WORK AND ENERGY

INTER CONVERSION OF POTENTIAL AND KINETIC ENERGY

Kinetic energy

A moving object is capable of doing work because of it" motion. Hence, we say that the object has kinetic energy. "Kinetikos" in Greek means "to move". Hence, kinetic energy means energy due to motion. The energy is stored in the object when work is done to change its velocity from a lower value to a higher value, or from rest to certain velocity. Kinetic energy of an object is defined as the energy which it possesses by virtue of its motion, and is measured by the amount of work that the object can do against an opposing force before it comes to rest. Kinetic energy of an object moving with a certain velocity is equal to the work done on it to enable it to acquire that velocity.

Examples of bodies possessing kinetic energy

1. A ball rolling on a surface because it can set another ball into motion by striking it.

2. A bullet fired from a gun as it is able to penetrate some distance into a target which it strikes.

3. A torpedo in motion as it can do work by penetrating into the side' of a ship.

4. Water in motion as it can turn a wheel or a turbine.

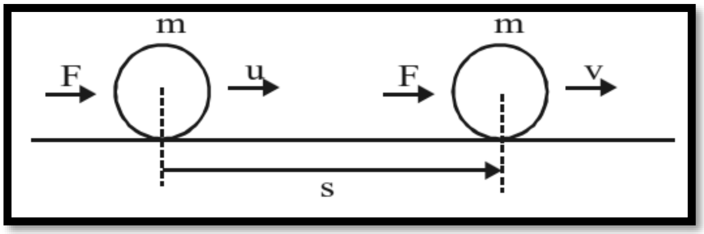
5. A fast wind as it can set a boat in motion when striking against its sail.

6. A moving hammer as it drives a nail into a wall against the resistance offered to it by the wall.

7. A falling body as it can break something on which it falls.

Expression for kinetic energy

Consider an object of mass m which is moving with an initial velocity u on a perfectly frictionless surface. Let a constant external force F act on it and produce an acceleration a in it. If v is the final velocity of the object after having undergone a displacement s, then from



$v^2 - u^2 = 2as, s = \frac{v^2 - u^2}{2a}$ ... (1)

Work done by the force in displacing the body through s, i.e.,

W= F × s ... (2)

We know from Newton's Second Law of Motion,

F = ma ... (3)

From equation (1), (2) and (3), we get

$$W = (ma) \times \frac{(v^2 - u^2)}{2a} = \frac{m(v^2 - u^2)}{2}$$

$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ ... (4)

If the object is initially at rest, u = 0 and as such from eqn. (4),

$W = \frac{1}{2}mv^2$ ... (5)

This work done (W) in making the object acquire a velocity v after starting from rest has not gone waste and is, in fact, stored in the object.

Work stored up in a moving object is called the kinetic energy of the object. If kinetic energy of an object is denoted by E_k then

$E_k = \frac{1}{2}mv^2$ ... (6)

Kinetic energy of a moving object is defined as half the product of the mass of the object and the square of the speed of the object.

Factors affecting Kinetic energy:

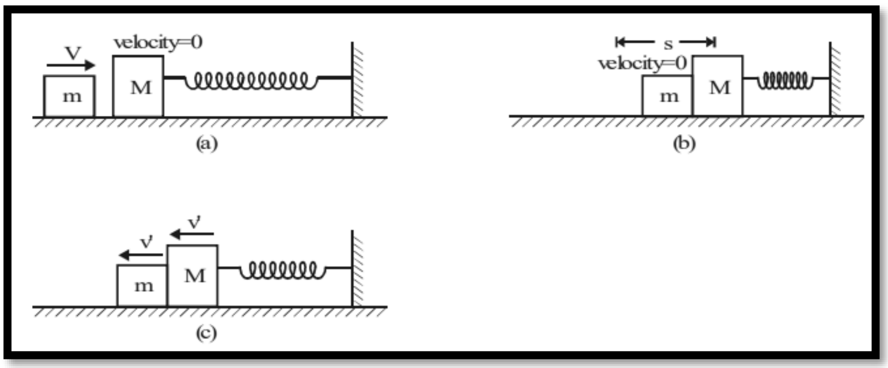
(i) The more the mass of a body, the greater its kinetic energy.

(ii) The more the velocity of a body, the more its kinetic energy.

(iii) Kinetic energy of a body depends both on its mass and velocity.

