
CHAPTER 06: WORK AND ENERGY

6.0 INTRODUCTION

Work and Energy are fundamental concepts in Physics that explain how forces cause motion and how energy is transferred and transformed. In daily life, work means any activity, but in Physics, work is done only when a force causes displacement. Energy is the ability to do work, and power tells us how fast work is done. This chapter explains work, different forms of energy, energy conversion, conservation of energy, energy resources, power, and efficiency in a systematic way.

6.1 WORK**Definition**

Work is said to be done when a force acting on a body causes displacement in the direction of the force.

Mathematical Expression

Work done:

$$W = F \times d$$

Where: - F = applied force (newton, N) - d = displacement (metre, m)

SI Unit

- Joule (J)
- $1 \text{ J} = 1 \text{ N} \times 1 \text{ m}$

Nature of Work

- Work is a **scalar quantity**.
- If there is no displacement, no work is done (e.g., holding a book without moving).

Work at an Angle

If force makes an angle θ with displacement:

$$W = F d \cos\theta$$

6.2 ENERGY AND ITS FORMS

Definition of Energy

Energy is defined as the capacity of a body to do work.

SI Unit of Energy

- Joule (J)

Forms of Energy

Energy exists in many forms, including: - Mechanical Energy - Chemical Energy - Electrical Energy - Heat Energy - Light Energy - Nuclear Energy - Sound Energy

All forms of energy can be broadly classified into **Kinetic Energy** and **Potential Energy**.

6.2.1 KINETIC ENERGY

Definition

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

Factors Affecting Kinetic Energy

- Mass of the body
- Velocity of the body

Derivation of Kinetic Energy

Kinetic Energy of a body:

$$E_k = \frac{1}{2}mv^2$$

Where: - m = mass (kg) - v = velocity (m/s)

Nature

- Scalar quantity

Work–Energy Theorem

The work done on a body is equal to the change in its kinetic energy.

$$W = \Delta E_k$$

Examples / Applications

- Moving vehicles
- Flowing water

- Rotating machines
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6.2.2 POTENTIAL ENERGY

Definition

Potential energy is the energy possessed by a body due to its position or configuration.

Gravitational Potential Energy

When a body is raised to a height, it gains gravitational potential energy.

Formula

$$E_p = mgh$$

Where: - m = mass (kg) - g = acceleration due to gravity (9.8 m/s^2) - h = height (m)

Nature

- Scalar quantity

Other Types of Potential Energy

- Elastic potential energy
- Chemical potential energy
- Electrical potential energy

Examples

- Water stored in a dam
 - Book on a shelf
 - Stretched spring
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6.2.3 MECHANICAL ENERGY

Mechanical Energy is the sum of kinetic energy and potential energy.

$$E_m = E_k + E_p$$

6.2.4 ENERGY CONVERSION

Definition

Energy conversion is the process of changing energy from one form to another.

Examples

- Electric bulb: Electrical → Light + Heat
- Car engine: Chemical → Kinetic
- Hydroelectric power: Potential → Electrical

During energy conversion, some energy is always dissipated as heat.

6.2.5 LAW OF CONSERVATION OF ENERGY

Statement

Energy can neither be created nor destroyed; it can only be converted from one form to another. The total energy of an isolated system remains constant.

Mathematical Form

$$E_i = E_f$$

Or

$$E_k + E_p = \text{constant}$$

With Friction

Initial Energy = Final Energy + Energy lost due to friction

Importance

- Explains motion
 - Basis of energy calculations
 - Rules out perpetual motion machines
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6.3 ENERGY RESOURCES

Energy resources are sources from which usable energy can be obtained.

Classification

1. Non-renewable energy resources
 2. Renewable energy resources
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6.3.1 NON-RENEWABLE ENERGY RESOURCES

Definition

Resources that cannot be replenished in a short time.

Examples

- Coal
- Oil
- Natural Gas
- Nuclear Fuel

Disadvantages

- Limited supply
 - Environmental pollution
 - Global warming
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6.3.2 FOSSIL FUELS

Fossil fuels are formed from remains of plants and animals buried for millions of years.

Types

- Coal
- Oil
- Natural Gas

Advantages

- High energy density
- Easy transportation

Disadvantages

- Air pollution
 - CO₂ emission
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6.3.3 NUCLEAR ENERGY

Energy obtained from nuclear fission reactions.

Advantages

- Large energy output

- No greenhouse gases

Disadvantages

- Radioactive waste
 - High installation cost
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6.3.4 BIOMASS ENERGY

Energy obtained from plant and animal waste.

Examples

- Biogas
- Wood
- Crop residues

Advantages

- Renewable
 - CO₂ neutral
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6.3.5 HYDROELECTRIC ENERGY

Energy generated using flowing water.

Advantages

- Renewable
- High efficiency

Disadvantages

- Ecosystem damage
 - Large area required
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6.3.6 SOLAR ENERGY

Energy obtained from sunlight using solar panels.

Advantages

- Clean and renewable
- Abundant

Disadvantages

- Depends on weather
 - Expensive setup
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6.3.7 WIND ENERGY

Energy obtained from moving air using wind turbines.

Advantages

- Eco-friendly
- Renewable

Disadvantages

- Requires strong winds
 - Large land area
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6.3.8 TIDAL AND WAVE ENERGY

Energy obtained from ocean tides and waves.

Advantages

- Predictable
- Renewable

Disadvantages

- Limited locations
 - High cost
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6.4 POWER

Definition

Power is the rate of doing work or rate of energy conversion.

Formula

$$P = W / t$$

SI Unit

- Watt (W)

- $1 \text{ W} = 1 \text{ J/s}$

Horsepower

$$1 \text{ hp} = 746 \text{ W}$$

Commercial Unit of Energy

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

6.5 EFFICIENCY

Definition

Efficiency is the ratio of useful output energy to total input energy.

Formula

$$\eta = (\text{Useful output energy} / \text{Input energy})$$

Percentage Efficiency

$$\eta\% = (\text{Output} / \text{Input}) \times 100$$

Why Efficiency Is Never 100%

- Energy losses due to friction
 - Heat dissipation
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ALL FORMULAE (COLLECTED AT END)

1. Work: $W = Fd$
 2. Work at angle: $W = Fd \cos\theta$
 3. Kinetic Energy: $E_k = \frac{1}{2}mv^2$
 4. Gravitational Potential Energy: $E_p = mgh$
 5. Mechanical Energy: $E_m = E_k + E_p$
 6. Power: $P = W/t$
 7. $1 \text{ hp} = 746 \text{ W}$
 8. Efficiency: $\eta = \text{Output} / \text{Input}$
 9. Percentage Efficiency: $\eta\% = (\text{Output}/\text{Input}) \times 100$
 10. Commercial unit: $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$
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END OF CHAPTER – WORK AND ENERGY