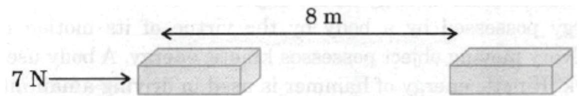
CHAPTER 11

Work and Energy

1. NCERT INTEXT QUESTIONS

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



Ans :

We know that if force F acting on an object to displace it through a distance s in one direction, then the work done W on the body by the force is given by :

$$\text{Work done} = \text{Force} \times \text{Displacement}$$

$$W = F \times s$$

Where, $F = 7\text{N}$

$s = 8 \text{ m}$

Therefore, work done,

$$W = 7 \times 8$$

$$= 56 \text{ Nm} = 56 \text{ J}$$

2. When do we say that work is done?

Ans :

Work is done whenever the given conditions are satisfied :

(a) A force acts on the body.

(b) There is a displacement of the body caused by the applied force along the direction of the applied force.

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

Ans :

When a force F displaces a body through a distance s in the direction of the applied force, then the work done W on the body is given by the expression :

$$\text{Work done} = \text{Force} \times \text{Displacement}$$

$$W = F \times s$$

4. Define 1 J of work.

Ans :

1 J is the amount of work done by a force of 1 N on an object that displaces it through a distance of 1 m in the direction of the applied force.

5. 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?

Ans :

Work done by the bullocks is given by the expression :

$$\text{Work done} = \text{Force} \times \text{Displacement}$$

$$W = F \times d$$

Where,

Applied force, $F = 140 \text{ N}$

Displacement, $d = 15 \text{ m}$

$$W = 140 \times 15 = 2100 \text{ J}$$

Hence, 2100 J of work is done in ploughing the length of the field.

6. What is the kinetic energy of an object?

Ans :

The energy possessed by a body by the virtue of its motion is called kinetic energy. Every moving object possesses kinetic energy. A body uses kinetic energy to do work. Kinetic energy of hammer is used in driving a nail into a log of wood, kinetic energy of air is used to run wind mills, etc.

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

Ans :

If a body of mass m is moving with a velocity v, then its kinetic energy E_k is given by the expression,

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

Its SI unit is joule (J).

8. 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 doubled? What will be its kinetic energy when its velocity is increased three times?

Ans :

$$\text{K.E. of the object} = 25 \text{ J}$$

$$\text{Velocity of the object, } v = 5 \text{ m/s}$$

$$\text{K.E.} = \frac{1}{2} mv^2$$

$$m = 2 \times \frac{\text{K.E.}}{v^2}$$

$$m = 2 \times \frac{25}{25} = 2 \text{ kg}$$

If velocity is double, $v = 2 \times 5 = 10 \text{ m/s}$

$$\text{K.E. (for } v = 10 \text{ m/s)} = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times 2 \times 100 = 100 \text{ J}$$

If velocity is tripled, $v = 3 \times 5 = 15$ m/s

$$\text{K.E. (for v = 15 m/s)} = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times 2 \times 225 = 225 \text{ J}$$

9. What is power?

Ans :

Power is the rate of doing work or the rate of transfer of energy. If W is the amount of work done in time t, then power is given by the expression,

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

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

It is expressed in watt (W).

10. Define 1 watt of power.

Ans :

If it does work at the rate of 1 joule in 1 s then a body is said to have power of 1 watt, i.e., 1 W = 1J / 1s

11. A lamp consumes 1000 J of electrical energy in 10 s. What is its power?

Ans : :

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

$$\text{Work done} = \text{Energy consumed by the lamp}$$

$$= 1000 \text{ J}$$

$$\text{Time} = 10 \text{ s}$$

$$\text{Power} = \frac{1000}{10} = 100 \text{ Js}^{-1} = 100 \text{ W}$$

12. Define average power.

Ans :

The average power of an agent may be defined as the total work done by it in the total time taken.

2. NCERT EXERCISE QUESTIONS

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'.

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.

Ans :

Work is done whenever the given two conditions are satisfied :

1. A force acts on the body.
2. There is a displacement of the body by the application of force in or opposite to the direction of force.

(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 has to 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 wind mill 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.

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?

Ans :

Work done by the force of gravity on an object depends only on vertical displacement. Vertical displacement is given by the difference in the initial and final positions/heights of the object, which is zero.