Potential energy

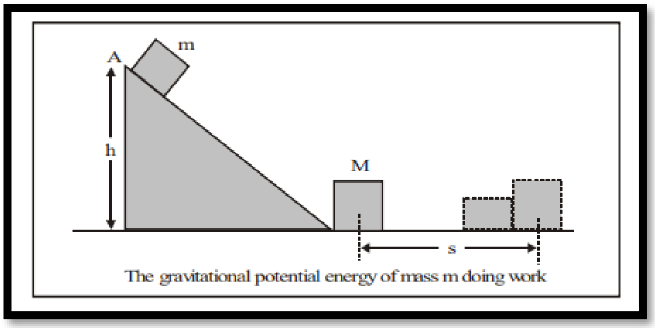
The energy possessed by an object by virtue of its position or configuration is called its potential energy. It is measured by the work that the object can do in passing from its present position or configuration to some standard position or configuration (known as zero position or zero configuration)



The kinetic energy of mass m converts into elastic potential energy of spring.

Let us take an example

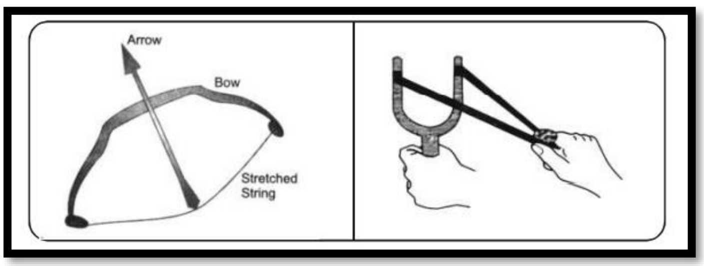
Let a small mass m be released from a smooth inclined plane. Another mass M is kept at a rough horizontal plane at rest. The mass m will move along the inclined plane and strike the mass M. Both the masses will move along the horizontal surface for some distance and come to rest. The mass M moves a distance s by the force applied by m. Thus, m does work for which it requires energy. This energy is possessed by m at A as it was at a height h from the horizontal surface. This energy due to position is called potential energy. Precisely speaking this energy is called gravitational potential energy.



The gravitational potential energy of mass m doing work

Thus, potential energy is defined as follows:

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



Note:

The energy possessed by a body due to its height from the surface of earth is called gravitational potential energy and that due to change in shape is called elastic potential energy. Other examples where elastic potential energy is stored are:

(i) a stretched bow

(ii) a stretched rubber band

(iii) a wound spring All above examples are because of change in shape

Expression for gravitational potential energy

Let us consider a block of mass m kept on the surface of earth. Let the block be lifted to a height h. For that a force F is required which is equal to mg.

This force lifts the block through a distance h. The work done by this force,

$W = F \times h$

$\therefore\ W = mg \times h \qquad [\therefore\ F = mg]$

This work is converted into potential energy (P.E.) of the block.

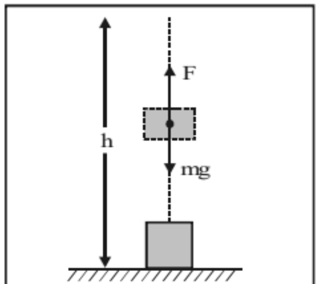
P.E = mgh

The expression shows that potential energy depends on

(a) mass m

(b) height h from ground

(c) acceleration due to gravity g



A mass m being lifted by force F

Interconversion of potential and kinetic energy

(i) For a freely falling body, potential energy changes into kinetic energy.

Let a body of mass m be at rest at a point at height (h) from the ground.

At highest point (h):

Potential energy of the body U1 = mgh

Kinetic energy of the body K1 = 0 [interconversion of potential and kinetic energy u = 0] body is at rest.

As the body falls freely, it gains velocity and reduces height. Let the body have velocity v when it reaches the ground.

At lowest point:

Potential energy of the body, U^2= 0 [interconversion of potential and kinetic energy h = 0]

Kinetic energy of the body, $k_2 = \frac{1}{2}mv^2$

From third equation of motion, $v^2 = u^2 + 2gh$

We have, $v^2 = 2gh$ [interconversions of potential and kinetic energy $u = 0$]

Hence, final kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}m(2gh)$

$= mgh =$ Initial potential energy

(ii) For an upward projected body, kinetic energy changes into potential energy.

Let a body of mass m be projected upwards with a velocity u from a point on the ground.

At lowest point:

Kinetic energy of the body, K2 = 0

Potential energy of the body U2 = mgh

From third equation of motion, $v^2 = u^2 + 2gh$

We have $0 = u^2 - 2gh$

(Interconversion of potential and kinetic energy $v = 0$ and g is negative for upward motion)

or u2 = 2gh

Hence, final $P.E = mgh = m\frac{u^2}{2}$

$P.E = \frac{1}{2}mu^2 = initial\ K.E$