Kinetic energy	Potential energy
The energy possessed by a body due to its motion is called its kinetic energy.	The energy possessed by a body on account of its specific state or position is called its potential energy.
It occurs only in one form and for doing work it does not have to be transformed into another form.	It occurs only in various forms such as gravitational potential energy and electric potential energy but work is not done till it is transformed into kinetic energy.
Kinetic energy $= \frac{1}{2} mv^2$	Gravitational potential energy $= mgh$.
Kinetic energy cannot be negative.	Potential energy can be negative.

b. Derive the formula for the kinetic energy of an object of mass m, moving with velocity v.

Consider a body of mass m moving with a uniform acceleration a along straight line. If u is the initial velocity of the body, v is the final velocity and s is the distance covered by the body during this change of velocity, we have

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

(the kinematical equation of motion)

$$\therefore \quad v^2 - u^2 = 2as$$

$$\therefore \quad s = \frac{v^2 - u^2}{2a} \qquad \ldots (1)$$

If F is the net force acting on the body and W is the work done by the force,

$$W = Fs \quad \ldots (2)$$

Now, $F = ma \quad \ldots (3)$

From Eqs. (1), (2) and (3), we get,

$$W = ma \times \frac{v^2 - u^2}{2a} = \frac{1}{2} m (v^2 - u^2)$$

For a body initially at rest, $u = 0$

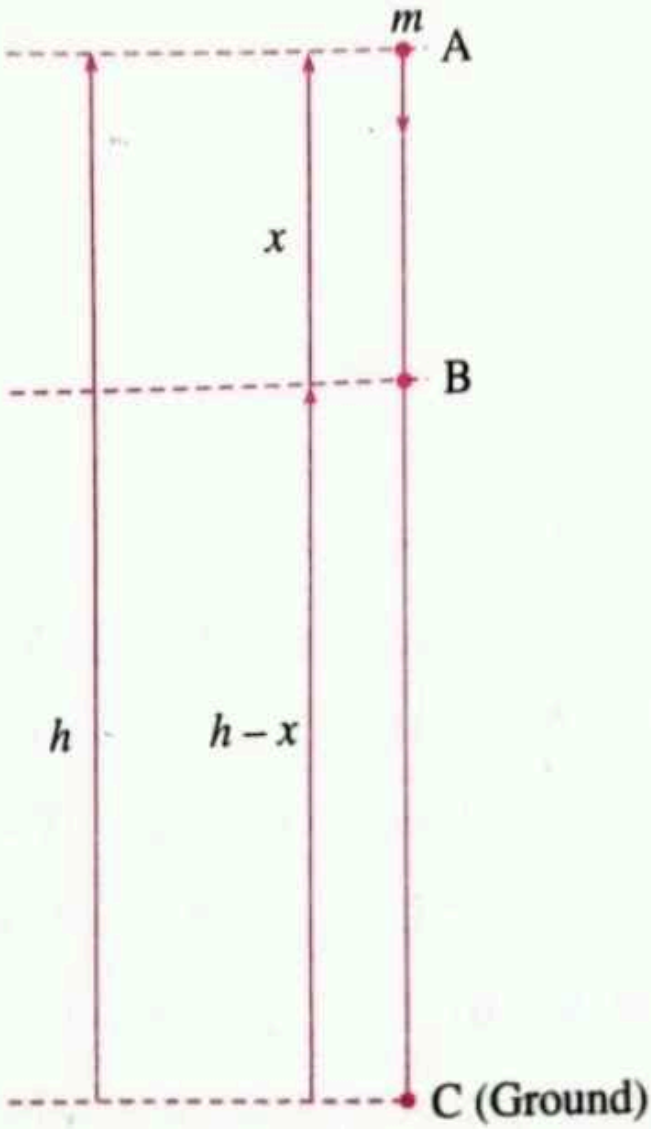
$$\therefore \quad W = \frac{1}{2} mv^2$$

Work done on a body = change in the kinetic energy of the body.

$$\therefore \text{ Kinetic energy of the body } = \frac{1}{2} mv^2$$

c. Prove that the kinetic energy of a freely falling object on reaching the ground is nothing but the transformation of its initial potential energy.

