WORK AND ENERGY

NCERT SOLUTIONS

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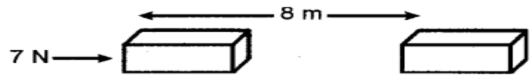
Q1: A force of 7 N acts on an object. The displacement is, say 8 m, in the direction of the force. Let us take it that the force acts on the object through the displacement. What is the work done in this case?



Given displacement = 8 m, Force = 7 N

Now, Work done = Force × Displacement

= 7 × 8 = 56 J

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Q1. When do we say that work is done?

Work is said to be done when a force causes displacement of an object in the direction of applied force.

Q2. Write an expression for the work done when a force is acting on an object in the direction of its displacement.

Work done = Force x Displacement.

Q3. Define 1J of work.

When a force of IN causes a displacement of 1m, in its own direction the work done is said to be one joule.

Q4. 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 the field?

Work done = Force x Displacement = 140 x 15 = 2,100 J

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Q1. What is the kinetic energy of an object?

The energy possessed by a body by virtue of its motion is called kinetic energy.

Q2. Write an expression for the kinetic energy of an object.

The expression is $KE = \frac{1}{2} mv^2$, where 'm' is the mass and 'v' is the velocity of the body.

Q3. The kinetic energy of an object of mass, m moving with a velocity of 5 ms^{-1} is 25 J. What will be its kinetic energy when its velocity is doubled? What will be its kinetic energy when its velocity is increased three times?

Given $v = 5\ m\ s^{-1}$, m = ?, KE = 25 J

Using the expression $KE = \frac{1}{2} mv^2$, we have

$$m = \frac{2 \times KE}{v^2} = \frac{2 \times 25}{(5)^2} = 2\ kg$$

(*i*) When velocity is double *i.e.*, $v = 10\ m\ s^{-1}$, then we have

$$KE = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \times (10)^2 = 100\ J$$

(*ii*) When velocity is tripled *i.e.*, $v = 15\ m\ s^{-1}$, then we have

$$KE = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \times (15)^2 = 225\ J$$

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Q1. What is power?

Power is defined as the rate of doing work.

Q2. Define 1 watt of power.

When a work of 1 joule is done in 1 s, the power is said to be one watt.
Q3. A lamp consumes 1000 J of electrical energy in 10 s. What is its power?
Given W = 1000J, t = 10s, P =?
We know, P = W/t = 1000/10 = 100W
Q4. Define average power.
When a machine or person does different amounts of work or uses energy in different intervals of time, the ratio between the total work or energy consumed to the total time is average power.
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Q1. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.
(a) Suma is swimming in a pond.
(b) A donkey is carrying a load on its back.
(c) A wind mill is lifting water from a well.
(d) A green plant is carrying out photosynthesis.
(e) An engine is pulling a train.
(f) Food grains are getting dried in the sun.
(g) A sailboat is moving due to wind energy.
Work is done whenever the given conditions are satisfied:
(i) A force acts on a body.
(ii) There is a displacement of the body.
(a) While swimming, Suma applies a force to push the water backwards. Therefore, Suma swims in the forward direction caused by the forward reaction of water. Here, the force causes a displacement. Hence, work is done by Suma while swimming.
(b) While carrying a load, the donkey must apply a force in the upward direction. But displacement of the load is in the forward direction. Since, displacement is perpendicular to force, the work done is zero.
(c) A windmill works against the gravitational force to lift water. Hence, work is done by the windmill in lifting water from the well.
(d) In this case, there is no displacement of the leaves of the plant. Therefore, the work done is zero.
(e) An engine applies force to pull the train. This allows the train to move in the direction of force. Therefore, there is a displacement in the train in the same direction. Hence, work is done by the engine on the train.
(f) Food grains do not move in the presence of solar energy. Hence, the work done is zero during the process of food grains getting dried in the Sun.
(g) Wind energy 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. Hence, work is done by wind on the boat.
Q2. 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?
Since the body returns to a point which is on the same horizontal line through the point of projection, no displacement has taken place against the force of gravity, therefore, no work is done by the force due to gravity.
Q3. A battery lights a bulb. Describe the energy changes involved in the process.
Within the electric cell of the battery the chemical energy changes into electrical energy. The electric energy on flowing through the filament of the bulb, first changes into heat energy and then into the light energy.
Q4. 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.

