

EXERCISE 2(C)

Solutions:

According to the principle of conservation of energy, energy can neither be created nor can it be destroyed. It only changes from one form to the other.

Solutions:

The law of conservation of mechanical energy states that, whenever there is an interchange between the potential energy and kinetic energy, the total mechanical energy remains constant i.e $K + U = \text{constant}$ when there are no frictional forces.

When there are no frictional forces for a given system only then the mechanical energy is conserved i.e between body and air. Hence, conservation of mechanical energy is strictly valid only in vacuum, where friction due to air is absent.

Solutions:

The two examples in which the mechanical energy of a system remains constant are motion of a simple pendulum and motion of a freely falling body.

Solutions:

When a body is thrown vertically upwards, its kinetic energy changes into potential energy and its velocity becomes zero.

Solutions:

- (a) An energy possessed by the body at the point from where it falls is potential energy.
- (b) The energy possessed by the body while falling are potential energy and kinetic

energy.

(c) The energy possessed by the body on reaching the ground is kinetic energy.

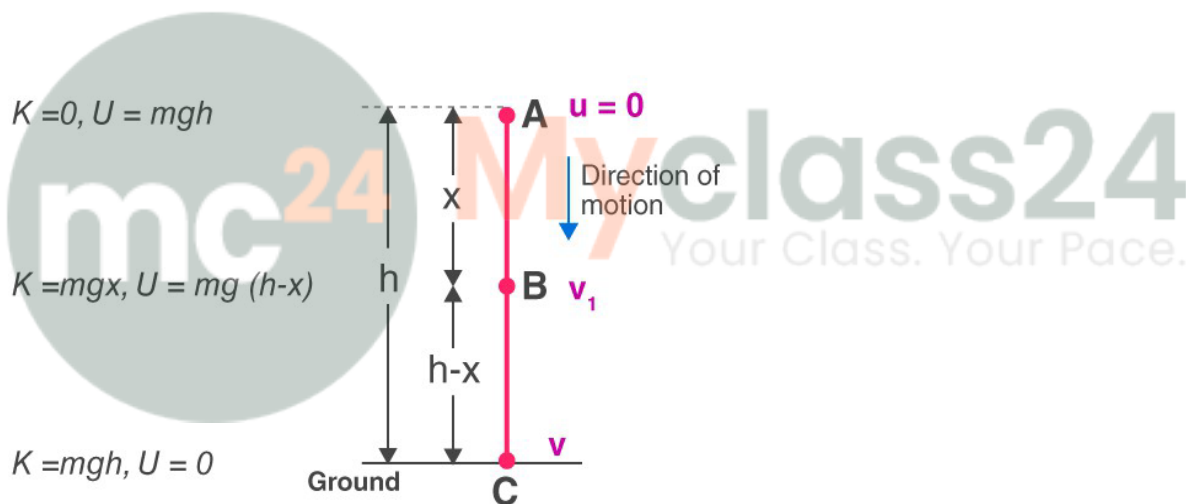
Question: 6

Show that the sum of kinetic energy and potential energy (i.e., total mechanical energy) is always conserved in the case of a freely falling body under gravity (with air resistance neglected) from a height h by finding it when

- (i) the body is at the top,
- (ii) the body has fallen a distance x ,
- (iii) the body has reached the ground.

Solutions:

Let a body of mass m be falling freely under gravity from a height h above the ground (i.e from position A). Now calculate sum of kinetic energy K and potential energy U at various positions, say at A (at height h above the ground), at B (when it has fallen through a distance x) and at C (on the ground).