Consider a body of mass m initially at rest at point A at a height h from the ground. Suppose that the body is released so that it follows the downward path ABC freely (i.e., the buoyancy due to air and air resistance are ignored).



Conversion of potential energy into kinetic energy

(1) At A

u (initial velocity) = 0

$\therefore$ Kinetic energy (KE) $= \frac{1}{2} mu^2 = 0$

Potential energy (PE) = mgh, where g is the acceleration due to gravity.

$\therefore$ Total energy = 0 + mgh = mgh

(2) At B

If v_1 is the velocity of the body at B after covering a distance x,

$v_1^2 = u^2 + 2gx = 2gx \quad (\because u = 0)$

$\therefore$ KE $= \frac{1}{2} mv_1^2$

$$= \frac{1}{2} m (2gx) = mgx$$

$$PE = mg(h - x) = mgh - mgx$$

$$\therefore \text{ Total energy } = mgx + mgh - mgx = mgh$$

(3) At C

If v is the velocity of the body at C,

$$v^2 = u^2 + 2gh$$

(Considering the motion from A to C)

$$\therefore \quad v^2 = 2gh \quad (\because u = 0)$$

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

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

PE = 0 at the ground level.

$\therefore$ Total energy = mgh + 0 = mgh

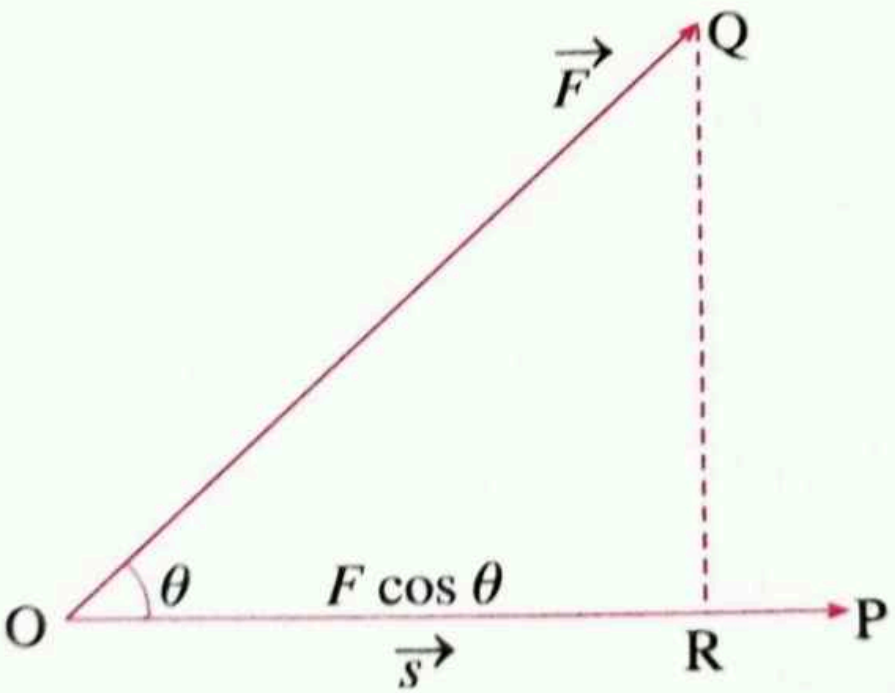
Thus, the total energy of the body is the same at points A, B and C, i.e., the total energy remains constant during the motion of the body.

d. Determine the amount of work done when an object is displaced at an angle of 30° with respect to the direction of the applied force.

Let $\vec{F}$ = constant force acting on a body,

$\vec{s}$ = displacement of the body and

θ = angle between $\vec{F}$ and $\vec{s}$.



