Work and Energy

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.

Solution:

Work involves the displacement of a body under the action of a net force in its direction.

(i) Suma is swimming in pond. When Suma applies force on water in the backward direction, which is the action, the water, in turn, pushes Suma in the forward direction, making her move. Hence, the net force acting on Suma is zero. Hence, according to the definition of work, the work done in this case is zero.

(ii) A donkey is carrying a load on its back. The weight of the load on the donkey, which is the force, acts in the downward direction, whereas the displacement of the load is in the forward direction. Here, as the directions of the force and its displacement are perpendicular to each other, the force is not responsible for the displacement of the load. In other words, the force in the direction of the displacement of the load is zero, and hence the work done in this case is zero.

(iii) A wind-mill is lifting water from a well. The action of lifting indicates the displacement, and as the water is lifted in the upward direction, the direction of the displacement of water is the same as that of the force applied to lift the water. Hence, work is done in this case.

(iv)A green plant is carrying out photosynthesis. In this case, there is no net force and no displacement of an object in the direction of the force. Hence, the work done in this case is zero.

(v) An engine is pulling a train. In this case, a force is exerted by the engine on the train and displaces the train in the direction of the force. Thus, there is work done in this case.

(vi)Food grains are getting dried in the sun. In this case, there is no net force and no displacement of an object in the direction of the force. Hence, the work done in this case is zero.

(vii) A sailboat is moving due to wind energy. In this case, the wind exerts force on the sail of the boat and displaces the boat in its direction. Hence, work is done in this case.

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?

Solution:

As the initial and final points of the object thrown at a certain angle to the horizontal, lie in the same horizontal plane, there is no displacement of the object in the vertical direction. However, gravitational force on the object acts in the vertical downward direction. Hence, the work done by gravitational force on the object is zero.

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

Solution:

The chemical energy of the chemicals stored in the battery is converted into electrical energy, and then into light energy given out by the bulb.

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.

Solution:

Given, Mass of the body, m = 20 Kg

Initial velocity u = 5 m/s and

Final velocity v = 2 m/s

Work done on a body is equal to the change in its Kinetic Energy .

Kinetic Energy, KE = ½ mv2 where m = mass, v = velocity

Initial kinetic Energy, Kei = ½ mu2

Final Kinetic Energy, Kef = ½ mv2

Hence, Change in Kinetic Energy, Δ KE = ½ mv2 - ½ mu2

= ½ m (v2 - u2)

Work done by the force W = Δ KE = ½ m (v2- u2)

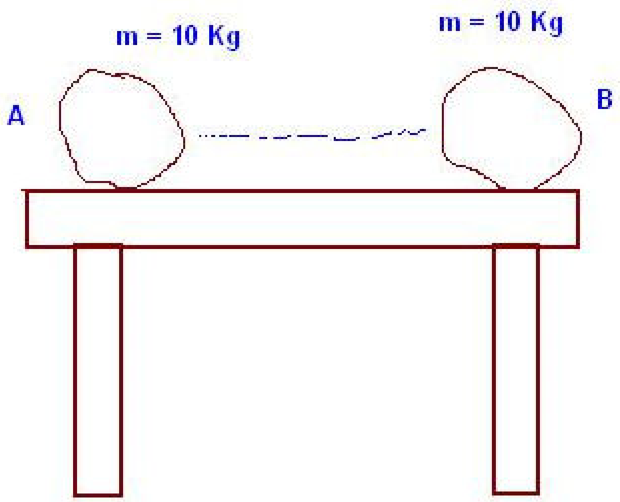
= ½ 20(22 - 52)

= 10 (4 - 25)

= -210

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.

Solution:



Work done on the object by gravitational force is zero.

The displacement of the object is Horizontal and gravitational force acting on it is vertical downwards. As displacement and force are perpendicular, work done on the object is zero.

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

Solution:

The law of conservation of energy is not violated in the case when an object falls freely under the gravitational force of the earth. As the object descends from the position of release due to the gravitational force of the earth, its height gradually decreases, its velocity increases gradually, and hence its kinetic energy as it falls to the earth, and the total energy of the body is conserved.

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

Solution:

When you ride a bicycle, your muscular energy is converted into mechanical energy of the motion of the pedals. This moves the bicycle along with you, thus converting the mechanical energy into kinetic energy of you and the bicycle.

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?

Solution:

If we push a rock and fail to move it, transfer of energy does not take place from our body to the rock. Yet, energy is consumed.

There exists friction between the rock and the ground. When we push the rock, it is the friction ("static friction" in this case) that opposes the motion of the rock. The rock cannot be moved till the applied force is greater than the friction between the rock and the ground. Hence, the net force on the rock is zero. This results in nil motion if the rock.

However, our muscular energy is consumed in overcoming the friction offered by the rock. Hence, we get tired in spite of failing to move the rock. In the process of applying force on the rock, some part of the energy is released as heat, due to which the temperature of our body increases slightly.

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

Solution:

Given,

Energy in a month = 250 units

One unit of energy = 1KWh

We know that 1KWh = 3.6×106J

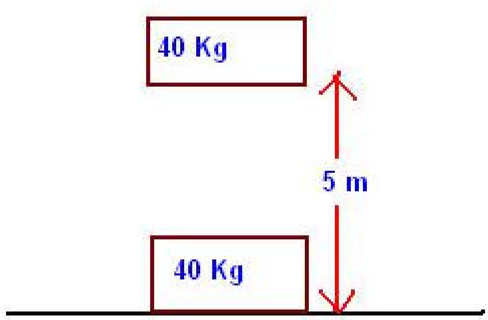
Hence 250 units = 250× 3.6×106J

= 900×106J

= 900 MJ

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.

