Physics IX

Date 05/01/22

Work And Energy

Scientific Conception of Work

* Work is said to be done, when a force is applied on a body and causes a displacement in the body.

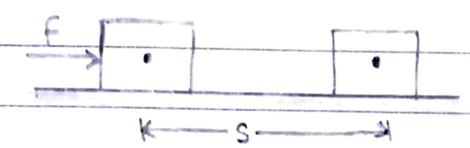
* Work done by a force depends upon:-
  i) The magnitude of applied force
  ii) The displacement of body on the application of force.

Work done by a constant force

Case 1: when a constant force is applied in the horizontal direction

work done = force x displacement

$W = F \times S$

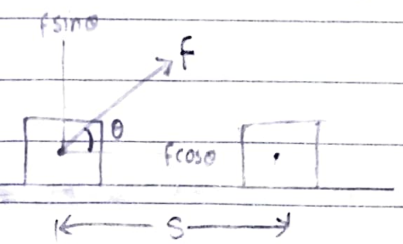


Case 2: when a constant force is applied at an angle with horizontal direction.

work done = force x displacement.

$W = \vec{F} . \vec{S}$

or, $W = FS\cos\theta$



* work done on a body by a force is given by the magnitude of displacement x the force in the direction of the displacement of body.

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Note: Work is a scalar quantity
SI unit of work is Nm or Joule.

1 Joule: work done is said to be 1 Joule if 1 newton force acting on a body displaces the body by 1 meter in its own direction.

when $\theta = 0$, Then

$W = \vec{F} \cdot \vec{S}$

or $W = FS\cos\theta$

$\Rightarrow W = FS\cos\theta$

$W = FS$ $\{\cos\theta = 1\}$

Thus, positive work is done

value of $\cos\theta$ for diff. value of θ

θ	0	30°	60°	90°	120	180°
$\cos\theta$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	-1

when $\theta = 90°$, Then

$W = FS\cos\theta$

$\Rightarrow W = FS\cos 90°$

$\Rightarrow W = FS \times 0$ $(\because \cos 90° = 0)$

$W = 0$

Thus, No work is done

Joule has been named in the honour of James Prescott Joule.

when $\theta = 180°$, Then

$W = FS\cos\theta$

$\Rightarrow W = FS\cos 180°$

$\Rightarrow W = FS \times (-1)$

$W = -FS$

Thus, negative work is done.

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Energy

→ Energy is the capacity of doing work by a body.

Note:- Unit of energy is same as that of the unit of work.
Thus, SI unit of Energy is Nm or Joule.

Forms of Energy

There are various forms of energy;-

1. mechanical energy - The sum of Kinetic energy and Potential energy of a body.
2. Heat or Thermal Energy.
3. Chemical Energy
4. Sound Energy
5. Electrical Energy
6. ~~Lt~~ Nuclear Energy
7. Solar energy.

Kinetic Energy

→ The energy possessed by a body by virtue of its motion is known as Kinetic Energy.
for E.g - A moving bus, Blowing winds.

Mathematical expressions of Kinetic Energy.
consider a body of mass 'm' lying at rest. Let a force 'F' be applied on the body so that it attains a velocity 'v' after travelling a distance 's'

We know that,

$$W = FS \quad \text{-(i)}$$

From Newton's 2nd law of motion we have:

$$F = ma \quad -(ii)$$

Substituting the value of F in equation i)

$$W = Fs$$

$$\Rightarrow W = (ma)s \quad -(iii)$$

From (iii)rd equation of motion we have,

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

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

$$\Rightarrow s = \frac{v^2}{2a} \quad \{\because u = 0 \text{ Here}\}$$

Substituting the value of s in eq (iii)

$$\Rightarrow W = m \times a \times \frac{v^2}{2a} \quad \left(\because s = \frac{v^2}{2a}\right)$$

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

This work done (W) = Kinetic energy of the body

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

Note: SI unit of Kinetic Energy is Joule.
Kinetic energy is a Scalar Quantity
K.E. of a body can never be negative.

* ~~to~~ Kinetic energy of a body is said to be 1 Joule, if a body of 1 Kg mass moves with a speed of $1ms^{-1}$.

Work-Energy Theorem

⇒ A/c to work energy theorem "work done by a force on a body is equal to the change in kinetic energy of the body."

Proof

from equation (iii) of pg no 04., we have.

$$W = mas$$

$$\Rightarrow W = m\cancel{a}\left(\frac{v^2-u^2}{2\cancel{a}}\right) \qquad \left(\because S = \frac{v^2-u^2}{2a}\right)$$

$$\Rightarrow W = \frac{m}{2}(v^2-u^2)$$

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

W = final K.E of body − Initial K.E. of Body.