- (i) At the position A (at height h above the ground):
 Initial velocity of body = 0 (since body is at rest at A)
 Therefore Kinetic energy $K = 0$
 Potential energy $U = mgh$
 Hence total energy = $K + U$
 $= 0 + mgh$
 $= mgh$ (1)

- (ii) At the position B (when it has fallen a distance x):
 Let v_1 be the velocity acquired by the body at B after falling through a distance x .
 Then $u = 0, s = x, a = g$
 From equation $v^2 = u^2 + 2aS$
 $V_1^2 = 0 + 2gx$

$$= 2gx$$

$$\therefore \text{Kinetic energy } K = \frac{1}{2} mv_1^2$$

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

$$= mgx$$

Now at B, height of body above the ground = $h - x$

$$\therefore \text{Potential energy } U = mg (h - x)$$

$$\text{Hence, total energy} = K + U$$

$$= mgx + mg (h - x)$$

$$= mgh \quad (2)$$

(iii) At position C (on the ground):

Let the velocity acquired by the body on reaching the ground be v . Then $u = 0$, $s =$

h , $a = g$

$$\text{From equation: } v^2 = u^2 + 2aS$$

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

$$v^2 = 2gh$$

or Kinetic energy $K = \frac{1}{2} mv^2$

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

$$= mgh$$

And potential energy $U = 0$ (at the ground when $h = 0$)

So, total energy = $K + U$

$$= mgh + 0$$

$$= mgh \quad (3)$$

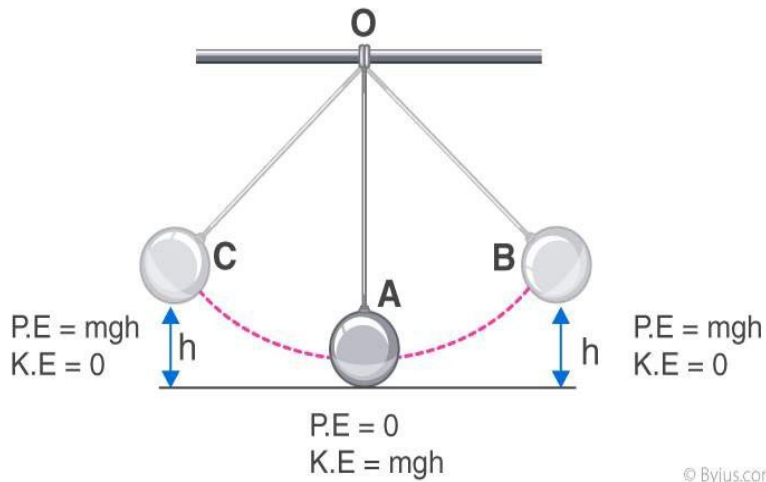
Thus from equation (1), (2) and (3) we note that the total mechanical energy i.e the sum of kinetic energy and potential energy always remain constant at each point of motion and it is equal to the initial potential energy at height h .

Question: 7

A pendulum is oscillating on either side of its rest position. Explain the energy changes that take place in the oscillating pendulum. How does the mechanical energy remain constant in it? Draw necessary diagram.

Solutions:

The kinetic energy decreases and the potential energy becomes maximum at B where it is momentarily at rest, when the bob swings from A to B.



From B to A, again the potential energy changes into kinetic energy and this process repeat again and again. So, while swinging, the bob has the potential energy at the extreme position B or C and kinetic energy at resting position A. The bob has both the kinetic energy and potential energy at an intermediate position (between A and B or between A and C) and the sum of both the energies (i.e the total mechanical energy) remains constant throughout the swing.

Question: 8

A pendulum with bob of mass m is oscillating on either side from its resting position A between the extremes B and C at a vertical height h above A. What is the kinetic energy K and potential energy U when the pendulum is at positions

- (i) A,
- (ii) B and
- (iii) C?

Solutions:

- (i) At position A: pendulum has maximum kinetic energy and its potential energy is zero at its resting position. So, $K = mgh$ and $U = 0$
- (ii) At position B: The kinetic energy decreases and the potential energy increases. So, $K = 0$ and $U = mgh$
- (iii) At position C: kinetic energy $K = 0$ and potential energy $U = mgh$.

Question: 9

Name the type of energy possessed by the bob of a simple pendulum when it is at

- (a) the extreme position,
- (b) the mean position, and
- (c) between the mean and extreme positions.

Solutions:

- (a) Energy possessed by the bob of a simple pendulum at extreme position is potential

energy

(b) Energy possessed by the bob of a simple pendulum at mean position is kinetic energy

(c) Energy possessed by the bob of a simple pendulum between mean and extreme position are both kinetic energy and potential energy.

