Work and Energy: Exercise 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'.

- **Suma is swimming in a pond.**
- **A donkey is carrying a load on its back.**
- **A wind mill is lifting water from a well.**
- **A green plant is carrying out photosynthesis.**
- **An engine is pulling a train.**
- **Food grains are getting dried in the sun.**
- **A sailboat is moving due to wind energy.**

Sol. *The* work is done, when the two conditions are satisfied:
(i) A force must act on the body.
(ii) There is a displacement of the body in or opposite direction of applied force.

(a) During swimming, Suma applies a force to push the water in the backward direction. The reaction force is also applied by water on Suma. Due to this, Suma swims in the forward direction. In this situation, the force causes a displacement. Therefore, work is done by Seema during swimming.

(b) While carrying a load, the donkey applies a force in the upward direction. But, the displacement of the load is in the forward direction. Here, displacement is perpendicular to force, so the work done is zero.

(c) A wind mill applies the force against the gravitational force to lift water. Here water displacement is in direction of force. So, work is done by the wind mill in lifting water from the well.

(d) In this situation, plant is making its food by the process of photosynthesis and there is no displacement of the leaves of the plant. So, the work done is zero.

(e) In this situation, the force is applied by an engine to pull the train. This force allows the train to move in the direction of force. So, work is done by the engine on the train.

(f) In this situation, there is no movement of food grains in the presence of solar energy. So, the work done is zero.

(g) In this situation, wind applies a force on the sailboat to push it in the forward direction. Therefore, there is a displacement in the boat in the direction of force. So, work is done by wind on the boat.

Q.2 An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?

Sol. Work done by the gravitational force on an object depends only on vertical displacement. Since the body return to a point which is on the same horizontal line. So, vertical displacement is zero.
Work done by gravity is given by the expression, work done = force x displacement

$W = mg \times h$

Where, h = Vertical displacement = 0

$W = mg \times 0 = 0$ J

hence, the work done by gravity on the given object is zero joule.

Q.3 A battery lights a bulb. Describe the energy changes involved in the process.

Sol. When a battery lights a bulb, then the chemical energy of the battery is converted into electrical energy. When the bulb receives this electrical energy, firstly it converts it into heat and then in to the light energy.

Q.4 Certain force acting on a 20 kg mass changes its velocity from 5 ms^{-1} to 2 ms^{-1}. Calculate the work done by the force.

Sol. The work done by the force is equal to change in kinetic energy:

Given: mass m =20 kg, initial velocity u =5 m/s and final velocity v = 2 m/s

So work done W = K. E. $_{Final}$ – K.E. $_{Initial}$

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

$W = \frac{1}{2} \times 20 \times (2^2-5^2)$

W = -210 J

Here negative sign shows that work has been done in slowing speed.

Q.5 A mass of 10 kg is at a point A on a 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.

Sol. As we know that work done by gravitational force depends only on the vertical displacement of the body. Here, object move in horizontal plane. So there is no vertical displacement. So, work done by gravity is given by the expression,

Work = force x displacement

W = mgh

Where, Vertical displacement, h = 0

$\therefore W = mg \times 0 = 0$

Thus, the work done by gravity on the body is zero.

Q.6 The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?

Sol. No, it does not violate the law of conservation of energy. This is because when the body freely falls from a certain height, then its potential energy converts into kinetic energy progressively. A decrease in the potential energy is transformed into kinetic energy of the body. During this process, total mechanical energy of the body remains unchanged. Therefore, the law of conservation of energy is not violated.

Q.7 What are the various energy transformations that occur when you are riding a bicycle?

Sol. During riding a bicycle, the chemical energy of food changes into muscular energy. This muscular energy of the rider gets changed into heat energy and kinetic energy of the bicycle. Heat energy heats the rider's body. Kinetic energy provides the velocity to the bicycle. During the transformation, the total energy remains conserved.

Q.8 Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going?

Sol. When we push a huge rock, the transfer of muscular energy does not take place due to no displacement in rock. Also, there is waste of energy because muscular energy is transferred into heat energy, which causes our body to become hot.

Q.9 A certain household has consumed 250 units of energy during a month. How much energy is this in joules?

Sol. Since, 1 unit of energy = 1 kilowatt hour (kWh).

1 unit = 1 kWh

1 kWh = 3.6×10^6 J

Therefore, 250 units of energy = $250 \times 3.6 \times 10^6 = 9 \times 10^8$J

Q10. 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.

Sol. Given: Mass of object m = 40kg
Gravitational acceleration g =10 m/s^2
Height h = 5 m
So, Potential energy = mgh
P.E. = 40 x 10 x 5 = 2000J
Now, the object is allowed to fall, find its kinetic energy when it is half-way down.
The height h' = 5/2 = 2.5
According to conservation of energy, at the half way, half to potential energy will convert in to kinetic energy.
K.E = mgh'
K.E. = 40 x 10 x 2.5 = 1000 J

Q.11 What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer

Sol. If the direction of applied force is perpendicular to displacement, then the work done will be zero. When a satellite moves around the Earth, then the direction of force of gravitation on the satellite is perpendicular to its displacement. So, the work done on the satellite by the Earth will be zero.