Work done by gravity is given by the expression,

$$W = mgh$$

Where, h = Vertical displacement = 0

$$W = mg \times 0 = 0 \text{ J}$$

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

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

Ans :

When a bulb is connected to a battery, then the chemical energy of the battery is transferred into electrical energy. When the bulb receives this electrical energy, then it converts it into light and heat energy. Hence, the transformation of energy in the given situation can be shown as :

Chemical Energy → Electrical Energy → Light Energy + Heat Energy

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.

Ans :

Kinetic energy is given by the expression,

$$(E_k)_v = \frac{1}{2}mv^2$$

Where,
E_k = Kinetic energy of the object moving with a velocity, v
Kinetic energy when the object was moving with a velocity 5 ms^{-1}

$$(E_k)_5 = \frac{1}{2} \times 20 \times (5)^2 = 250 \text{ J}$$

Kinetic energy when the object was moving with a velocity 2 ms^{-1}

$$(E_k)_2 = \frac{1}{2} \times 20 \times (2)^2 = 40 \text{ J}$$

$$W = -210 \text{ J}$$

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

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.

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,

$$h = 0$$

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

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

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

Ans :

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.

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

Ans :

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

Muscular Energy → Kinetic Energy + Heat Energy
The total energy remains conserved during the transformation.

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?

Ans :

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.

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

Ans :

1 unit of energy is equal to 1 kilowatt hour (kWh).

$$1 \text{ unit} = 1 \text{ kWh}$$

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

Therefore, 250 units of energy

$$= 250 \times 3.6 \times 10^6 = 9 \times 10^8 \text{ J.}$$

10. 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.

Ans :

$$\text{Mass, } m = 40 \text{ kg}$$

$$\text{Initial height, } h = 5 \text{ m}$$

$$g = 10 \text{ m/s}^2$$

Potential energy of the object,

$$E_p = mgh = 40 \times 10 \times 5 = 2000 \text{ J}$$

When an object is allowed to fall and it is half way down, then

$$h' = \frac{h}{2}$$

Hence, potential energy of the object reduces to

$$E_p' = \frac{E_p}{2} = \frac{2000}{2} = 1000 \text{ J}$$

Kinetic energy of the object,

$$E_k = \text{Loss in potential energy} = E_p - E_p' = (2000 - 1000) \text{ J} = 1000 \text{ J}$$

11. 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 :

1. A force acts on the body.
2. 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.

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

Ans :

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.

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.

Ans :

Work is done whenever the given two conditions are satisfied :

1. A force acts on the body.
2. There is a displacement of the body by the application of force in or opposite to the direction of force.

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.

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

Ans :

Energy consumed by an electric heater can be obtained with the help of the expression,

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

Where,
Power rating of the heater,

$$P = 1500 \text{ W} = 1.5 \text{ kW}$$

Time for which the heater has operated, t = 10 h

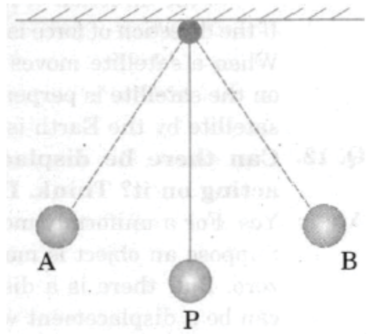
Work done = Energy consumed by the heater
Therefore,

$$\text{Energy consumed} = \text{Power} \times \text{Time}$$
$$= 1.5 \times 10 = 15 \text{ kWh}$$

Hence, the energy consumed by the heater in 10 h is 15 kWh.

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?

Ans :



The law of conservation of energy states that energy can neither be 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.

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?

Ans :

Kinetic energy of an object of mass, moving with a velocity, v is given by the expression,

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

To bring the object to rest, $\frac{1}{2}mv^2$ amount of work is required to be done on the object.