Solution:



Given,

Mass of the Object m = 40 Kg

Height to which it is raised h = 5m

Acceleration due to gravity, g = 9.8 m/s2

Potential Energy of an object PE = mgh

Therefore PE = 40 × 9.8 × 5

= 1960 J

KE of the Object when it is half way down its fall = ½ PE

Therefore KE of half way down = ½ × 1960

= 980 J

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

Solution:

The force of gravity on a satellite moving around the earth is directed towards the centre of the earth. The displacement of the satellite is along an approximately circular path. Hence, the displacement of the satellite is not along the direction of the gravitational force and the force is not the displacement of the satellite. Thus, the work done by the force of gravity on the satellite is zero.

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.

Solution:

Since force is the agent that brings a body at rest to motion, there cannot be displacement of an object in the absence of any force acting on it.

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.

Solution:

A person does not do any work by holding a bundle of hay over his head for 30 minutes. Irrespective of the time for which the bundle of hay is held over the head, no work is done by the person .Even then, the person gets tired. This is due to the fact that his energy is consumed in resisting the weight of the bundle of hay. The weight of the bundle acts in the downward direction and tends to displace downward. The person holding it on his head exerts an upward force and resists the weight of the load. In doing so, he expends his energy and hence becomes tired.

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 do the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

Solution:

When the bob of a pendulum is drawn to a side, it has some potential energy, and when it is released, the potential energy is converted into kinetic energy. As the pendulum oscillates about its mean position, there is an inter-conversion of its energy from potential to kinetic, and vice-versa. The kinetic energy is the maximum at its mean position, and zero at the extreme positions. Similarly, the potential energy is the maximum at its extreme positions, and zero at its mean position. In the process of oscillations, its energy is spent in overcoming the resistance due to air. Thus, the pendulum comes to rest in the process. It is not a violation of the law of conservation of energy.

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?

Solution:

A moving object has kinetic energy. In order to bring the body to rest, the work to be done on the body must be equal to its kinetic energy, which is $\frac{1}{2} mv^2$.

Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h?

Solution:

Given,

Mass of the car, m = 1500 Kg

Its initial velocity, u = 60 Kmph

$= 60 \times \frac{5}{18} = \frac{50}{3}$ m/s

Its final velocity, v = 0m/s [The car comes to rest]

We know that the work done on the car is equal to the change in its kinetic energy.

Kinetic Energy, KE = $\frac{1}{2} mv^2$ Where m = mass of the car and v = velocity of the car.

Initial Kinetic energy of the car KEi = $\frac{1}{2} mu^2$

Final Kinetic energy of the car KEf = $\frac{1}{2} mv^2$

Therefore, Change in Kinetic Energy, Δ KE = $\frac{1}{2} mv^2 - \frac{1}{2} mu^2$

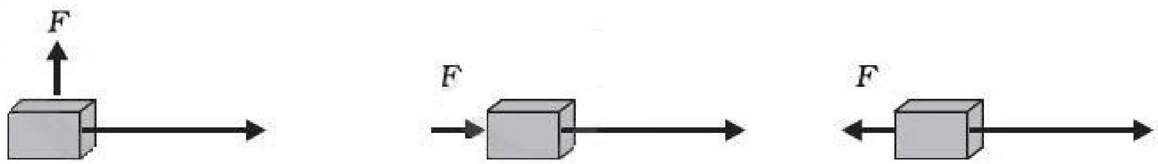
Therefore the work done by the force W = Δ KE = $\frac{1}{2} m(v^2 - u^2)$

$= \frac{1}{2}\, 1500(0^2 - (\frac{50}{3})^2)$

= - 208333.33 J.

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.

Solution:



In the first figure, the directions of the force and the displacement of the given object are perpendicular to each other. Hence, the applied force is not responsible for the displacement of the object. Hence, the work done is zero. In the second figure, the displacement of the object and the applied force are in the same direction. Hence, the work done is positive. In the third figure, the directions of the applied force and the displacement of the object are opposite to each other. Hence, in this case, the work done in negative

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?

Solution:

Yes, we agree with Soni. The acceleration of an object is zero when the net force on it is zero. If a number of forces act on an object and the result of all these forces is zero, there can be a situation where the acceleration of the object is zero even when a number of forces act on the object.

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

Solution:

Given,

Power of each divine = 500 W

No. of devices = 4

Therefore power, P = 4 × 500 = 2000 W

The time for which they are used, t = 10 h

= 10 × 3600 = 36000 sec

Energy (E) = Power (P) × Time (t)

E = 2000 × 36000

$= 72\times10^6 J$

We know that

$1 kWh = 3.6\times10^6 J$

Hence, $72\times10^6 J = 72\times10^6/3.6\times10^6 = 20$ kWh

Thus, the energy consumed by 4 devices of 500 W each = 20 kWh

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

Solution:

When an object falls freely, its potential energy is converted into kinetic energy. As soon it strikes the ground, some of its energy is dissipated in the form of sound and heat. Depending on the type of collision between the ground and the object, it rebounds to certain height, converting the remaining kinetic energy into potential energy. As it rebounds, it gains a height where the kinetic energy is converted into potential energy, and then starts converting back into kinetic, and the object starts falling down. This process of inter conversion of potential to kinetic and vice-versa takes place till all its energy dissipates in the form of sound and heat to the surroundings. It is then that the object comes to rest.

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

Solution:

Given,

Power of the heater, P = 1500 W

Time for which it is used, t = 10 h

Power is the rate of consumption of Energy.

Mathematically, Power (P) = Energy(E)Time(t)

⇒Energy (E) = Power (P) × time (t)

⇒ E = P × t

= 1500 × 10

= 15000 Wh

$= 15 kWh$