WORK AND ENERGY

CBSE CLASS 9 SCIENCE • CHAPTER 11 • COMPLETE HIGH-YIELD TEXTBOOK NOTES

1. Introduction & The Scientific Definition of Work

In colloquial communication, mental or physical exertion like reading, deep studying, or holding heavy loads is called "work". However, in Physics, work has a strict mechanical definition that links force explicitly with spatial shift.

- **Physics Concept:** Work is done if and only if an applied force causes an object to move through a distance in the direction of that force.
- **Non-Work Scenarios:** Pushing against a rigid stone wall without moving it, or holding a heavy block stationary in one spot results in **zero work done**, regardless of the physical fatigue experienced.

2. Mathematical Formulations of Work Done

The work done (W) by a constant force acting on an object is calculated as the product of the force magnitude (F) and the displacement (s) achieved along the line of action.

```
$$W = F imes s$$
```

Mandatory Conditions for Mechanical Work to Occur:

1. A net, external **Force** must actively operate on the targeted body ($F eq 0$).
2. The body must undergo a physical shift or **Displacement** ($s eq 0$).

SI Unit: **Joule ($ ext{J}$)** or $ ext{Newton-metre }(ext{N}\cdot ext{m})$.

> **Definition of 1 Joule:** One Joule ($ ext{1 J}$) is the exact amount of work executed when a uniform force of $1 ext{ Newton}$ displaces an object through a distance of $1 ext{ metre}$ along the direction of the applied force.

3. Mathematical Signs of Work: Positive, Negative, & Zero

Work is a scalar property that can take positive, negative, or zero values depending on the angular orientation between the force vector and the displacement pathway:

Work Classification	Vector Alignment Definition	Standard Laboratory Examples
Positive Work ($W > 0$)	The applied force and the resulting displacement align in the **identical direction** ($ heta = 0^\circ$).	• Pulling a child's toy trolley forward. • An apple dropping freely under gravitational pull.
Negative Work ($W < 0$)	The force operates in a direction exactly **opposite to the displacement** track ($ heta = 180^\circ$).	• Kinetic friction resisting a sliding cardboard box.

Work Classification	Vector Alignment Definition	Standard Laboratory Examples
		• Applying friction brakes to slow down a bicycle.
Zero Work ($W = 0$)	Displacement is zero, or the force vector acts completely **perpendicular** to the direction of motion ($ heta = 90^\circ$).	• Pushing hard against an immovable concrete wall. • A porter carrying luggage horizontally on his head (gravity is perpendicular to displacement).

4. The Nature of Energy & Its Multi-Form Profiles

An object that can perform work contains **Energy**. Therefore, energy is defined as the scalar capacity or ability of a system to perform mechanical work. Because energy is measured by the total work it can produce, both parameters share the identical SI unit: the **Joule ($ ext{J}$)**.

Primary Energetic Forms:

`Mechanical Energy` `Thermal Heat Energy` `Light Energy` `Electrical Current` `Acoustic Sound Energy` `Chemical Bonds` `Nuclear Core Forces`

5. Mechanical Energy Core: Kinetic vs. Potential

Mechanical energy represents the total sum of an object's motion-based and position-based energy stores.

Kinetic Energy (E_k)

The energy stored inside a physical object due to its active state of motion.

```
$$E_k =  rac{1}{2}mv^2$$
```

- Directly proportional to the object's mass (m).
- Proportional to the square of its linear speed (v^2).
- *Examples:* A speeding vehicle, a running track athlete, or a rushing wind turning turbine blades.

Potential Energy (E_p)

The energy stored within an object due to its relative vertical position or structural configuration shape.

```
$$E_p = mgh$$
```

- Depends on mass (m), gravitational field strength (g), and height (h) above a reference plane.
- Can manifest as gravitational or elastic strain energy.
- *Examples:* Water stored behind a reservoir dam, or a compressed steel spring.

6. The Law of Conservation of Energy

This foundational principle governs all energetic interactions in the universe:

> *"Energy can neither be created nor destroyed; it can only be transformed from one distinct form into another. The total energy inside an isolated system remains absolutely constant."*

Analysis of a Freely Falling Body ($E_{\text{total}} = E_k + E_p$):

Consider an object of mass m held at rest at a high point h. Its initial kinetic energy is zero, and its potential energy is maximum (mgh). When released:

- As the object falls, its height (h) decreases, causing its potential energy to drop steadily.
- Simultaneously, its velocity (v) increases, causing its kinetic energy to rise.
- At any intermediate location during the fall, the loss in potential energy matches the gain in kinetic energy. Just before striking the ground, the potential energy drops to zero, and the kinetic energy reaches its maximum value ($\frac{1}{2}mv^2 = mgh$). Thus, the total mechanical energy remains conserved throughout the fall.

7. Power: The Temporal Rate of Doing Work

Two systems can perform identical amounts of work, but the one that completes it faster is more powerful. **Power (P)** is defined as the rate of doing work or the rate at which energy is consumed over time.

```
$$ ext{Power } (P) =  rac{ ext{Work Done } (W)}{ ext{Time Taken } (t)}$$
```

- **SI Unit:** **Watt ($ ext{W}$)**, where $1 ext{ Watt} = 1 ext{ Joule per second } (ext{J/s})$.
- **Definition of 1 Watt:** One Watt is the power of an engineering device that performs work at the uniform rate of $1 ext{ Joule}$ per second.
- **Larger Scaled Engineering Units:**
  - $1 ext{ Kilowatt }(ext{kW}) = 10^3 ext{ Watts}$
  - $1 ext{ Megawatt }(ext{MW}) = 10^6 ext{ Watts}$

8. Commercial Unit of Energy

Because the Joule is a small unit, it is impractical for measuring large amounts of industrial or domestic electrical energy consumption. Instead, utility bills use a larger commercial unit called the **kilowatt-hour ($ ext{kWh}$)**, commonly referred to as a **"Unit"**.

Definition of 1 Kilowatt-hour: The total electrical energy consumed when an appliance with a power rating of $1 ext{ kilowatt }(1000 ext{ W})$ runs continuously for an interval of exact $1 ext{ hour}$.

Mathematical Conversion: Linking the Commercial Unit to Joules

$$ ext{1 kWh} = 1 ext{ kW} imes 1 ext{ hour}$$ $$ ext{1 kWh} = 1000 ext{ Watts} imes 3600 ext{ seconds}$$ $$ ext{1 kWh} = 1000 ext{ J/s} imes 3600 ext{ s} = 3,600,000 ext{ Joules}$$

```
$$ ext{1 kWh} = 3.6 imes 10^6 \ ext{J}$$
```

9. High-Yield Numerical Step-by-Step Solutions

Problem 1 (Potential Energy Calculation): A mass of $2 ext{ kg}$ is lifted vertically through a clearance height of $5 ext{ metres}$ above a room floor. Find its potential energy change ($g = 9.8 ext{ m/s}^2$).
Solution Workflow: Given parameters are $m = 2 ext{ kg}$, $h = 5 ext{ m}$, $g = 9.8 ext{ m/s}^2$. Using the Potential Energy formula: $$E_p = m \cdot g \cdot h \implies E_p = 2 imes 9.8 imes 5 = 98 ext{ Joules}$$

Problem 2 (Rate of Power Output): An electric hoist performs exactly $1200 ext{ Joules}$ of lifting work over a duration of $2 ext{ minutes}$. Calculate its operational power output in Watts.
Solution Workflow: Convert time into standard SI units: $t = 2 ext{ minutes} = 2 imes 60 = 120 ext{ seconds}$. Work $W = 1200 ext{ J}$. Applying the Power equation: $$P = rac{W}{t} \implies P = rac{1200 ext{ J}}{120 ext{ s}} = 10 ext{ Watts}$$

10. Mandatory NCERT Laboratory Activities

Activity 1: Evaluating Displacement Alignment Conditions

Lift a heavy object directly upward from the floor to a table top. Analyze the work done by the lifting force versus the work done by gravity.

Observations & Conclusions: The upward lifting force aligns with the direction of motion, performing *positive work*. However, the downward gravitational force acts opposite to the upward movement, performing *negative work*. This confirms that mechanical work is highly dependent on vector angles.

Activity 2: Potential to Kinetic Energy Transformation

Incline a smooth wooden plank track, place a small toy car at the top peak, and release it so it hits a light foam block resting at the bottom.

Observations & Conclusions: Higher release points give the car greater initial potential energy (mgh). Upon release, this potential energy converts entirely into kinetic energy ($ rac{1}{2}mv^2$). The increased speed at the bottom delivers a harder impact, displacing the foam block further. This directly demonstrates energy conversion and the capacity to do work.

11. Comprehensive Chapter Revision Summary Index

Chapter Synopsis: Mechanical work requires both an active force and a parallel spatial displacement ($W = F \cdot s$). Energy represents the capacity to perform work, taking the form of motion-based kinetic stores ($ rac{1}{2}mv^2$) or height-dependent potential stores (mgh). The Universal Law of Conservation ensures total energy remains constant during transformations. Power measures the time rate of work ($P = W/t$), and the commercial unit for energy utility billing is the kilowatt-hour ($1 ext{ kWh} = 3.6 imes 10^6 ext{ J}$).

Essential Core Exam Keywords for High Scoring:

`Vector Work Dot-Alignment` `1 Joule Definition` `Orthogonal Zero Work` `Mechanical Total Sum` `Velocity-Squared Kinetic Store` `Gravitational Height Constant` `Joule per Second Watt` `Commercial Kilowatt-Hour`