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

Ans :

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

Where,

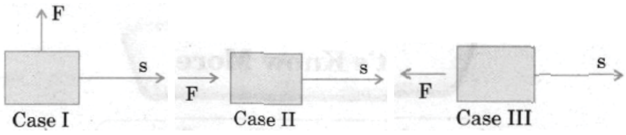
$$\text{Mass of car, } m = 1500 \text{ kg}$$

$$\text{Velocity of car, } v = 60 \text{ km/h} = 60 \times \frac{5}{18} \text{ ms}^{-1}$$

$$E_K = \frac{1}{2} \times 1500 \times \left(60 \times \frac{5}{18}\right)^2$$
$$= 20.8 \times 10^4 \text{ J}$$

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

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.



Ans :

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

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?

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.

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

Ans :

Energy consumed by an electric device can be obtained with the help of the expression for power,

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

Where,
Power rating of the device,

$$P = 500 \text{ W} = 0.50 \text{ kW}$$

Time for which the device runs,

$$T = 10 \text{ h}$$

Work done = Energy consumed by the device

Therefore,

energy consumed = Power × Time

$$= 0.50 \times 10 = 5 \text{ kWh}$$

Hence, the energy consumed by four equal rating devices in 10 h will be 4×5 kWh = 20 kWh = 20 units.

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

Ans :

When an object falls freely towards the ground, its potential energy decreases and kinetic energy increases. As the object touches the ground, all its potential energy gets converted into kinetic energy. As the object hits the hard ground, all its kinetic energy gets converted into heat energy and sound energy. It can also deform the ground depending upon the nature of the ground and the amount of kinetic energy possessed by the object.

3. NCERT EXEMPLAR

Objective Type Questions

1. When a body falls freely towards the Earth, then its total energy :
(a) Increases
(b) Decreases
(c) Remains constant
(d) First increases and then decreases

Ans : (c) Remains constant

2. 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 to that of initial
(c) Becomes 4 times that of initial
(d) Becomes 16 times that of initial

Ans : (a) Does not change

3. In case of negative work the angle between the force and displacement is :
(a) 0°
(b) 45°
(c) 90°
(d) 180°

Ans : (d) 180°

4. 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 :
(a) Acceleration
(b) Momentum
(c) Potential energy
(d) Kinetic energy

Ans : (a) Acceleration

5. 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})
(a) 6 × 103 J
(b) 6 J
(c) 0.6 J
(d) zero

Ans : (d) zero

6. Which one of the following is not the unit of energy?
(a) Joule
(b) Newton metre

(c) Kilowatt (d) Kilowatt hour

Ans : (c) Kilowatt

7. The work done on an object does not depend upon the :
(a) Displacement
(b) Force applied
(c) Angle between force and displacement
(d) Initial velocity of the object

Ans : (d) Initial velocity of the object

8. Water stored in a dam possesses :
(a) No energy
(b) Electrical energy
(c) Kinetic energy
(d) Potential energy

Ans : (d) Potential energy

9. A body is falling from a height h. After it has fallen a height 2 m, it will possess :
(a) Only potential energy
(b) Only kinetic energy
(c) Half potential and half kinetic energy
(d) More kinetic and less potential energy

Ans : (c) Half potential and half kinetic energy

Short Answer Questions

10. A rocket is moving up with a velocity v. If the velocity of this rocket is suddenly tripled, what will be the ratio of two kinetic energies?

Ans :

$$\text{Initial velocity} = u;$$
$$\text{Final velocity } (v) = 3u$$
$$\text{Initial kinetic energy } (KE_i) = \tfrac{1}{2}mv_2$$
$$\text{Final kinetic energy } (KE_f) = \tfrac{1}{2}m(3u)^2$$
$$\text{Final kinetic energy} = \tfrac{1}{2} \times m \times 9u^2$$
$$= 9 \times (\tfrac{1}{2}mu^2)$$

Therefore,

Ratio of the two kinetic energies $= KE_i : KE_f = 1 : 9$

11. Avinash can run with a speed of 8 ms^{-1} against the frictional force of 10 N, and Kapil can move with a speed of 3 ms^{-1} against the frictional force of 25 N. Who is more powerful and why?

Ans :

As work equals to product of force and distance, you can write the equation for power in the following way, assuming that the force acts along the direction of travel :

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

But, work done = Force × distance

Therefore, $P = \frac{W}{t} = \frac{F_s}{t}$

Where s is the distance travelled.

