5 CHAPTER

WORK, ENERGY AND POWER

INTRODUCTION

In our daily life work means "to do anything". But in science, work has specific meaning, i.e. when force is applied and some distance is covered. For example, a man carrying a physics book is doing work but he is not doing work if he is not moving while keeping the physics book on his head. Scientifically, work is done only when an effort or force moves an object. When work is done, energy is used. Thus, work and energy are related to each other. The concept of energy is an important concept in Physics. It helps us to explain the changes that occur when work is done This unit deals with the concepts of work, energy and power.

6.1 WORK

LONG QUESTIONS

Q.1 Define Work Derive its mathematical formula:

Ans: **WORK**

Definition:

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

Mathematically:

Work is equal to the product of force **F** and displacement **S** covered in the direction of force.

$$W = FS$$

Explanation:

Suppose a force **'F'** is acting on a body. It makes the body to move from point **'A'** to **'B'**. If the distance between these two points is **'S'** then we say that force has done some work as shown in the figure:

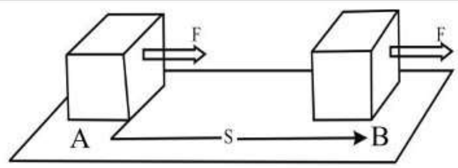


Figure: Work Done in Displacing a Body in the Direction of Force

If 'W' stands for work, 'F' for force and 'S' for distance.

Then,

$$\text{Work} = \text{Force} \times \text{Displacement}$$
$$W = FS$$

Unit of Work: **(LHR 2017)**

In System International, its unit is Nm that is also called as joule (J).

Joule:

"The amount of Work done is **one joule** if a force of **one newton** displaces a body through **one meter** in the **direction of the force."**

Thus,

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

Bigger Units:

Joule is a smaller unit of work. Commonly bigger units of work are also in use.

$$1 \text{ kilo joule (kJ)} = 1000\text{ J} = 10^3\text{J}$$
$$1 \text{ Mega Joule (MJ)} = 1000000\text{J} = 10^6\text{J}$$

Quantity:

Work is a scalar and derived quantity.

Conditions:

For work, the following two conditions must be fulfilled:

- A **force should** act on a body.
- The body should **cover some distance** under the action of this force in the direction of force.

Work Done on a Body When a Force Makes an Angle:

Sometimes force and displacement do not have same direction. Here the force **F** is making an angle **θ** with the surface on which the body is moved. Resolving **F** into its perpendicular components **'F_x'** and **'F_y'** as shown in the figure:

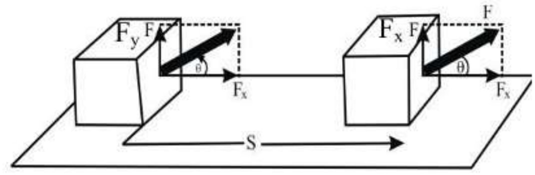


Figure: **Work Done by a Force Inclined with the Displacement**

$$F_x = F \cos\theta$$
$$F_y = F \sin\theta$$

In case when force and displacement are not parallel **the**n **x-component F_x** parallel to the surface causes the body to move on the surface and not **y-component F_y.**

Hence $W = F_x S$

$$W = (F\cos\theta) S$$
$$W = FS \cos\theta$$
$$\text{if } \theta = 0^\circ, \cos 0^\circ = 1$$
$$\text{then } W = FS(1)$$
$$W = FS$$

Zero Work:

If θ 90°, Cos 90° = 0

Then W = FS(0)

W = 0

If a person carries a bag to some distance then W = 0.

Negative Work:

If θ = 180°

Then Cos180 = -1

W = FS(-1)

W = - FS

Dependence:

Work depends upon following factors:

- **Force:** Greater the force greater will be the work done.
- **Displacement of The Body:** Greater the distance covered in the direction of the force greater will be the work done on the body.
- **Angle:** Work done also depends upon angle between force and displacement covered by the body.

Calculation of Work Done by Graph:

When a constant force *F* acts through a distance *S*, the event can be plotted on a force-distance graph as shown in Fig. 5.7. If the force and distance covered are in the same direction, the work done is $F \times S$. Clearly the shaded area in the figure is also $F \times S$. Hence the area under a force distance curve can be taken to represent the work done by that force.

SHORT QUESTIONS

Q.1 Define work.

