10 Work and Energy

Fastrack Revision

- **Work:** It is said to be done when the force applied on the body displaces its position in the direction of the applied force.
  - **Conditions for Work to be Done:**
    - A force should act on the body.
    - The body must be displaced from its position.
  - **Work Done by a Constant Force:** It is the product of the force and the distance moved by the body in the direction of the applied force, *i.e.*, $W = F \times s$. It is a scalar quantity.
  - **SI Unit of Work:** The SI unit of work is Newton-metre (N-m) or Joule (J).
  - **1 Joule:** It is the amount of work done on a body when a force of 1N displaces it by 1 m along the line of action of the force.
  - **Nature of Work Done**
    - If displacement is in the direction of force, $W = F \times s$.
    - If displacement is in the direction opposite to the force, $W = -F \times s$ or $F \times (-s)$.
    - If displacement is perpendicular to the force, $W = 0$.

Knowledge BOOSTER

Frictional force acts in the direction opposite to the direction of displacement, so work done by friction will be negative.

- **Energy:** It is the capacity or the ability of the body to do work. Its SI unit is Joule (J) and is a scalar quantity.
  - **Forms of Energy:** There are various forms of energy such as kinetic energy, potential energy, etc.
    - **Kinetic Energy:** It is the energy possessed by a body due to its motion. It increases with the speed of the body. It is given as,

$$\text{KE or } E_k = \frac{1}{2}mv^2$$

Knowledge BOOSTER

Heavy objects which are moving with a high speed possess more kinetic energy as compared to smaller objects moving with less speed.

- **Potential Energy:** It is the energy possessed by a body due to its change in position or shape.

Knowledge BOOSTER

The sum of kinetic and potential energies of an object is called its mechanical energy.

- **Gravitational Potential Energy:** It is the work done in raising a body from the ground to the point above the ground against gravity. It is given as,

$$\text{PE or } E_p = mgh$$

- **Law of Conservation of Energy:** 'Energy can neither be created nor be destroyed, it can only be transformed from one form to another.' The total energy before and after transformation remains the same.

$$mgh + \frac{1}{2}mv^2 = \text{Constant}$$

- **Transformation of Energy:** One form of energy can be converted into other form of energy. When a body is dropped from a certain height, its potential energy converts into kinetic energy and when it is thrown upwards, its kinetic energy is converted to potential energy.
  - **Some Energy Transformations**
    - **Electric Motor:** Electrical energy into mechanical energy.
    - **Electric Generator:** Mechanical energy into electrical energy.
    - **Steam Engine:** Heat energy into kinetic energy.
    - **Electric Bulb:** Electrical energy into light energy.
    - **Dry Cell:** Chemical energy into electrical energy.
    - **Solar Cell:** Light energy into electrical energy.
- **Power:** It is the rate of doing work or the rate of transfer of energy. Its SI unit is watt and is a scalar quantity.

$$\text{Power, } P = \frac{W}{t}$$

1 watt is the power of an agent, which does work at the rate of 1 joule per second.

- **Average Power:** It is the ratio of the total energy consumed by the total time taken. It may vary with time depending on the energy consumed.

Practice Exercise

Multiple Choice Questions

Q 1. A soldier makes a swing jump between two points, by holding one end of a rope, other end of which is tied to some higher point. Work done by rope in jumping of soldier from one point to another is an example of:

a. negative work
b. positive work
c. zero work done
d. None of these

Q 2. A runner, while moving, is facing a wind from the opposite direction. The work done by the wind on runner will be:

a. zero
b. negative
c. positive
d. infinity

Q 3. In first case, a force of 5 N is applied on a object for 6 min and displaces it by 10 m. In second case, a force of 10 N is applied on the same object for 3 min and displaces it by 5 m. In which case, there is more work done?

a. First case
b. Second case
c. In both cases, work done is same
d. In both cases, work done is zero

Q 4. A cyclist is moving at a speed of 5 ms^{-1} on leveled road. While going down the slope, his speed increases to 7 ms^{-1}. Here the nature of work done by gravitational force in increasing the speed of cyclist is an example of:

a. positive work done
b. negative work done
c. infinite work done
d. zero work done

Q 5. In case of negative work the angle between the force and displacement is: *(NCERT EXEMPLAR)*

a. $0°$
b. $45°$
c. $90°$
d. $180°$

Q 6. A girl is carrying a school bag of 3 kg mass on her back and moves 200 m on a levelled road. The work done against the gravitational force will be: ($g = 10$ m/s^2) *(NCERT EXEMPLAR)*

a. 6×10^3 J
b. 6 J
c. 0.6 J
d. zero

Q 7. The work done on an object does not depend upon the: *(NCERT EXEMPLAR)*

a. displacement
b. force applied
c. angle between force and displacement
d. initial velocity of the object

Q 8. If the angle between force and displacement is θ, then for what value of θ work done is zero?

a. $60°$
b. $45°$
c. $180°$
d. $90°$

Q 9. A pair of bullocks exert a force of 1500 N on a plough. The field being ploughed is 20 m long. The work done in ploughing the given length of the field will be:

a. 21,000 J
b 30,000 J
c. 45,000 J
d. 3,000 J

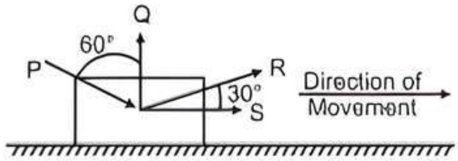
Q 10. The work done by a weight of 1 kg mass when it moves up through 1 m is:

a. 10 J
b. −10 J
c. 0.1 J
d. −0.1 J

Q 11. A ball of mass 1 kg thrown upwards reaches a maximum height of 5.0 m. Calculate the work done by the force of gravity during this vertical displacement.

a. −49 J
b. 49 J
c. 5.0 N
d. −5.0 N

Q 12. Four forces of equal magnitude are acting on an object as shown in figure. Which of the following forces does the least work?



a. P
b. Q
c. R
d. S

Q 13. When we stretch a rubber band, the elastic potential energy of rubber band:

a. remains unchanged
b. becomes zero
c. increases
d. decreases

Q 14. The person will have maximum potential energy, when:

a. he is sleeping on the ground
b. he is sitting on the ground
c. he is sleeping on the bed
d. he is standing on the roof

Q 15. If two bodies one light and other heavy have equal kinetic energies, then which one has a greater momentum?

a. Heavy body
b. Light body
c. Both have equal momentum
d. It depends on the actual velocities

Q 16. In keying of watch, we store:

a. potential energy
b. kinetic energy
c. gravitational energy
d. power

Q 17. How fast should a man weighing 600 N run to achieve a kinetic energy of 750 J? (Take, $g = 10$ m/s^2)

a. 5 m/s
b. 7 m/s
c. 10 m/s
d. 7.5 m/s

Q 18. When a body falls freely towards the Earth, then its total energy: *(NCERT EXEMPLAR)*

a. increases
b. decreases
c. remains constant
d. first increases and then decreases

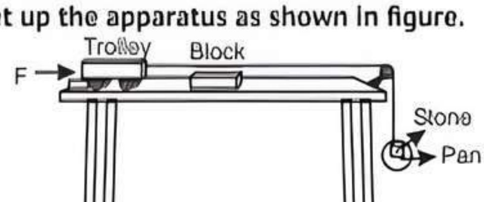
Q 19. A car is accelerated on a levelled road and attains a velocity 4 times of its initial velocity. In this process the potential energy of the car: *(NCERT EXEMPLAR)*
a. does not change
b. becomes twice to that of initial
c. becomes 4 times that of initial
d. becomes 16 times that of initial

Q 20. An iron sphere of mass 10 kg has the same diameter as an aluminium sphere of mass is 3.5 kg. Both spheres are dropped simultaneously from a tower. When they are 10 m above the ground, they have the same: *(NCERT EXEMPLAR)*
a. acceleration b. momenta
c. potential energy d. kinetic energy

Q 21. Which one of the following is not the unit of energy? *(NCERT EXEMPLAR)*
a. Joule b. Newton metre
c. Kilowatt d. All of these

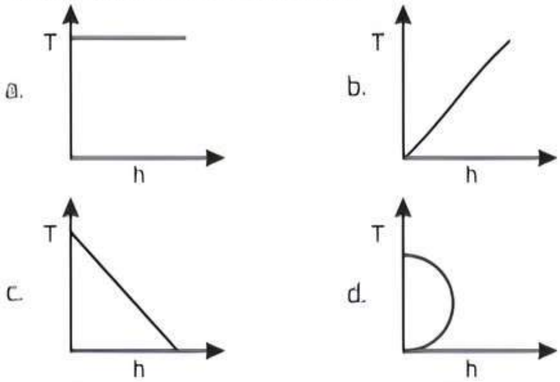
Q 22. Potential energy of a person is minimum when:
a. person is sitting on a chair
b. person is standing
c. person is lying on the ground
d. person is sitting on the ground

Q 23. Set up the apparatus as shown in figure.



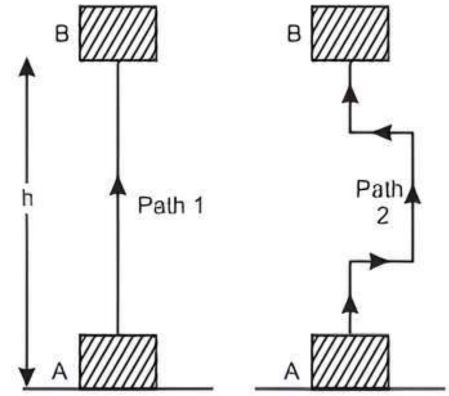
When stone is placed in the pan, trolley moves forward. If you have two stones of masses 10 kg and 5 kg, then in which of the following cases, the block placed in path of trolley suffers maximum displacement? (Assume that trolley stops after hitting the block.)
a. When stone of 5 kg is placed in the pan.
b. When stone of 10 kg is placed in the pan.
c. When both the stones are placed in the pan.
d. When the pan is empty.

Q 24. Which of the following graphs best represents the total energy (T) of a freely falling body versus its height (h) above the ground?



Q 25. A rocket rises up vertically. What happens to its potential energy?
a. It increases.
b. It initially increases then decreases.
c. It initially decreases then increases.
d. It increases, till it becomes maximum.

Q 26. A block is raised from position A to B by taking two different paths as shown in the figure given below. If $AB = h$, then:



a. the work done on the block is greater in case of path 1 than in case of path 2
b. the work done on the block is greater in case of path 2 than in case of path 1
c. the work done on the block is same for both paths
d. the work done cannot be determined

Q 27. Water stored in a dam possesses: *(NCERT EXEMPLAR)*
a. no energy b. electrical energy
c. kinetic energy d. potential energy

Q 28. A body is falling from a height h. After it has fallen a height $\frac{h}{2}$, it will possess: *(NCERT EXEMPLAR)*
a. only potential energy
b. only kinetic energy
c. half potential and half kinetic energy
d. more kinetic and less potential energy

Q 29. A car is accelerating up a slope. What are the changes in its kinetic energy and potential energy as it is moving up a slope?

	Kinetic energy	Potential energy
a.	decrease	decrease
b.	decrease	increase
c.	increase	increase
d.	increase	decrease

Q 30. The rate of doing work by a machine is called:
a. power b. energy
c. force d. momentum

Q 31. A rock climber of weight 600 N climbs up a rock face of vertical height 300 m in 3600 s. What is the average power she generates against gravity during this time?
a. 0.020 W b. 50 W
c. 1800 W d. 7200 W

Q 32. A 0.5 kg stone takes 4 seconds to reach the ground from a 80 m high building. What is the power of the stone during the fall? (Take $g = 10$ N kg^{-1})
a. 100 W b. 160 W
c. 400 W d. 1600 W

Q 33. The power output of a motor is 5kW. What is the work done by the motor in 5s?
a. 2.5 kJ b. 25 kJ
c. 250 kJ d. 2500 kJ

Assertion & Reason Type Questions

Directions (Q. Nos. 34-42): *Each of the following questions consists of two statements, one is Assertion (A) and the other is Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:*

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
c. Assertion (A) is true but Reason (R) is false.
d. Assertion (A) is false but Reason (R) is true.