As $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

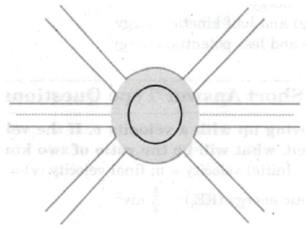
Therefore, the object's speed, v is

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

$$\text{Power of Avinash} = 10 \times 8 = 80 \text{ W}$$
$$\text{Power of Kapil} = 25 \times 3 = 75 \text{ W}$$

Therefore, Avinash is more powerful than Kapil.

12. 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 roundabout figure of radius 100 m. However, he moves on the circular path for one and half cycle and then he moves forward upto 2.0 km. Calculate the work done by him.



Ans :

$$F = 5 \text{ N}$$

As work equals force times distance

$$W = F.s$$
$$W = 5 \times [1500 + 200 + 2000]$$
$$= 18500 \text{ J}$$

Here, 1.5 km = 1500 m; 2 km = 2000 m

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

Ans :

Yes, mechanical energy comprises both potential energy and kinetic energy. Momentum is zero which means velocity is zero. Hence, there is no kinetic energy but the object may possess potential energy.

Mechanical energy = Potential energy + Kinetic energy

Momentum = my

Given, Momentum is zero which means velocity is zero.

Therefore,

$$\text{Kinetic energy} = \tfrac{1}{2}mv^2$$

As $v = 0$ (given)

$$\text{Kinetic energy} = \tfrac{1}{2} \times m \times 0$$
$$KE = 0$$

Mechanical energy = Potential energy + Kinetic energy

Mechanical energy = Potential energy + 0

Mechanical energy = Potential energy

Therefore, we can say that an object can have mechanical energy even if its momentum is zero.

14. The power of a motor pump is 2 kW. How much water per minute the pump can raise to a height of 10 m? (Given, g = 10 m s^{-2})

Ans :

Given,

power of the pump = 2 kW = 2000 W;

t = 1 min = 60 sec;

height = 10 m;

g = 10 ms^{-2}

Power = work done per unit time

(The force on an object of mass m at the surface of the Earth is mg, from F = ma, when acceleration is g, the acceleration at the surface of the Earth. If the object falls through a distance h, then the work done on the object by the force of gravity is mg times h, force times distance.)

$$\text{Work} = mgh$$

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

$$2000\text{ W} = m \times 10\text{ m s}^{-2} \times 10\text{ m}$$

$$2000\text{ W} = \frac{m \times 100\text{ m}}{60\text{ s}}$$

$$m = \frac{2000 \times 60}{100}100$$

$$m = 1200\text{ kg}$$

Therefore, the pump can raise 1200 kg of water in one minute.

15. The weight of a person on a planet A is about half that on the Earth. He can jump up to 0.4 m height on the surface of the Earth. How high he can jump on the planet A?

Ans :

As per the definition of force, the equation of force due to gravity is given by, W = mg, i.e., weight is equal to mass times gravitational acceleration

In this case, the force is better known as the weight of the object.

Weight of a person on Earth = w = mg_1 (given);
height the person can jump (h_1) = 0.4 m

U = potential energy from height,

m = mass of the object,

g = gravity and height = h

U = mgh

Therefore,

$$\text{potential energy} = mg_1h_1 \quad ....(1)$$

where (h_1) = 0.4 m; g_1 = g

Now,

Weight of the person on planet A = $= \frac{W}{2} = \frac{mg_2}{2}$

Let the height the person can jump = h_2;

$$g_2 = \frac{1}{2}g_1 = \frac{1}{2}g \quad ....(2)$$

Therefore,

Potential energy on planet A = mg_2h_2

Potential energy of the person on the Earth

$$= mg_1h_1 \quad ...(3)$$

Substituting (1) in (3), we get

$$mg_1h_1 = m \times g \times 0.4$$

Now,

Potential energy of the person on the planet

$$A = mg_2h_2 \quad ...(4)$$

Substituting (2) in (4), we get

$$mg_2h_2 = m \times \tfrac{1}{2}g \times h_2$$

As potential energy of the person will remain the same on the Earth and on planet A.

