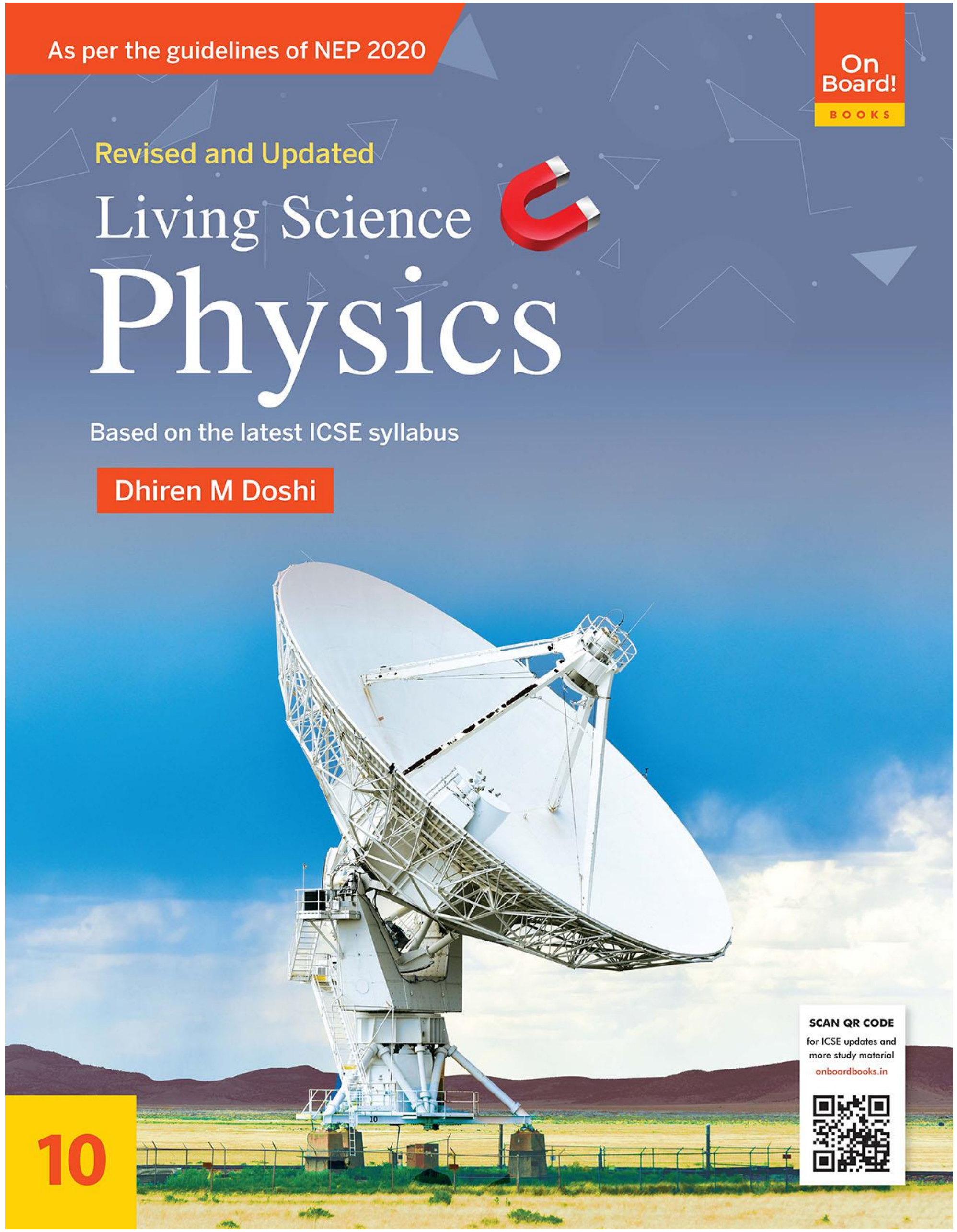
ICSE
Living Science
Physics

Class 10

Chapter 2 Work, Energy and Power

On Board! BOOKS



LEARNING OBJECTIVES

Work

- ❖ Factors Work Depend on
- ❖ Measurement of Work
- ❖ Units of Work
- ❖ Special cases

Energy

- ❖ Units of Energy

Power

- ❖ Units of Power

Different Forms of Energy

- ❖ Kinetic Energy

Principle of Conservation of Energy

What is work?

Work is said to be done only when the force acting on a body produces motion in it, in the direction of the force applied.