Ans: **WORK**

Definition:

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

Mathematically:

When an object moves distance S in the direction of applied force F, then work done W is given mathematically as

Work done = Force × Displacement

$$W = F \times S$$

Q.2 Write condition for work to be done.

Ans: **CONDITION FOR WORK**

Condition:

For work the following two conditions must be fulfilled

- A force should act on a body.
- The body should cover some distance under the action of this force.

Q.3 A man is pushing the wall is he doing work? Explain

Ans: Work done (W) = force × displacement. Hence, work is said to be done when there is displacement. In this case the wall does not displace form its position even through the force is applied but displacement is zero, so work is said to be zero.

Q.4 A man is pushing the truck but truck is at rest, is he doing work? Explain.

Ans: A man is pushing the truck but turck is at rest because displacement is zero.

So, Work done is zero.

$$W = F \times S$$

$$W = F \times 0$$

$$W = 0J$$

MULTIPLE CHOICE QUESTIONS

18. Product of force and distance covered in the direction of force is

(A) Acceleration (B) resistance
(C) work (D) specific heat

19. Work is quantity:

(A) scalar (B) vector
(C) base (D) none of these

20. Unit of work is

(A) N (B) Nm
(C) J (D) both b & c

21. Work done well be zero if displacement and force are:

(A) parallel (B) perpendicular
(C) tangent (D) Normal

22. What will be magnitude of work if a force of 25N pushes a stone through a distance of 5 m in its direction:

(A) 25J (B) 50J
(C) 75J (D) 125J

23. The work done will be maximum when the angle between F & S is

(A) 0^o (B) 90^o
(C) 180^o (D) None of these

24. Work done against friction will be

(A) Zero (B) Negative
(C) Positive (D) All

5.3 ENERGY
KINETIC ENERGY
POTENTIAL ENERGY

LONG QUESTIONS

Q.1 Define kinetic energy and derive its relation.

Ans:

KINETIC ENERGY

Definition:

"The energy possessed by a body due to its motion is called Kinetic energy."

Formula:

It is denoted by K.E and its formula is given below:

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

Example:

- A moving bullet is able to do work by overcoming forces when it strikes something e.g. wood. Similarly kinetic energy in is felt during a collision.
- A football is kicked by a boy it moves because it possess Kinetic energy.

Explanation:

Consider a constant force 'F' is acting on an object of mass 'm' and as a result the object moves on a frictionless surface. The kinetic energy of an object will be equal to work done.

The work done on force-displacement graph can be calculated by finding area of figure under force-displacement graph.

Change in kinetic energy (E_k) = Work done = F.S

Work done = area under force displacement graph

Derivation:

The area under force displacement graph is the area of rectangle, thus:

Change in kinetic energy (E) = Area of rectangle = width × length = Fd

or

$$Ek = Fd$$

$$\text{Here } V_{ave} = \frac{V_i + V_f}{2}$$

As the speed is increasing its velocity from $V_i = 0$ to $V_f = V$, As, $F = ma$, $d = V_{av} \times t$

$$E_k = ma,\ V_{av} \times t \ \_\_\_\_\_\_\_(1)$$

therefore the average speed $\mathbf{V_{ave}}$ are is

therefore,

$$V_{ave} = \frac{0+V}{2} = \frac{v}{2} \ \ldots\ldots\ldots(2)$$

And acceleration can also be written as:

$$a = \frac{V}{t} \ \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Putting equation 2 and equation 3 in equation 1, we get

$$E_k = m\frac{v}{t}.\frac{1}{2}vt$$

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

100 g cricket ball moving with a speed of 2.0 m/s has a Kinetic energy of 0.2 J. Equally important, it demonstrate the work kinetic energy

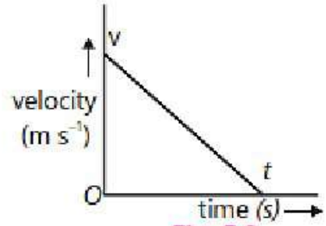


Fig. 5.9

Q.2 Define potential energy and derive its relation.

Ans:

POTENTIAL ENERGY

Definition:

"The energy possessed by a body by virtue of its position is called potential energy'."

Formula:

Potential energy is denoted by $E_{p.grav}$ and its formula is given below:

$$E_{p.grav} = mgh$$

Example:

Consider the work you do on a book when you lift from the floor and place it on the top shelf. The work you did on your book is now stored in the book by virtue of its position.

