Work and Energy

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:

Q1. 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

Q2. 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)

Q3. 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?

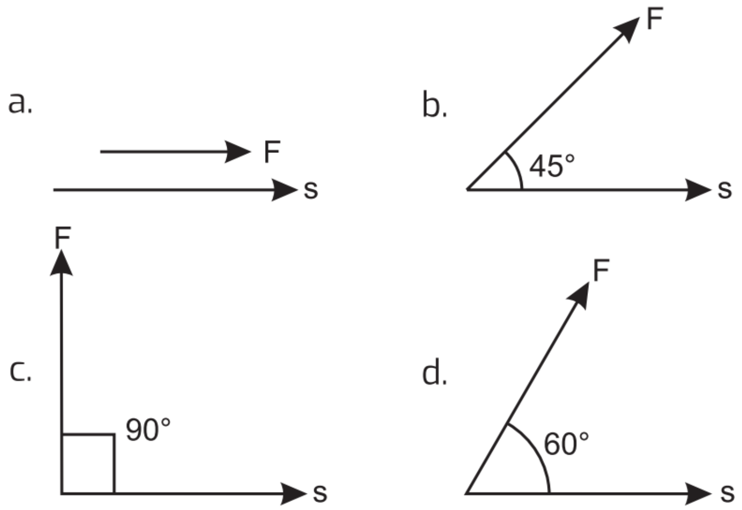
a. The displacement of the bucket is zero.

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.

Q4. In which of the following cases the work done is maximum?



Q5. 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

Solutions

1. (c) moves along the direction of applied force

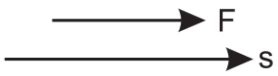
2. (c) (ii) and (iv)

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 (ie., 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 x Displacement

Initially work done W_1 = F x 5

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

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

$\Rightarrow W_2 = (2F) \times (25)$

$\Rightarrow W_2 = 4W_1$

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:

Q1. 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

Q2. 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

Q3. 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

Q4. 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

Q5. 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

Solutions

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

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

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

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

or $\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{9}$ 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:

Q1. 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

Q2. 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. 3/2

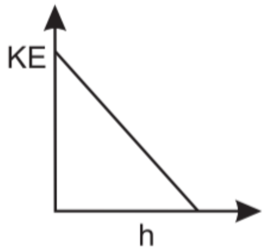
b. 1/2

c. 5/2

d. 4/2

Q3. Which of the following graphs best represents the kinetic energy (KE) of a freely falling body versus its height h above the ground?

a.



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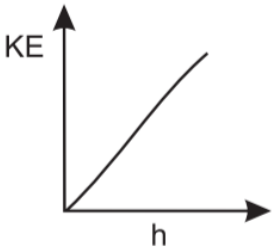
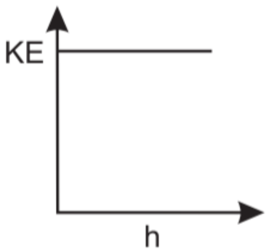
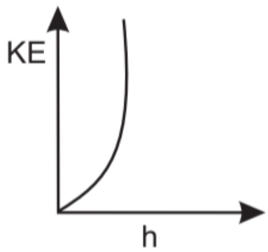


c.

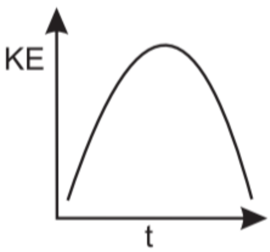


d.

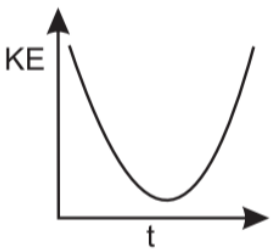


Q4. A cricket ball is projected vertically upward such that it returns back to the thrower. The variation in kinetic energy with time is best represented by:

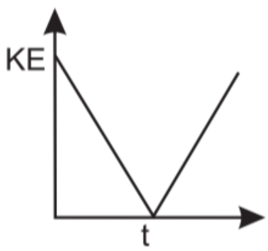
a.



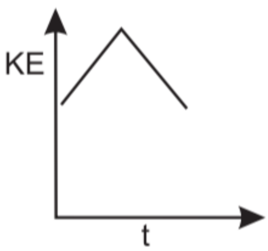
b.



c.

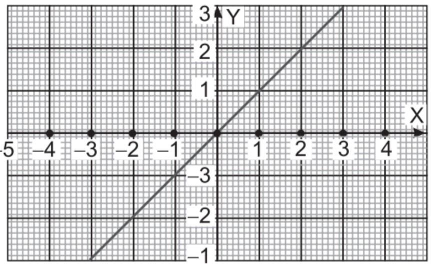


d.



Q5. 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.



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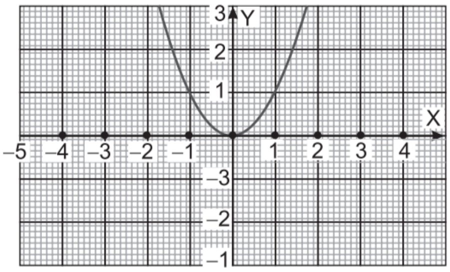
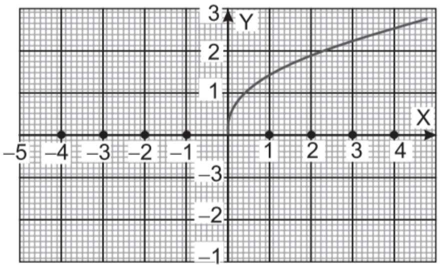
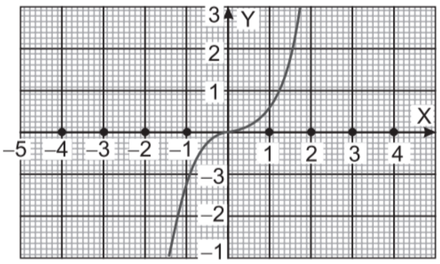


c.



d.



