Work, Energy and Power

Introduction

Work, Energy and Power are fundamental concepts in physics used to describe the motion and interaction of objects. **Work** is done when a force causes displacement, **energy** is the capacity to do work, and **power** measures the rate at which work is done. These concepts are closely related and are used in mechanics, machines, engineering, and everyday life.

Work

Definition

Work is said to be done when a force acting on an object produces displacement in the direction of the force.

Formula:

$W = F\, s \cos\theta$

where:

- **F** = Force
- **s** = Displacement
- **θ** = Angle between force and displacement

SI Unit: **Joule (J)**

Work is a **scalar quantity**.

Positive, Negative and Zero Work

Types of Work

- **Positive Work:** When force and displacement are in the same direction.
- **Negative Work:** When force and displacement are in opposite directions.
- **Zero Work:** When there is no displacement or the force is perpendicular to displacement.

Example: The centripetal force acting on a body in uniform circular motion does **zero work**.

Work Done by a Variable Force

Variable Force

When the force changes with position, the work done is calculated using the **area under the Force-Displacement (F-x) graph**.

For a small displacement:

$dW = F\,dx$

Total work is obtained by integrating the force over displacement.

Energy

Definition

Energy is the capacity of a body or system to do work.

SI Unit: **Joule (J)**

Energy can exist in different forms, such as:

- Kinetic Energy
- Potential Energy
- Thermal Energy
- Chemical Energy
- Electrical Energy

Kinetic Energy

Energy of Motion

Kinetic Energy is the energy possessed by a body due to its motion.

Formula:

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

where:

- **m** = Mass
- **v** = Velocity

The kinetic energy increases with the square of velocity.

Work-Energy Theorem

Statement

The **Work-Energy Theorem** states that the **net work done on a body is equal to the change in its kinetic energy**.

$W_{net} = \Delta K$

or

$W_{net} = K_f - K_i$

This theorem connects work done by a force with the motion of an object.

Potential Energy

Definition

Potential Energy is the energy possessed by an object due to its position or configuration.

Gravitational Potential Energy

For an object at height **h**:

$U = mgh$

where:

- **m** = Mass
- **g** = Acceleration due to gravity
- **h** = Height

Elastic Potential Energy

Spring Energy

A stretched or compressed spring stores **elastic potential energy**.

Formula:

$U = \frac{1}{2}kx^2$

where:

- **k** = Spring constant
- **x** = Extension or compression

Law of Conservation of Energy

Statement

The **Law of Conservation of Energy** states that energy can neither be created nor destroyed. It can only be **transformed from one form to another**.

For an isolated system:

Total Energy = Constant

Power

Definition

Power is the rate at which work is done or energy is transferred.

Formula:

P = W/t

SI Unit: **Watt (W)**

One watt is the power when one joule of work is done in one second.

For a body moving with velocity **v**:

P = Fv

when force and velocity are in the same direction.

Collision

Definition

A **collision** is an interaction between two bodies in which they exert large forces on each other for a short period.

Types:

- **Elastic Collision** – Both momentum and kinetic energy are conserved.
- **Inelastic Collision** – Momentum is conserved, but kinetic energy is not conserved.
- **Perfectly Inelastic Collision** – The bodies stick together after collision.

Applications

Importance

The concepts of work, energy, and power are used in:

- Machines and Engines
- Vehicles
- Power Plants
- Construction
- Sports
- Industrial Processes
- Mechanical Systems

Key Points

- Work is done when force produces displacement.
- Work is a scalar quantity.
- Energy is the capacity to do work.
- Kinetic energy is **$\frac{1}{2}mv^2$**.
- Potential energy depends on position or configuration.
- Net work equals change in kinetic energy.
- Energy is conserved but can change its form.
- Power is the rate of doing work.
- SI unit of work and energy is **Joule**.
- SI unit of power is **Watt**.

Chapter Summary

This chapter explains the fundamental concepts of work, energy, and power. It covers work done by constant and variable forces, kinetic and potential energy, the work-energy theorem, conservation of energy, power, and collisions. These principles help us understand how forces transfer energy and how energy changes from one form to another in physical systems.