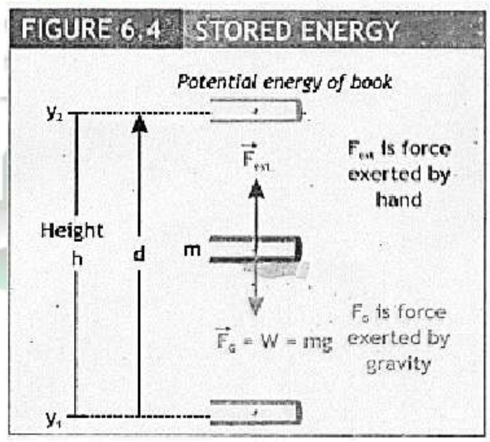
By doing work against the force of gravity, you have given your book a special form of potential energy.

Types of potential energy:

Elastic potential energy:

Definition:

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 reactions. Thermal or internal energy is released by burning fossil fuels i.e. coal, oil or gas through chemical reactions.



Example:

Doing work on an elastic spring by stretching it stores elastic potential energy in elastic spring, (slingshot, shock absorber, winding spring in toys and watches are all example of elastic potential energy).

Nuclear energy:

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.

Chemical potential energy:

Chemical potential contains both chemical and electrical potential energy stored in the food you eat. A battery during working of battery.

Gravitational potential energy:

The energy possessed by an object by virtue of its position relative to the Earth is known as **gravitational 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 potential energy every as gravitational. 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 reactions. Thermal or internal energy is released by burning fossil fuels i.e. coal, oil or gas through chemical reactions.

SHORT QUESTIONS

Q.1 Define energy and give its example.

ENERGY

Definition:

"Ability of a body to do work"

Example:

- A boy is pushing a toy car. The boy exerts a force on the toy car to move on floor. The work done on toy car is transfer of energy from boy to the toy car.
- A Sharpening a pencil by a child is due to energy transfer to the sharpener.
- Riding a bicycle is possible due to transfer of energy to bicycle by a person.

UNIT OF ENERGY

The unit of energy is the same as that of work i.e. Joule (J = N m)

Q.2 What is energy conversion and conservation:

Ans:

ENERGY CONVERSION AND CONSERVATION

Introduction:

Think of a book lying on a shelf. The book has gravitational potential energy when it is on the shelf. What happens if the book falls off the shelf? Its potential energy changes into kinetic energy. This change in energy from one form to another is conversion of energy. For example, consider the following examples

A. Generation of electricity:

Potential energy of water which is stored at a certain height is converted into kinetic energy by making it fall on turbine to produce electricity.

Law of conversation of energy:

Energy cannot be destroyed or created it is only converted from one form to the other. The law of conservation of energy states that,

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 calculations. 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.

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.5.12). Its total energy is P.E is mgh,

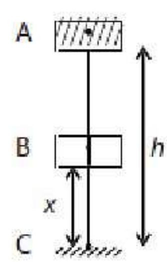


Fig. 5.12

Example:

$$E_p = mgh$$

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 $E = mg(h - x) + mgx = mgh$
Just before hitting the ground at point C, the whole of potential energy is changed into kinetic energy. Thus,

$$E_p = 0 \text{ and } E = mgh$$

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

5.4 SOURCES OF ENERGY

LONG QUESTIONS

Q.1 Write a note on sources of Energy

Ans: **Fossil Fuel Energy:**

Fossil fuel energy comes out from burning of oil, coal and natural gas. These materials are known as fossil fuels. The burning of these fuels gives out heat which is used to generate steam that runs the turbines to produce electricity.

Hydroelectric Generation:

Hydroelectric generation is the electricity generated from the power of falling water. 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. 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 run the electric generator.

Solar Energy:

Definition:

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

Uses:

Solar energy can be used in two ways.

1st Method:

Either it can be used for heating system or can be converted to electricity. In one way, solar panels absorb heat of the Sun. They consist of large metal plates which are painted black. 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. At this high temperature, water can be boiled to produce steam that can run the turbine of an electric generator. In this way, electricity can be produced.

2nd Method:

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.

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

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.

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.

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 250°C. This energy is known as geothermal energy which can be extracted to run electric generators.

Method to extract energy:

A typical geothermal power plant is shown in 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.

Wind Energy:

For thousands of years, people have been using wind mills to draw water from the well or to grind grains in to flour. The modern windmill is used to run generators that produce 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 wind mills is needed.

Energy from 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 be utilized to turn on turbine for electricity generation.

Method:

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.