MULTIPLE CHOICE TYPE

Question: 1

A ball of mass m is thrown vertically up with an initial velocity so as to reach a height h . The correct statement is:

- a. Potential energy of the ball at the ground is mgh .
- b. Kinetic energy to the ball at the ground is zero.
- c. Kinetic energy of the ball at the highest point is mgh .
- d. Potential energy of the ball at the highest point is mgh .

Solutions:

The correct statement is 'potential energy of the ball at the highest point is mgh .

Question: 2

A pendulum is oscillating on either side of its rest position. The correct statement is :

- (a) It has only the kinetic energy at its each position.
- (b) It has the maximum kinetic energy at its extreme position.
- (c) It has the maximum potential energy at its mean position.
- (d) The sum of its kinetic and potential energy remains constant throughout the motion.

Solutions:

The correct statement is 'the sum of its kinetic and potential energy remains constant throughout the motion.

NUMERICALS

Question: 1

A ball of mass 0.20 kg is thrown vertically upwards with an initial velocity of 20m/s^{-1}

Calculate the maximum potential energy it gains as it goes up.

Solutions:

$$\begin{aligned}\text{Potential energy at the maximum height} &= \text{initial kinetic energy} \\ &= \frac{1}{2} mv^2 \\ &= \frac{1}{2} \times 0.20 \times 20 \times 20 \\ &= 40\text{J}\end{aligned}$$

Question: 2

A stone of mass 500 g is thrown vertically upwards with a velocity of 15m/s^{-1} .

Calculate:

- (a) the potential energy at the greatest height,
- (b) the kinetic energy on reaching the ground
- (c) the total energy at its half way point.

Solutions:

(a) Potential energy at maximum height = initial kinetic energy

$$\begin{aligned} mgh &= \frac{1}{2} mv^2 \\ &= \frac{1}{2} \times 0.500 \times 15 \times 15 \\ &= 56.25\text{J} \end{aligned}$$

(b) Kinetic energy on reaching the ground = potential energy at the greatest height
= 56.25J

(c) Total energy at its half way point = $\frac{1}{2} (K + U)$
= 56.25J

Question: 3

A metal ball of mass 2kg is allowed to fall freely from rest from a height of 5m above the ground.

(a) Taking $g = 10\text{m/s}^2$, calculate:

(i) the potential energy possessed by the ball when it is initially at rest.

(ii) the kinetic energy of the ball just before it hits the ground?

(b) What happens to the mechanical energy after the ball hits the ground and comes to rest?

Solutions:

(a)

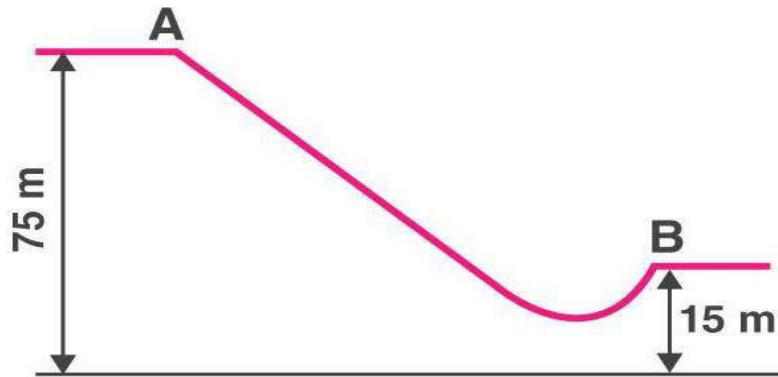
(i) Potential energy of the ball = mgh
 $= 2 \times 10 \times 5$
 $= 100\text{J}$

(ii) Kinetic energy of the ball just before hitting the ground = initial potential energy = mgh
 $= 2 \times 10 \times 5$
 $= 100\text{J}$

(b) Mechanical energy converts into heat and sound energy after the ball hits the ground and comes to rest.

Question: 4

The diagram given below shows a ski jump. A skier weighing 60kgf stands at A at the top of ski jump. He moves from A and takes off for his jump at B.



