Revision Notes for Class 9 Science

Chapter 10 – Work and Energy

Introduction:

For the average person, the term "work" refers to any task that requires bodily or mental effort. However, in physics, the phrase has a different meaning. It denotes a measurable quantity. We say that a force has done work on an object when it acts on it and causes it to move in the direction of the force.

When you push a book on a table, you apply force to the book, which causes it to move in the direction of the force. We say the force has done its job.

You will be exhausted if you push a wall, but the wall will not move. There is no work done in terms of science.

1. Work and Measurement of Work

When a force acts on an object and the point of application moves in the direction of the force, work is said to be completed.

2. Conditions to be Satisfied for Work to be Done:

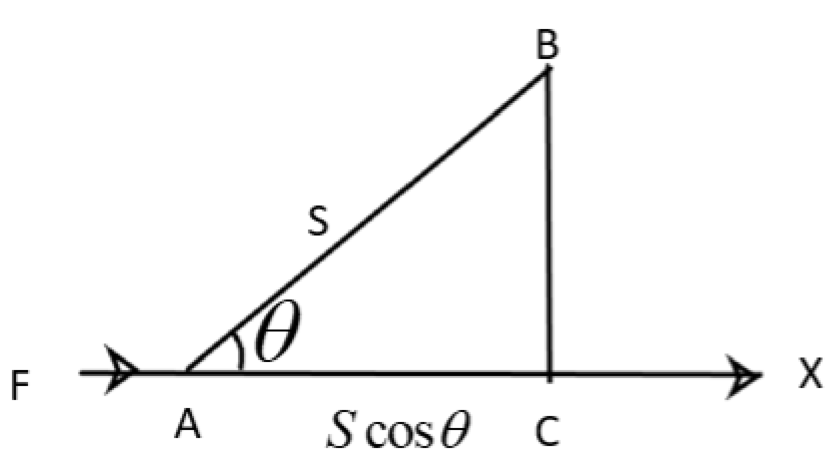
- There must be some force acting on the object
- The point of application of force must move in the force's direction
- Work is calculated by multiplying the force by the distance travelled.

$W = F \times S$

Where W denotes the amount of work done, F is the force exerted, and S denotes the distance travelled by the moving object. The amount of work completed is a scalar quantity.

3. Work Done When the Force is not Along the Direction of Motion:

Assume that a constant force F acts on a body, resulting in a displacement S as illustrated in the diagram. Let θ be the angle formed by the force and displacement directions.