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. It consists of two parts.

(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 generators.

Bio fuel Energy:

It is that energy which is obtained from the biomass. Biomass consists of organic materials such as 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 in to other types of fuels.

Method (i):

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 used to generate electricity.

Method (ii):

In another process, the rotting of bio mass in a closed tank called a 'digester' produces methane rich biogas. In this process, micro-organisms break down biomass material in the absence of oxygen. Bio gas produced in the tank is piped out and can be used for heating and cooking like natural gas.

Bio fuel such as ethanol (alcohol) can also be obtained from the bio mass. It is a replacement of petrol. In this case, bacteria converts it into ethanol.

Q.1 Explain some non-renewable sources of Energy. ***(K.B+A.B)***

Ans: Renewable and nonrenewable energy sources can be differentiated as:

RENEWABLE SOURCES	NON-RENEWABLE SOURCES
Definition	

The resources of energy which are replaced by new ones after their use are called renewable energy source. 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 example, 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 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, fuels 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.
Natural Recycling	
• They have natural recycling cycle	• They do not have natural recycling cycle.
Examples	
• Water • Sun light • Wind energy	• Coal • Gas • Oil

ADVANTAGES AND DISADVANTAGES OF METHODS OF ENERGY PRODUCTION:

Advantages:

The production of hydroelectric power is more economical and pollution free. The solar power, wind, tidal and wave power need more initial cost but they do not produce pollution and are also economical as well.

Disadvantages:

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. They enhance direct pollution to atmosphere. Wind-mills are very noisy. Some people think that wind turbines spoil the beauty of landscape.

Effects of nuclear power generators:

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 another problem for the nuclear power generation. However, any form of waste energy ends up as thermal energy that goes to the environment. Thus, thermal pollution is increasing day by day causing global warming.

EFFICIENCY
POWER

LONG QUESTIONS

Q.1 What is Efficiency? Write its formula and unit (if any) ***(K.B+U.B+A.B)***

Ans:

EFFICIENCY

Introduction:

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 is 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.

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

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:

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

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 losses are inevitable in the working of a machine, hence, an ideal or perpetual machine cannot be constructed.

Q.2 Define the ideal system. Why is it not possible to construct 100% efficient system? *(K.B)*

Ans:

IDEAL SYATEM

Definition:

An ideal system is that which gives an output equal to the total energy used by it. In other words, its efficiency is **100 %**. People have tried to design a working system that would be 100 % efficient. But practically such system does not exist.

Reason For Not Existing 100% Efficient System:

Every system meets energy losses due to friction that causes heat, noise etc. These are not the useful forms of energy and go waste. This means we cannot utilize all the energy given to working system. The energy in the required form obtained from working system always less than the energy given to it as input.

Q.3 What is Power? Write down its unit and define it. ***(K.B+U.B+A.B)***

Ans:

POWER

Definition:

"Rate of doing work with respect to time is called the power.**"**

Formula:

Formula for power is given below:

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

If we represent power by 'P', work by 'W' and time by 't', then

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

Quantity:

Since work is scalar quantity so power is also a scalar quantity.

Unit of Power:

In System International, the unit of power is watt (W).

Watt:

"The power of a body is **one watt** if it does work at the **rate of 1 joule per second** ($1 Js^{-1}$)**"**.

Bigger Units:

Bigger units of power are kilowatt (kW), megawatt (MW) etc.

$$1 \text{ KW} = 1000\text{W} = 10^3 \text{ W}$$

$1\ MW = 1000000 = 10^6\ W$
1 horsepower = 1hp = 746 W

MULTIPLE CHOICE QUESTIONS

Q.I Choose the best possible option.

5.1 Work done is maximum when the angle between the force F and the displacement d is:
(a) 0° (b) 30°
(c) 60° (d) 90°

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

5.3 The SI unit of power is:
(a) joule (b) newton
(c) watt (d) second

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

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

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

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

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

5.9 Which of the following is not renewable energy source?
(a) Hydro electric energy **(b) Fossil fuels**
(c) Wind energy (d) Solar energy

SHORT ANSWER QUESTIONS

1. What is the work done on an object that remains at rest when a force is applied on it?

Ans: When a force is applied to an object that remains at rest (i.e., there is no displacement), the **work done** on the object is zero.

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

Ans: A slow-moving car can have more kinetic energy than a fast-moving motorcycle if the car has a significantly greater mass. The mass plays a key role in determining kinetic energy, and while velocity has a larger influence due to its squared relationship in the formula, mass can still compensate for a lower velocity.