Q 34. Assertion (A): Work has no magnitude and no direction.

Reason (R): 1 J is the amount of work done on an object when a force 1N displaces it by 1 m along the line of action of force.

Q 35. Assertion (A): Work done is zero when the displacement of the object is zero.

Reason (R): Work done is equal to the magnitude of the force multiplied by the distance moved in the direction of the force.

Q 36. Assertion (A): When the force retards the motion of a body, the work done is negative.

Reason (R): Work done depends on angle between force and displacement.

Q 37. Assertion (A): No work is done when a woman carrying a load on her head, walks on a level road with a uniform velocity.

Reason (R): No work is done if force is perpendicular to the direction of displacement.

Q 38. Assertion (A): A falling coconut, a flying aircraft and a running athlete possess kinetic energy.

Reason (R): Kinetic energy is the energy possessed by an object due to its motion.

Q 39. Assertion (A): According to law of conservation of mechanical energy, change in potential energy is equal and opposite to the change in kinetic energy.

Reason (R): The sum total of an object's kinetic and potential energy at any given point in time is its total mechanical energy.

Q 40. Assertion (A): If a light body and a heavy body possess the same momentum, the lighter body will possess more kinetic energy.

Reason (R): The kinetic energy of a body varies as the square of its velocity.

Q 41. Assertion (A): A spring has potential energy, both when it is compressed or stretched.

Reason (R): In compressing or stretching, work is done on the spring against the restoring force.

Q 42. Assertion (A): A winded toy car, when placed on floor, starts moving.

Reason (R): Toy car has kinetic energy stored in it which facilitates its motion.

Answers

1. (c) zero work done

2. (b) negative

Because Force acts opposite to the direction of displacement.

3. (c) In both cases, work done is same

In first case, work done $= F_1 \times s_1 = 5 \times 10 = 50$ J

In second case, work done $= F_2 \times s_2 = 10 \times 5 = 50$ J

4. (a) Positive work done

5. (d) 180°

Work done is negative when force acts opposite to the direction of displacement, *i.e.*, the angle between the two directions is 180°.

6. (d) Zero

The gravitational force on the bag, *i.e.*, the weight of bag is in vertically downward direction whereas the distance moved by her is in horizontal direction. It means that the force and displacement are perpendicular to each other, therefore no work (zero) is done.

7. (d) Initial velocity of the object

The work done on an object does not depend upon the initial velocity of the object.

8. (d) 90°

For $\theta = 90°$, work done is zero.

9. (b) 30,000 J

Given, force, $F = 1500$ N

Displacement, $s = 20$ m

Work done in ploughing the field, $W = F \times s$

$\therefore W = 1500 \text{ N} \times 20 \text{ m} = 30{,}000$ J

10. (b) – 10 J

Weight (*i.e.*, force) acts vertically downwards whereas the displacement is in upward direction

Here, $m = 1$ kg, $F = 10$ N and $s = 1$ m

$W = -Fs = -10 \text{ N} \times 1 \text{ m} = -10$ J

11. (a) – 49 J

The force of gravity on the ball is

$F = mg = 1 \text{ kg} \times 9.8 \text{ ms}^{-2} = 9.8$ N

The displacement of the ball is $s = 5.0$ m.

The force and the displacement are in opposite directions. Hence,

$W = -Fs = -9.8 \text{ N} \times 5.0 \text{ m} = -49$ J

We can also say that a work of 49 J has been done against the force of gravity.

12. (b) Q

There is no work done when the force and the displacement are perpendicular to each other.

The maximum work is done when the force applied is parallel to the direction of movement.

13. (c) Increases

14. (d) he is standing on the roof

Potential energy = mgh

'h' is maximum when a person is at roof.

Hence, potential energy is maximum when a person is standing on the roof.

15. (a) Heavy body

Given, $(KE)_1 = (KE)_2$

$$\Rightarrow \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2$$

$$\Rightarrow \frac{v_2}{v_1} = \sqrt{\frac{m_1}{m_2}} \text{ or } \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$$

We know that momentum = $m \times v$

$$\Rightarrow \frac{P_1}{P_2} = \frac{m_1 v_1}{m_2 v_2} = \frac{m_1}{m_2} \times \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{m_1}{m_2}}$$

$\because \quad m_1 > m_2 \qquad [\because P_1 > P_2]$

i.e., heavier body has greater momentum.

16. (a) potential energy

17. (a) 5 m/s

Given, $W = 600$ N, KE = 750 J, V = ?

$W = mg$

$600 = m \times 10$

$\Rightarrow \quad m = 60$ kg

Also, $KE = \frac{1}{2} mv^2$

$$\Rightarrow \quad v^2 = \frac{2KE}{m} = \frac{2 \times 750}{60} = 25$$

$\Rightarrow \quad v = 5$ m/s

18. (c) remains constant

When a body falls freely towards the Earth, its potential energy decreases which in turn increases the kinetic energy. Therefore, its total energy remains constant.

19. (a) does not change

In the given process, the potential energy of the car does not change as it does not depend on velocity.

20. (a) acceleration

Both spheres have the same acceleration that is acceleration due to gravity g. Momenta, potential energy and kinetic energy depend on mass which is different for the two spheres and hence the quantities will differ for the two spheres.

21. (c) Kilowatt

Kilowatt is the unit of power, not of energy.

22. (c) person is lying on the ground

PE = mgh

When the person is lying on the ground it will have minimum height above the ground.

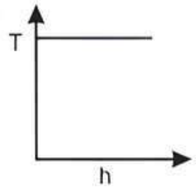
$\therefore$ PE will also be minimum.

23. (c) When both the stones are placed in the pan.

When a heavier mass is placed on the pan the trolley moves with higher speed and displaces the block by longer distance, *i.e.*,

Displacement of block $\propto$ Mass of stone in pan.

24. (a)



Total energy of the body remains the same.

25. (d) It increases, till it becomes maximum.

PE goes on increasing till the rocket stops rising.

26. (c) the work done on the block is same for both paths

Work done by gravity in moving an object from one place to another depends only on the initial and final positions, not on the path taken. In both the situations, work done on the block is same, *i.e.*, mgh.

27. (d) potential energy

Water stored in a dam possesses potential energy as it is stored at a certain height from the ground level.

28. (c) half potential and half kinetic energy

When a body falls from a height h to $\frac{h}{2}$, its potential energy becomes half (as potential energy = mgh). The rest half of initial potential energy gets converted into kinetic energy. Hence, the body will possess half potential energy and half kinetic energy.

29. (c) Kinetic Energy → increase

Potential Energy → increase

'Accelerating' indicates that the car is increasing speed and thus the KE must increase. 'Up a slope' indicates that the car is increasing height and thus the PE must increase.

30. (a) Power

31. (b) 50W

Total work done by climber = weight × height

= (600 × 300) J

$W = 1.8 \times 10^5$ J

Total time taken by climber, T = 3600 s

$$\text{Average power, } P_{av} = \frac{W}{t} = \frac{1.8 \times 10^5 \text{ J}}{3600 \text{ s}} = 50 \text{ W}$$

32. (a) 100W

Work done by the stone = mgh

= (0.5)(10)(80) = 400 J

$$\text{Power of the stone} = \frac{\text{Work done}}{\text{Time}} = \frac{400}{4} = 100\text{W}$$

33. (b) 25kJ

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

$\Rightarrow$ Work = Power × Time

= 5 kW × 5 sec

= 25 kJ

34. (d) Assertion (A) is false but Reason (R) is true.

Assertion (A) is false because work has only magnitude and no direction.

35. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

36. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

When the force retards the motion, the force and displacement are in opposite directions to each other. Hence, the work done by the force is negative.

37. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

Work done

$W = \vec{F} \cdot \vec{ds} = Fds\cos\theta = 0$ when $\theta = 90°$.

No work is done when force is perpendicular to the displacement.

38. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

39. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

The sum total of an object's kinetic and potential energy at any given point in time is its total mechanical energy.

40. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

The momentum of an object is directly proportional to its velocity whereas the kinetic energy is directly proportional to the square of velocity. If the momentum of the two objects is same, the lighter object has greater velocity and hence more kinetic energy.

41. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

When spring is compressed or stretched, the work is done on the spring. Due to this work, the energy gets stored in it as elastic potential energy.

42. (c) Assertion (A) is true but Reason (R) is false.

Reason (R) is false because when a toy car is winded, work done on it gets stored in the form of elastic potential energy and when it is placed on the ground, this elastic potential energy slowly converts into kinetic energy of the toy and facilitates its motion.

Case Study Based Questions

Case Study 1

In ordinary language the word 'work' means almost any physical or mental activity but in physics it has only one meaning: Work is done when a force produces motion. Two conditions need to be satisfied for work to be done: (i) a force should act on an object, and (ii) the object must be displaced.

The work done by a force can be positive, negative or zero. It is positive when a force acts in the direction of motion of the body. It is negative when a force acts opposite to the direction of motion of the body and is zero when a force acts at right angles to the direction of motion of the body.

Read the given passage carefully and give the answer of the following questions:

Q 1. The work done by a force on a body will be positive if the body:

a. moves perpendicular to the direction of applied force

b. does not move

c. moves along the direction of applied force

d. moves opposite to the direction of applied force

Q 2. Which of the following statements is true about work done?

(i) Work done by a force is always positive.

(ii) SI unit of work is joule.

(iii) Work has both, magnitude and direction.

(iv) Work is said to be done if an object is displaced when a force acts on it.

a. (i) and (ii) b. (ii) and (iii)

c. (ii) and (iv) d. (i), (ii), (iii) and (iv)

Q 3. A man carrying a bucket of water and walking on a rough level road with a uniform velocity does no work while carrying the bucket. Which of the following statements gives the correct reason for this?

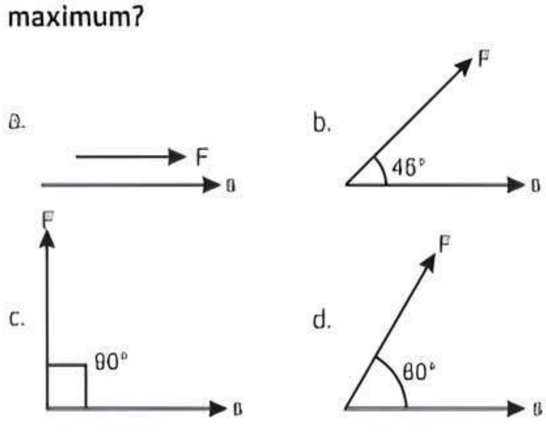
a. The displacement of the bucket is zero.

b. There is no force acting on the bucket.

c. The displacement of the bucket is in the direction of force applied.

d. There is no displacement in the direction of the force applied.

Q 4. In which of the following cases the work done is maximum?



Q 5. If force and displacement of the particle (in direction of force) are doubled. Work should be:

a. doubled b. 4 times

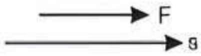
c. halved d. 1/4 times

Answers

1. (c) moves along the direction of applied force
2. (c) (ii) and (iv)

   Work done by a force can be negative, positive or zero, depending upon the direction of force applied. Work is a scalar quantity. It has magnitude but no direction.
3. (d) There is no displacement in the direction of the force applied.