Displacement in the direction of the force = Component of S along AX $= AC$

But we know that,

$$\cos\theta = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{AC}{S}$$

$$AC = S\cos\theta$$

Displacement in the direction of the force $= S\cos\theta$

Work done =Force $\times$ displacement in the direction of force

$W = FS\cos\theta$

If the displacement S is in the direction of the force $FS = 0, \cos\theta = 1$

Then,

$W = FS \times 1$

$W = FS$

If,

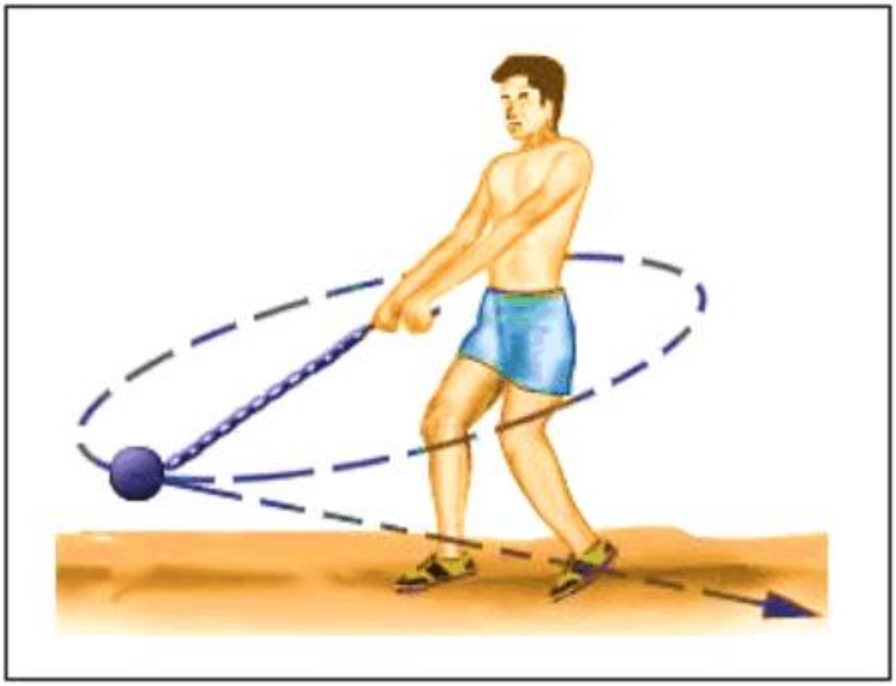
$\theta = 90^{\circ}$

$\cos 90^{\circ} = 0$

Therefore, $W = F.S \times 0 = 0$ i.e., no work is done by the force on the body.

4. The Centripetal Force is Activated When a Stone at the End of a String is Whirled Around in a Circle at a Constant Speed.

This force is perpendicular to the stone's velocity at any given time. So, despite the fact that it is responsible for retaining the stone in a circular motion, this force does not work.



5. SI Unit of Work:

$W = F \times S$

SI unit of F is N and that of S is m [N = newton]

SI unit of work $= N \times m$

1Nm is defined as 1 joule.

i.e., 1 joule $= 1Nm$

So, SI unit of work is Joule.

A joule is the amount of work done when the point of application of a one-newton force moves one metre in the direction of the force.

The joule unit of measurement is named after British scientist James Prescott Joule.

Joule is represented by the letter 'J.'

Kilojoule and megajoule are higher units of work.

$1\text{kilojoule} = 1000J$

$1\ \text{kilojoule} = 10^3 J$ or,

$1\text{megajoule} = 1000,000J$

$1\text{megajoule} = 10^6 J$

6. Energy:

Anything that has the ability to work has energy. The capacity to work is defined as energy. The amount of work that a body can accomplish is how much energy it has. As a result, the SI unit of energy is the joule.

7. Different Forms of Energy:

Mechanical energy, thermal energy, electrical energy, and chemical energy are examples of diverse types of energy. We'll look at mechanical energy in this chapter. Mechanical energy is divided into two types: kinetic energy and potential energy.

8. Kinetic Energy:

A fast-moving stone can break a windowpane, falling water can crank turbines, and moving air can rotate windmills and drive sailboats, as we all know. The moving body in all of these situations has energy. The body in motion does the work. Kinetic energy is the form of energy that is possessed by moving objects.

“Kinetic energy is defined as the energy that an object possesses as a result of its motion. The letter 'T' is used to symbolise kinetic energy. Kinetic energy is present in all moving objects.”

9. Expression for Kinetic Energy of a Moving Body:

Consider a mass 'm' body that is initially at rest. Allow the body to begin moving with a velocity of 'v' and cover a distance of 'S' when a force ' F' is applied to it. In the body, the force causes acceleration 'a'.

When the force 'F' moves the body over a distance 'S' it does work, and this work is stored in the body as kinetic energy.

$W = F \times S$ ……..(1)

$F = ma$ [Newton’s second law of motion]

$W = mas$ ……….(2)

Also, $v^2 - u^2 = 2aS$ [Newton’s third law of motion]

$v^2 - 0 = 2aS$ [Initial velocity $u = 0$ as the body is initially at rest]

$v^2 = 2aS$

$\Rightarrow a = \dfrac{v^2}{2aS}$

Substituting the value of 'a' in equation (2) we get,

$W = \dfrac{mv^2}{2S} S$

$W = \frac{mv^2}{2}$ ……..(3)

But since work done is stored in the body as its kinetic energy equation (3) can be written as

Kinetic energy $(T) = \frac{1}{2}mv^2$

We can deduce from the above equation that a body's kinetic energy is proportional to (1) its mass and (2) the square of its velocity.

10. Momentum and Kinetic Energy:

All moving objects, we know, have momentum. The product of a body's mass and velocity is defined as its momentum.

Let's look at how a body's kinetic energy is related to its momentum.

