Physics: IX Work, Energy and Power

Work : Product of magnitude of force and the magnitude of displacement of the body during time in which force acts is called **work**. Work is a scalar quantity.

If W, F and s indicate work, force and displacement respectively then the work is given by the following formula. $W = F s$

SI unit of work is newton metre (Nm) which is also known as joule in memory of famous physicist Joule.

Thus, for work to be done, action of force is necessary as well as displacement in the direction of force is also necessary.

What will be the work done if angle between the force and displacement is 90^0 ?

Ans: work done is zero

Illustration 1 : .A body of mass 15 kg undergoes downward displacement of 40 m under the effect of gravitational force. Calculate work done (g = 10 m/s2)

Solution : here: Acceleration a = g = 10 m/s2 , mass m = 15 kg displacement s = 40 m

Work W = $F \times s$ = m $\times$ a $\times$ s = 15 $\times$ 10 $\times$ 40 = 6000 J

Note : Here gravitational force and displacement are in same direction. So, work is said to be done on the body.

Illustration 2 : A body of mass 120 g is taken vertically upwards to reach the height of 5m. Calculate work done (g = 10 m/s2)

Solution : Here m = 120 g = 0.120 kg a = – g = –10 m/s2 s = 5 m

Work W = F $\times$ s = m $\times$ a $\times$ s = m $\times$ (–g) $\times$ 5 = (0.120) (–10) $\times$ 5 = – 6 J

Note : Here since force and displacement are in opposite directions, work is negative. So, work is considered to be done by the body against the force.

Energy

Ability to do work is energy. If work is done on the body, energy of the body increases. If workis done by the body, energy of the body reduces

Ability of a body to do work due to its motion is called kinetic energy.

There are two ways to measure kinetic energy of a body moving with velocity *v*.

(1) A body moving with velocity *v*, becomes stationary after some time, if force is applied opposite to its motion. We can calculate work done during this time and calculate kinetic energy.

(2) Work required to be done to make a stationary body, move with velocity *v*, gives the value of kinetic energy acquired by it.

Suppose a body of mass m is lying stationary on a frictionless horizontal surface. When a force F acts on it, in time *t*, it undergoes a displacement s, and acquires velocity *v*. If work done during this process is W then,

$W = F \times s$ $\quad$ $W = ma \times s$ -------------(i)

Also $v^2 - u^2 = 2as$ and taking initial velocity $u = 0$, we get $v^2 = 2\,a\,s$

$a\,s = 1/2v^2$ --------------------(ii)

From (i) and (ii)

$K_E = 1/2mv^2$

when force F acts on a body moving with initial velocity u if the body acquires velocity v during displacement s then work done

$w = 1/2m(v^2 - u^2)$

when work is done, there is change in kinetic energy of a body.

In the case of uniform circular motion.

Since its speed is constant ($v = u$). Thus, change in its kinetic energy is zero. So, work is also zero. Also centripetal force is perpendicular to displacement. So, work is zero.

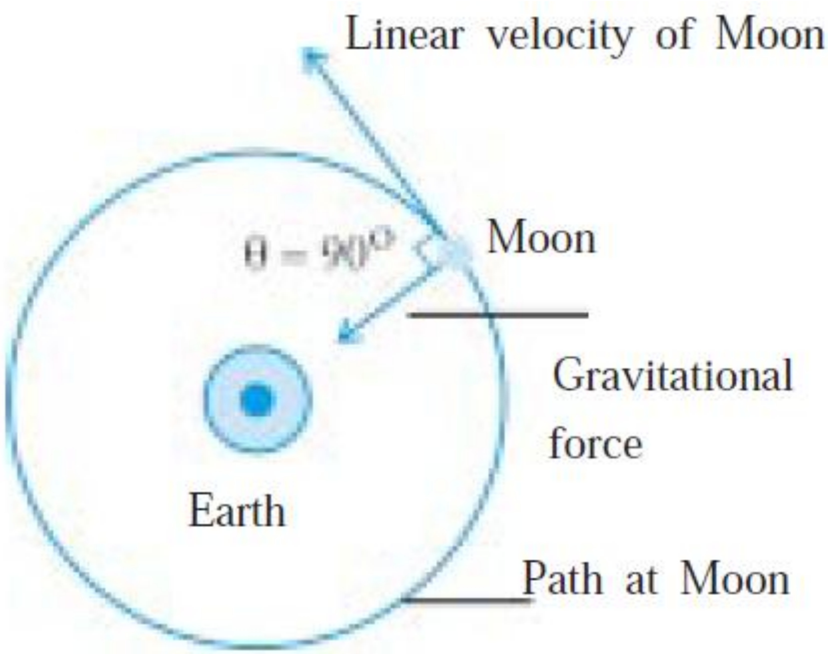


Illustration 3 : A ball of mass 200g is moving with 27 km/h. Calculate its kinetic energy.

Solution : m = 200 g = 0.2 kg, v = 27 km/h = 7.5 m/s

Kinetic Energy K = ?