Work done by the force is equal to the change in kinetic energy produced in the body.

Now, $m = 20$ kg, $u = 5$ m s^{-1}, $v = 2$ m s^{-1}, W = ?

Using the expression $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$, we have

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

Or $W = -210$ J

The negative sign indicates that work has been done in slowing the body.

Q5. 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.

Ans: Work done by gravity depends only on the vertical displacement of the body. It does not depend upon the path of the body. Therefore, work done by gravity is given by the expression,

W = mgh

where, Vertical displacement, h = 0

Therefore, W = mg × 0 = 0

Hence, the work done by gravity on the body is zero

Q6. The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?

No. The process does not violate the law of conservation of energy. This is because when the body falls from a height, then its potential energy changes into kinetic energy progressively. A decrease in the potential energy is equal to an increase in the kinetic energy of the body. During the process, total mechanical energy of the body remains conserved. Therefore, the law of conservation of energy is not violated.

Q7. What are the various energy transformations that occur when you are riding a bicycle?

While riding a bicycle, the muscular energy of the rider gets transferred into heat energy and kinetic energy of the bicycle. Heat energy heats the rider's body. Kinetic energy provides a velocity to the bicycle. The transformation can be shown as:

Mechanical Energy → Kinetic Energy + Heat Energy

During the transformation, the total energy remains conserved.

Q8. 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?

When we push a huge rock, there is no transfer of muscular energy to the stationary rock. Also, there is no loss of energy because muscular energy is transferred into heat energy, which causes our body to become hot.

Q9. A certain household has consumed 250 units of energy during a month. How much energy is this in joules?

Energy consumed in a month = 250 units

= 250 kW h

= 250 kW × 1 h

= 250 × 1000 W × 3600 s

= 900,000,000 J = 9.0×10^8 J

Q10. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy?

Ans: Gravitational potential energy is given by the expression, W = mgh

Where,

h = Vertical displacement = 5 m, m = Mass of the object = 40 kg

g = Acceleration due to gravity = 9.8 m/s^2 Therefore, W = 40 × 5 × 9.8 = 1960 J.

At half-way down, the potential energy of the object will be

=1960/2= 980 J.

At this point, the object has an equal amount of potential and kinetic energy. This is due to the law of conservation of energy. Hence, half-way down, the kinetic energy of the object will be 980 J.

Q11. What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer.

Ans: Work is done whenever the given two conditions are satisfied:
A force acts on the body.
There is a displacement of the body by the application of force in or opposite to the direction of force.
If the direction of force is perpendicular to displacement, then the work done is zero.
When a satellite moves around the Earth, then the direction of force of gravity on the satellite is perpendicular to its displacement. Hence, the work done on the satellite by the Earth is zero.

Q12. 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.

Yes. For a uniformly moving object.
Suppose an object is moving with constant velocity. The net force acting on it is zero. But there is a displacement along the motion of the object. Hence, there can be a displacement without a force.

Q13. 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.

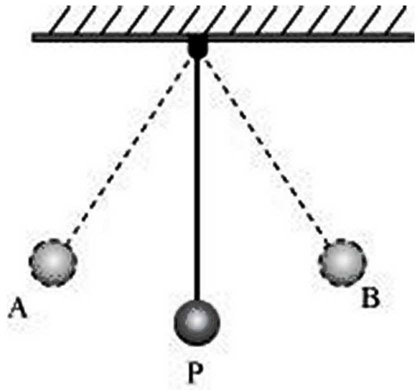
When a person holds a bundle of hay over his head, then there is no displacement in the bundle of hay. Although, force of gravity is acting on the bundle, the person is not applying any force on it. Hence, in the absence of force, work done by the person on the bundle is zero.

Q14. An electric heater is rated 1500 W. How much energy does it use in 10 hours?