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?

Ans: According to the formula
P=W/t
1) P=5/10=0.5 W
2) P=3/5=0.6W
Hence, F_2 will delivers greater power

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

Ans: **S**ince the change in gravitational potential energy depends only on the height and mass, and these factors are unchanged by her speed, her **gain in potential energy will still be 4500 J**. The speed does not affect the potential energy gain because the height climbed is the same.

Thus, **her gain in potential energy remains 4500 J** even when she runs at twice the speed

5. Define work and its SI unit.

Ans:

WORK

Definition:

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

Mathematically:

Work is equal to the product of force **F** and displacement **S** covered in the direction of force.

$$W = \mathbf{FS}$$

Unit of Work:

In System International, its unit is Nm that is also called as joule (J).

Joule:

"The amount of Work done is **one joule** if a force of **one newton** displaces a body through **one meter** in the **direction of the force."**

Thus,

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

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

Ans: Potential energy of a mass m lifted to the height h is denoted by P.E. and its formula is given below:

P.E. = m g h

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

Ans:

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

Above equation shows that if we increase or decrease the speed of a body its kinetic energy will be increase or decrease.

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

Ans: **EFFICIENCY**

Introduction:

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 is 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.

The efficiency of a system is defined as:

Definition:

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

OR $$\text{Efficiency} = \frac{\text{Useful output energy}}{\text{Total input energy}}$$

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:

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

Reason For Not Existing 100% Efficient System:

Every system meets energy losses due to friction that causes heat, noise etc. These are not the useful forms of energy and go waste. This means we cannot utilize all the energy given to working system. The energy in the required form obtained from working system always less than the energy given to it as input.

9. What is power? Define the unit used for it.

Ans: POWER

Definition:

"Rate of doing work with respect to time is called the power."

Formula:

Formula for power is given below:

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

If we represent power by 'P', work by 'W' and time by 't', then

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

Quantity:

Since work is scalar quantity so power is also a scalar quantity.

Unit of Power:

In System International, the unit of power is watt (W).

Watt:

"The power of a body is **one watt** if it does work at the **rate of 1 joule per second** ($1Js^{-1}$)".

Bigger Units:

Bigger units of power are kilowatt (kW), megawatt (MW) etc.

$$1\ KW = 1000W = 10^3\ W$$
$$1\ MW = 1000000 = 10^6\ W$$
$$1\ \text{horsepower} = 1hp = 746\ W$$

10. Differentiate between renewable and non-renewable energy sources

Ans:

RENEWABLE SOURCES	NON-RENEWABLE SOURCES
Definition	
The resources of energy which are replaced by new ones after their use are called renewable energy source. 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 example, 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	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, fuels 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.

remain available forever. Same is the case with wind and tidal energy. These are not going to run out in future.	
Natural Recycling	
• They have natural recycling cycle	• They do not have natural recycling cycle.
Examples	
• Water • Sun light • Wind energy	• Coal • Gas • Oil

CONSTRUCTED RESPONSE QUESTIONS

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

Ans: Kinetic energy can never be negative because it depends on the square of the velocity, which cannot result in a negative value.

According to formula

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

Speed is squared so K.E never be negative.

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*?

Ans: The object traveling with velocity v (Object 1) has greater kinetic energy than the object that is twice as heavy but traveling with velocity v/2 (Object 2).

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

Ans: If the car's speed is constant, its kinetic energy does not change as it moves along the curved road. The direction of motion does not affect kinetic energy, only changes in speed do.

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

Ans: An object has one joule of potential energy means its mass is 1kg and is lifted to the height of 1m.

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

Ans: The bursts of tyre may be due to nail on a road which penetrate in tyre.

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

Ans: When the player hit the ball he delivered his mechanical energy which converted in ball's kinetic energy sound & heat energy released. Ball hits the window and its kinetic energy smashes the window.

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

Ans: no net work on the boat: Since the boat does not move relative to the shore, there is any **net work** done on the boat in terms of displacement.

Work is done by the rower: The man is still doing work **physically**, as he is applying force to the oars, even though the boat stays stationary. This work is essentially used to overcome the forces of the current and friction, not to cause a displacement of the boat.

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

Ans: Timber or wood can be considered a **renewable source of heat energy** as long as it is harvested sustainably and managed properly. If forests are replenished and managed to ensure long-term availability, wood can continue to be a renewable resource for energy. However, overharvesting and improper management can make it unsustainable, leading to environmental harm.