Consider a body of mass 'm' moving with a velocity 'v'. Then, the momentum of the body is got by $p = mv$

But, Kinetic energy $(T) = \frac{1}{2}mv^2$

Substituting the value of 'v' in equation (1) we get,

$$T = \frac{1}{2}m\left(\frac{p}{m}\right)^2$$
$$= \frac{1}{2}m\frac{p^2}{m^2}$$
$$= \frac{p^2}{2m}$$

11. Potential Energy:

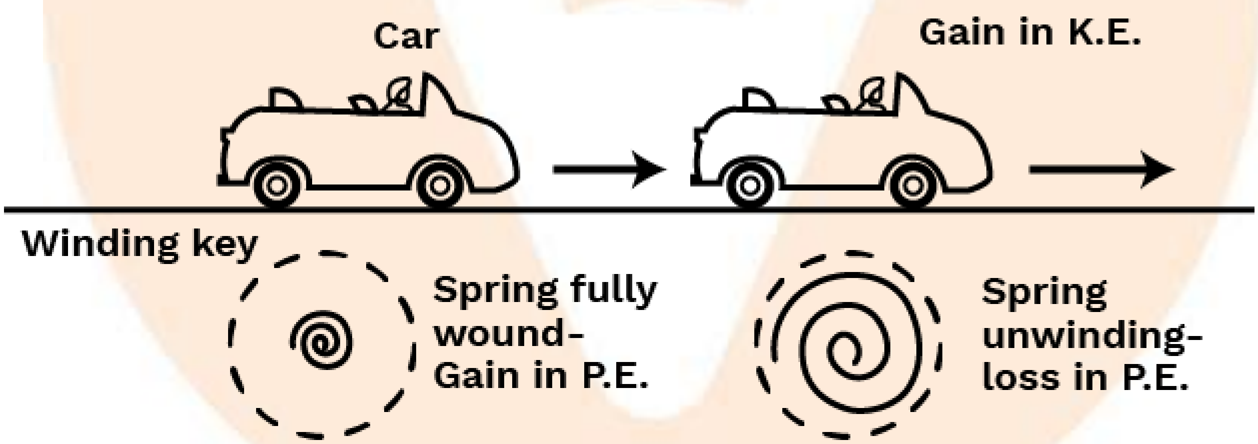
Consider the following scenarios:

- Water held in a reservoir can be used to rotate turbines at a lower level. Because of its location, water kept in a reservoir has energy.

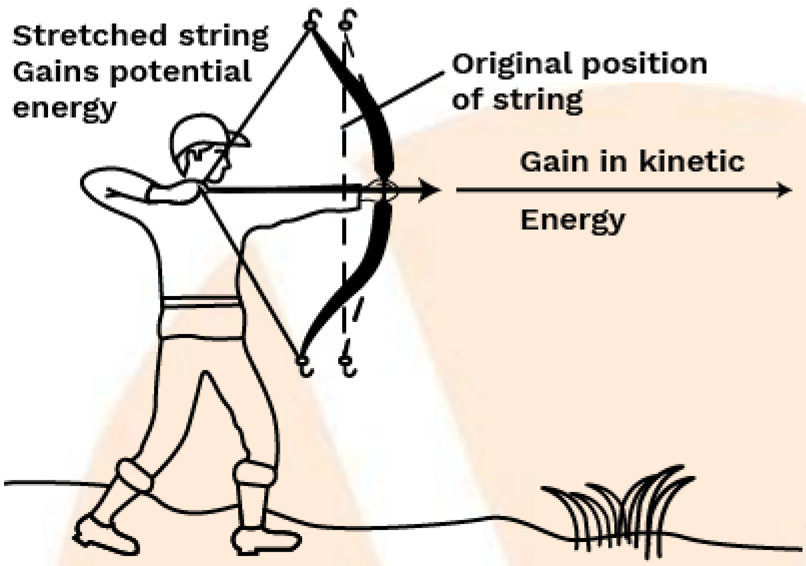
- A hammer strike on a nail fixes it, however, if the hammer is simply placed on the nail, it barely moves. The raised hammer possesses energy as a result of its posture.

- A winding key-driven toy car: The spring is wound when we turn the key. When we let go, the toy car's wheels begin to roll as the spring unwinds, and the car moves if left on the floor. The wound spring is energised. The gain in energy is attributed to the spring's location or condition.