Solutions

1. (d) 4 m/s

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

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

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

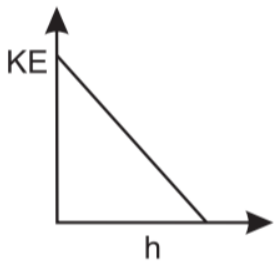
So, the girl of 40 kg should run at 4 m/s so that her kinetic energy is 320 J.

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

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

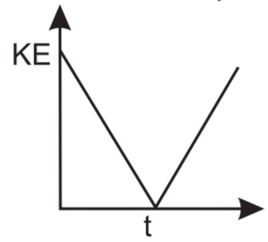
$$\frac{KE_A}{KE_B} = \frac{\frac{1}{2}m_A v_A^2}{\frac{1}{2}m_B v_B^2} = \frac{m_A}{m_B}\left(\frac{v_A}{v_B}\right) = 2 \times \left(\frac{1}{2}\right)^2 = \frac{1}{2}$$

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

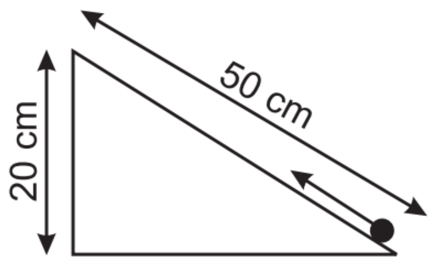
Kinetic Energy (KE) is directly proportional to the square of the velocity of the particle.

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:

Q1. 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

Q2. By stretching the rubber strings of a catapult, we store .... energy in it.

a. potential

b. electrical

c. heat

d. kinetic

Q3. 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:

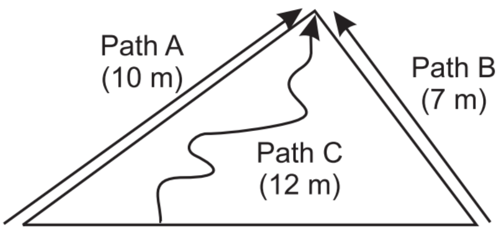
a. does not change

b. becomes twice of initial

c. becomes 4 times of initial

d. becomes 16 times of initial

Q4. 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?



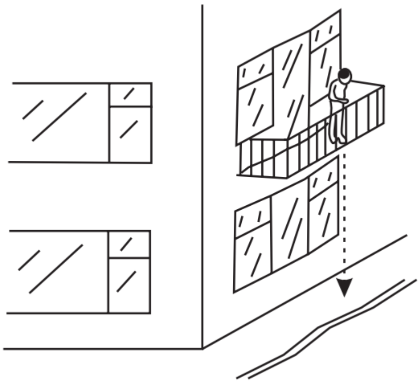
a. All three paths require the same amount of energy to reach the top.

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.

Q5. 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

Solutions

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 x 9.8 x 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:

Q1. 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?

Q2. If force and displacement of the particle (in direction of force) are doubled, what should be the amount of work?

Q3. 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?

Q5. Calculate the value of work done in holding a suitcase of 15 kg while waiting for a bus for 40 minutes.

Solutions

1. We know that, W = F x s

⇒ Work done is independent of time taken.

Hence, in both the cases, W = 50 x 10 x 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, 5 = 1.8 m

Work done, W = F x s = mg x 5

= 10 x 10 x 1.8 = 180 J

4. Here, mass of bag, m = 5 kg and displacement, 5 = 2 m

Work done, W = F x s = mg x 5

= 5 kg x 10 m s^{-2} x 2 m = 100 J

5. Displacement in holding a suitcase while waiting for a bus, i.e., stationary position = 0

∴ Work done = force x 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 hours 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:

Q1. What type of energy is possessed by the car while running on the flat road?

Q2. What type of energy transformations take place in a car engine?

Q3. 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.

Q4. Why does Rajeev increase the speed of his car on approaching the hilly road?

Q5. What types of energy is possessed by the car going up on the hilly road?

Solutions

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→ Heat energy → Kinetic energy (of petrol)

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:

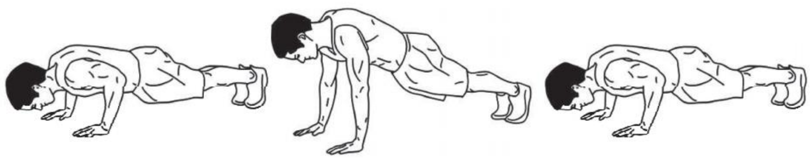
$$\text{Power} = \text{Work} / \text{Time}$$

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

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

Q1. Water is falling on the blades of a turbine at the rate of 8 x 10^2 kg per minute, height of fall is 50 m. Calculate the power given to turbine. (g = 10 m/s^2)

Q2. 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?

Q3. How many hp are present in one kilowatt?

Q4. 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 ($g = 10\ ms^{-2}$)

Q5. 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?

Solutions

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, $P = \dfrac{W}{t}$

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

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

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

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.