$K_E = 1/2mv^2 \quad = ½ \times 0.2 \times 7.5 \times 7.5 \quad = 5.625J$

Illustration 4 : At what speed a person having 60 kg mass should run to acquire 750 J kinetic energy ?

Solution : m = 60 kg kinetic energy k = 750 J, v = ?

$K_E = 1/2mv^2 \quad \Rightarrow 750 = ½ \times 60 \times v^2 \quad \Rightarrow v = 5$ m/s

Illustration 5 : Kinetic energy of a car, having mass 1000 kg, is 1,12,500 J. Driver applies brakes when an obstacle is sighted, and car comes to halt after travelling 100 m distance. (Without meeting with an accident) Calculate frictional force.

Solution : Here work = F s   Initial kinetic energy K0 = 1,12,500J, mass m = 1000 kg, Final kinetic energy K = 0   Distance s = 100 m   Work W = F s and W = K – K0

F s = K - K0 = 0 – K0

F(100) = 0 - 1,12,500

F = - 1125N

Work W = change in K.E = K – K0

Here force and displacement are in opposite direction, so force is negative.

Potential Energy

Ability of a body to do work due to its position or configuration is known as potential energy of the body.

Potential energy at reference level is zero.

As magnitude of applied force is equal to the magnitude of gravitational force,

Force = mg   work = $mg \times h$

Energy spent in doing this work is stored in the body in form of potential energy, so potential energy at height h from the reference level can be given by the following formula.

U = mgh

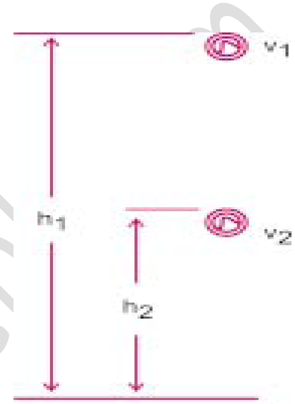
The sum of kinetic energy and potential energy is known as mechanical energy.

Consider a freely falling body of mass m. When it is at height h1 from reference level its velocity is *v*1 and at height h2 its velocity is *v*2.

Thus, change in its kinetic energy = work done = $1/_{2mv2}{}^{2}$ $- 1/2mv_1{}^2$

Here force acting on the body is gravitational force and displacement is s = (h1 - h2)

work done = mg(h1 - h2)



$\Rightarrow$ $1/_{2mv2}{}^{2}$ $- 1/2mv_1{}^2$ = mg(h1 - h2)

$\Rightarrow$ $1/_{2mv2}{}^{2}$ $- 1/2mv_1{}^2$ = mgh1 -mg h2

$\Rightarrow$ $1/_{2mv2}{}^{2}$ + mg h2 = mgh1 + $- 1/2mv_1{}^2$

K2 + *U*2 = K1 + *U*1

Illustration 6 : Calculate potential energy of a person having 60 kg mass on the summit of Mt. Everest. Height of Mt. Everest is 8848 m from sea level. (g = 9.8 m/s2)

Solution : mass m = 60 kg height h = 8848 m g = 9.8 m/s2

Potential energy U = mgh = (60) (9.8) (8848) = 52,02,624 J

Elastic Potential energy-

A spring under compression or extension has ability to do work due to its configuration. This type of potential energy is known as elastic potential energy.

Mechanical watch (which requires winding) are operated by energy stored in the spring in form of elastic

Potential energy.

Power : The **rate of doing work is known as power.**

Power P = work (W)/time (t)

\ P = W/t

SI units of work and time are joule and second. So, unit of power is joule / second (J/S) or watt (in memory of scientist James Watt).'watt' is a small unit of power.

In practice kilowatt (kW) and mega watt (MW) are used as bigger units of power.

1 kW = 10^3 W

1 MW = 10^6W

Horse power (hp) is also one of the well known units of power. (This is a British unit of power). This unit is used to indicate power of water pumps or automobiles.

1 hp » 746W

Also, power = work/time, Work can be expressed as work = power × time

When you are consuming 1000 watt power for 1 hour, you have consumed 1 unit of electrical energy.

Thus 1 kWh = 1 kilowatt × 1 hour = 10^3 watt × 3600 s. = 10^3 J/s × 3600 s = 3.6 × 10^6 J

Thus 1 unit = 1kWh = 3.6 × 10^6 J

Illustration 7 : 5 tube lights each of 40 w are operated for 10 hours. Calculate electrical energy consumed in 'units'.

Solution : Work = 5 × 40 W × 10 hour = 2000 Watt hour = 2 kWh = 2 units

Illustration 8 : Hetasvi, having her own mass 50 kg, climbs 20 m height along with 30 kg mass in 40 s. Calculate her power and work done. (take g = 10m/s2)

Solution : Total mass m = 50 + 30 = 80 kg, height h = 20 m, time t = 40 s

Work done against gravitational force W = m g h = 80 × 10 × 20 = 16000 J

Power P = W/t = 16000 J/40 s = 400 W