   Man exerts a force in vertical upward direction (*i.e.*, opposite to gravity) to hold the bucket and displace the bucket along the rough level road *i.e.*, perpendicular to the direction of force applied. Also, the man is moving with uniform velocity, therefore, there is no force in the horizontal direction. Since, there is no displacement in the direction of force applied by man, hence he does no work.
4. (a)



   Force and displacement are in the same direction.
5. (b) 4 times

   We know that, Work = Force × Displacement

   Initially work done $W_1 = F \times s$

   Given that, $F_2 = 2F$ and $s_2 = 2s$

   Then, new work done $W_2 = F_2 \times s_2$

   $\Rightarrow W_2 = (2F) \times (2s) \quad \Rightarrow W_2 = 4W_1$

   Hence, work done is quadrupled.

Case Study 2

Kinetic energy of an object is the measure of the work an object can do by virtue of its motion. It is a scalar quantity and it is entirely described by magnitude alone. Simple act like walking, jumping, throwing and falling involves kinetic energy. The kinetic energy of a body is directly proportional to the mass of the body and to the square of velocity of the body (or square of the speed of the body).

Read the given passage carefully and give the answer of the following questions:

Q 1. Which one of the following possessed kinetic energy?

a. A dog chasing a hare

b. A compressed spring

c. Water stored in the reservoir of a dam

d. A car parked in the garage

Q 2. Kinetic energy of a body depends:

a. on its mass only

b. on its velocity only

c. on its mass as well as on its velocity

d. neither on its mass nor on its velocity

Q 3. The speed of a motor bike decreases by 4 times. Its kinetic energy will decrease by:

a. four times b. eight times

c. sixteen times d. thirty two times

Q 4. Two bodies have their masses $m_1/m_2 = 3$ and their kinetic energies $\frac{KE_1}{KE_2} = \frac{1}{3}$. The ratio of their velocities are:

a. 1 : 1 b. 1 : 2 c. 1 : 3 d. 2 : 3

Q 5. An object of mass 500 g falls from a height of 2m. If $g = 9.8\ m/s^2$, what is its kinetic energy just before touching the ground?

a. Zero b. 19.6 J c. 9.8 J d. 9800 J

Answers

1. (a) A dog chasing a hare

   Kinetic energy is the energy possessed by an object due to its motion. Thus, option (a) is the answer.
2. (c) on its mass as well as on its velocity

   Kinetic energy of a body depends on its mass as well as on its velocity, *i.e.*, $KE = \frac{1}{2}mv^2$
3. (c) sixteen times

   Say the speed of motor bike of mass m is v.

   So, its kinetic energy $KE_1 = \frac{1}{2}mv^2$

   When its speed is decreased by 4 times then its kinetic energy KE_2.

   $$= \frac{1}{2}m\left(\frac{v}{4}\right)^2 = \frac{1}{16}\left(\frac{1}{2}mv^2\right) = \frac{1}{6}KE_1$$

   ∴ Its kinetic energy will decrease by sixteen times.
4. (c) 1 : 3

   $$\text{As } \frac{KE_1}{KE_2} = \frac{1}{3} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2} = \frac{1}{3} \qquad \left[\because KE = \frac{1}{2}mv^2\right]$$

   $$\text{or} \quad \left(\frac{m_1}{m_2}\right)\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{3}$$

   Since $m_1/m_2 = 3$, we have $3\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{3}$

   $$\text{or} \quad \left(\frac{v_1}{v_2}\right)^2 = \frac{1}{9} \text{ or } \frac{v_1}{v_2} = \frac{1}{3} = 1:3.$$
5. (c) 9.8J

   Given that, Mass of the object $(m) = 500\ g = 0.5\ kg$

   Height $(s) = 2\ m$

   Acceleration due to gravity $(a) = 9.8\ m/s^2$

   Initial velocity of object $(u) = 0\ m/s$

   Using equation of motion,

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

   $$\Rightarrow \quad v = \sqrt{2as}$$

   $$\Rightarrow \quad v = \sqrt{2 \times 9.8 \times 2} \Rightarrow v^2 = 39.2$$

   We know that, $KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.5 \times 39.2 = 9.8\ J$

Case Study 3

A moving object can do work. An object moving faster can do more work than an identical object moving relatively slow. A moving bullet, blowing wind, a rotating wheel, a speeding stone can do work. Objects in motion possess energy. We call this energy as kinetic energy.

A falling coconut, a speeding car, a rolling stone, a flying aircraft, flowing water, blowing wind, a running athlete, etc. possess kinetic energy. In short, kinetic energy is the energy possessed by an object due to its motion. The kinetic energy of an object increases with its speed.

Read the given passage carefully and give the answer of the following questions:

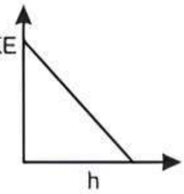
Q 1. How fast should a girl of 40 kg run so that her kinetic energy is 320 J?

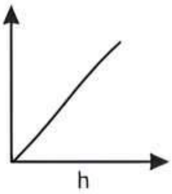
a. 64 m/s b. 8 m/s
c. 16 m/s d. 4 m/s

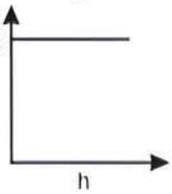
Q 2. The mass of a ball A is twice the mass of another ball B. The ball A moves at half the speed of the ball B. The ratio of the kinetic energy of A to that of B is:

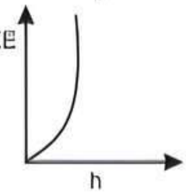
a. $\frac{3}{2}$ b. $\frac{1}{2}$ c. $\frac{5}{2}$ d. $\frac{4}{2}$

Q 3. Which of the following graphs best represents the kinetic energy (KE) of a freely falling body versus its height h above the ground?

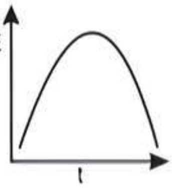
a.


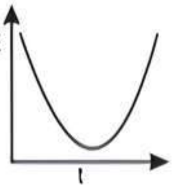
b.


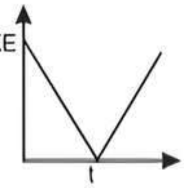
c.


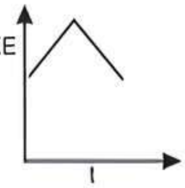
d.


Q 4. A cricket ball is projected vertically upward such that it returns back to the thrower. The variation in kinetic energy with time is best represented by:

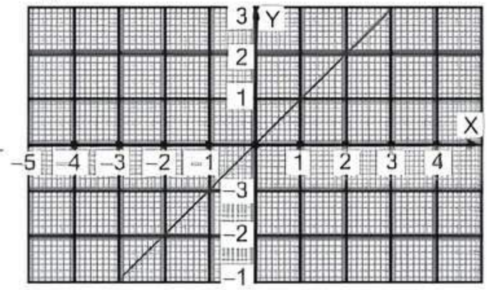
a.


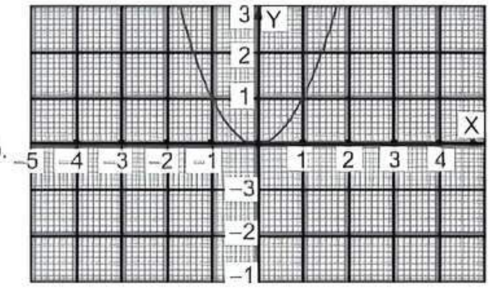
b.


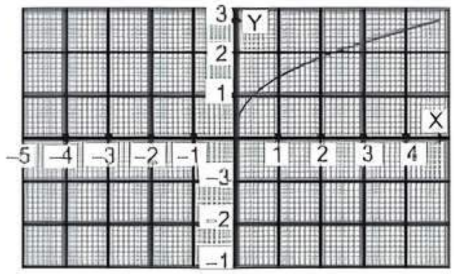
c.


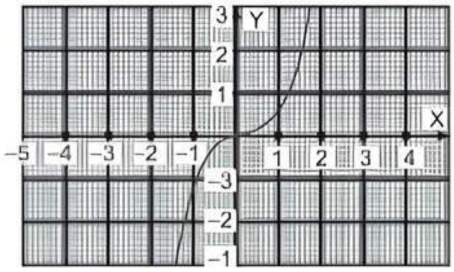
d.


Q 5. Which of the following graphs denotes the variation of kinetic energy with velocity? Assume velocity on the X-axis and kinetic energy on the Y-axis.

a.


b.


c.


d.


Answers

1. (d) 4 m/s

Given, mass $m = 40$ kg, KE $= 320$ J, $v = ?$

$$KE = \frac{1}{2}mv^2 \Rightarrow 320 = \frac{1}{2} \times 40v^2$$

$$v^2 = \frac{640}{40} = 16 \Rightarrow v = 4 \text{ m/s}$$

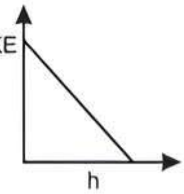
So, the girl of 40 kg should run at 4 m/s so that her kinetic energy is 320 J.

2. (b) $\frac{1}{2}$

As $m_A = 2m_B$ and $v_A = \frac{1}{2}v_B$

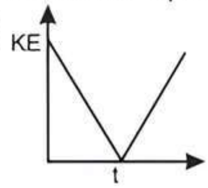
$$\frac{KE_A}{KE_B} = \frac{\frac{1}{2}m_A v_A^2}{\frac{1}{2}m_B v_B^2} = \frac{m_A}{m_B}\left(\frac{v_A}{v_B}\right)^2 = 2 \times \left(\frac{1}{2}\right)^2 = \frac{1}{2}$$

3. (a)



At maximum height, kinetic energy is zero and as the height decreases, kinetic energy increases. This is best represented by option (a) only.

4. (c)



When the ball rises up, its KE decreases, till it becomes zero. On falling down, its KE increases.

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

Kinetic Energy (KE) is directly proportional to the square of the velocity of the particle.

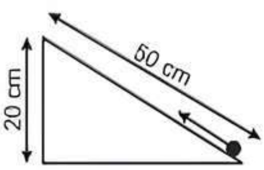
Case Study 4

An object increases its energy when raised through a height. This is because work is done on it against gravity while it is being raised. The energy present in such an object is the gravitational potential energy. Elastic potential energy is the energy an object has in it due to being deformed. Any object that can be deformed and then return to its original shape can have elastic potential energy. Examples of such objects are rubber bands, sponges, and bungee cords, and many others.

The gravitational potential energy as well as elastic potential energy is commonly known as just potential energy.

Read the given passage carefully and give the answer of the following questions:

Q 1. An 800 g ball is pulled up a slope as shown in the figure. Calculate the potential energy it gains.



a. 1.96 J
b. 1.568 J
c. 7.84 J
d. 1.26 J

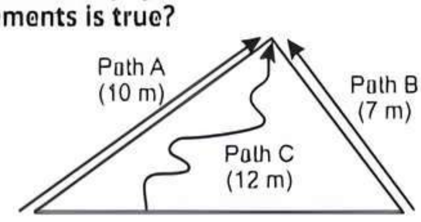
Q 2. By stretching the rubber strings of a catapult we store .... energy in it.

a. potential
b. electrical
c. heat
d. kinetic

Q 3. A car is accelerated on a levelled road and attains a velocity 4 times of its initial velocity. In this process, the potential energy of the car:

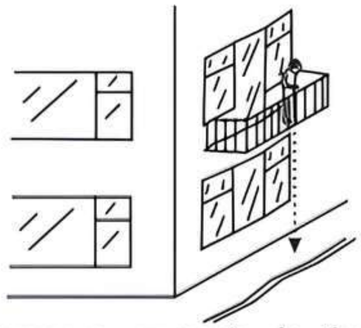
a. does not change
b. becomes twice of initial
c. becomes 4 times of initial
d. becomes 16 times of initial

Q 4. There are 3 paths leading to the top of the hill as shown. Assuming that the friction of the ground is negligible, which of the following statements is true?



a. All three paths require the same amount of energy to reach the top.
b. Path B requires the least energy to reach the top.
c. Path C requires most energy to reach the top.
d. Path B requires more energy than path A to reach the top.

