Chapter-4

ENERGY

STUDY NOTES

WORK

Work (W)

➢ Work is defined as a force acting upon an object to cause a displacement

➢ It is expressed as the product of force and displacement in the direction of force.

W=F x s

Here, W= work done on an object

F **=** Force on the object

s **=** Displacement of the object

The unit of Work is Newton metre (Nm) or joule (J).

1 Joule is defined as the amount of work done by force of 1 N when displacement is 1 m.

Sign Conventions for Work Done

- when both the force and the displacement are in the same direction, positive work is done.

W = F x s

- when force acts in a direction opposite to the direction of displacement, the work done is negative.

W= − F x s

Angle between force and displacement is 180º.

- If force and displacement are inclined at an angle less than 180º, then work done is given as:

W= Fs cosθ

- If force and displacement act at an angle of 90° then work done is zero.

Necessary Conditions for Work to be done

Two conditions need to be satisfied for work to be done:

- Force should act on the object.
- Object must be displaced.

Energy

The capacity of a body to do work is called the energy of the body.

Unit of energy = Joules

1KJ = 1000 J

▶ 1 Joule: A body is said to possess an energy of 1 joule if it can do one joule work.

MECHANICAL ENERGY:

▶ The energy possessed by a body due to its state of rest or state of motion is called mechanical energy.

▶ Mechanical energy is found in two forms.

Potential energy

Kinetic energy

▶ The total mechanical energy of a body is the sum of its potential energy and kinetic energy.

POTENTIAL ENERGY:

The energy possessed by a body due to its position or shape is called its potential energy.

For Example:

- Water stored in a dam has large amount of potential energy due to its height above the ground.
- A stretched rubber band possesses potential energy due to its distorted shape.

Types of Potential Energy
On the basis of position and change in shape of object, potential energy is of two types:

1. Gravitational Potential Energy:
It is the energy possessed by a body due to its position above the ground.

2. Elastic Potential Energy:
It is the energy possessed by a body due to its change in shape.

Expression for Potential Energy
The potential energy (E_p) is equal to the work done over an object of mass 'm' to raise it by a height 'h'.
Thus, $E_p = mgh$,   where g = acceleration due to gravity.

KINETIC ENERGY:
- It is the energy possessed by a body due to its motion. Kinetic energy of an object increases with its speed.
- Kinetic energy of body moving with a certain velocity = work done on it to make it acquire that velocity

Derivation

Let an object of mass m, starts from rest and attains a uniform velocity v, after a force F is applied on it. Let during this period the object be be displaced by distance s.

Thus, Work done on object, $W = F \times s$ ....(i)

Let the acceleration produced after applying force on object be a.

So, using third equation of motion, we have:

$$v^2 - u^2 = 2as$$

$$\Rightarrow \quad s = \frac{v^2 - u^2}{2a} \quad ....(ii)$$

Also, Force is given as, $F = ma$ ....(iii)

Substituting F and s frome quations (ii) and (iii) in equation (i), we get:

$$W = F \times s$$

$$\Rightarrow \quad W = ma \times \frac{v^2 - u^2}{2a}$$

$$\Rightarrow \quad W = \frac{1}{2}mv^2 \left[\text{As, initial velocity}, u = 0\right]$$

But, work done on object = Change in kinetic energy of object

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

Law of Conservation of Energy

It states that energy can neither be created nor destroyed, but it can be transformed from one form to another.

The total energy before and after the transformation remains the same.

Proof of Law of Conservation of Energy

Let a body of mass m falls from a point A, which is at a height h from the ground as shown in the following figure:
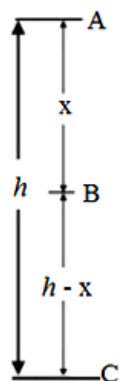
At point A,
Kinetic energy E_k = 0
Potential energy E_p = mgh
Total energy, E_A = E_p + E_k
$\implies$ E_A = mgh + 0
$\implies$ E_A = mgh
During the fall, after moving a distance x from A, the body has reached at B.

At point B,
Let the velocity at this point be v.

We know, $v^2 = u^2 + 2as$
$\implies$ v^2 = 0 + 2ax = 2ax [As, velocity at A, u = 0]
Also, Kinetic energy, E_k = 1/2 mv^2
$\implies$ E_k =1/2 m × 2gx
$\implies$ E_k = mgx
Potential energy, E_p = mg(h – x)
So, total energy, E_B = E_p + E_k
$\implies$ E_B = mg (h – x) + mgx
$\implies$ E_B = mgh – mgx + mgx
$\implies$ E_B = mgh
At the end the body reaches the position C on ground.

At point C,
Potential energy, E_p = 0
Velocity of the body is zero here.

So, $v^2 = u^2 + 2as$
$\implies$ v^2 = 0 + 2gh = 2gh
Kinetic energy, E_k = 1/2 mv^2
$\implies$ E_k = 1/2 x m x 2gh = mgh
Total energy at C

$E_C = E_p + E_k$

$E_C = 0 + mgh$

$E_C = mgh$

Hence, energy at all points remains same.

FACTORS AFFECTING KINETIC ENERGY OF AN OBJECT:

1. Mass of the body.
2. Speed of the body.

TRANSFORMATION OF ENERGY: