Table of Contents

"

Work Energy Simple Machines

Introduction to Work, Energy, and Power

Work, energy, and power are fundamental concepts that help us understand how forces cause motion and how energy is transferred or transformed in various processes. Work is done when a force causes an object to move in the direction of the force. Energy is the capacity to do work, and power is the rate at which work is done.

Work Done by a Constant Force

When a constant force acts on an object causing it to move in the direction of the force, the work done is calculated as the product of the force and the displacement in the direction of the force. Mathematically,

Work done (W) = Force (F) × Displacement (s)

The SI unit of work is the joule (J), where 1 joule is the work done when a force of 1 newton displaces an object by 1 meter in the direction of the force.

Positive and Negative Work

Work done by a force can be positive or negative depending on the direction of the force relative to the displacement. If the force and displacement are in the same direction, the work is positive. If they are in opposite directions, the work is negative. For example, pushing a wheelchair forward involves positive work, while a goalkeeper stopping a ball applies negative work.

Work-Energy Theorem

The work-energy theorem states that the work done on an object is equal to the change in its energy. When positive work is done, the object gains energy; when negative work is done, the object loses energy. This theorem helps us analyze motion and energy changes without directly using forces and accelerations.

Forms of Energy

Energy exists in various forms including mechanical, thermal, light, sound, electrical, nuclear, and chemical energy. Mechanical energy is associated with the motion and position of objects and includes kinetic energy (energy of motion) and potential energy (energy stored due to position or configuration).

Kinetic Energy

Kinetic energy is the energy possessed by an object due to its motion. It is given by the formula:

K = \\(\\frac{1}{2} m v^2 \\)

where m is the mass of the object and v is its velocity. The unit of kinetic energy is joule (J).

Potential Energy

Potential energy is the energy stored in an object due to its position or configuration. Gravitational potential energy near the Earth's surface is given by:

U = mgh

where m is the mass, g is the acceleration due to gravity, and h is the height above the reference point. Potential energy is also measured in joules.

Conservation of Mechanical Energy

The total mechanical energy (sum of kinetic and potential energy) of an object remains constant if only conservative forces like gravity act on it. As an object falls, potential energy converts into kinetic energy, keeping the total mechanical energy constant.

Power

Power is the rate at which work is done. It is calculated as:

P = \\(\\frac{W}{t} \\)

where W is work done and t is time taken. The SI unit of power is watt (W), where 1 watt equals 1 joule per second.

Simple Machines

Simple machines are devices that make work easier by changing the magnitude or direction of the applied force. They do not reduce the total work done but help us perform tasks more conveniently. Examples include pulleys, inclined planes, and levers.

Pulley

A pulley is a wheel with a groove that guides a rope. A fixed pulley changes the direction of the force but does not reduce the effort needed. Movable pulleys or pulley systems can reduce the effort required by increasing the mechanical advantage.

Inclined Plane

An inclined plane is a flat surface tilted at an angle to the horizontal. It allows lifting heavy objects with less force over a longer distance. The mechanical advantage of an inclined plane is the ratio of its length to its height.

Lever

A lever is a rigid bar that rotates about a fixed point called the fulcrum. It has three parts: fulcrum, load, and effort. By increasing the effort arm, a lever allows a smaller effort to move a larger load. The mechanical advantage is the ratio of the effort arm to the load arm.

Solved Examples

Example 1: Calculating Work Done

A force of 10 N moves an object 5 meters in the direction of the force. Calculate the work done.

Work done, W = F × s = 10 N × 5 m = 50 J

Example 2: Kinetic Energy Calculation

A 2 kg ball is moving with a velocity of 3 m/s. Calculate its kinetic energy.

K = \\(\\frac{1}{2} m v^2 \\) = 0.5 × 2 kg × (3 m/s)² = 9 J

Example 3: Potential Energy Calculation

A 5 kg object is lifted to a height of 4 meters. Calculate its potential energy. Take g = 10 m/s².

U = mgh = 5 kg × 10 m/s² × 4 m = 200 J

Example 4: Power Calculation

A person does 1000 J of work in 20 seconds. Calculate the power.

P = W / t = 1000 J / 20 s = 50 W

Example 5: Mechanical Advantage of Inclined Plane

An inclined plane is 5 m long and raises a load to a height of 1 m. Calculate its mechanical advantage.

Mechanical advantage = Length / Height = 5 m / 1 m = 5

Example 6: Lever Balance

A lever has an effort arm of 2 m and a load arm of 0.5 m. Calculate the mechanical advantage.

Mechanical advantage = Effort arm / Load arm = 2 m / 0.5 m = 4

Practice Set

Conceptual Questions

- Explain why no work is done when you push against a wall that does not move.
- What is the difference between kinetic energy and potential energy?

Application-Based Question

- A 10 kg box is lifted vertically by 2 meters using a pulley system. If the effort applied is 50 N, calculate the work done by the effort and the mechanical advantage of the pulley system.

Numerical Questions

- Calculate the power required to lift a 100 kg load to a height of 10 meters in 20 seconds. Take g = 10 m/s^2.

Answer Key

Conceptual Questions

- No work is done because the wall does not move; displacement is zero.
- Kinetic energy is energy due to motion; potential energy is energy stored due to position or configuration.

Application-Based Question

- Work done = Force × Displacement = 50 N × 2 m = 100 J. Load = mg = 10 kg × 10 m/s² = 100 N. Mechanical advantage = Load / Effort = 100 N / 50 N = 2.

Numerical Questions

- Work done = mgh = 100 kg × 10 m/s² × 10 m = 10000 J. Power = Work / Time = 10000 J / 20 s = 500 W.

Quick Reference Table

Key Formulas and Units

- Work done: W = F × s (joule, J)
- Kinetic energy: K = \\(\\frac{1}{2} m v^2 \\) (joule, J)
- Potential energy: U = mgh (joule, J)
- Power: P = W / t (watt, W)
- Mechanical advantage: MA = Load / Effort

Common Mistakes and Misconceptions

- Assuming work is done whenever a force is applied, even if there is no displacement.
- Confusing kinetic energy with potential energy.
- Believing simple machines reduce the total work done rather than just making it easier.

- Ignoring the direction of force and displacement when calculating work.

Glossary

- **Work:** Product of force and displacement in the direction of the force.
- **Energy:** Capacity to do work.
- **Kinetic Energy:** Energy possessed by an object due to its motion.
- **Potential Energy:** Energy stored due to position or configuration.
- **Power:** Rate of doing work.
- **Mechanical Advantage:** Ratio of load to effort in a machine.
- **Simple Machine:** Device that changes the magnitude or direction of a force to make work easier.

"