- (a) Calculate the change in the gravitational potential energy of the skier between A and B.
 (b) If 75% of the energy in part (a) becomes the kinetic energy at B, calculate the speed at which the skier arrives at B.
 (Take $g = 10 \text{ m s}^{-2}$).

Solutions:

(a) Mass of skier = 60 kg

Loss in potential energy = $mg(h_1 - h_2)$

$$= 60 \times 10 \times (75 - 15)$$

$$= 60 \times 10 \times 60$$

$$= 3.6 \times 10^4 \text{ J}$$

(b) Kinetic energy at B = $75 / 100 \times 3.6 \times 10^4$

$$= 27000 \text{ J}$$

$$= 2.7 \times 10^4 \text{ J}$$

Kinetic energy = $1 / 2 mv^2$

$$27000 = 1 / 2 mv^2$$

$$27000 = 1 / 2 \times 60 \times v^2$$

$$v^2 = 27000 / 30$$

$$= 900$$

$$= 30 \text{ m / s}$$

Question: 5

A hydro electric power station takes its water from a lake whose water level is 50m above the turbine. Assuming an overall efficiency of 40%, calculate the mass of water which must flow through the turbine each second to produce power output of 1MW.

($g=10 \text{ m s}^{-2}$).

Solutions:

Potential energy = mgh

Efficiency = 40%

Useful work done = 40% of potential energy

$$= 40 / 100 (mgh)$$

$$= 0.4 (m \times 10 \times 50)$$

$$= 200 \text{ m}$$

Power = work done per second

$$1\text{MW} = 200 \times \text{mass of water flowing each second}$$

$$1 \times 10^6 \text{W} = 200 \times \text{mass of water flowing each second}$$

$$\text{mass of water flowing each second} = (1 \times 10^6) / 200$$

$$= 5000 \text{ kg}$$

Question: 6

The bob of a simple pendulum is imparted a velocity of 5m s^{-1} when it is at its mean position. To what maximum vertical height will it rise on reaching at its extreme position if 60% of its energy is lost in overcoming the friction of air?

(Take $g = 10 \text{ m s}^{-2}$).

Solutions:

$$\text{Total kinetic energy at mean position} = 1 / 2 mv^2$$

$$= 1 / 2 m \times 5^2$$

$$\text{Energy lost} = 1 / 2 m \times 5^2 \times 60 / 100$$

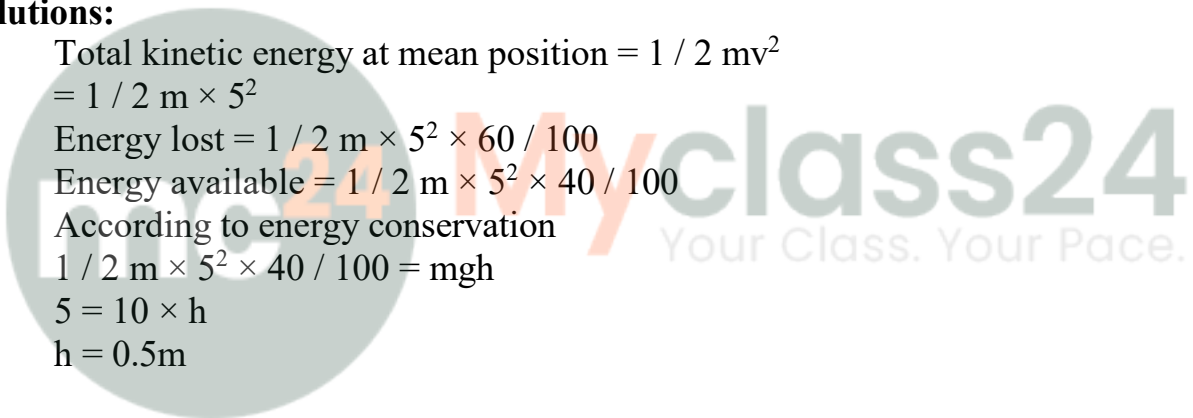
$$\text{Energy available} = 1 / 2 m \times 5^2 \times 40 / 100$$

According to energy conservation

$$1 / 2 m \times 5^2 \times 40 / 100 = mgh$$

$$5 = 10 \times h$$

$$h = 0.5\text{m}$$





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