Chapter 10: Work and Energy

Introduction to Work and Energy

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

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

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

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

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

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

Variety

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

Kinetic Energy

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

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

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

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

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

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)

Definition

Power is defined as the rate of doing work or the rate of transfer of energy. Power = Work / Time.

Unit

The unit of power is watt (W). 1 W = 1 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

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 kWh = 3.6×10^6 J. This is commonly known as one 'unit' of electricity.