Q 5. A young child holds a ball over the edge of a balcony. He gently releases the ball, the ball fall on to a concrete floor and bounces back up.



Which sequence represents, in the correct order, the transformations of the gravitational potential energy after the ball is released?

a. Elastic potential energy → Kinetic energy → Chemical potential energy
b. Elastic potential energy → Kinetic energy → Elastic potential energy
c. Kinetic energy → Elastic potential energy → Kinetic energy
d. Kinetic energy → Gravitational potential energy → Elastic potential energy

Answers

1. (b) 1.568 J

Given that:

h = 20 cm = 20/100 = 0.2 m

Mass of the ball (m) = 800 g = 0.8 kg

PE = mgh = 0.8 × 9.8 × 0.2 = 1.568 J

2. (a) Potential

3. (a) does not change

The potential energy of the car remains the same and will not change as the road is levelled and the height of the body remains the same, although its speed increases.

4. (a) All three paths require the same amount of energy to reach the top.

The work done to reach the top of the hill is the same for all three routes when there is no friction along the ways. The height achieved by the three routes is the same.

5. (c) Kinetic energy → Elastic potential energy → Kinetic energy

When the ball is released, its gravitational potential is transformed into kinetic energy as it falls. As it continues to fall onto the concrete path and bounce up, its kinetic energy is transformed into elastic potential energy. As it bounces up, its elastic potential energy is transformed back into kinetic energy.

Case Study 5

Work is said to be done when the force applied on an object produces a displacement of the object in the direction of force applied. For example, when we push or pull a heavy load or lift it above the floor then we are doing work, but a man carrying heavy load and standing still is not doing any work. Work, which is the product of force and displacement, has only magnitude and no direction. So, it is a scalar quantity.

Read the given passage carefully and give the answer of the following questions:

Q 1. A man raises a box of mass 50 kg to a height of 2 m in 10 s, while another man raises the same box to the same height in 50 s. What is the ratio of work done by them?

Q 2. If force and displacement of the particle (in direction of force) are doubled, what should be the amount of work?

Q 3. A coolie lifts a luggage of 10 kg from the ground and put it on his head 1.8 m above the ground. What would be the work done by him on the luggage?

Q 4. A student carries a bag weighing 5 kg from the ground floor to his class on the first floor that is 2 m high. What is the work done by the boy?

Q 5. Calculate the value of work done in holding a suitcase of 15 kg while waiting for a bus for 40 minutes.

Answers

1. We know that, $W = F \times s$
   ⇒ Work done is independent of time taken.
   Hence, in both the cases, $W = 50 \times 10 \times 2 = 1000$ J
   Thus, ratio of work done = 1000:1000 = 1:1
2. The work should be 4 times.
3. Mass of luggage, $m = 10$ kg and
   displacement, $s = 1.8$ m
   Work done, $W = F \times s = mg \times s$
   $= 10 \times 10 \times 1.8 = 180$ J
4. Here, mass of bag, $m = 5$ kg and
   displacement, $s = 2$ m
   Work done, $W = F \times s = mg \times s$
   $= 5\text{ kg} \times 10\text{ m s}^{-2} \times 2\text{ m} = 100$ J
5. Displacement in holding a suitcase while waiting for a bus, *i.e.*, stationary position = 0
   ∴ Work done = force × zero
   ⇒ Work done = zero.

Case Study 6

Rajeev is a college student in Uttar Pradesh. Rajeev and his family are going by car to visit a hill station. Rajeev himself is driving the car. Rajeev drives the car very carefully. On the flat highway road, Rajeev is keeping the car speed within a range of 50 to 60 kmph (which is well within the prescribed speed limit on this highway). He does not accelerate the car unnecessarily. After driving for about three hour continuously on a flat road, there is a sight of hills in view. On approaching the hilly road, Rajeev increases the speed of his car. Rajeev's younger brother Sanjeev, who is a student of class VI, is surprised to see his brother increasing the speed of car suddenly. Sanjeev asks Rajeev why the speed of car has been increased. Rajeev explains the reason for increasing the speed of car to everyone.

Read the given passage carefully and give the answer of the following questions:

Q 1. What type of energy is possessed by the car while running on the flat road?

Q 2. What type of energy transformations take place in a car engine?

Q 3. When the car is moving on an uphill road, it has to do work to overcome three types of forces. Name these three types of forces.

Q 4. Why does Rajeev increase the speed of his car on approaching the hilly road?

Q 5. What types of energy is possessed by the car going up on the hilly road?

Answers

1. The car running on a flat road possesses 'kinetic energy'.
2. The transformations of energy taking place in a car engine are as follows:
   Chemical energy (of petrol) ⟶ Heat energy ⟶ Kinetic energy
3. When the car is moving on an uphill road, then it has to do work to overcome (i) friction of the road (ii) air resistance, and (iii) force of gravity.
4. Rajeev increases the speed of car on approaching a hilly road to give more kinetic energy to the car so that it may go up the hill against gravity.
5. The car going up on the hilly road possessed (i) kinetic energy, and (ii) gravitational potential energy.

Case Study 7

Power measures the speed of work done, *i.e.*, how fast or slow work is done. Power is defined as the rate of doing work or the rate of transfer of energy. If an agent does a work W in time t, then power is given by:

Power = Work / Time

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

Read the given passage carefully and give the answer of the following questions:

Q 1. Water is falling on the blades of a turbine at the rate of 8×10^2 kg per minute, height of fall is 50 m. Calculate the power given to turbine. ($g = 10$ m/s^2)

Q 2. An athlete keeps fit by doing push-ups.

He applies a force of 300 N as he pushes up a distance of 0.5 m. He does 10 push-ups in 30 s. What is his average power output in 30 s?

Q 3. How many hp are present in one kilowatt?

Q 4. A boy of mass 50 kg runs up a staircase of 45 steps in 9 s. If the height of each step is 15 cm, find his power. Take ($g = 10$ m s^{-2})

Q 5. Two boys *A* and *B* lift 100 bricks through the same height in 5 minutes and 6 minutes respectively. Who has more power *A* or *B*?

Answers

1. Given, $m = 8 \times 10^2$ kg, $h = 50$ m,
$g = 10$ m/s^2, $t = 1$ min $= 60$ s

$$\text{Power} = \frac{W}{t} = \frac{mgh}{t}$$
$$= \frac{8 \times 10^2 \times 10 \times 50}{60} = 6.67 \times 10^3 \text{ W.}$$

2. Average power, $P = \frac{W}{t}$
$$P = \frac{300\text{ N} \times 0.5\text{ m} \times 10\text{ m/s}^2}{30\text{ s}} = 50\text{ W}$$

3. $1\text{ hp} = 0.746\text{ kW}$

or $1\text{kW} = \frac{1}{0.746}\text{hp} = \underline{1.34\text{ hp}}$

4. Weight of the boy,
$mg = 50\text{ kg} \times 10\text{ m s}^{-2} = 500\text{ N}$
Height of the staircase,
$h = 45 \times 15 / 100\text{ m} = 6.75\text{ m}$
Time taken to climb, $t = 9$ s
Power, P = Work done / time taken
$$= \frac{mgh}{t} = \frac{500\text{ N} \times 6.75\text{ m}}{9\text{ s}} = 375\text{ W.}$$

5. The rate of doing work of A is more than B because power is inversely proportional to time.
So, A has more power than B.

Very Short Answer Type Questions

Q 1. Write an expression for the work done when a force is acting on an object in the direction of its displacement. *(NCERT INTEXT)*

Ans. Expression for the work done is given by
Work done, W = Force × Displacement $= F \times s$
[F and s are in same direction]

Q 2. When is work done by a force zero?

Ans. Work done by a force is zero when the direction of force and displacement of an object are perpendicular to each other or when the displacement is zero.

Q 3. A student sitting in a class does his examination paper in three hours. How much work is done by the student?

Ans. No work is done by the student as there is no displacement.

Q 4. A child is watching a movie on TV. Is the child doing work? Give reason, why?

Ans. No, because there is no displacement involved.

Q 5. Define 1 J of work. *(NCERT INTEXT)*

Ans. 1 J of work is defined as the amount of work done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.

Q 6. Work done against gravity is negative. Why?

Ans. Because force and displacement are in opposite directions to each other.

Q 7. What is the work done by the boy when he is running along a circular path with a uniform speed?

Ans. Displacement is zero for a circular path because the initial and final point is same. Hence, work done is zero.

Q 8. Seema tried to push a heavy rock of 100 kg for 200 s but was unable to move it. Find the work done by Seema at the end of 200 s.

Ans. Work done = 0 as displacement, $s = 0$.

Q 9. A pair of bullocks exerts a force of 140 N on a plough. The field being ploughed is 15 m long. How much work is done in ploughing the length of field? *(NCERT INTEXT)*

Ans. Given, force $F = 140$ N, displacement, $s = 15$ m
$\therefore$ Work done, $W = Fs$
[F and s are in same direction]
So, $W = Fs = 140 \times 15 = 2100$ J

Q 10. What is the kinetic energy of an object? *(NCERT INTEXT)*

Ans. Kinetic energy is defined as the energy possessed by an object due to its motion.

Q 11. Write an expression for the kinetic energy of an object. *(NCERT INTEXT)*

Ans. The kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is:
$$KE = \frac{1}{2}mv^2$$

Q 12. What will cause greater change in kinetic energy of a body-changing its mass or changing its velocity?

Ans. Change in velocity will cause greater change in kinetic energy because $KE \propto m$ and $KE \propto v^2$.

Q 13. Name the term used for the sum of kinetic energy and potential energy of a body.

Ans. Kinetic energy + Potential energy = Mechanical energy

Q 14. In which situation is the potential energy of a spring minimum?

Ans. The potential energy of a spring is minimum when it is at its natural length, *i.e.*, neither stretched nor compressed.

Q 15. In the given figure, when the arrow is released from a stretched bow, the arrow moves in air from where does the arrow receive kinetic energy?

Ans. The potential energy stored in the bow due to the change of shape is used in the form of kinetic energy in throwing off the arrow.

Q 16. Can any object have mechanical energy even if the momentum is zero? *(NCERT EXEMPLAR)*

Ans. Since momentum of the object is zero, the velocity of the object is also zero. So, its kinetic energy is equal to zero. But the object may have potential energy. Hence, even if the momentum of the object is zero, have it may have mechanical energy.

Q 17. What are the various energy transformations that occur when you are riding a bicycle? *(NCERT EXERCISE)*

Ans. In case of riding a bicycle, the muscular energy is converted into heat energy and kinetic energy of the bicycle.

∴ Muscular energy = Heat energy + Kinetic energy

Q 18. A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy? *(NCERT EXERCISE)*

Ans. When a freely falling object eventually stops on reaching the ground, its kinetic energy gets converted into heat energy, sound energy as well as into potential energy (due to change in shape).

Q 19. What is power? *(NCERT INTEXT)*

Ans. Power is defined as the rate of doing work or the rate of transfer of energy. Its unit is J s^{-1} or watt.

Q 20. Define 1 watt of power. *(NCERT EXERCISE)*

Ans. 1 watt is the power of an appliance, which does work at the rate of 1 joule per second.

Q 21. A lamp consumes 1000 J of electrical energy in 10 s. What is the power? *(NCERT INTEXT)*

Ans. Given, energy = 1000 J

i.e., work done, W = 1000 J

Time, t = 10 s

$$\therefore \text{Power of lamp, } P = \frac{W}{t} = \frac{1000}{10} = 100 \text{ W}$$

Q 22. Define average power. *(NCERT INTEXT)*

Ans. Average power is defined as the ratio of the total energy consumed to the total time taken.

i.e., $$\text{Average power} = \frac{\text{Total energy consumed}}{\text{Total time taken}}$$

Short Answer Type-I Questions

Q 1. List two conditions which need to be satisfied for the work to be done on an object.

Ans. The conditions are:

(i) A force should act on an object.