Factors On Which Work Depend on

1. **Magnitude of the force applied:**

Work done ∝ Force applied (provided the body is displaced)

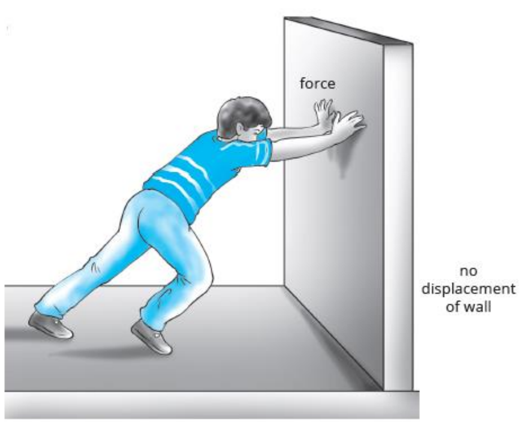
$$W \propto F$$

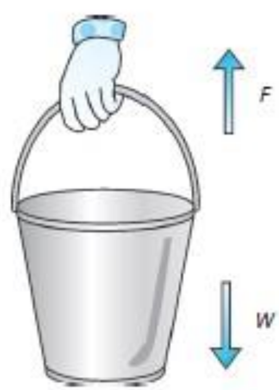
2. Displacement of the body:

Work done ∝ Displacement of the body in the direction of the force

Work done by the force on a body is directly proportional to the displacement of the body in the direction of the force applied.

No work is done in the following cases as there is no displacement





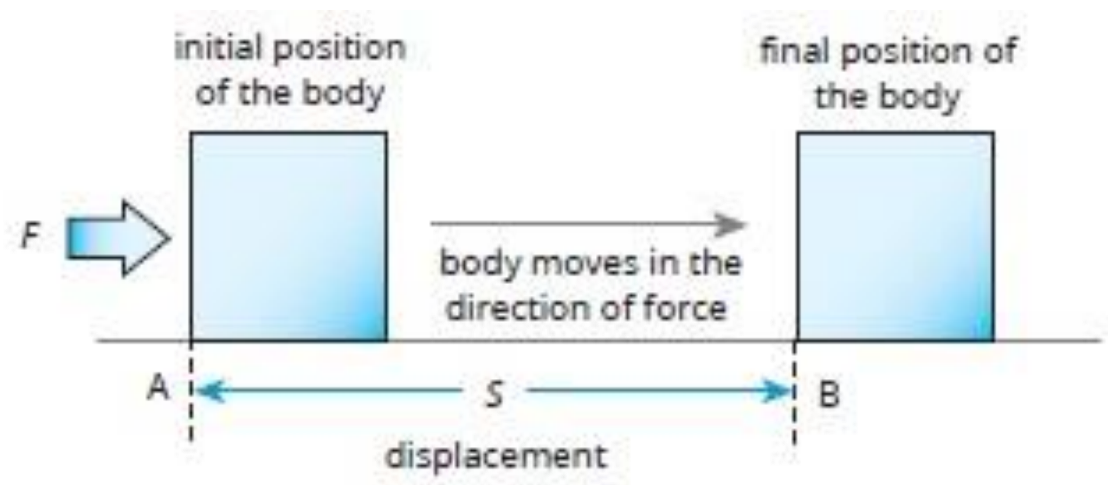
Measurement of Work

Work done when the body moves in the direction of the applied force

When a force *F* acting on a body produces a displacement *S* in its direction then work done (*W*) by the force (*F*) is the product of the force and the displacement, i.e.