Displacement of the body O→P, direction of the force O→Q

$$\text{Now, } \cos\theta = \frac{OR}{OQ}$$

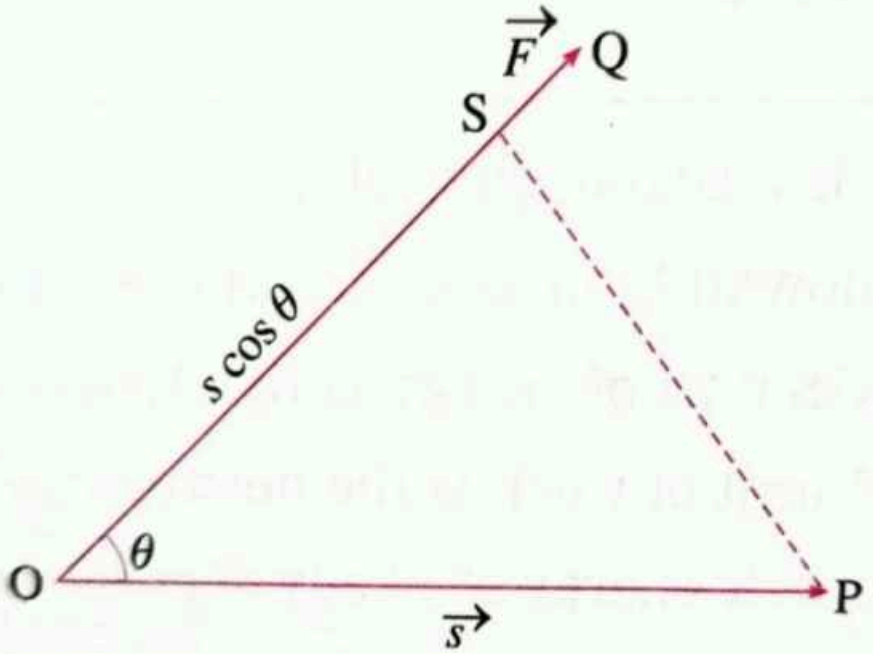
$$\therefore \quad OR = OQ\cos\theta = F\cos\theta$$

This is the component of the force in the direction of the displacement.

$\therefore$ Work done by the force,

$$W = (F\cos\theta)\, s = Fs\cos\theta$$

OR



Displacement of the body O → P,
direction of the force O → Q

$$\cos\theta = \frac{OS}{OP}$$

$$\therefore \quad OS = s\cos\theta$$

This is the component of the displacement in the direction of the force.

$\therefore$ Work done by the force,

$$W = F\,(s\cos\theta) = Fs\cos\theta.$$

For $\theta = 30°$, $\cos\theta = \frac{\sqrt{3}}{2}$

$$\therefore \quad W = Fs \frac{\sqrt{3}}{2}$$

e. If an object has 0 momentum, does it have kinetic energy ? Explain your answer.

Kinetic energy of a body of mass m and speed v

$$= K = \frac{1}{2} mv^2 = \frac{m^2 v^2}{2m}$$

$$= \frac{p^2}{2m}$$

where $p = mv$ is the momentum of the body.

It follows that if $p = 0$,
the kinetic energy of the body is zero.

f. Why is the work done on an object moving with uniform circular motion zero ?

(1) The work done is positive when the force acting on the body and the displacement of the body have the same direction.

(2) The work done is negative when the force acting on the body and the displacement of the body have opposite directions.

(3) The work done is zero when there is no displacement of the body due to the applied force or when the force acting on the body and the displacement of the body are perpendicular to each other as in uniform circular motion where the force is always towards the centre of the circle and the displacement is always tangential.

2. Choose one or more correct alternatives.

a. For work to be performed, energy must be .....

(i) transferred from one place to another

(ii) concentrated

(iii) transformed from one type to another

(iv) destroyed

b. Joule is the unit of .....

(i) force

(ii) work

(iii) power

(iv) energy

c. Which of the forces involved in dragging a heavy object on a smooth, horizontal surface, have the same magnitude ?

(i) the horizontal applied force

(ii) gravitational force

(iii) reaction force in vertical direction

(iv) force of friction

d. Power is a measure of the .....

(i) the rapidity with which work is done

(ii) amount of energy required to perform the work

(iii) The slowness with which work is performed

(iv) length of time

e. While dragging or lifting an object, negative work is done by .....

(i) the applied force

ii) gravitational force

(iii) frictional force

(iv) reaction force

3. Rewrite the following sentences using proper alternative.

a. The potential energy of your body is least when you are .....

(i) sitting on a chair

(ii) sitting on the ground

(iii) sleeping on the ground

(iv) standing on the ground

b. The total energy of an object falling freely towards the ground .....

(i) decreases

(ii) remains unchanged

(iii) increases

(iv) increases in the beginning and then decreases

c. If we increase the velocity of a car moving on a flat surface to four times its original speed, its potential energy .....