(ii) The object must be displaced.

Q 2. Given below are a few situations, study them and state in which of the given cases work is said to be done. Give reasons for your answer.

(i) A person pushing hard a huge rock but the rock does not move.

(ii) A bullock pulling a cart up to 1 km on road.

(iii) A girl pulling out water from a well.

(iv) Moon revolving around the Earth in circular path.

Ans. (i) Work done is zero because the displacement is zero.

(ii) Positive work done because the direction of application of force and the displacement is the same.

(iii) Negative work done because the direction of application of force is opposite to the direction of displacement.

(iv) Work done is zero because force of Earth acts on the Moon at right angles to the direction of motion of Moon.

Q 3. Give two examples each of (i) positive work done, (ii) negative work done.

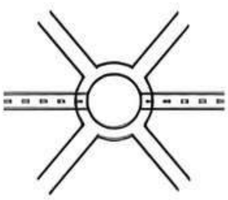
Ans. (i) (a) A boy pulls an object towards himself.

(b) Players kicking the football in the direction of force applied.

(ii) (a) Work done by frictional force on a rolling object.

(b) Work done by force of gravity on an object when lifted.

Q 4. A boy is moving on a straight road against a frictional force of 5 N. After travelling a distance of 1.5 km, he forgot the correct path at a round about (figure) of radius 100 m. However, he moves on the circular path for one and half cycle and then he moves forward up to 2.0 km. Calculate the work done by him. *(NCERT EXEMPLAR)*



Sol. Given, F = 5 N

Displacement on circular path = One cycle + Half cycle

= 0 + half cycle

= Diameter of circular path

= $2r$ = 2 × 100 = 200 m.

We know that, $W = Fs$

Total displacement (s) = 1500 m + 200 m + 2000 m

[∵ 1 km = 100 m]

= 3700 m

W = 5 × 3700 = 18500 J

Q 5. **In a tug of war, one team wins and the other team loses. Which team does positive work and which one does negative work? Justify your answer.**

Ans. Winning team does positive work on the rope because the force applied by the team on the rope acts in the direction of the displacement of the rope. On the other hand, losing team does negative work as the force applied by the team on the rope acts in the direction opposite to the direction of the displacement of the rope.

Q 6. **A mass of 10 kg is at a point A on the table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain your answer.**

(NCERT EXERCISE)

Ans. The work done by the gravitational force acting on the object of mass 10 kg is zero because gravitational force (which is in downward direction) and displacement of the object (which is in horizontal direction) are at right angles to each other.

Q 7. **Define energy. Name and define its SI unit.**

Ans. Energy is defined as the ability of an object to do work. The object which does the work loses energy and object on which work is done gains energy.

Its SI unit is joule (J).

The energy required to do 1 joule of work is called 1 joule energy.

Q 8. **Write the form of energy possessed by the body in the following situations.**

(i) a coconut falling from tree
(ii) an object raised to a certain height
(iii) blowing wind
(iv) A child driving a bicycle on road.

Ans. (i) Kinetic energy (ii) Potential energy
(iii) Kinetic energy (iv) Kinetic energy

Q 9. **If two bodies have masses in the ratio 1 : 8, have their speed in the ratio 4 : 5, find the ratio of their KE.**

Sol. Given, $m_1 : m_2 = 1 : 8$ and $v_1 : v_2 = 4 : 5$

$$\Rightarrow \frac{KE_1}{KE_2} = \frac{1/2\, m_1 v_1^2}{1/2\, m_2 v_2^2} = \frac{m_1}{m_2}\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{8} \times \left(\frac{4}{5}\right)^2$$

$$= \frac{1}{8} \times \frac{16}{25} = \frac{2}{25} = 2 : 25$$

$\therefore$ Ratio of their KE is 2 : 25.

Q 10. **A child drops a stone of 1 kg from the top of a tower. Find its kinetic energy, 5 s after it starts falling. (Take $g = 10 \text{ m s}^{-2}$)**

Sol. Given, mass of stone $(m) = 1$ kg

Initial velocity $(u) = 0$, time $(t) = 5$ s

Acceleration due to gravity $(g) = 10 \text{ m s}^{-2}$

From the equation of motion, we have

$v = u + gt$ [for downward motion]

$\Rightarrow v = 0 + 10 \times 5 \Rightarrow v = 50 \text{ m s}^{-1}$

$\therefore$ Kinetic energy of the stone after it starts falling

$$= \frac{1}{2} mv^2 = \frac{1}{2} \times 1 \times (50)^2 = 1250 \text{ J}$$

Q 11. **Suppose that a hammer, which falls freely on a nail placed on a piece of wood, has a mass of 1 kg. If it falls from a height of 1 m, how much kinetic energy will it have just before hitting the nail?**

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

Sol. Given, mass of the hammer, $m = 1$ kg

and height, $h = 1$ m.

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

$$v^2 - 0 = 2 \times 10 \times 1$$

$$\therefore \quad v^2 = 20$$

$$\text{Kinetic energy} = \frac{1}{2} \times m \times v^2$$

$$= \frac{1}{2} \times 1 \times 20 = 10 \text{ J}$$

Hence, the kinetic energy of the hammer just before hitting the nail is 10 joule.

Q 12. **The kinetic energy of an object of mass m moving with a velocity of 5 m s^{-1} is 25 J. What will be its kinetic energy when its velocity is increased three times?** *(NCERT INTEXT)*

Sol. Given, $KE_i = 25$ J, $v_i = 5 \text{ m s}^{-1}$

$$KE_i = \frac{1}{2} mv_i^2$$

$$\Rightarrow \quad 25 \text{ J} = \frac{1}{2} m (5^2)$$

$$\Rightarrow \quad m = \frac{25 \times 2}{5 \times 5}$$

$$\Rightarrow \quad m = 2 \text{ kg}$$

Also, final velocity $(v_f) = 3\, v_i$

$$\Rightarrow \quad v_f = 3 \times 5 = 15 \text{ m s}^{-1}$$

Now, kinetic energy, $KE_f = \frac{1}{2} mv_f^2 = \frac{1}{2} \times 2 \times 15 \times 15$

$= 225$ J

Q 13. **The mass of body *A* is less than that of body *B*. Both the bodies have equal momentum. Which of the two will have more kinetic energy?**

Ans. Given, $m_A < m_B$

and, $p_A = p_B$ i.e., $m_A v_A = m_B v_B$

$$\Rightarrow \frac{m_B}{m_A} = \frac{v_A}{v_B}$$

Since, $m_B > m_A$, or $\frac{m_B}{m_A} > 1$

Hence, $\frac{v_A}{v_B} > 1$ or $v_A > v_B$

i.e., KE of $A >$ KE of B

Body *A* has more kinetic energy.

Q 14. **Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 kmh^{-1}.**

(NCERT EXERCISE)

Sol.

TiP

Change in kinetic energy is equal to the work done.

Given, initial velocity, $u = 60 \text{ kmh}^{-1}$

$$= 60 \times \frac{5}{18} = \frac{50}{3} \text{ m s}^{-1}$$

$[\because 1 \text{ km h}^{-1} = 5/18 \text{ m s}^{-1}]$

Final velocity, $v = 0$

$\therefore$ Work done (W) = Change in kinetic energy

$$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$\Rightarrow \quad W = \frac{1}{2}m(v^2 - u^2)$$

$$= \frac{1}{2} \times 1500 \times \left[0^2 - \left(\frac{50}{3}\right)^2\right]$$

$$= -\frac{1}{2} \times \frac{1500 \times 50 \times 50}{9}$$

$$W = -\frac{625000}{3}$$

$$= -208333.3 \text{ J}$$

Hence, the work required to be done to stop the car is 208333.3 J.

Q 15. Certain force acting on a 20 kg mass changes its velocity from 5 m s^{-1} to 2 m s^{-1}. Calculate the work done by the force. *(NCERT EXERCISE)*

Sol. Given, mass, $m = 20$ kg

Initial velocity, $u = 5 \text{ m s}^{-1}$

Final velocity, $v = 2 \text{ m s}^{-1}$

$\therefore$ Work done by the force = Change in kinetic energy

= Final kinetic energy − Initial kinetic energy

$$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2}m(v^2 - u^2) = \frac{1}{2} \times 20\,((2)^2 - (5)^2)$$

$$= 10\,(4 - 25) = 10 \times (-21) = -210 \text{ J}$$

Q 16. A body of mass 2 kg is thrown up with a speed of 25 ms^{-1}. Find its maximum potential energy.

Sol. Given, mass $(m) = 2$ kg, initial velocity $(u) = 25 \text{ m s}^{-1}$,

Final velocity $(v) = 0$, $g = -9.8 \text{ m s}^{-2}$

Height to which body rises,

$$h = \frac{v^2 - u^2}{2g} = \frac{0 - (25)^2}{2 \times (-9.8)} = \frac{625}{19.6} \text{m}$$

Maximum potential energy $(E_p) = mgh$

$$= 2 \times 9.8 \times \frac{625}{19.6} = 625 \text{ J}$$

Q 17. Find the ratio of gravitational potential energy if height of an object is doubled and mass is tripled. Also, find the ratio of work done by gravity in bringing the object to zero height in both the cases.

Sol. Let an object of mass 'm' be placed at a height 'h' from the ground level.

The gravitational potential energy of the object is $PE_1 = mgh$.

When the height of the object is doubled and its mass is tripled, the gravitational potential energy becomes

$$PE_2 = 3m \times g \times 2h = 6\,mgh$$

$$\frac{PE_1}{PE_2} = \frac{6\,mgh}{mgh} = 6:1$$

When the object is at zero height, its PE = 0. Work done by the gravity to bring the object of mass m placed at a height h to zero height is given as

W_1 = Change in energy = $mgh - 0 = mgh$.

So, the work done by gravity to bring the object of mass 3m placed at a height $2h$ to zero height is

$W_2 = 6mgh - 0 = 6\,mgh$.

$$\therefore \quad \frac{W_2}{W_1} = \frac{6}{1} = 6:1.$$

COMMON ERR(!)R

Students forget to find the ratio in both the cases or skip the 2nd part of the question.

Q 18. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half way down. *(NCERT EXERCISE)*

Sol. Given, mass, $m = 40$ kg, height, $h = 5$ m

As potential energy is given by PE = mgh

So, PE = $40 \times 10 \times 5 = 2000$ J $\quad [\because g = 10 \text{ ms}^{-2}]$

Due to law of conservation of energy at half-way down, the object has an equal amount of potential and kinetic energy or half of its PE gets converted to KE.

$$i.e., \text{ KE} = \frac{1}{2}\text{ PE} = \frac{2000}{2} = 1000 \text{ J}.$$

Q 19. A shotput player throws a shotput of mass 3 kg. If it crosses the top of wall 2 m high at a speed of 4 ms^{-1}, compute the total mechanical energy gained by the shotput when it crosses the wall. (Given $g = 9.8 \text{ ms}^{-2}$)

Sol. Given, $m = 3$ kg, $h = 2$ m, $v = 4 \text{ ms}^{-1}$ and $g = 9.8 \text{ ms}^{-2}$

$$\text{Total mechanical energy} = \text{KE} + \text{PE} = \frac{1}{2}mv^2 + mgh$$

$$= \frac{1}{2} \times 3 \times 16 + 3 \times 9.8 \times 2$$

$$= 24 + 58.8 = 82.8 \text{ J}$$

i.e., the total mechanical energy gained by the shotput when it crosses the wall is 82.8 J.

Q 20. Define watt. Express kilowatt in terms of joule per second. A 150 kg car engine develops 500 W for each kilogram. What force does it exert in moving the car at a speed of 20 m s^{-1}?