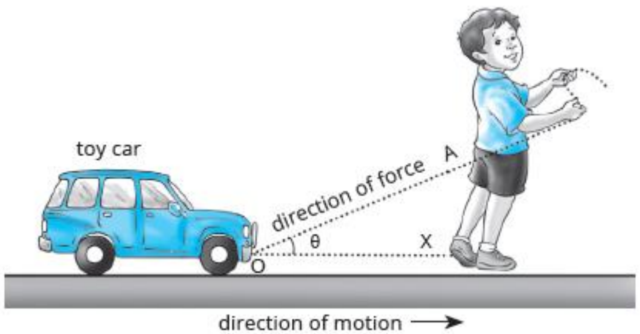
Work done = Force × Displacement

$$W = F \times S$$



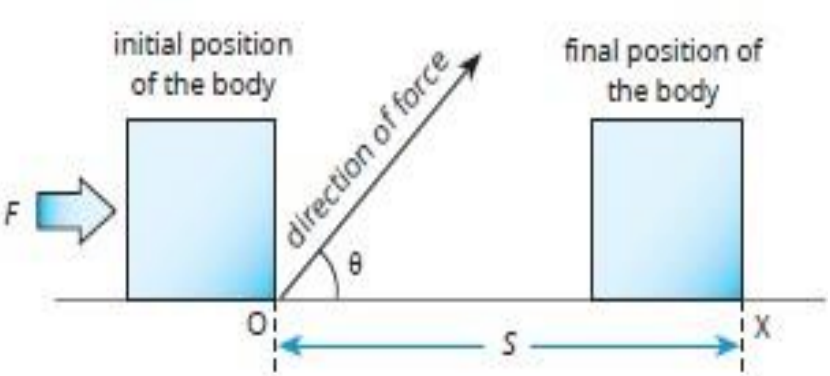
The body moves in the direction of the applied force

Work done when the body moves at an angle to the direction of force



When a child pulls a toy car, the toy car moves on the horizontal ground OX but the force applied is along the string OA, at an angle θ to the direction of motion.

Suppose a body lying at a point O is being pulled by a man. Now, though the body is moving on the horizontal floor and reaches the point X after covering a distance *S*, the force is being applied in the direction of the string OA, making an angle θ with the direction of motion of the body. The body moves in a direction inclined at an angle θ to the direction of the applied force.



$W = F \cos\theta \times S$, where, W = Work done

F = Force applied

θ = Angle between the direction of the force and the direction of motion ,and

S = Displacement

Units of Work

The SI unit of work is joule.

Work done = Force × Displacement

Thus, 1 joule = 1 newton × 1 metre

The work done is said to be of 1 joule if a force of 1 newton displaces a body through a distance of 1 metre in its own direction.

In MKS system the unit of work is kg m2 s–2.

The CGS unit of work is erg.

Thus, 1 erg = 1 dyne × 1 centimetre

Special Cases

A. When the displacement is in the direction of the force.

$\theta = 0°$ then $\cos 0° = 1$. $\therefore W = F \cos 0° \times S$

$W = F(1) \times S$

$W = F \times S$ The work done is maximum and positive.

B. When the displacement is in the direction opposite to the applied force.

In this case, the angle θ between the direction of displacement and the direction of force is 180°.

Then $\cos 180° = -1$. $\therefore W = F \cos\theta \times S$

$$= -F \times S$$

The work done by the force is negative. This implies that the force acts in the opposite direction in which the body moves. The work done is negative.

C. When the displacement is at right angle to the direction of force.

As, $W = F \cos\theta \times S$

when $\theta = 90°$, $\cos\theta = \cos 90°$

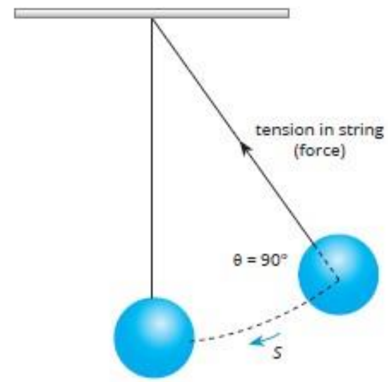
$= 0$, Hence, work done is zero.

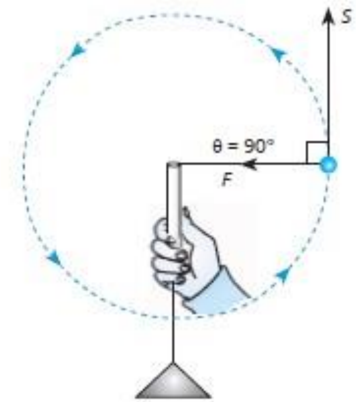
Example1:

When a body moves in a circular path, work done is zero.

Example2:

Work done by the tension in a string of a simple pendulum is zero as the tension is always perpendicular to the displacement





Energy

Energy of a body is defined as the capacity or ability of the body to do work. Also, the amount of energy possessed by a body is equal to the amount of work it can do when its energy is released.

Units of Energy

The SI unit of energy is joule (J).

1 J is the energy required or consumed to do 1 joule of work.

The bigger units of energy are watt-hour (Wh) and kilowatt-hour (kWh) where,

1 watt-hour (Wh) = 1 watt × 1 hour
= 1 J s–1 × 3600 s
= 3600 J = 3.6 × 103 J

Power

The rate of doing work is known as the power. Power of a body is defined as the rate at which the body can do the work.