Q.12 Can there be displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher.

Sol. Yes. It is possible in situation of uniformly moving object. If object is moving with constant velocity. The net force acting on it is zero. But, there is a displacement. Hence, there can be a displacement without any force.

Q.13 A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not? Justify your answer.

Sol. Work is done whenever the given two conditions are satisfied:
(i) A force must act on the body.
(ii) There is a displacement of the body by the applied force in or opposite to the direction of force.
When a person holds a bundle of hay over his head for 30 minutes, then there is no displacement in the bundle of hay. The gravitational force is acting on the bundle, the person is not applying any force on it. So, work done by the person on the bundle is zero.

Q.14 An electric heater is rated 1500 W. How much energy does it use in 10 hours?

Sol. Energy consumed by an electric heater:
Given: Power of the heater, P = 1500 W = 1.5 kW
Time for which the heater is used, T = 10 h
energy consumed = Power × Time
= 1.5 × 10 = 15 kWh
Hence, the energy consumed by the heater in 10 h = 15 kWh.

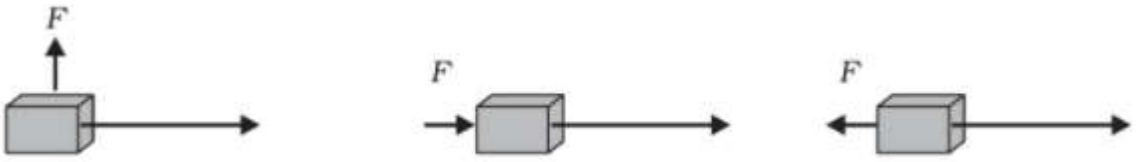
Q.15 Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

Sol. According to law of conservation of energy, energy can be neither created nor destroyed. It can only be transformed from one form to another.
When a pendulum is pushed from its mean position P to either of its extreme positions A or B, it rises through a height h above the mean level P. At this point, the kinetic energy of the bob converts completely into potential energy and kinetic energy becomes zero. The bob possesses only potential energy. As it moves towards mean position P, its potential energy decreases progressively and the kinetic energy increases. As the bob reaches point P, it's all potential energy converts into kinetic energy. This process repeats as long as the pendulum oscillates. It does not oscillate forever. It comes to rest because of air resistance. This air resistance resists its motion and pendulum loses its kinetic energy to overcome this friction and stops after some time. There is no violation of the law of conservation of energy because the energy lost by the pendulum to overcome friction. Hence, the total energy of the pendulum and the surrounding system remain conserved.

Q.16 An object of mass, m is moving with a constant velocity, v. How much work should be done on the object in order to bring the object to rest?
Sol. Kinetic energy of an object of mass, m moving with a velocity, v is given by the expression, K.E. = ½ mv^2. So, to bring the object to rest, ½ mv^2 amount of work has to be done.

Q.17 Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h?
Sol. Given:
The mass of the body m = 1500kg
Velocity v = 60km/hr = 60 x (5/18) = 50/3 m/s
The work required to stop the car = change in kinetic energy of the car
$W = K.E_f - K.E._i$
$W = ½ \times 1500 \times (50/3)^2 - ½ \times 1500 \times (0)^2$
$W = ½ \times 1500 \times (50/3)^2$
W=208333.3 J

Q.18 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 diagrams carefully and state whether the work done by the force is negative, positive or zero.



Sol. Work done by the force, in the following cases are:
Case-I: In this situation, the direction of applied force on the block is perpendicular to the displacement. So, work done by force on the block is zero.
Case-II: In this situation, the direction of applied force on the block is in the direction of displacement. So, work done by force on the block is positive.
Case-III: In this situation, the direction of applied force on the block is opposite to the direction of displacement. So, work done by force on the block is negative.

Q.19 Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her? Why?
Sol. Yes, Soni is right**.** Acceleration in an object could be zero even when several forces are acting on it. This occurs when all the forces cancel out each other, it means that the net applied force on the object is zero.

Q.20 Find the energy in kW h consumed in 10 hours by four devices of power 500 W each.

Sol. Energy consumed by four electric device:

Power rating of the one device, P = 500 W = 0.50 kW

Time for which the device runs, T = 10 h

So, energy consumed by one device = Power × Time

= 0.50 × 10 = 5 kWh

Thus, the energy consumed by four equal rating devices in 10 h = 4 × 5 kWh

= 20 kWh = 20 Units.

Q.21 A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy?

Sol. When an object is dropped from the certain height, its potential energy converts into kinetic energy. As the object hits the ground, all its kinetic energy gets converted into sound energy and heat energy. It can also deform the ground depending upon the nature of the ground and the amount of kinetic energy possessed by the object.