Sol. 1 watt is the power of an agent which does work at the rate of 1 Joule per second.

$$1 \text{ kilowatt} = 1000 \text{ J s}^{-1}$$

Given, power = 500 W for each kg, Velocity = 20 m s^{-1}

Total power developed by 150 kg car engine

$$= 150 \times 500 = 7.5 \times 10^4 \text{ W}$$

$$\text{Force} = \frac{\text{Power}}{\text{Velocity}} = \frac{7.5 \times 10^4}{20} = 3.75 \times 10^3 \text{ N}$$

Hence, a force of 3.75×10^3 N is exerted in moving the car.

Q 21. The power of a motor pump is 2 kW. How much water per minute the pump can raise to a height of 10 m? (Take $g = 10 \text{ ms}^{-2}$) *(NCERT EXEMPLAR)*

Sol. Given, $P = 2 \text{ kW} = 2000 \text{ W}$, $t = 1 \text{ min} = 60 \text{ s}$,

$h = 10 \text{ m}$ and $g = 10 \text{ ms}^{-2}$

$$\because \quad P = \frac{W}{t} = \frac{mgh}{t} \Rightarrow 2000 \frac{m \times 10 \times 10}{60}$$

$$\text{or,} \quad m = \frac{2000 \times 6}{10} = \frac{12000}{10} = 1200 \text{ kg}$$

Therefore, the pump can raise 1200 kg of water per minute up to 10 m height.

Q 22. A woman pulls a bucket of water of total mass 5 kg from a well, which is 10 m deep in 10 s. Calculate the power used by her.

Sol. Given, mass of the bucket of water, $m = 5$ kg,

Depth of the well, $h = 10$ m,

Acceleration due to gravity, $g = 10 \text{ ms}^{-2}$

and time taken, $t = 10$ s.

Now, work done by the woman $= mgh$

$= 5 \times 10 \times 10$

$= 500$ J

$$\text{We know that, power} = \frac{\text{Work}}{\text{Time taken}}$$

$$= \frac{500}{10} = 50 \text{ J s}^{-1} \text{ or } 50 \text{ watt}$$

Hence, the power used by her is 50 W.

Q 23. Avinash can run with a speed of 8 m s^{-1} against the frictional force of 10 N and Kapil can move with a speed of 3 m s^{-1} against the frictional force of 25 N. Who is more powerful and why? *(NCERT EXEMPLAR)*

Sol. $$\text{Power} = \frac{\text{Work done}}{\text{time}}$$

$$= \frac{\text{Force} \times \text{Displacement}}{\text{Time}}$$

$= \text{Force} \times \text{Velocity}$

$$\left(\because \frac{\text{displacement}}{\text{time}} = \text{velocity}\right)$$

$\therefore$ Power of Avinash, $P_A = F_A \cdot u_A = 10 \times 8 = 80$ W

Power of Kapil, $P_K = F_K \cdot u_K = 25 \times 3 = 75$ W

So, Avinash is more powerful than Kapil.

? Short Answer

Type-II Questions

Q 1. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.

(i) Seema is swimming in a pond.

(ii) A donkey is carrying a load on its back.

(iii) A wind mill is lifting water from a well.

(iv) A green plant is carrying out photosynthesis.

(v) An engine is pulling a train.

(vi) Food grains are getting dried in the Sun.

(NCERT EXERCISE)

Ans. (i) Work is done by Seema because she displaces the water backwards by applying the force in forward direction.

(ii) No work is done because the direction of force, *i.e.*, load (vertically downward) and displacement (along horizontal) are perpendicular to each other.

(iii) Work is done because wind mill is changing the position of water against the gravity.

(iv) No work is done because there is no force and displacement.

(v) Work is done because engine is changing the position of train.

(vi) No work is done because there is no force and no displacement.

Q 2. A student lifts an object in the upward direction. In doing so, he applies the force on the object in the upward direction and displaces it in that direction. (However, the force of gravity is also acting on the object.)

(i) State the direction in which force of gravity is acting on it.

(ii) Which one of these forces is doing positive work? Give reason.

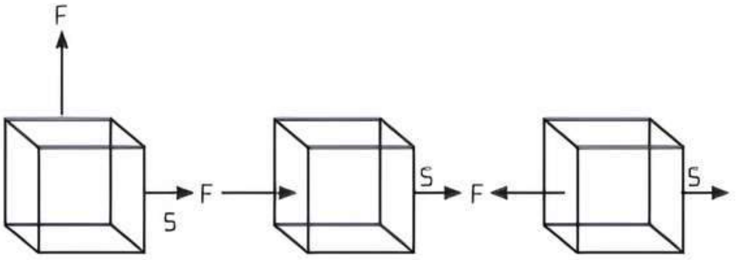
(iii) Which one of these forces is doing negative work? Give reason.

Ans. (i) Force of gravity is acting on it in downward direction.

(ii) The applied force is doing positive work because force and displacement are in the same direction.

(iii) The force of gravity is doing negative work because force and displacement are in opposite direction.

Q 3. In each of the following, a force F is acting on an object of mass m. The direction of displacement is from West to East shown by the longer arrow. Observe the figure carefully and state whether the work done by the force is negative, positive or zero. *(NCERT EXERCISE)*



(i) (ii) (iii)

Ans. (i) In Fig. (i), angle between F and s is 90° or force and displacement are perpendicular to each other so work done is zero.

(ii) In Fig. (ii), angle between F and s is 0° or force and displacement are in the same direction so work done is positive.

(iii) In Fig. (iii), angle between F and s is 180° or force and displacement are in the opposite direction so work done is negative.

Q 4. A truck of mass 1800 kg is moving with a speed of 54 kmh^{-1}. When brakes are applied, it stops with uniform negative acceleration at a distance of 200 m. Calculate the force applied by the brakes of the truck and the work done before stopping.

Sol. Given, mass, $m = 1800$ kg.

Velocity, $u = 54$ kmh^{-1}

$$= 54 \times \frac{5}{18} \text{ms}^{-1} = 15 \text{ms}^{-1}$$

$v = 0$ and distance, $s = 200$ m.

From third equation of motion,

$$a = \frac{v^2 - u^2}{2s} = \frac{0-(15)^2}{2 \times 200} = \frac{-9}{16} \text{ms}^{-2} \quad \text{(Retardation)}$$

Force, $F = ma = 1800 \times \left(\frac{-9}{16}\right) = -1012.5$ N

Hence, force applied by the brakes of the truck is 1012.5 N.

The negative sign indicates force which acts in the direction opposite to the direction of motion.

Work done before stopping

$= \text{Force} \times \text{Distance moved} = Fs$

$= 1012.5 \times 200 = 202500$ J

Hence, the work done before stopping is 202500 J.

Q 5. A girl having mass of 35 kg sits on a trolley of mass 5 kg. The trolley is given an initial velocity of 4 ms^{-1} by applying a force. The trolley comes to rest after traversing a distance of 16 m.
(i) How much work is done on the trolley?
(ii) How much work is done by the girl?

(NCERT EXEMPLAR)

Sol. Given, $u = 4$ ms^{-1}, $v = 0$ and $s = 16$ m

From the third equation of motion,

[$\because$ for retardation, the acceleration is negative, i.e., $a = -a$]

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

$\Rightarrow (0)^2 = (4)^2 - 2a \times 16$

$0 = 16 - 32a \quad \Rightarrow \quad a = \frac{16}{32} = 0.5$ ms^{-2}

(i) Total mass $= 35 + 5 = 40$ kg

Work is done on the trolley,

$W = F \cdot d = ma.s \quad [\because F = ma]$

$= 40 \times 0.5 \times 16 = 320$ J

(ii) Given, mass of girl, $m = 35$ kg

Work done by the girl,

$W = F \cdot d = ma.\ s = 35 \times 0.5 \times 16 = 280$ J

Q 6. A car weighing 1200 kg is uniformly accelerated from rest and covers a distance of 40 m in 5 seconds. Calculate the work done by the engine of car during this time. What is the final kinetic energy of car?

Sol. Given, Mass, $m = 1200$ kg; Initial velocity, $u = 0$; Displacement, $s = 40$ m; Time, $t = 5$ s

By second equation of motion,

$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2$$

or $$a = \frac{2s}{t^2} = \frac{2 \times 40}{(5)^2} = 3.2 \text{ ms}^{-2}$$

Work done = Force × Displacement

$= ma.s = 1200 \times 3.2 \times 40 = 153600$ J

Final KE = Work done = 153600 J

Q 7. (i) Earth is revolving around the Sun. What is the work done by the gravitational force exerted by the Sun on Earth? Justify your answer.

(ii) A rocket of 3×10^6 kg mass takes off from a launching pad and acquires a vertical velocity of 1 km s^{-1} at an altitude of 25 km. Calculate: (a) the potential energy and (b) kinetic energy. (Take the value of $g = 10$ ms^{-2})

Ans. (i) Work done by the Sun or Earth revolving around it in circular orbits is zero because the gravitational force of Sun acts on Earth at right angles to the direction of motion of Earth.

(ii) Given, mass of the rocket $(m) = 3 \times 10^6$ kg

Velocity $= 1$ km s^{-1} $= 1000$ m s^{-1}

Altitude $(h) = 25$ km $= 25 \times 1000$ m.

$= 25000$ m

(a) Potential energy $= mgh$

$= 3 \times 10^6 \times 10 \times 25000$

$= 75 \times 10^6$ J

(b) Kinetic energy $= \frac{1}{2} mv^2$

$= \frac{1}{2} \times 3 \times 10^6 \times (1000)^2$

$= 1.5 \times 10^{12}$ J

Q 8. A light and a heavy object have the same momentum. Find out the ratio of their kinetic energies. Which one has a larger kinetic energy? *(NCERT EXEMPLAR)*

Sol. Suppose m_1 and m_2 are masses of a light and a heavy objects, respectively. As we know,

Kinetic energy, $K = \frac{1}{2} mv^2$ ...(1)

(where, v = velocity of objects.)

and momentum, $p = mv$ ... (2)

On multiplying and dividing with m in Eq. (1), we get

So, $K = \frac{1}{2} \frac{mv^2 \times m}{m}$

$\Rightarrow K = \frac{1}{2} \frac{(mv)^2}{m}$

So, $K = \frac{p^2}{2m} \quad (\because p = mv)$

We have, kinetic energy, $K = \frac{p^2}{2m}$

$\because$ Momentum is same for light and heavy body.

So, kinetic energy, $K \propto \frac{1}{m}$

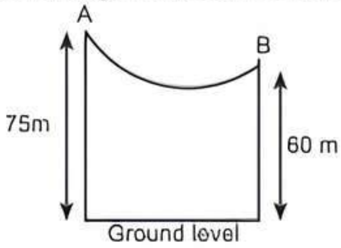
Thus, kinetic energy is inversely proportional to the mass.

So, lighter body has larger kinetic energy.

Q 9. (i) Define potential energy.

(ii) Give an example where potential energy is acquired by a body due to change in its shape.

(iii) A skier of mass 50 kg stands at A at the top of a ski jump. He takes off at A for his jump to B. Calculate the change in his gravitational potential energy between A and B.



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

(ii) In stretching of a bow, potential energy is acquired due to change in shape.

(iii) Given, $m = 50$ kg, $g = 10$ m s^{-2}

PE at $A = mg \times 75 = 75\,mg$

PE at $B = mg \times 60 = 60\,mg$

Difference in PE $= (75 - 60)\,mg$

$= 15\,mg = 15 \times 50 \times 10$

$= 7500$ J $= 7.5$ kJ

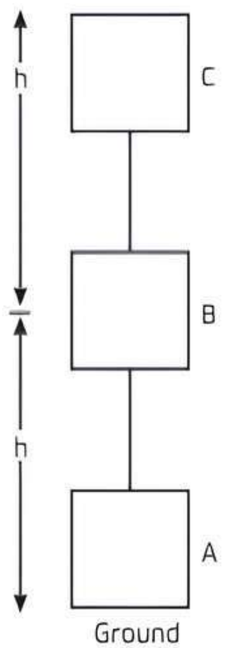
Hence, change in his gravitational potential energy between A and B is 7.5 kJ.