COMPREHENSIVE QUESTIONS

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

Ans:

KINETIC ENERGY

Definition:

"The energy possessed by a body due to its motion is called Kinetic energy."

Formula:

It is denoted by K.E and its formula is given below:

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

Example:

- A moving bullet is able to do work by overcoming forces when it strikes something e.g. wood. Similarly kinetic energy in is felt during a collision.
- A football is kicked by a boy it moves because it possess Kinetic energy.

Explanation:

Consider a constant force 'F' is acting on an object of mass 'm' and as a result the object moves on a frictionless surface. The kinetic energy of an object will be equal to work done.

The work done on force-displacement graph can be calculated by finding area of figure under force-displacement graph.

Change in kinetic energy (E_k) = Work done = F.S

Work done = area under force displacement graph

Derivation:

The area under force displacement graph is the area of rectangle, thus:

Change in kinetic energy (E) = Area of rectangle = width × length = Fd

or

$$Ek = Fd$$

$$\text{Here } V_{ave} = \frac{V_i + V_f}{2}$$

As the speed is increasing its velocity from $V_i = 0$ to $V_f = V$, As, $F = ma$, $d = V_{av} \times t$

$$E_k = ma, V_{av} \times t \_\_\_\_\_\_(1)$$

therefore the average speed $\mathbf{V_{ave}}$ are is

therefore,

$$V_{ave} = \frac{0+V}{2} = \frac{v}{2} \ldots\ldots\ldots(2)$$

And acceleration can also be written as:

$$a = \frac{V}{t} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Putting equation 2 and equation 3 in equation 1, we get

$$E_k = m\frac{v}{t}.\frac{1}{2}vt$$

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

100 g cricket ball moving with a speed of 2.0 m/s has a Kinetic energy of 0.2 J. Equally important, it demonstrate the work kinetic energy

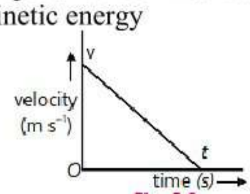


Fig. 5.9

5.2 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.

Ans: **<u>ENERGY CONVERSION AND CONSERVATION</u>**

Introduction:

Think of a book lying on a shelf. The book has gravitational potential energy when it is on the shelf. What happens if the book falls off the shelf? Its potential energy changes into kinetic energy. This change in energy from one form to another is conversion of energy. For example, consider the following examples

A. Generation of electricity:

Potential energy of water which is stored at a certain height is converted into kinetic energy by making it fall on turbine to produce electricity.

Law of conversation of energy:

Energy cannot be destroyed or created it is only converted from one form to the other. The law of conservation of energy states that,

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 calculations. 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.

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.5.12). Its total energy is P.E is mgh,

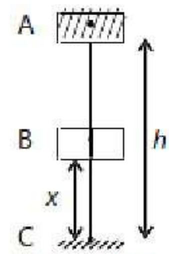


Fig. 5.12

Example:

$$E_p = mgh$$

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 $E = mg\,(h - x) + mgx = mgh$

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

$E_p = 0$ and $E = mgh$

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

5.3 Differentiate between renewable and nonrenewable sources of energy. Give three examples for each.

Ans:

RENEWABLE SOURCES	NON-RENEWABLE SOURCES
Definition	

The resources of energy which are replaced by new ones after their use are called renewable energy source. 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 example, 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 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, fuels 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.
Natural Recycling	
• They have natural recycling cycle	• They do not have natural recycling cycle.
Examples	
• Water • Sun light • Wind energy	• Coal • Gas • Oil

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

Ans:

SHORT QUESTIONS

Q.4 What is Efficiency? Write its formula and unit (if any) *(K.B+U.B+A.B)*

Ans: **EFFICIENCY**

Introduction:

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 is 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.