Power = Work done /Time taken

or $P = W / t$ Thus, power depends on two factors **1.** the amount of work done, and **2.** the time taken.

Expression for power ($P = Fv$)

If a force F is applied on a body and it displaces the body by a distance S (in the direction of the applied force) in time t, the work done is

$W = F \times S$, We know, $P = W/t$

or $P = F \times S / t$ [Since, $W = F \times S$]

∴ $P = F \times v$ [Since, $v = S/t$]

or Power = Force × Average speed

Note: Please refer Table 2.1, P-30 of Living Science Physics, to know the Equivalence of various units of energy in joules.

Units of power

SI Unit: The SI unit of work is joule ‘J’ and that of time is second ‘s’, therefore, SI unit of power is ‘joule per second’. This unit is called watt (W). Thus, the SI unit of power is watt. The power of a body is 1 W if it is doing 1 J of work in 1 s.

1 watt = 1 joule /1 second

Different Forms of Energy

In nature, we find energy in different forms.

1. Chemical Energy 2. Sound Energy 3. Light Energy 4. Electrical Energy
5. Heat Energy 6. Magnetic Energy 7. Nuclear Energy 8. Hydro Energy
9. Geothermal Energy 10. Mechanical Energy

Kinetic Energy

Mechanical energy is of two types – kinetic energy and potential energy.

The energy possessed by a body by virtue of its motion is called kinetic energy

Kinetic energy = $1/2\ mv^2$,

where, m = mass of the body and v = velocity of the body

Thus, a body of mass m and moving with a velocity v has the capacity of doing work equal to $1/2\ mv^2$ before it stops.

Forms of Kinetic Energy

Corresponding to each type of motion, there are following three forms of kinetic energy:

1. Translational kinetic energy **2.** Rotational kinetic energy **3.** Vibrational kinetic energy

Potential Energy

The potential energy of a body is defined as the energy possessed by the body by virtue of its position or configuration (change in shape or size).

Two important forms of potential energy are:

1. Gravitational potential energy **2.** Elastic potential energy

Formula for gravitational potential energy ($U = mgh$)

Suppose a body of mass m is raised to a height h above the surface of the earth. The force applied just to overcome the gravitational attraction is,

$F = m \times g$, where, g = acceleration due to gravity.

As the distance moved is in the direction of the force applied, therefore

Work done = Force $\times$ Displacement

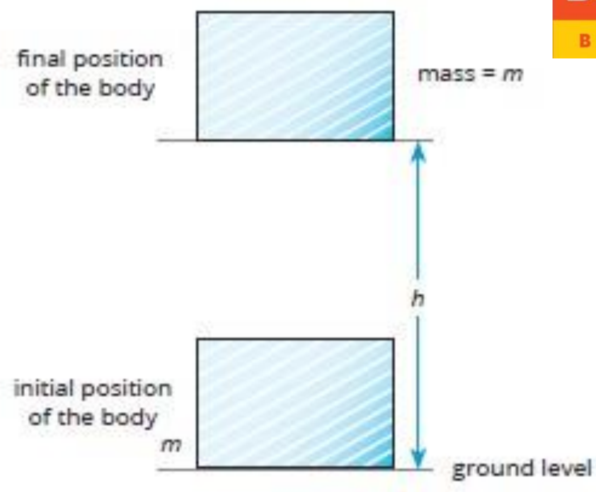
$$W = F \times h$$

We get

$W = m \times g \times h$

This work gets stored up in the body as gravitational potential energy. Thus,

Gravitational potential energy, $U = m \times g \times h$



Principle of Conservation of Energy

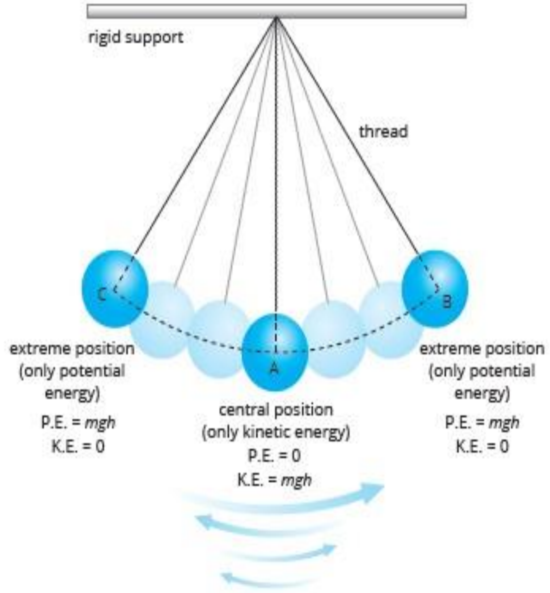
According to the principle of conservation of energy, **the sum total of energies of all kinds in an isolated system always remains constant**. In other words, **energy can neither be created nor destroyed. Energy can only be changed from one form to another**.