Q 10. Study the given figure and answer the questions:

(i) What is the potential energy of the object of mass 'm' at point B and C when it is raised from point A to B and B to C?

(ii) Calculate the potential energy of the object when raised directly from point A to C.

(iii) Calculate whether the same amount of work is done against the gravity in each case. Write your inference.



Ans. (i) Point A to B: PE $= mgh$ Point B to C: PE $= mgh$

The potential energy of the object in both the cases would be same.

(ii) Point A to C:

PE $= mg \times 2h = 2mgh$

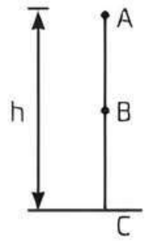
(iii) Work done $= F \times$ Distance

In part (i), $W = mgh + mgh = 2mgh$

In part (ii), $W = mg \times 2h = 2mgh$

So, the work done is equal in each case.

Q 11. State Law of Conservation of Energy and express it in the form of an equation for a body of mass m falling from a point A at height h, above the ground at (a) A, (b) B at a height from ground, (c) at C.



Ans. The law of conservation of energy states that energy can neither be created nor destroyed. It can only be transformed from one form into another. The total energy before and after the transformation always remains constant.

At point A: PE $= mgh$, KE $= 0$

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

Consider point B is at x distance below point A. So, w.r.t ground point B will be at distance $(h - x)$.

At point B: PE $= mg\,(h - x)$

From equation of motion,

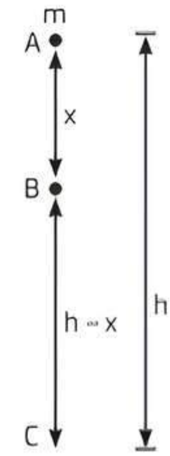
$v^2 = u^2 + 2as$

or $v^2 = (0)^2 + 2gx$

$\Rightarrow v^2 = 2gx$

Now, KE $= \frac{1}{2} mv^2 = \frac{1}{2} m \times 2gx$

$= mgx$



Total mechanical energy

$= mg\,x + mg\,(h - x)$

$= mgx + mgh - mgx$

$= mgh$

At point C: PE $= 0$

KE $= \frac{1}{2} mv^2 = \frac{1}{2} m\,(2gh) = mgh$

Total mechanical energy $= mgh + 0 = mgh$

The total mechanical energy of the body at A, B and C is the same. So, the total mechanical energy of the body throughout the free fall is conserved.

Q 12. (i) Define average power. Give its unit.

(ii) A moving body of mass 20 kg has 40 J of kinetic energy. Calculate its speed.

(iii) A person carrying a load of 20 kg climbs 4 m in 10 s. Calculate the work done and his power. (Take $g = 10$ m s^{-2})

Ans. (i) Average power can be defined as the ratio of total energy consumed by the total time taken.

The SI unit of power is watt (W).

(ii) Given, mass, $m = 20$ kg, kinetic energy, $E_K = 40$ J.

$\therefore$ Speed, $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 40}{20}} = 2\,ms^{-1}$

Hence, the required speed is 2 m s^{-1}.

(iii) Given, mass, $m = 20$ kg, height, $h = 4$ m, time, $t = 10$ s and $g = 10\ ms^{-2}$.

Total work done, $W = mgh = 20 \times 10 \times 4$

$= 800$ J

Power, $P = \frac{W}{t} = \frac{800}{10} = 80$ W

Hence, the work done is 800 J and his power is 80 W.

Q 13. How is the power related to the speed at which a body can be lifted? How many kilograms will a man working at the power of 100 W, be able to lift at constant speed of 1 ms^{-1} vertically? (Take, $g = 10\ ms^{-2}$) *(NCERT EXEMPLAR)*

Sol. The power delivered to a body can also be expressed in terms of the force F applied to the body and the velocity v of the body.

We know that, Power $(P) = \frac{\text{Work}}{\text{Time}} \Rightarrow P = \frac{F.s}{t}$ $[\because W = F.s]$

where, F = force, s = displacement and t = time

$\Rightarrow \quad P = F.v \quad \left(\because v = \frac{s}{t}\right)$

(where, v = velocity of the body)

Given, power, $P = 100$ W, $v = 1\ ms^{-1}$

and $g = 10\ ms^{-2}$

We know that, power,

$P = F.v \Rightarrow P = mg.v \quad (\because F = mg)$

$100 = mg.v$

$100 = m \times 10 \times 1$

$\Rightarrow \quad m = \frac{100}{10} \Rightarrow m = 10$ kg

Therefore, a man working at the power of 100 W can lift 10 kg.

Q 14. Compare the power at which each of the following is moving upwards against the force of gravity? (Given, $g = 10\ ms^{-2}$) *(NCERT EXEMPLAR)*

(i) A butterfly of mass 1 g that flies upward at a rate of 0.5 ms^{-1}.

(ii) A 250 g squirrel climbing up on a tree at a rate of 0.5 ms^{-1}.

Sol.

TiP

Firstly, we find the power by using the formula $P = mg.v$ in both parts and then comparing both powers.

(i) Given, mass of butterfly, $m = 1\text{ g} = \frac{1}{1000}$ kg. $[\because 1 \text{ kg} = 1000 \text{ g}]$

$g = 10\ ms^{-2}$

and speed, $v = 0.5\ ms^{-1}$

$\therefore$ Power = Force × Speed

$P = mgv$ (force, $F = mg$)

$\Rightarrow \quad P = \frac{1}{1000} \times 10 \times 0.5$

$\Rightarrow \quad P = 0.005$ W

(ii) Given, mass of squirrel = $250\text{ g} = \frac{250}{1000}$ kg $[\because 1 \text{ kg} = 1000 \text{ g}]$

and speed = $0.5\ m\ s^{-1}$

$\therefore$ Power = Force × Speed

$P = mg \times v \quad (\because \text{force}, F = mg)$

$\Rightarrow \quad P = \frac{250}{1000} \times 10 \times 0.5$

$\therefore \quad P = 1.25$ W

Therefore, a squirrel exerts more power than butterfly in moving upwards against the force of gravity.

Long Answer Type Questions

Q 1. (i) Define work. Give SI unit of work. Write an expression for positive work done.

(ii) Calculate the work done in pushing a cart through a distance of 50 m against the force of friction equal to 250 N. Also, state the type of work done.

(iii) Sarita lives on 3rd floor of building at a height of 15 m. She carries her school bag weighing 5.2 kg from the ground floor to her house. Find the amount of work done by her and identify the force against which she has done work. (Take $g = 10\ m\ s^{-2}$)

Ans. (i) Work is said to be done if an applied force displaces a body in the direction of application of force. Its SI unit is Joule (J).

For positive work done, $W = Fs$, where F = force, s = displacement in the direction of force.

(ii) Given, distance, $s = 50$ m, force, $f = 250$ N (opposite to direction of friction).

We know that, work, $W = Fs$

$= 250 \text{ N} \times 50 \text{ m} = 12500$ J

Hence, work done by applied force will be positive and that done by friction will be negative.

(iii) Given, mass, $m = 5.2$ kg, $g = 10\ m\ s^{-2}$ and height, $h = 15$ m.

We know that, work done, $W = mgh$

$= 5.2 \times 10 \times 15 = 780$ J

Hence, work is done against the force of gravity acting on the bag.

Q 2. (i) Define kinetic energy of an object. Can kinetic energy of an object be negative? Give reason.

(ii) A car weighing 1200 kg is uniformly accelerated from rest and covers a distance of 40 m in 5 s. Calculate the work, the car engine had to do during this time.

Ans. (i) The energy possessed by an object by virtue of its motion is called kinetic energy.

Let us consider a mass m moving with a speed u and a force F applied on it, which changes its velocity to v on displacing by s.

We know that, work done $W = (ma)\left(\frac{v^2-u^2}{2a}\right)$

$[\because W = Fs]$

Thus, $W = \frac{1}{2}m(v^2-u^2)$

If initial velocity u is zero, then $W = \frac{1}{2}mv^2$

or $KE = \frac{1}{2}mv^2$

Thus, kinetic energy cannot be negative because mass cannot be negative and the square of the speed is also a non-negative number.

Knowledge BOOSTER

The change in kinetic energy can be negative

(ii) Given, $m = 1200$ kg, $s = 40$ m, $u = 0$ and $t = 5$ s.

From second equation of motion,

$$s = ut + \frac{1}{2}at^2 \Rightarrow s = 0 + \frac{1}{2}at^2$$

$$\Rightarrow \quad a = \frac{2s}{t^2} = \frac{2\times 40}{(5)^2} = \frac{80}{25}\,m\,s^{-2}$$

Now, work done $= Fs = ma \times s$

$$= 1200 \times \frac{80}{25} \times 40$$

$$= 153600\ J$$

$$= 153.6\ kJ$$

Hence, car engine had to do 153.6 kJ of work during this time.

Q 3. Give reason for the following:

(i) The kinetic energy of a freely falling object increases, yet it holds law of conservation of energy.

(ii) A girl fills up 10 pages of a notebook in order to practise sums, yet she has not done 'work' in terms of science or scientific concept.

(iii) Work done by gravitational force on an object moved along a horizontal path is zero.

A boy sits and stands repeatedly for 5 min. Draw a graph to show the variation of potential energy of his body with time.

Ans. (i) The kinetic energy gained is due to transformation of potential energy into kinetic energy, so the conservation of energy holds good.

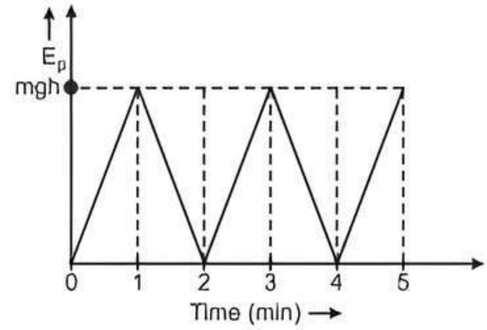
$\therefore$ Gain in KE = Loss in PE

(ii) Work done is zero as force applied by girl has not displaced the object, i.e., pages from their place. Since, displacement = 0, so work will also be zero.

(iii) Work done is zero because the gravitational force is perpendicular to the displacement.

Let 'm' be the mass of boy, 'h' be the position of centre of gravity while standing above the sitting position.

The PE while standing is $+ mgh$ and while sitting is zero.



Q 4. A vehicle of 1 tonne travelling with a speed of 60 ms^{-1} notices a cow on the road 9 m ahead applies brakes. It stops just in front of the cow.

(i) Find out the KE of the vehicle before applying brakes.

(ii) Calculate the retarding force provided by the brakes.

(iii) How much time did it take to stop after the brakes were applied?

(iv) What is the work done by the braking force?

Sol. Given, mass of the vehicle, m = 1 tonne = 1000 kg

Initial speed, $u = 60$ m s^{-1}

Distance between vehicle and the cow, $s = 9$ m

Final velocity, $v = 0$.

(i) KE of vehicle before applying brakes $= \frac{1}{2}mu^2$

$$= \frac{1}{2}\times 1000\times 60\times 60 = 1800000\ J$$

(ii) From the third equation of motion,

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

$$(0)^2 - (60)^2 = 2\times a\times 9$$

or $a = -200\ ms^{-2}$

Hence, retarding force provided by the brakes

$$= ma = 1000\ kg \times (-200)\ ms^{-2}$$

$$= -200000\ N$$

(iii) From second equation of motion,

$$s = ut + \frac{1}{2}at^2$$

$$9 = 60\,t + \frac{1}{2}\times(-200)\,t^2$$

or $9 = 60t - 100\,t^2$

or $100t^2 - 60t + 9 = 0$

or $(10t - 3)^2 = 0$

or $t = \frac{3}{10} = 0.3 s$

(iv) Work done by the braking force

$Fs = -200000 \text{ N} \times 9 \text{ m}$

$= -1800000 \text{ J}$

Q 5. 75 kg missile is dropped downwards from an air plane and has a speed of 60 ms^{-1} at an altitude of 850 m above the ground. Determine:

(i) The KE possessed by the missile at 850 m.