- A Toy Car Driven by a Winding Key:



- Stretched String Gains Potential Energy

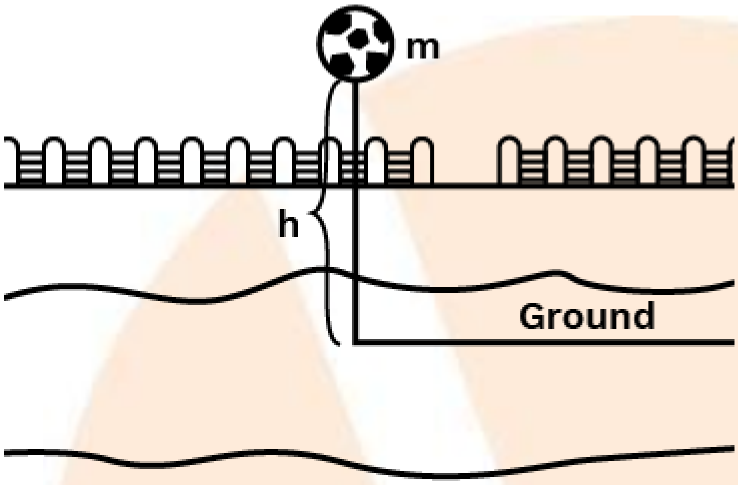


- The energy possessed by an object as a result of its position or state is known as potential energy.

12. Expression for Potential Energy:

Consider a mass 'm' object lifted to a height 'h' above the surface of the earth. The work done against gravity is stored as potential energy in the object (gravitational potential energy).

As a result, potential energy equals the work done in lifting an object to a certain height.



Object of Mass 'm', Raised Through a Height 'h'

Potential energy $= F \times S \ldots (1)$

But $F = mg$ [Newton's second law of motion]

$S = h$

Substituting for F and S in equation (1), we get

Potential energy$= mg \times h$

Potential energy $= mgh$

It is obvious from the above relationship that an object's potential energy is proportional to its height above the ground.

13. Law of Conservation of Energy:

Let's have a look at what's going on in the following scenarios:

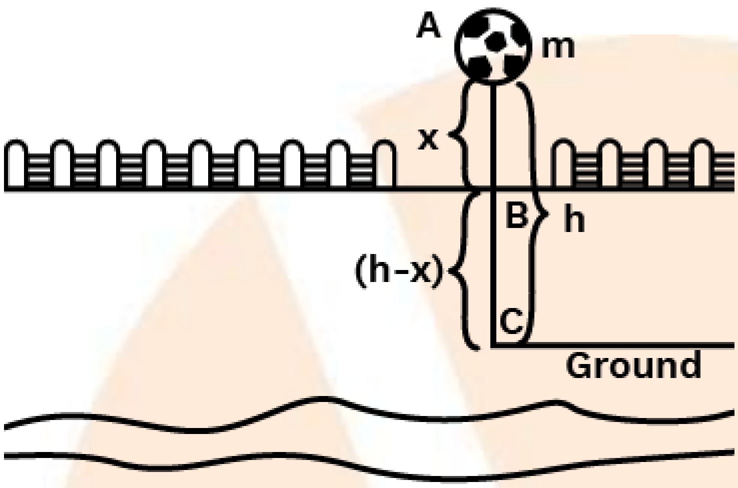
- Steam engine: Coal is burned in a steam engine. Water is converted to steam by the heat generated by coal burning. The locomotive is moved by the expansion force of steam on the piston of the engine. Chemical energy is transferred to heat energy, which is then converted to steam's expansion power. When the locomotive travels, this energy is converted to kinetic energy.

- Hydroelectric power plant: Water from a reservoir is forced to fall on turbines that are held at a lower level and connected to the coils of an a.c. generator. The potential energy of the water in the reservoir is converted to kinetic energy, and the kinetic energy of falling water is converted to turbine kinetic energy, which is then converted to electrical energy. As a result, if the energy in one form vanishes, an equal quantity of energy in another form emerges, resulting in constant total energy.

14. Law of Conservation of Energy:

“The law of conservation of energy asserts that energy cannot be generated or destroyed, only converted from one form to another.”

Let us now demonstrate that the preceding law applies to a freely falling body. Allow a body of mass 'm' to begin falling down from a height 'h' above the earth. In this example, we must demonstrate that the body's total energy (potential energy + kinetic energy) remains unchanged at points A, B, and C,i.e., potential energy is totally turned into kinetic energy.



Body of Mass 'm'placed at a height 'h'

At A,

Potential energy $= mgh$

Kinetic energy $= \frac{1}{2}mv^2$

$= \frac{1}{2}m \times 0$

Kinetic energy $= 0$ [the velocity is zero as the object is initially at rest]

Total energy at A=Potential energy + Kinetic energy

$= mgh + 0$

Total energy at $A = mgh \ldots (1)$

At B,

Potential energy $= mgh$

$= mg(h-x)$ [height from the ground is $(h-x)$

Potential energy $= mgh - mgx$

The body covers the distance x with a velocity 'v'. We make use of the third equation of motion to obtain the velocity of the body.

$v^2 - u^2 = 2aS$

Here,

$u = 0$

$a = g$ and

$S = x$

$v^2 - 0 = 2gx$

$v^2 = 2gx$

Kinetic energy $= mgx$

Total energy at $B =$ Potential energy + Kinetic energy

$= mgh - mgx + mgx$

$= mgh \ldots (2)$

At C,

Potential energy $= m \times g \times 0 (h = 0)$

Potential energy $= 0$

Kinetic energy $= \frac{1}{2}mv^2$

The distance covered by the body is h,

$v^2 - u^2 = 2aS$

Here, $u = 0,$

$a = g$ and

$S = h$

$v^2 - 0 = 2gh$

$\Rightarrow v^2 = 2gh$

Kinetic energy $= \frac{1}{2}m \times 2gh$

Kinetic energy $= mgh$

Total energy $= mgh$

Total energy at C = Potential energy + Kinetic Energy

$= 0 + mgh$

Total energy at $C = mgh \ \ldots \ (3)$

The total energy of the body is constant at all points, as shown by equations 1, 2 and 3. As a result, we can deduce that the law of conservation of energy applies to a freely falling body.

15. Power:

Imagine two pupils positioned at opposite ends of a 100-meter track transferring 10 bricks from one end to the other. What is the total amount of work that each of them has completed? The amount of work done is consistent, but the time it takes to complete it varies. We calculate the work done in unit time to determine which of the two is the fastest.

That is, the amount of work done and the amount of work done per unit of time are two separate quantities.

Power is defined as the amount of work done per unit of time or the rate at which work is completed.

The letter 'P' stands for power.

$P = \frac{w}{t}$, where w is the work done and t is the time taken

Power can be described as the amount of energy consumed in a given amount of time, as energy represents the capacity to conduct work.

$P = \frac{E}{t}$, where E is the energy consumed.

16. SI unit of power:

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

The joule is the SI unit of work, and the second is the SI unit of time. As a result, the SI unit of power is the joule/second. 1 watt = 1 joule/second

When an agent performs one joule of work in one second, its power is measured in watts. Kilowatts and megawatts are higher power units.

$1 \text{ kilowatt} = 1000 \text{ watts}$

$1 \text{ kilowatt} = 10^3 \text{ watts}$

Or, 1 megawatt= 1000,000watts

$1 \text{ megawatt} = 10^6 \text{ watts}$

Another unit of power is horsepower.

$1 \text{ horse power} = 746 \text{ watts}$

17. Commercial Unit of Energy:

The SI unit joule is insufficient for expressing very high amounts of energy. As a result, we use a larger measure known as the kilowatt-hour (kWh) to express energy.

A kWh is the amount of energy utilised by an electrical device in one hour at $1000J/s\ (1kW)$.

A kilowatt-hour is a unit of measurement for energy utilised in homes, businesses, and industries.

18. Numerical Relation Between SI and Commercial Unit of Electrical Energy:

SI unit of energy is Joule. Commercial unit of energy is kWh.

$1kWh = 1kW \times 1h$

$1kWh = 1000W \times 3600s$

$1kWh = 3600000J$

$1 kWh = 3.6 \times 10^6 J$

$1 kWh = 1 unit$