

# Chapter 10: Work and Energy

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## Introduction to Work and Energy

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### Life Processes

All living beings need food for energy to perform basic activities. We also need energy for playing, singing, reading, etc.

### Machines

Machines also need energy for their working. Some engines require fuel like petrol and diesel.

### Connection

Work, energy, and power are closely related concepts that help us understand natural phenomena.

## Scientific Conception of Work

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### Difference in Meaning

There is a difference between 'work' in day-to-day life and 'work' in science. Mental labour like studying is not considered work in science.

### No Displacement, No Work

Pushing a huge rock that doesn't move involves a lot of effort but no work is done on the rock because there is no displacement.

## Two Conditions for Work

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### The Conditions

For work to be done in science, two conditions must be satisfied: (i) a force should act on an object, and (ii) the object must be displaced.

### Examples

A girl pulling a trolley is doing work because force is applied and displacement occurs. A book lifted up involves work.

## Work Done by a Constant Force

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### Definition

Work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force.

### Formula

Work (W) = Force (F) × Displacement (s). Work has only magnitude and no direction.

### Unit

The unit of work is newton metre (N m) or joule (J). 1 J is the work done when a force of 1 N displaces an object by 1 m.

## Positive and Negative Work

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### Positive Work

Work done is positive when the force is in the direction of displacement. Example: A baby pulling a toy car parallel to the ground.

### Negative Work

Work done is negative when the force acts opposite to the direction of displacement. Example: Retarding force applied to a moving object.

## Energy

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### Capacity to Do Work

An object having a capability to do work is said to possess energy. The object doing work loses energy, and the object on which work is done gains energy.

### Measurement

Energy possessed by an object is measured in terms of its capacity of doing work. The unit of energy is the same as work: joule (J).

### Sources

The Sun is the biggest natural source of energy. Other sources include nuclei of atoms, interior of earth, and tides.

## Forms of Energy

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### Variety

Energy exists in many forms: mechanical energy (potential + kinetic), heat energy, chemical energy, electrical energy, and light energy.

## Kinetic Energy

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### Energy of Motion

Kinetic energy is the energy possessed by an object due to its motion. A moving bullet, blowing wind, and a running athlete possess kinetic energy.

### Speed Factor

The kinetic energy of an object increases with its speed. An object moving faster can do more work than an identical object moving relatively slow.

## Formula for Kinetic Energy

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### Derivation

Work done to accelerate an object from velocity  $u$  to  $v$  is the change in kinetic energy. If starting from rest ( $u=0$ ), Work =  $\frac{1}{2}mv^2$ .

### Formula

Kinetic Energy ( $E_k$ ) =  $\frac{1}{2}mv^2$ , where  $m$  is the mass and  $v$  is the velocity.

## Potential Energy

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### Stored Energy

The energy transferred to an object is stored as potential energy if it is not used to cause a change in velocity. It is the energy present by virtue of position or configuration.

### Examples

Stretching a rubber band or winding a toy car stores potential energy.

## Potential Energy of an Object at a Height

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### Gravitational Potential Energy

When an object is raised through a height, work is done against gravity. The energy gained is gravitational potential energy.

### Formula

$E_p = mgh$ , where  $m$  is mass,  $g$  is acceleration due to gravity, and  $h$  is the height.

### Path Independence

The work done by gravity depends on the difference in vertical heights, not on the path taken.

## Interconversion of Energy

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### Transformation

Energy can be converted from one form to another. In nature, green plants convert solar energy to chemical energy (food).

### Gadgets

Many human activities and gadgets involve energy conversion, like an electric bulb converting electrical energy to light and heat.

## Law of Conservation of Energy

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### Statement

Energy can only be converted from one form to another; it can neither be created nor destroyed. The total energy before and after the transformation remains the same.

### Free Fall Example

During free fall, potential energy decreases while kinetic energy increases. The sum (mechanical energy) remains constant at all points:  $mgh + \frac{1}{2}mv^2 = \text{constant}$ .

## Rate of Doing Work (Power)

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### Definition

Power is defined as the rate of doing work or the rate of transfer of energy.  $\text{Power} = \text{Work} / \text{Time}$ .

### Unit

The unit of power is watt (W).  $1 \text{ W} = 1 \text{ Joule/second}$ . Larger unit is kilowatt (kW).

### Average Power

Since power may vary with time, we use average power = Total energy consumed / Total time taken.

## Commercial Unit of Energy

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### Kilowatt-hour

The joule is too small for large energy quantities. We use kilowatt-hour (kWh). 1 kWh is the energy used in one hour at the rate of 1000 J/s.

### Conversion

$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$ . This is commonly known as one 'unit' of electricity.