Energy consumed by an electric heater can be obtained with the help of the expression,
$P=W/t$
where,
Power rating of the heater, $P = 1500$ W = 1.5 kW
Time for which the heater has operated, $t = 10$ h
Work done = Energy consumed by the heater
Therefore, energy consumed = Power × Time
$= 1.5 \times 10 = 15$ kWh
Hence, the energy consumed by the heater in 10 h is 15 kWh or 15 units.

Q15. 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?

Ans: The law of conservation of energy states that energy can be neither created nor destroyed. It can only be converted from one form to another.
Consider the case of an oscillating pendulum.



When a pendulum moves 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 changes completely into potential energy. The kinetic energy becomes zero, and the bob possesses only potential energy. As it moves towards point P, its potential energy decreases progressively. Accordingly, the kinetic energy increases. As the bob reaches point P, its potential energy becomes zero and the bob possesses only kinetic energy. This process is repeated as long as the pendulum oscillates.
The bob does not oscillate forever. It comes to rest because air resistance resists its motion. The pendulum loses its kinetic energy to overcome this friction and stops after some time.
The law of conservation of energy is not violated because the energy lost by the pendulum to overcome friction is gained by its surroundings. Hence, the total energy of the pendulum and the surrounding system remain conserved.

Q16. 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?

Kinetic energy of an object of mass m moving with a velocity v is given by the expression $1/2mv^2$. To bring the object to rest, an equal amount of work i.e. $1/2mv^2$ is required to be done on the object.

Q17. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h.

Mass of car, m = 1500 kg

Velocity of car, v = 60 km/h = $60\times\frac{5}{18}$ m/s

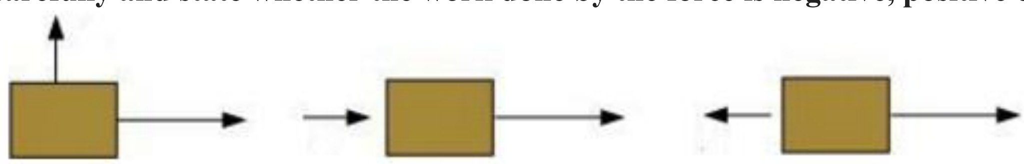
Kinetic energy, $E_k = \frac{1}{2}mv^2$

$$E_k = \frac{1}{2}\times1500\times\left(60\times\frac{5}{18}\right)^2 = 20.8\times10^4 J$$

To stop the car, an amount of work equal to E_k is required to be done.

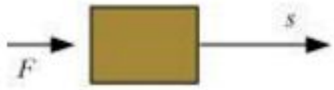
Hence, 20.8×10^4 J of work is required to stop the car.

Q18. 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.

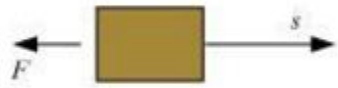


In this case, the direction of force acting on the block is perpendicular to the direction of displacement. Therefore, work done by force on the block will be zero.

Case II



Case III



In this case, the direction of force acting on the block is opposite to the direction of displacement. Therefore, work done by force on the block will be negative.

Q19. 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?

Ans: Acceleration in an object could be zero even when several forces are acting on it. This happens when all the forces cancel out each other i.e., the net force acting on the object is zero. For a uniformly moving object, the net force acting on the object is zero. Hence, the acceleration of the object is zero. Hence, Soni is right.

Q20. Find the energy in kWh consumed in 10 hours by four devices of power 500 W each.

Power rating of each device, P = 500 W = 0.50 kW

Time for which each device runs, t = 10 h

Work done = Energy consumed by each device (E)

We know, power = Energy consumed / Time

Energy consumed by each device= Power × Time

E = P x t

= 0.50×10 = 5 kWh

Hence, the energy consumed by four devices of power 500 W each in 10 h will be

4 × 5 kWh = 20 kWh = 20 units

Q21. A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy?

As the object hits the hard ground, its kinetic energy gets converted into

(i) heat energy (the object and the ground become slightly warm)

(ii) sound energy (sound is heard when the object hits the ground)

(iii) potential energy of configuration of the body and the ground (the object and the ground get deformed a little bit at the point of collision).

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