Thus, $mg_1h_1 = mg_2h_2$

As mass remains the same

Therefore,

$$mg_1h_1 = mg_2h_2$$

$$g_1h_1 = g_2h_2$$

Therefore, by substituting the values, we get

$$g \times 0.4 = \tfrac{1}{2}g \times h_2$$

$$h_2 = \frac{g \times 0.4}{g/2}$$

$$h_2 = \frac{g \times 0.4 \times 2}{g}$$

$$h_2 = 0.4 \times 2 = 0.8\text{ m}$$

Hence, he can jump double the height with the same muscular force.

16. The velocity of a body moving in a straight line is increased by applying a constant force F, for some distance in the direction of the motion. Prove that the increase in the kinetic energy of the body is equal to the work done by the force on the body.

Ans :

Consider that a force 'F' is applied on a body having mass 'm' and the distance travelled be 's'.

Work Done (joules) = Force (Newton) × Distance (meter)

$$W = F \times s \quad ...(1)$$

As,

$$\text{Force } (F) = ma \quad ...(2)$$

By substituting (2) in (1), we get

$$W = ma \times s \quad ...(3)$$

Using the Newton's third equation of motion,

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

$$\frac{v^2 - u^2}{2} = as \quad ...(4)$$

Substituting (3) in (4), we get

$$W = m\left(\frac{v^2 - u^2}{2}\right) \quad ...(5)$$

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

W = final kinetic energy − initial kinetic energy

Work done = change in kinetic energy

17. Is it possible that an object is in the state of accelerated motion due to external force acting on it, but no work is being done by the force? Explain it with an example.

Ans :

Yes, it is possible when force is acting perpendicular to the direction of displacement. For uniform circular motion, the force acts perpendicular to the direction of the motion and so, the force never does any work upon the object. E.g., an eraser tied to a string and moving the eraser in a circle at constant speed by holding onto the end of the string.

18. A ball is dropped from a height of 10 m. If the energy of the ball reduces by 40% after striking the ground, how much high can the ball bounce back? (g = 10 m s^{-2})

Ans :

Given, g= 10 m s^{-2}; h = 10 m

Energy possessed by the ball

$$= mgh = m \times 10 \times 10 = 100 \text{ m joules}$$

Energy left in the ball after striking the ground

$$= \frac{100-40}{100} = \frac{60}{100}$$

(As energy is reduced by 40% after striking the ground)

Therefore,

remaining energy = 60 m joules ...(1)

Let the height at which the ball bounces back

$$= h_1 \quad ....(2)$$

Therefore,

Energy possessed by the ball = mgh

Using (1) and (2), we get

$$60 \text{ m} = m \times 10 \times h_1$$

$$h_1 = 6 \text{ metres.}$$

Thus, the height at which the ball bounces back = 6 m

19. If an electric iron of 1200 W is used for 30 minutes every day, find electric energy consumed in the month of April.

Ans :

Given,

$$\text{Power (P)} = 1200 \text{ W} = \frac{1200}{1000} = 1.2 \text{ KW};$$

$$\text{Time (t)} = 30 \text{ min} = \frac{30}{60}\text{hr} = \frac{1}{2}\text{hr} = 0.5 \text{ hr}$$

Number of days in april = 30 days

We need the time for a month (april) :

Therefore, $0.5 \times 30 = 15$ h

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

Therefore, Energy = power × time

$$E = 1.2 \times 15 = 18 \text{ kWh}$$

Long Answer Questions

20. 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?

Ans :

Consider the mass and velocity of the light object to be m_1 and v_1 respectively. Similarly, let the mass and velocity of the heavy object to be m_2 and v_2 respectively

Momentum = mass × velocity

i.e., $p = mv$ ...(1)

Momentum of light object = m_1v_1

Momentum of heavy object = m_2v_2

Given, light and a heavy object have the same momentum

Therefore, $m_1v_1 = m_2v_2$

But, we know that

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

Thus,

Kinetic energy of light object (KE_l)

$$= \frac{1}{2}pv_1 \text{ \{from (1)\}} \quad ...(2)$$

Kinetic energy of heavy object (KE_h)

$$= \frac{1}{2}pv_2 \text{ \{from (1)\}} \quad ...(3)$$

Given that $m_1 < m_2$; then $v_1 > v_2$ ...(4)

$$P = m_1v_1 = m_2v_2 = P,$$

then $\frac{v_1}{v_2} = \frac{m_2}{m_1} > 1$

Ratio of kinetic energy of light and heavy object

$$= \frac{\text{eq.}(2)}{\text{eq.}(3)}$$

$$= \frac{(\frac{1}{2}pv_1)}{(\frac{1}{2}pv_2)} = \frac{v_1}{v_2}$$

But, $v_1 > v_2$ {from (4)}

Therefore, (K.E.)l > (K.E.)h

The lighter one will have more kinetic energy than the heavy one. Moreover, Kinetic energy is directly proportional to the mass of the object.