(ii) The PE possessed by the missile at 850 m.

(iii) The total mechanical energy possessed by the missile.

(iv) The KE and velocity with which it strikes the ground.

Ans. (i) Given, $m = 75$ kg, $v = 60$ m s^{-1}

$KE = 1/2\, mv^2$

$= 1/2 \times 75 \times 60 \times 60$

$= 135000$ J

(ii) $PE = mgh = 75 \times 10 \times 850 = 637500$ J

(iii) Total mechanical energy = KE + PE

$= 135000 + 637500$

$= 772500$ J

(iv) Given, $u = 60$ m s^{-1}, $h = 850$ m.

From equation of motion,

$v^2 - u^2 = 2gh$

$\Rightarrow v^2 - 3600 = 2 \times 10 \times 850$

$\Rightarrow v^2 - 3600 = 17000 \Rightarrow v^2 = 20600$

$\therefore KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 75 \times 20600 = 772500$ J

Q 6. (i) A body *A* of mass 3.0 kg and a body *B* of mass 10 kg are dropped simultaneously from a height of 14.9 m. Calculate (a) their momenta, (b) their potential energies, and (c) their kinetic energies when they are 10 m above the ground.

(ii) A truck and a car having equal kinetic energies are stopped by applying equal retarding forces. What is the relation of distances covered by them before stopping?

Sol. (i) As the two bodies are dropped, they fall with the same acceleration of 9.8 ms^{-2}. When they are 10 m above the ground, they have already fallen through 14.9 m – 10 m = 4.9 m.

The velocity at this point may be worked out from

$v^2 = u^2 + 2gh = 0 + 2 \times (9.8 \text{ m s}^{-2}) \times (4.9 \text{ m})$

$= 9.8 \times 9.8 \text{ m}^2 \text{ s}^{-2}$ or $v = 9.8$ m s^{-1}

(a) The momentum of *A* is

$p_A = m_A v = (3.0 \text{ kg}) \times (9.8 \text{ m s}^{-1}) = 29.4 \text{ kg m s}^{-1}$

The momentum of *B* is

$p_B = m_B v = (10 \text{ kg}) \times (9.8 \text{ m s}^{-1}) = 98 \text{ kg m s}^{-1}$

(b) The bodies are at a height of 10 m above the ground. The potential energy of *A* is

$U_A = m_A gh$

$= (3.0 \text{ kg}) \times (9.8 \text{ m s}^{-2}) \times (10 \text{ m}) = 294$ J

The potential energy of *B* is

$U_B = m_B gh$

$= (10 \text{ kg}) \times (9.8 \text{ m s}^{-2}) \times (10 \text{ m}) = 980$ J

(c) The kinetic energy of *A* is

$K_A = \frac{1}{2} m_A v^2$

$= \frac{1}{2} \times (3.0 \text{ kg}) \times (9.8 \text{ m s}^{-1})^2 \approx 144$ J

The kinetic energy of *B* is

$K_B = \frac{1}{2} m_B v^2$

$= \frac{1}{2} \times (10 \text{ kg}) \times (9.8 \text{ m s}^{-1})^{-2} \approx 480$ J

(ii) Suppose m_1 and m_2 are the masses of truck and car and u_1, u_2 are their initial velocities. As KE of both are equal so,

$\frac{1}{2} m_1 u_1^2 = \frac{1}{2} m_2 u_2^2$ or $\frac{m_1}{m_2} = \frac{u_2^2}{u_1^2}$ ... (1)

As equal retarding force is applied on both, if the distances covered by truck and car before stopping are s_1 and s_2 then,

$0 = u_1^2 - 2\frac{Fs_1}{m_1} \Rightarrow s_1 = \frac{m_1 u_1^2}{2F}$ $\left[\because a = \frac{F}{m}\right]$

and $0 = u_2^2 - 2\frac{Fs_2}{m_2} \Rightarrow s_2 = \frac{m_2 u_2^2}{2F}$

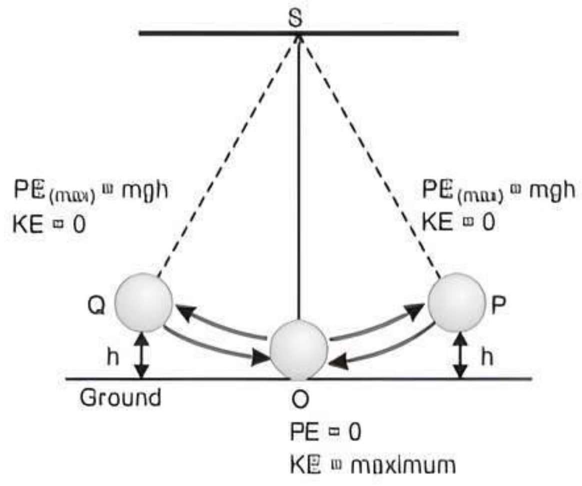
so, $\frac{s_1}{s_2} = \frac{m_1}{m_2} \times \frac{u_1^2}{u_2^2} = \frac{u_2^2}{u_1^2} \times \frac{u_1^2}{u_2^2}$ (Using eq. (1))

$\Rightarrow s_1 = s_2$

Q 7. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

(NCERT EXERCISE)

Ans. In the given pendulum, there are three cases to be discussed, *i.e.*, at the points *O*, *P* and *Q*.



Let a simple pendulum be suspended from a rigid support S and OS be the equilibrium position of the pendulum. Let the pendulum be displaced to a position P, where it is at rest. At position P, the pendulum has potential energy (mgh). When the pendulum is released from position P, it begins to move towards position O. The speed of the pendulum increases and its height decreases that means the potential energy is converting into kinetic energy.

At position O, whole of the potential energy of the pendulum is converted into its kinetic energy.

Then, the pendulum swings to other side due to inertia of motion. As the pendulum begins to move towards position Q, the speed of pendulum decreases and height increases that means kinetic energy is converting into potential energy. At point Q, whole of the kinetic energy is converted into potential energy.

Thus, we find that the potential energy is converted into kinetic energy and *vice-versa* during the motion of the pendulum. But the total energy remains constant.

When the pendulum oscillates in air, the air friction opposes its motion. So, some part of kinetic energy of pendulum is used to overcome this friction. With the passage of time, energy of the pendulum goes on decreasing and finally becomes zero.

The energy of the pendulum is transferred to the atmosphere. So, energy is being transferred, *i.e.*, is converted from one form to another. So, no violation of law of conservation of energy takes place.

Chapter Test

Multiple Choice Questions

Q 1. A car is accelerated on a levelled road and attains a velocity 4 times of its initial velocity. In this process, the potential energy of the car:

a. does not change
b. becomes twice of that of initial
c. becomes 4 times that of initial
d. becomes 16 times of that of initial

Q 2. A ball is projected upwards. As it rises, there is increase in its:

a. momentum
b. kinetic energy
c. potential energy
d. Both b. and c.

Q 3. A body is acted upon by a force that is proportional to the distance covered. If the distance covered is denoted by x, then work done by the force will be proportional to:

a. x
b. x^2
c. $x^{3/2}$
d. x^4

Q 4. A machine raises a load of 750 N through a height of 16 m in 5 s. Calculate work done by machine.

a. 12000 kJ
b. 12 kJ
c. 1200 J
d. 120 kJ

Assertion and Reason Type Questions

Directions (Q. Nos. 5-6): *Each of the following questions consists of two statements, one is* ***Assertion*** *(A) and the other is* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:*

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
c. Assertion (A) is true but Reason (R) is false.
d. Assertion (A) is false but Reason (R) is true.

Q 5. Assertion (A): An object of mass 15 kg is moving with a uniform velocity of 4 m/s and kinetic energy of that object will be 120 J.

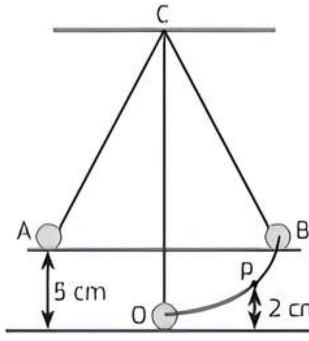
Reason (R): The kinetic energy possessed by an object of mass, 'm' moving with a uniform velocity, 'V' is $E_K = \frac{1}{2} mv^2$

Q 6. Assertion (A): A more powerful vehicle would complete a journey in a shorter time than a less powerful one.

Reason (R): Power measures the speed of work done, *i.e.*, how fast or slow work is done.

Case Study Based Question

Q 7. The following diagram shows a simple pendulum consisting of a bob of mass 100 g. Initially the bob of the pendulum is at rest at 'O'. It is then displaced to one side at A. The height of 'A' above 'O' is 5 cm. (Take $g = 10$ m/s^2)



Read the given passage carefully and give the answer of the following questions:

(i) What is the value of potential energy at 'A'?

(ii) What is the value of total energy of the bob at position A?

(iii) What is the value of kinetic energy of the bob at mean position 'O'?

(iv) What is the value of kinetic energy and potential energy of the bob at position 'P' whose height above O is 2 cm?

Very Short Answer Type Questions

Q 8. In an oscillating pendulum, at what position the potential and kinetic energies are maximum?

Q 9. A porter carrying load on his head moves up a stair. Is he doing work? Explain.

Short Answer Type-I Questions

Q 10. A car of mass 1200 kg travelling at 72 km/hr is brought to rest in 80 m. Find the average braking force on the car.

Q 11. Can any object have momentum even if its mechanical energy is zero? Explain.

Q 12. What is the amount of work done in the following cases? Justify your answer by giving the appropriate reason.

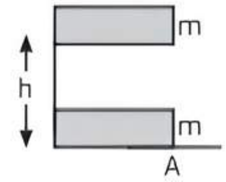
(i) By an electron revolving in a circular orbit of radius 'r' around a nucleus.

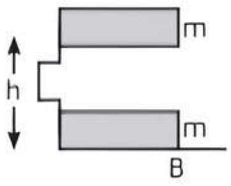
(ii) By the force of gravity when a stone of mass m is dropped from the top of a multi-storeyed building of height 'h'.

Short Answer Type-II Questions

Q 13. (i) A body of mass m is raised to a vertical height h through two different paths A and B.

What will be the potential energy of the body in the two cases? Give reason for your answer.





(ii) Give two examples each of the following:

(a) A body having potential energy due to change of shape.

(b) A body having potential energy due to its position.

Q 14. Justify the statement that the energy of a free falling body is conserved during its motion.

Q 15. (i) What are the various energy transformations that occur when you are riding a bicycle?

(ii) Give one example of (a) positive work and (b) negative work done.

Long Answer Type Questions

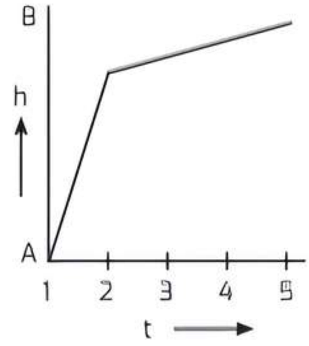
Q 16. (i) Derive an expression for kinetic energy possessed by an object of mass m, moving with velocity v.

(ii) A body of mass 25g has a momentum of 0.40 kg m/s. Find its kinetic energy.

(iii) State the law of conservation of energy.

Q 17. (i) A mass of 10 kg is at a point A on the table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain.

(ii) Read the graph depicting change in height of an object with time.



(a) Explain the changes in components of total mechanical energy with reasons.

(b) Find the velocity with which the object is projected.

(c) Find the maximum height achieved by the stone if it takes 4 s to reach that height.