The efficiency of a system is defined as:

Definition:

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

OR

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

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:

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

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

1) Hydro electric power generations (ii) Fossil fuels

Ans:

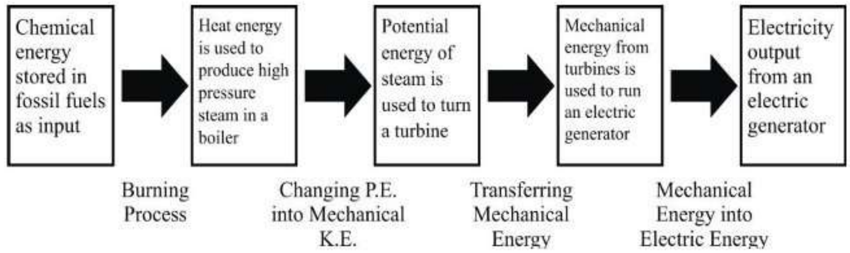


Figure: **Several Energy Conversion Process are Involved in Producing Electricity**

NUMERICAL QUESTIONS

5.1 A force of 20 N acting at an 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?

Given Data:

Force = F = 20N

Angle = θ = 60

Distance = S = 3m

To Find:

Work done = W = ?

Solution:

Formula:

W = FSCosθ

$$W = (20)(3)\cos 60^o$$

(60) (0.5)

$$W = (20)(3)(0.5)$$

$$\boxed{W = 30J}$$

Result:

Work done will be 30J.

5.2 A body moves a distance of 5 metres in a straight line under the action of a force of 8 Newtons. If the work done is 20 Joules, find the angle which the force makes with the direction of motion of the body.

Given Data:

Distance = S = 5m

Force = F = 8N

Work = W = 20J

To Find:

Angle = θ= ?

Solution

Formula:

$$W = Fs\cos\theta \qquad \therefore Cos\theta = \frac{W}{Fs}$$

$$\theta = cos^{-1}\left(\frac{W}{Fs}\right)$$

$$\theta = \cos^{-1}\left(\frac{20}{8\times 5}\right)$$

$$\theta = \cos^{-1}\left(\frac{20}{40}\right)$$

$$\theta = \cos^{-1}(0.5)$$

$$\theta = 60^o$$

Result:

Angle of force will be 60^o.

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

Given Data:

Mass = m = 100 kg
Height = h = 80m
Time = t = 25 sec

To Find:

Power = P = ?

Solution:

Formula:

$$P = \frac{mgh}{t} \therefore mgh = P.E = W \therefore g = 10ms^{-2}$$

$$P = \frac{((100)\times(10)(80))}{25} \Rightarrow \frac{80000}{25}$$

$$\boxed{P = 3200W}$$

Result:

Power of pump will be 3200W.

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?

Given Data:

Mass = m = 20kg
Initial velocity = v_i = 0ms^{-1}
Time = t = 5 sec
Force = F = 40N

To Find:

Kinetic energy = K.E = ?

Solution:

Formula:

$$a = \frac{F}{m}$$

$$vf = vi + at$$

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

$$a = \frac{40}{20} = \boxed{2ms^{-2}}$$

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

$$vf = 0 + 10$$

$$\boxed{vf = 10ms^{-1}}$$

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

$$K.E = (10)(100) = \frac{1}{2}(20)(10)^2$$

$$\boxed{K.E = 1000J}$$

Result:

Kinetic energy will be 1000J.

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

Given Data:

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

Height = h = 20 m

To Find:

Potential energy = P.E = ?

Solution:

Formula:

$$P.E = mgh \therefore g = 10ms^{-2}$$

$$P.E = (0.16)(10)(20)$$

$$\boxed{P.E = 32J}$$

Result:

Potential energy of the ball will be 32 J.

5.6 A 0.14 kg ball is thrown vertically upward with an initial velocity of 35 m s¹. Find the maximum height reached by the ball.

Given Data:

Mass = m = 0.14 kg

Initial velocity = V_i = 35 ms^{-1}

Final velocity = Vf = 0 ms^{-1}

To Find:

Maximum height = h = ?

Solution

Formula:

$$2gh = V_f^{\ 2} - V_i^2 \therefore g = -10ms^{-2}$$

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

$$(-20)H = -1225$$

$$h = \frac{-1225}{-120}$$

$$\boxed{h = 61.25m}$$

Result:

Maximum height reached by the ball will be 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?

Given Data:

Highest point = h_1 = 2.0m

Lowest point = h_2 = 1.2m

Change in height = $\Delta h = h_1 - h_2$ = 2m-1.2m = 0.8m

To Find:

Maximum velocity = V = ?

Point of maximum velocity = ?