21. An automobile engine propels a 1000 kg car (A) along a levelled road at a speed of 36 km h^{-1}. Find the power if the opposing frictional force is 100 N. Now, suppose after travelling a distance of 200 m, this car collides with another stationary car (B) of same mass and comes to rest. Let its engine also stop at the same time. Now, car (B) starts moving on the same level road without getting its engine started. Find the speed of the car (B) just after the collision.

Ans :

Given, m(A) = m(B) = 1000 kg; Final velocity of car A(v_A) = 0 (since it comes to rest after colliding with car B); Initial velocity of the car (u_A) = 36 km/h = 10 m/s (since, 1 km/hr = 518 m/s);

Frictional force = 100 N

Since, the car A moves with a uniform speed, it means that the engine of car applies a force equal to the frictional force

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

$$\text{Distance} = (\text{Speed} \times \text{Time})$$

$$\text{Power} = \frac{\text{Force} \times (\text{Speed} \times \text{Time})}{\text{Time}}$$

Therefore, Power = Force × Speed

$$\text{Power of car A} = F\,v = 100\text{ N} \times 10\text{ m/s}$$
$$= 1000\text{ W}$$

Initial velocity of car $B(u_B) = 0$;

Final velocity of car $A(u_A) = 0$

By using the law of conservation of momentum,

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

Momentum before collision = momentum after collision

$$1000 \times 10 + 1000 \times 0 = 1000 \times 0 + 1000 \times v_B$$
$$= 10\text{ m s}^{-1}$$
$$v_B = 10\text{ m s}^{-1}$$

The speed of the car (B) just after the collision = 10 m s^{-1}.

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

Ans :

Given,

$$\text{Mass of the girl} = 35\text{ kg};$$
$$\text{Mass of the trolley} = 5\text{ kg};$$
$$\text{Initial velocity } (u) = 4\text{ m s}^{-1};$$
$$\text{Final velocity } (v) = 0 \text{ (as it comes to rest)};$$
$$\text{distance } (s) = 16\text{ m}$$

Therefore, by using equation of motion, we get

$$v^2 = u^2 + 2as$$
$$0 = (4)^2 + 2 \times a \times (16)$$
$$0 = 16 + 32a$$
$$-16 = 32a$$
$$-\frac{16}{32} = a$$
$$-\frac{1}{2} = a$$
$$-0.5\text{ m/s}^2 = a$$

(Acceleration is negative, therefore, retardation)

$$\text{Force exerted } (F) = ma$$
$$F = 40 \times -\frac{1}{2}$$
$$F = -20\text{N}$$

(a) Work done = force × distance

$$W = F \times d$$
$$W = \text{mass (As } F = ma)$$

Total mass of the trolley

$$= \text{mass of girl} + \text{mass of trolley}$$
$$= 35 + 5 = 40\text{ kg}$$

Therefore,

$$\text{Work done on the trolley} = 40 \times \frac{1}{2} \times 16$$
$$= 20 \times 16 = 320\text{ J}$$

(b) Work done by the girl = F × d × mass

Work done by the girl = 35 × 0.5 × 16

Work done by the girl = 280 J

23. Four men lift a 250 kg box to a height of 1 m and hold it without raising or lowering it.
(a) How much work is done by the men in lifting the box?
(b) How much work do they do in just holding it?
(c) Why do they get tired while holding it? ($g = 10\text{ ms}^{-2}$)

Ans :

(a) Given, mass = 250 kg;

$$\text{height}(s) = 1\text{ m};$$
$$g = 10\text{ ms}^{-2}$$
$$F = mg \text{ (g = gravity)}$$
$$F = 250\text{ kg} \times g \text{ } (g = 10\text{ ms}^{-2})$$
$$= 2500\text{ N}$$
$$s = 1\text{ m}$$
$$W = F.s$$
$$= 2500 \times 1\text{ N m} = 2500\text{ J}$$

(b) The men did not do any work in just holding it because the box does not move at all. Therefore, kinetic energy is zero (when the box is held up, it is at rest, no movement, thus it has zero speed).