Law of Conservation of Mechanical Energy

According to the law of conservation of mechanical energy **whenever there is an interchange between the potential energy and the kinetic energy, the total mechanical energy [i.e. the sum of kinetic energy, (*K*) and potential energy, (*U*)] remains constant when there are no frictional forces**.

Note: Please refer to the Table 2.2 for Examplesof Energy Transformation in the book Living Science, Physics-10, P-38

Application of the law of conservation of energy of a simple pendulum



At position B

Potential energy of the bob, $U = mgh$

At position B, the bob of the simple pendulum is at rest.

∴ Kinetic energy of the bob, $K = 0$

Total mechanical energy of the bob.

$E1 = K + U = 0 + mgh = mgh$

Thus at position B, the total energy is potential energy

At position A

The vertical height decreases from h to 0.

∴ Potential energy of the bob, $U = 0$

Let the velocity of the bob at position A = v

From $v2 – u2 = 2aS$, $So, v2 – 0 = 2gh$

$$v^2 = 2gh$$

Kinetic energy of the bob, $K = 1/2\ mv^2 = mgh$

Total mechanical energy of the bob

$E2 = K + U = mgh + 0 = mgh$

Thus, at position A, the total energy is kinetic energy.

At position C

Potential energy of the bob, $U = mgh$

At position C, the bob of the simple pendulum is at rest.

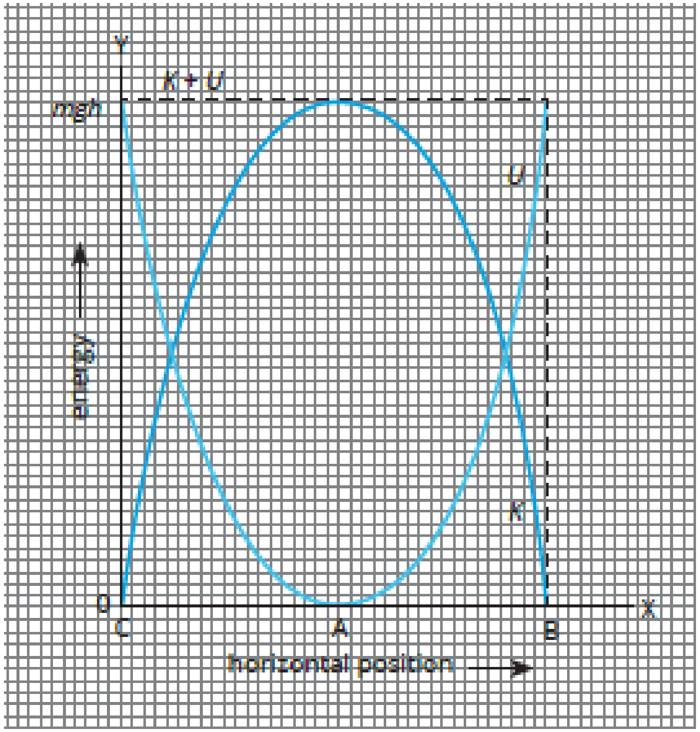
$\therefore$ Kinetic energy of the bob, $K = 0$

Total mechanical energy of the bob

$$E3 = K + U = 0 + mgh = mgh$$

At position C, the total energy is potential energy.

Thus, we have $E1 = E2 = E3 = mgh$



Conservation of mechanical energy during motion of a simple pendulum

The variation of potential energy and kinetic energy with horizontal position is shown in the graph.

SUMMARY

1. Work: Work is said to be done only when the force acting on a body produces motion in it in the direction of force.

2. Energy: The ability of a body to do work is called its energy.

3. Power: The rate of doing work is called power.

4. Kinetic energy: The energy possessed by a body by virtue of its motion is called kinetic energy.

5. Work-energy theorem: According to this principle, work done by the net force on a body is equal to the change in its kinetic energy of the body.

6. Forms of kinetic energy: a. Translational kinetic energy **b.** Rotational kinetic energy **c.** Vibrational kinetic energy.

7. Potential energy: The energy possessed by a body by virtue of its position is called potential energy.

8. Principle of conservation of energy: The sum total of energy of all kinds in an isolated system always remains constant at all times.