(i) will be twice its original energy

(ii) will not change

(iii) will be 4 times its original energy

(iv) will be 16 times its original energy

d. The work done on an object does not depend on .....

(i) displacement

(ii) applied force

(iii) initial velocity of the object

(iv) the angle between force and displacement

4. Study the following activity and answer the questions.

1. Take two aluminium channels of different lengths.

2. Place the lower ends of the channels on the floor and hold their upper ends at the same height.

3. Now take two balls of the same size and weight and release them from the top end of the channels. They will roll down and cover the same distance.

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1. At the moment of releasing the balls, which energy do the balls have ?

Potential energy

2. As the balls roll down which energy is converted into which other form of energy.

Potential energy → Kinetic energy

3. Why do the balls cover the same distance on rolling down.

They have the same speed.

4. What is the form of the eventual total energy of the balls ?

Kinetic energy

5. Which law related to energy does the above activity demonstrate ? Explain.

Law of conservation of energy.

Energy can neither be created nor destroyed. It can be converted from one form into another. Thus, the total amount of energy in the universe always remains constant.

a. An electric pump has 2 kW power. How much water will the pump lift every minute to a height of 10 m ?

$P = 2\,kW = 2000\,J/s,\ t = 60\,s,$
$h = 10\,m,\ g = 9.8\,m/s^2,\ m = ?$

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

$$\therefore\ m = \frac{pt}{gh} = \frac{2000\,J/s \times 60\,s}{9.8\,m/s^2 \times 10\,m}$$

$$= \frac{12000}{9.8}\,kg = \text{nearly } 1224\,kg$$

This gives the required mass of water.

b. If a 1200 W electric iron is used daily for 30 minutes, how much total electricity is consumed in the month of April ?

Data : P = 1200 W,

$$t = 30 \text{ days} \times \frac{30 \text{ minutes}}{\text{day}} \times \frac{60 \text{ s}}{\text{minute}} = 54000 \text{ s}$$

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$$W = ?$$

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

$$\therefore W = Pt$$

$$\therefore W = 1200 \text{ W} \times 54000 \text{ s}$$

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$$= 648 \times 10^5 \text{ J}$$

$$= 6.48 \times 10^7 \text{ J}$$

$$= \frac{6.48 \times 10^7 \text{ J}}{3.6 \times 10^6} \text{ units} = 18 \text{ units}$$

This gives the required electricity.

c. If the energy of a ball falling from a height of 10 metres is reduced by 40%, how high will it rebound ?

Data : $h_1 = 10\ m$,

$$E_2 = E_1 - E_2 = E_1 - E_1 \times \frac{40}{100}$$

$= E_1 (1 - 0.4) = 0.6\ E_1$, $h_2 = ?$

$E_1 = mgh_1$, $E_2 = mgh_2$

$E_2 = 0.6\ E_1$

$h_2 = 0.6\ h_1 = 0.6 \times 10\ m = 6\ m$

The ball will rebound to a height of 6 m.

d. The velocity of a car increase from 54 km/hr to 72 km/hr. How much is the work done if the mass of the car is 1500 kg ?

Data : $m = 1500\ kg$, $u = 54\ km/h$

$$= \frac{5400\ m}{3600\ s} = 15\ m/s,$$

$$v = 72\ \text{km/h} = \frac{72000\ \text{m}}{3600\ \text{s}} = 20\ \text{m/s},\ W = ?$$

Work done,

W = increase in kinetic energy

$$= \frac{1}{2} mv^2 - \frac{1}{2} mu^2 = \frac{1}{2} m\ (v^2 - u^2)$$

$$= \frac{1}{2} \times 1500\ \text{kg} \times \{(20\ \text{m/s})^2 - (15\ \text{m/s})^2\}$$

$$= 750 \times (400 - 225)\ \text{J} = 750 \times 175\ \text{J}$$

$= 131250\ J$

The work done to increase the velocity of the car = 131250 J

e. Ravi applied a force of 10 N and moved a book 30 cm in the direction of the force. How much was the work done by Ravi ?

Data : $F = 10\ N, s = 30\ cm = 0.3\ m, W = ?$

$W = Fs = 10\ N \times 0.3\ m = 3\ J$

The work done by Ravi = 3 J