(c) In order to hold the box, men are applying a force which is opposite and equal to the gravitational force acting on the box. They are working against gravity, air friction, etc. to hold the box up thereby making them feel tired.

24. What is power? How do you differentiate kilowatt from kilowatt hour? The Jog Falls in Karnataka state are nearly 20 m high. 2000 tonnes of water falls from it in a minute. Calculate the equivalent power if all this energy can be utilized? ($g = 10\text{ ms}^{-2}$)

Ans :

(i) Power is defined as the rate of doing work. Power measures the rate of work done, i.e., how fast or how slow the work is done.

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

kW defines how much energy a device uses or generates in a given amount of time. Meanwhile kWh defines how much energy that device actually uses or generates.
kW is a measure of power while, kWh is a measure of energy.

$$\text{kilowatt hour} = \text{kilowatt} \times \text{hour}$$

or $\text{kWh} = \text{kW} \times \text{hr}$

Similarly, kilowatt = kilowatt hour/hour

or $\text{kW} = \text{kWh/h}$

(ii) Given, h = 20 m, and

$$\text{mass} = 2000 \times 10^3\text{ kg} = 2 \times 10^6\text{ kg}$$

$$\text{Power} = \frac{\text{work done}}{\text{time taken}}$$

(here, work done = potential energy gained)

$$\text{Power} = \frac{mgh}{t}$$

$$= \frac{2 \times 10^6 \times 10 \times 20}{60}$$

$$= \frac{2}{3 \times 10^7}\,\text{W}$$

25. 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 m s^{-1} vertically? g = 10 m/s^{-2}

Ans :

Given, power = 100 W,

speed = 1 m s^{-1};

g = 10 m/s^{-2}

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

(here, work done = potential energy gained)

Therefore, $$\text{Power} = \frac{mgh}{t} \quad ...(1)$$

But, $\frac{h}{t}$ = speed at which the body is being lifted ...(2)

By substituting (2) in (1), we get

Power = m × g × speed

Thus, $$m = \frac{\text{power}}{g \times \text{speed}}$$

$$m = \frac{100}{10 \times 1}$$

m = 10 kg

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

Ans :

One watt is defined as the energy consumption rate of one joule per second. The power is said to be one watt, when a work of 1 joule is done in 1 s

$$1\text{ W} = \frac{1\text{ J}}{1\text{ s}}$$

One watt is also defined as the current flow of one ampere with voltage of one volt.

kilowatt = 1000 J s^{-1}

Given, m = 150 kg;

power = 500 w/kg;

speed = 20 m/s

Power is 500 W/kg. So, total power developed by the engine of 150 kg,

Total Power = 150 × 500 = 7.5 × 10^4 W

As Power = force × speed

$$\text{Force} = \frac{\text{Power}}{\text{Speed}} = \frac{47.5 \times 10^4}{20}$$

$= 3.75 \times 10^3$ N

27. Compare the power at which each of the following is moving upwards against the force of gravity? (given g = 10 ms^{-2})

(i) A butterfly of mass 1.0 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}.

Ans :

(i) Given, mass of butterfly = 1 g = $\frac{1}{1000}$ kg;

g = 10 ms^{-2};

speed (v) = 0.5 ms^{-1}

Power = force × speed

But, Force = mg

Therefore, Power = mg × v

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

$$P = \frac{0.5}{100} = 5 \times 10^3\text{ W}$$

(ii) Given, mass of squirrel = 250 g = $\frac{250}{1000}$ kg

$= \frac{1}{4}$ kg

g = 10 ms^{-2};

speed (v) = 0.5 ms^{-1}

Power = force × speed

But, Force = mg

Therefore, Power = mg × v

$$P = \frac{1}{4} \times 10 \times 0.5$$

P = 1.25W

Thus, the power with which the squirrel is climbing is more than that of a butterfly flying.

Science IX