Work, Energy and Power

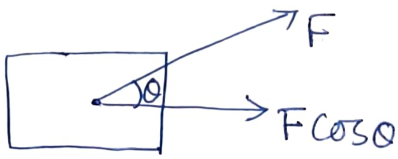
Work is said to be done whenever a force acts on a body and the body moves through some distance in the direction of the force.

(i) Measurement of workdone when the force acts along the direction of motion.

Workdone = Force × distance moved in the direction of force

$$\Rightarrow W = Fs$$

(ii) Measurement of workdone when force and displacement are inclined to each other.



Workdone = Component of force in the direction of displacement × magnitude of displacement

$$\Rightarrow W = F\cos\theta \times s$$

$$= Fs\cos\theta$$

$$\Rightarrow W = \vec{F} \cdot \vec{s}$$

Thus workdone is dot product of force and displacement. Hence work is scalar quantity.

Zero work

Workdone by force is zero if the body gets displaced along a direction perpendicular to the direction of the applied force. Also, the workdone is zero if $\vec{F}$ or $\vec{s}$ or both are zero.

SI unit → Nm or joule (J)

CGS unit → dynecm or erg.

$$1 J = 10^7 erg$$

$$[W] = [ML^2T^{-2}]$$

Power : Power is defined as the ~~ratio of~~ rate of doing work.

$$\text{avg power} = \frac{\text{workdone}}{\text{time}}$$

SI unit → Js^{-1} or Watt (W)

CGS unit → $erg\,s^{-1}$

$$[P] = [ML^2T^{-3}]$$

Q. Define 1 Watt power?

⇒ The power of an agent is one watt if it does work at the rate of 1 joule per sec.

* 1 killowatt = 10^3 Watt
* 1 horsepower = 746 watt

Energy : Energy of a body is defined as its capacity or ability to do work. The energy of a body is measured by the amount of work the body can perform.

SI unit is joule, CGS unit is erg.

Different forms of energy

(i) Mechanical energy → a) kinetic energy
b) Potential energy

(ii) Heat or thermal energy.

(iii) Chemical energy

(iv) Electrical energy

(v) Nuclear energy

(vi) Solar or light energy

Kinetic Energy

The energy possessed by a body because of its motion is called its kinetic energy.

expression for kinetic energy : K.E can be calculated by the amount of work required to bring the body into motion from its state of rest.

Let m = mass of the body
$u = 0$ = initial velocity of the body
F = Constant force applied on the body

a = acceleration produced in the body in the direction of force.

v = final velocity of the body

s = distance covered by the body

$\therefore$ WKT

$$v^2 = u^2 + 2as$$

$$\Rightarrow a = \frac{v^2 - u^2}{2s}$$

$$= \frac{v^2}{2s}$$

As the force and displacement are in same direction, so the workdone is -

$$W = Fs$$

$$= ma.s$$

$$= m.\frac{v^2}{2s}.s$$

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

This workdone appears as kinetic energy (k) of the body.

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

Potential energy

Potential energy is the energy stored in a body or a system ~~by~~ because of its position in a field of force or by its configuration.

Gravitational potential energy of a body is the energy possessed by the body because of its position above the surface of the earth.

$$U = mgh$$

Principle of conservation of energy

"Energy can neither be created, nor destroyed. It may be transformed from one form to another."

or

"The total energy of an isolated system remains Constant"

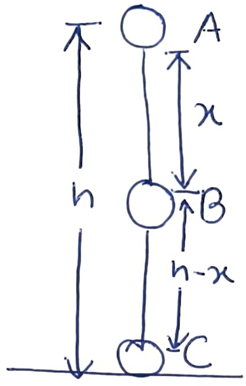
Einstein's Mass-Energy equivalence

$$E = mc^2$$

A/c to Einstein's mass-energy relation if m mass disappears, an energy $E (= mc^2)$ appears in Some form. Conversely, when energy E disappears a mass $m (= E/c^2)$ appears

Conservation of Mechanical energy in a freely falling Body

Let us consider a body of mass 'm' lying at position A at a height 'h' above the ground. As the body falls it kinetic energy increases at the expense of potential energy.



At point A : The body is at rest.

$K.E = 0$

$P.E = mgh$

Total mechanical Energy $= 0 + mgh$

$= mgh$.

At point B

Suppose the body falls freely through height 'x' and reaches the point B with velocity v then,

$$v^2 = u^2 + 2as$$
$$= 0 + 2gx$$
$$\Rightarrow v = \sqrt{2gx}$$

$$\therefore K.E = \frac{1}{2}mv^2 = \frac{1}{2}m(\sqrt{2gx})^2 = \frac{1}{\cancel{2}}m.\cancel{2}gx = mgx$$

$$P.E = mg(h-x)$$

$\therefore$ Total mechanical energy $= mgx + mg(h-x)$

$= mgx + mgh - mgx$

$= mgh$.

At point C

Suppose the body finally reaches a point 'C' on the ground with velocity 'v'. Then considering motion from A to C.

$v^2 = u^2 + 2as$

$\Rightarrow v^2 = 0 + 2gh$

$\Rightarrow v = \sqrt{2gh}$

$\therefore$ K.E $= \frac{1}{2}mv^2 = \frac{1}{2}m.2gh = mgh$

P.E $= 0$

$\therefore$ Total Mechanical Energy $= mgh + 0$

$= mgh$.

Clearly, as the body falls, its P.E decreases and K.E increases by an equal amount. However its total ~~megha~~ mechanical energy remains constant at all points. Thus total mechanical energy is conserved during free fall of a body.