Solution:

Formula:

At highest point:

P.E = mgh

K.E = 0
At lowest point
P.E = 0

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

Total energy at highest point = Total energy at lowest point

$$mgh + 0 = 0 + \frac{1}{2}mv^2$$

$$\not{m}gh = \frac{1}{2}\not{m}v^2$$

$$gh = \frac{1}{2}v^2$$

$$2gh = v^2$$

$$\sqrt{V^2} = \sqrt{2gh} \quad \therefore g = 10ms^{-2}$$

$$V = \sqrt{2(10)(0.8)}$$

$$V = \sqrt{16}$$

$$\boxed{V = 4ms^{-1}}$$

Result:

Maximum velocity will be $4ms^{-1}$ and it will at the lowest position.

5.8 A person pushes a lawn mower with a force of 50 N making an angle of 45° with the horizontal. If the mower is moved through a distance of 20 m, how much work is done?

Given Data:

Force = F = 50N
Angle = θ = 45°
Distance = S = 20m

To Find:

Work done = W = ?

Solution:

Formula:

W = FScosθ

$$W = (50)(20)\cos(45^\circ)$$

$$W = (1000)(0.7071)$$

$$\boxed{W = 707\text{J}}$$

Result:

Work done will be 707 J.

5.9 Calculate the work done in (i) Pushing a 5 kg box up a frictionless inclined plane 10 m long that makes an angle of 30° with the horizontal. (ii) Lifting the box vertically up from the ground to the top of the inclined plane.

Given Data:

Mass = m = 5 kg
Weight of mass = W = mg

$$=(5)(10) \therefore g=10ms^{-2} =50N$$

Distance/height = S/h = 10m

Angle = θ = 30

To Find:

i- Work done on inclined plane = W = ?

ii- Work done in vertical direction = W = ?

Solution:

Formula:

i- W = F S sinθ

(i) $W=(5)(10)(10)\sin(30^o) \quad \therefore F=W=mg$

$W=500(0.5)\Rightarrow \boxed{250J}$

(ii) $W=mgh\Rightarrow(5)(10)(10)$

$\boxed{W=500J}$

Result:

Work done in lifting the box through inclined plane will be 250J and through height work done will be 500J.

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

Given Data:

Mass = m = 10kg

Distance = S = 15m

Force = F = 80 N

Height = h = 5m

To Find:

Efficiency = ?

Solution:

Formula:

$W=FS$

$P.E=mgh$

$$Efficiency=\frac{P.E}{W}\times 100$$

$W=(80)(15)=\boxed{1200J}$

$P.E=(10)(10)(5)\Rightarrow 500J$

$$\%Efficiency=\frac{500}{1200}\times 100$$

$\boxed{=41.7\%}$

Result:

Efficiency of the system will be 41.7%

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

Given Data:

Force = F = 600N

Distance = S = 5m

Time = t = 15 sec

To Find:

Power = P = ?

Solution:

Formula:

$$P = \frac{Fs}{t} \quad \therefore W = FS$$

$$P = \frac{(600)(5)}{15} \Rightarrow \frac{3000}{15}$$

$$\boxed{P = 200W}$$

Result:

Power will be 200 W.

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

Given Data:

Mass = m = 40 kg
Height = h = 10m
Time = t = 8sec

To Find:

Power = P = ?

Solution:

Formula:

$$P = \frac{mgh}{t} \quad \therefore W = P.E = mgh$$

$$P = \frac{(40)(10)(10)}{8} \quad \therefore g = 10ms^{-2}$$

$$P = \frac{4000}{8} \Rightarrow \boxed{500W}$$

Result:

Power developed by the boy will be 500W

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

Given Data:

Force = F
Distance = L
Force = 2F
Distance = 2L

To Find:

Total work done = w = ?

Solution:

Formula:

$$W = F \times L$$

$$W_1 = F \times L$$

$$W_2 = 2F \times 2L \Rightarrow 4F \times L$$

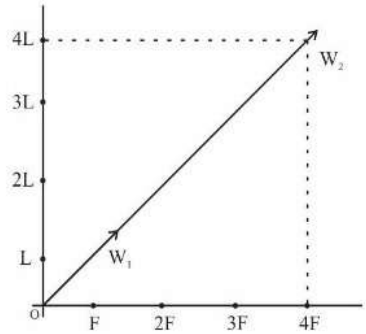
Total work = K1

$$W = W_1 + W_2$$

$$W = (F \times L) + (4F \times L) = FL + 4L$$

$$\boxed{W = 5FL}$$

Graph



Result:

Total Work done will be 5FL or 5 unit.

MCQ'S

TEXT BOOK EXERCISE

1	2	3	4	5	6	7	8	9
A	D	C	D	A	D	B	B	B