WORK AND ENERGY

Work and Energy

- **Work** is said to be done if (i) a force is applied on the object and (ii) the object is displaced from its original position.
- **Work done by a force** acting on an object is equal to the product of the force (F) and the displacement (s) of the object in the direction of the force, i.e., $W = F \times s = Fs$.
- Work done by a force is **positive** if the force and the displacement are in ***same direction.***
- Work done by a force is **negative** if the force and the displacement are in ***opposite direction.***
- Work done by a force is **zero** if the force is ***perpendicular*** to the displacement, i.e., if there is no displacement in the direction of force. Work done by a force is also **zero,** when there is ***no displacement*** at all.
- Work is a scalar quantity.
- The unit of work is **joule (J).** One joule work is said to be done on an object when a force of one newton displaces it by one metre along the line of action of the force.

$$1\ J = 1\ N \times 1\ m = 1\ Nm$$

Further, 1 kilo joule (1 kJ) = 1000 J and 1 mega joule (1 MJ) = 10^6 J.

Energy

- **Energy** of an object is defined as its capacity for doing work and it is measured by the total quantity of work it can do. It is a scalar quantity.
- The **unit** of energy is the same as that of work, i.e., **joule (J).**

Forms of Energy

- **Kinetic energy** of an object is defined as the energy, which it possesses by virtue of its motion. It is **measured** by the amount of work that the object can do against an opposing force before it comes to rest.

Derivation of kinetic energy

Now work done = $F \times s$ ... (i)

Thus, kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is

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

- The kinetic energy (E_k) of an object is defined as half the product of its mass (m) and the square of the speed (v) of the object, i.e., $E_k = \frac{1}{2} mv^2$.

- **Work-energy theorem** states that net work done (W) by external forces on an object is equal to the change in its kinetic energy, i.e., W = change in kinetic energy.

$$W = E_{Kf} - E_{Ki}$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

- The energy possessed by an object by virtue of its position or configuration (shape) is called its **potential energy.** It is measured by the amount of work that the object can do in passing from its present position or configuration (shape) to some standard position or configuration.

- Potential energy is also termed as **configuration energy** or **mutual energy.**

- Potential energy may be (i) gravitational potential energy (i.e., potential energy due to **position** of an object) or (ii) elastic potential energy (i.e., potential energy due to **configuration** of an object).

- The potential energy of an object due to its height is called **gravitational potential energy** (E_p).

- Gravitational potential energy of an object of mass m at a height h is given by $E_p = mgh$, where g is the acceleration due to gravity at the place under consideration.

- Gravitational potential energy is due to the force of attraction (mg) between the Earth and the object.

- Gravitational potential energy of an object depends on the difference in vertical heights of the initial and the final positions of the object and not on the path the object is moved, i.e., **gravitational potential energy is path independent.**

Law of Conservation of Energy and Its Transformation

- **Energy exists in nature in several forms** such as solar energy, ocean energy, hydro energy, wind energy, mechanical energy, kinetic energy, potential energy, heat energy, chemical energy, light energy, sound energy etc.

- **Mechanical energy** is the sum of the kinetic and potential energies.

- One form of energy can be changed into another form – this process is called **energy conversion or energy transformation.**

- Energy can neither be created nor destroyed, it can only be changed from one form to the other. This is called the **Law of Conservation of Energy.**

- The total mechanical energy of a body throughout its free fall is conserved.

- Gravitational potential energy depends on the choice of zero level. **Positive gravitational potential energy** implies that the body will do work while returning to zero level. **Negative gravitational potential energy** on the other hand implies that the work has to be done to bring the body back to the zero level.

Power

- **Power** of an agent is the rate at which work is done by it. If W is the work done by an agent in time t, its power (P) is given by $P = W/t$.

- The **SI unit of power** is called watt (W) where

$$1 \text{ watt (W)} = \frac{1 \text{ joule (J)}}{1 \text{second (s)}}, \text{ i.e., } 1 \text{ W} = 1 \text{ J/s} = 1 \text{ Js}^{-1}$$

- **Power** is also defined as the product of force (F) and velocity (v), i.e., $P = F \times v$.
- The **commercial unit of energy** is called kilowatt hour (kWh) or simply a unit.

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