joule.

5.9 Calculate the work done in: 09105081

i. **Pushing a 5 kg box up a frictionless inclined plane of 10 m long that makes an angle of 30^o with horizontal.**

ii. **Lifting the box vertically up from the ground to the top of the inclined pane.**



Solution:

To calculate the work done pushing the box up the inclined plane:

Force (F) = $m \times g \times \sin(\theta)$

$= 5 \text{ kg} \times 10 \text{ m/s}^2 \times \sin(30°)$

$= 5 \text{ kg} \times 10 \text{ m/s}^2 \times 0.5$

$= 25$ N

Work done (W) = $F \times d$

$= 25 \text{ N} \times 10 \text{ m}$

$= 250$ J

To calculate the work done lifting the box vertically:

Force (F) = $m \times g$

$= 5 \text{ kg} \times 10 \text{ m/s}^2$

$= 50$ N

Height (h) = $d \times \sin(\theta)$

$= 10 \text{ m} \times \sin(30°)$

$= 10 \text{ m} \times 0.5$

$= 5$ m

Work done (W) = $F \times h$

$= 50 \text{ N} \times 5 \text{ m}$

$= 250$ J

Interestingly, the work done in both cases is the same, 250 J.

5.10 A box of mass 10 kg is pushed up along a ramp 15 m long with force of 80 N. IF the box rises up a height of 5 m, what is the efficiency of the system? 09105082

Solution:

To calculate the efficiency of the system, we need to find the work done by the applied force and the work done against gravity.

Work done by applied force (W applied)

$= F \times d$

$= 80 \text{ N} \times 15 \text{ m}$

$= 1200$ J

Work done against gravity

$= m \times g \times h$

$= 10\text{ kg} \times 9.8\text{ m/s}^2 \times 5\text{ m}$

$= 490\text{ J}$

Efficiency (η) = (Work done against gravity) / (Work done by applied force)

$= W_{gravity} / W_{applied}$

$= 490\text{ J} / 1200\text{ J}$

$= 0.4083$ or 40.83%

So, the efficiency of the system is approximately 40.83%.

5.11 A force of 600 N acts on a box to push it 5m in 15 s. Calculate the power.
09105083

Given Data:

Force F = 600 N

Distance S = 5m

Time t = 15 s

To find:

Power P =?

Solution:

We know that

$$P = \frac{\text{work}}{\text{time}} = \frac{F.S}{t}$$

$$P = \frac{600 \times 5}{15}$$

P = 200 watt

Result:

Thus, power is 200 watts.

5.12 A 40 kg boy runs up-stair 10 m high in 8 s. What power he developed.
09105084

Given Data:

Mass m = 40 kg

Height h = 10m

Acceleration due to gravity $g = 10\text{m/s}^2$

Time t = 8s

To Find:

Power P =?

Solution:

We know that

$$P = \frac{\text{work}}{\text{time}} = \frac{mgh}{t}$$

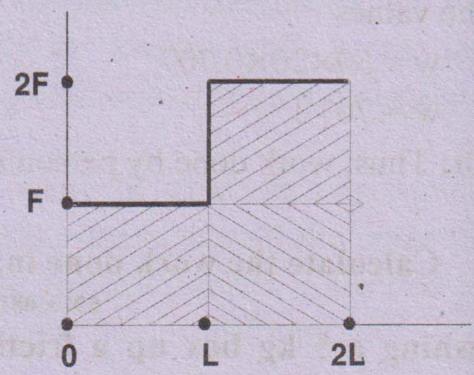
$$P = \frac{40 \times 10 \times 10}{8}$$

P = 500 watts

Result:

Thus, power is 500 watts.

5.13 A force F acts through a distance L on a body. The force in then increased to 2F that further acts through 2L. Sketch a force-displacement graph and calculate the total work done. **09105085**



Solution:

Work done = area under force displacement graph

Work done = F ×L + 2F ×2L

Work done = FL + 4 FL

Work done = 5 FL unit