Basic Concepts and Interrelations of Work, Power, and Energy

1. Work

Definition:
Work is said to be done when a force is applied on an object and the object moves in the direction of the applied force.
Mathematical Formula: $W = F \times d \times \cos(\theta)$
Where:
W = work done (Joule, J)
F = magnitude of force (Newton, N)
d = displacement (meter, m)
θ = angle between force and displacement direction

Cases:
- **If θ = 0°, cos(θ) = 1 → maximum positive work (e.g., pulling a cart)**
- **If θ = 90°, cos(θ) = 0 → no work (e.g., carrying a bag vertically)**
- **If θ = 180°, cos(θ) = -1 → negative work (e.g., friction)**

2. Power

Definition:
Power is the rate at which work is done or energy is transferred.
Formula: $P = W / t$
Where:
P = power (Watt, W)
W = work done (Joule)
t = time (second)
1 Watt = 1 Joule / 1 second

Larger Units:
- **Kilowatt (kW): 1 kW = 1000 W**
- **Horsepower (hp): 1 hp = 746 W**

3. Energy

Definition:
Energy is the capacity to do work.
Unit: Joule (J), same as work.
It exists in various forms: mechanical, thermal, chemical, electrical, nuclear, etc.

Types of Mechanical Energy

1. Kinetic Energy (K.E.):
Energy possessed by a body due to its motion.
Formula: KE = $(1/2)mv^2$
Where m = mass (kg), v = velocity (m/s)
Example: Moving car, flying bullet.

2. Potential Energy (P.E.):
Energy possessed by a body due to its position or configuration.
Formula: PE = mgh
Where h = height above ground (m), g = acceleration due to gravity (9.8 m/s^2)
Example: Water in a dam, compressed spring.

4. Interrelation of Work, Power, and Energy

- **Work and energy are scalar quantities and both are measured in joules.**
- **When work is done on a body, energy is transferred to the body.**
- **Power describes how quickly the work is done or energy is transferred.**
- **Energy is the cause and work is the effect: Energy → Work → Power**

5. Law of Conservation of Energy

Energy can neither be created nor destroyed; it can only be transformed from one form to another. The total energy of an isolated system remains constant.
Example: In a pendulum, energy transforms between potential and kinetic but total remains constant.

6. Commercial Unit of Energy

1 kilowatt-hour (kWh) = 1000 W × 3600 s = 3.6×10^6 J
Used for electricity bills and energy consumption.

7. Solved Numerical Problems

- **Q1: Calculate the work done when a force of 10 N moves an object 5 m in the direction of force.**

W = F × d = 10 × 5 = 50 J

- **Q2: A body of mass 2 kg is moving with a speed of 3 m/s. Find its kinetic energy.**

KE = $(1/2)mv^2$ = (1/2) × 2 × 9 = 9 J

- **Q3: Find power if 500 J of work is done in 10 seconds.**

P = W/t = 500 / 10 = 50 W

- **Q4: Convert 2 kWh into joules.**

1 kWh = 3.6×10^6 J ⇒ 2 kWh = 7.2×10^6 J