Relation Between K.E. and Linear momentum.

we have,

$$K.E = \frac{1}{2}mv^2$$

multiplying and dividing RHS by m,

$$K.E. = \frac{1\, m v^2 m}{2\, m}$$

$$K.E. = \frac{m^2v^2}{2m} = \frac{(mv)^2}{2m}$$

$$K.E. = \frac{p^2}{2m} \qquad (P(\text{momentum}) = m \times v)$$

Potential Energy

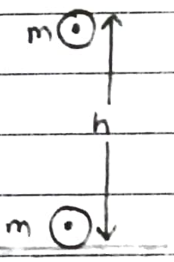
⇒ The energy possessed by an object by virtue of its position or shape or configuration is called Potential energy.

for e.g → water stored in a dam.
A stretched spring
A stretched bow and arrow.

Potential Energy of an object at a Height.

⇒ The potential energy stored in an object due to its vertical position with respect to the surface of the earth is called Gravitational Potential energy.

Consider an object of mass m raised to a height h against gravity



minimum force required to lift object = weight of body = mg.
Distance travelled by the object = h

Work Done = F×S
= mg×h
W = mgh.

Work done against gravity = gravitational Potential energy

$$P.E = mgh.$$

Note: SI unit of potential energy is Joule.

Note: Gravitational Potential energy depends upon the difference in heights of the initial and final position of a body but is independent of the path followed by body while going from initial position to final position.

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Transformation of Energy:

⇒ The process of changing or converting one form of energy to another form is called transformation of energy.

Devices used to transform Energy from one form to another.

i) Heat engine - Heat energy into mechanical energy.
ii) Thermal Power Plant - chemical energy of coal into electrical energy.
iii) Electric generator - mechanical energy into electrical energy
iv) Electric motor - electrical energy into mechanical energy.
v) Photocell - Light energy into electric energy.

Law of Conservation of Energy:

⇒ According to this law "Energy can neither be created nor be destroyed, but can be changed from one form to another."

or.

* Total energy before transformation = The sum of different energies transformed.

Law of conservation of energy of a freely falling body.

Consider a body of mass m at a height h above the ground.
Suppose this position of body is at A,

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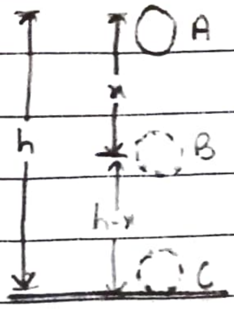

At Position A

Total energy of body at position A

$= P.E + K.E$

$= mgh + 0$ {$\because$ body is at rest}

$= mgh.$

Let the body falls freely under the action of gravity to position B through a height x.

At Position B.

Total energy of body at position B.

$= KE + P.E$

$= \frac{1}{2}mv^2 + mg(h-x)$

$= \frac{1}{2}m(2gx) + mgh - mgx$ {$\because v^2 = u^2 + 2as$, $v^2 = 0 + 2gx$, $v^2 = 2gx$}

$= mgx + mgh - mgx$

$= mgh.$

Finally, let the body just touches the ground at C,

At position C.

Total energy of body at position C.

$= P.E + K.E.$

$= 0 + \frac{1}{2}mv^2$

$= \frac{1}{2}m(2gh)$

$= mgh.$

* From above, it is clear that the total energy of a body at any instant during free fall of the body remains constant.

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Power (Rate of doing work)

→ Power is defined as the rate of doing work or the rate of transfer of energy.
mathematically,

$$\text{Power } (P) = \frac{\text{work } (W)}{\text{time } (t)}$$

Note: SI unit of Power = Js^{-1} or Watt

1 watt - power of machine is 1 watt if it does 1 joule work in 1 second.

1 Horse power (h.p) = 746 W

Bigger units of Power
1. 1 Kilowatt = 10^3 Watt
2. 1 megawatt = 10^6 watt
3. 1 gigawatt = 10^9 watt

Average power = $\frac{\text{Total work done}}{\text{Total time}}$

Power in terms of force and velocity.

We know that,

$$P = \frac{W}{t}$$

$$\Rightarrow P = \frac{FS}{t} \quad (\because W = FS)$$

$$\Rightarrow P = F \times \left(\frac{S}{t}\right)$$

$$\Rightarrow \boxed{P = F \times V} \quad \left(\because \frac{S}{t} = v\right)$$

Commercial unit of energy: Kilowatt-hour.

→ A Kilowatt hour is the amount of electric energy used by 1000 watt electric appliance when it operates for 1 hour.

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* 1 kWh is also known as "Board of Trade unit."

Relation between kWh and Joule.

1 kWh = 1000 Wh   ($\because$ 1 kW = 1000 W)

$\Rightarrow$ ~~1W~~ 1 kWh = 1000 Js^{-1} x 3600 s

$\Rightarrow$ 1 kWh = 3600000 J

$\Rightarrow$ 1 kWh = 3.6×10^6 J

Note:- 1 unit means 1 kilowatt hour.

NEVER STOP LEARNING
BECAUSE
LIFE NEVER STOPS TEACHING