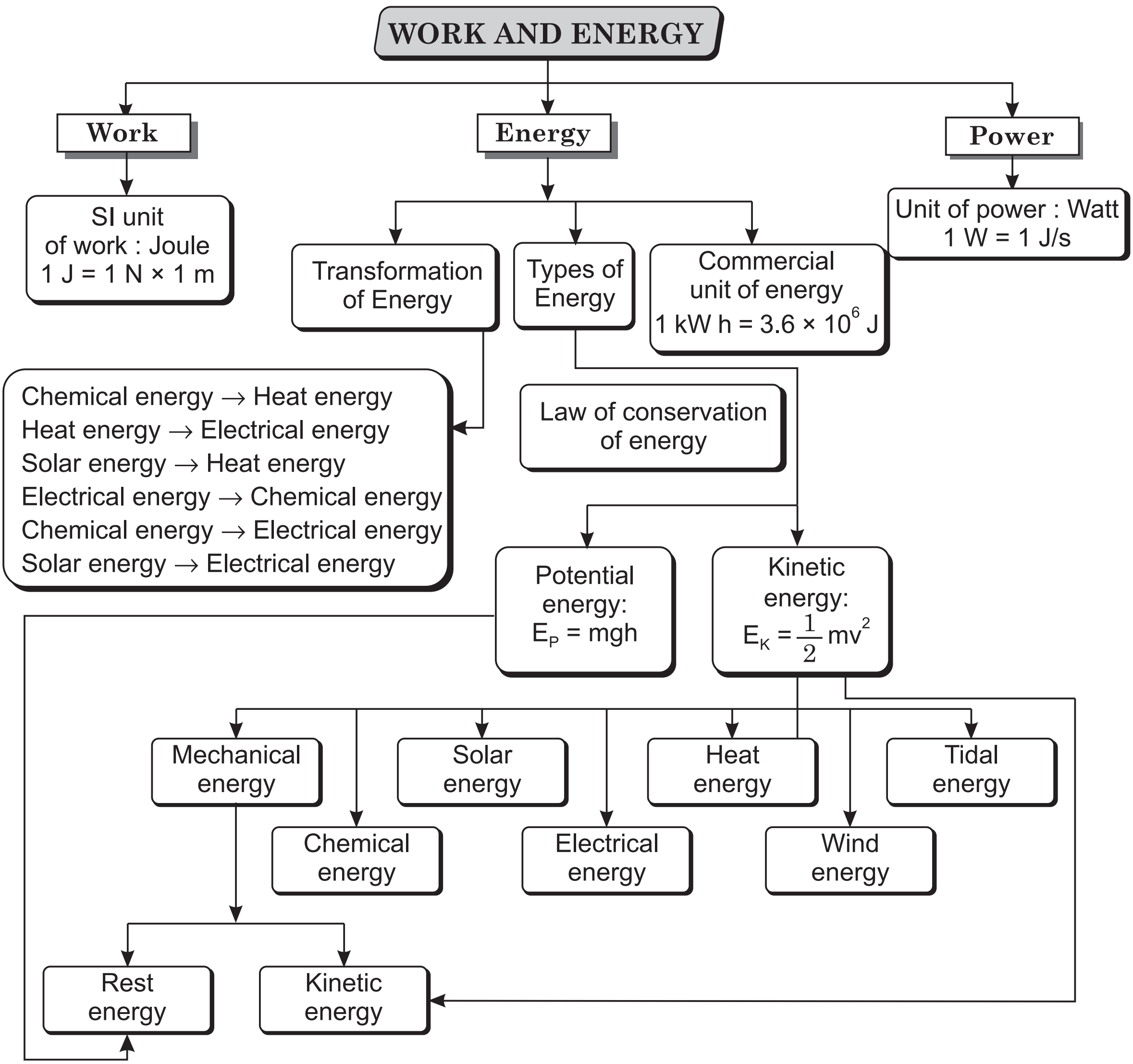
11 Work and Energy

TOPICS COVERED

11.1 Work
11.2 Energy

CHAPTER MAP



QUICK REVISION NOTES

Work is said to be done if a force is exerted on an object and makes it to move in the direction of force.

- The amount of work done by a constant force is defined as the product of the force and the distance moved in the direction of the force.

  or $W = \vec{F} \times \vec{S}$

  where F is force, *S* is displacement in the direction of force.
- If the force is in Newtons and distance is in meters, the work done is measured in **Joules** (J).

  1J = 1 N m
- Work done may be +ve, –ve or even zero, work done is –ve if force and displacement of the body are in opposite direction. Work done is positive if the force and displacement both are in the same direction.
- If the direction of the applied force and the direction in which the object moves are perpendicular to one another, then work done is zero.
- If the force is applied on the object and the object does not move, no work is done.
- $W = F.d \cos \theta$ [where θ is angle between the direction of force and the direction of displacement]

  When $\theta = 0°$ $W = Fd$ ($\because \cos \theta = 1$) maximum work

  When $\theta = 90°$ $W = 0$ ($\because \cos 90° = 0$) zero work

  When $\theta = 180°$ $W = -Fd$ ($\because \cos 180° = -1$) (Negative work)

  Power is the rate of doing work.
- The unit of power is J s^{-1}. It is also called Watts (W). Another bigger unit of power is 1 kW = 1000 W
- Power is not energy. It cannot be transferred like energy. It is merely a rate.
- If two cars of same weight climb up the same hill, they do the same amount of work. But if car 'A' climbs the hill in shorter time than 'B', it means that it has more power.
- **Energy** is defined as the ability to do work. It has no direction, so it is a scalar quantity.
- S.I. unit of energy is Joules (J).
- Both living and non-living systems require energy to work.
- Everything around us has some energy which exists in many different forms.
- Fuels, electric cells, foods, explosives have **chemical energy**.
- The energy associated with current is called **electrical energy**.
- All objects in motion have **kinetic energy**.
- Potential energy is an energy which is stored in a body by virtue of its position, or change in configuration.
- A water fall, water stored at a height in dam i.e. energy due to its height is called **potential energy**. It is also called gravitational potential energy.
- A compressed or stretched spring or rubber bands have **potential energy** by virtue of change in the configuration of spring or rubber band.
- The energy released from nuclear reactions like fission (breaking) of nucleus or fusion (combining) is called **Nuclear energy**.
- If a coconut and an apple are at the same height from the ground, the fruit with a greater mass will have more **gravitational potential energy**.
- Objects having same mass at different heights will have more potential energy at a greater height among the two.
- Elastic potential energy is the energy stored in an elastic object when it is pushed or pulled e.g., stretched bow, bent vaulting pole, coiled spring of a toy.

- Kinetic energy is directly proportional to the mass and square of the velocity of an object.

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

where m is the mass of the body which is moving with a velocity v.
- The energy possessed by a body on account of its motion or position is called **mechanical energy**.
- The change of one form of energy into another form of energy is known as transformation of energy.
- Energy can neither be created nor be destroyed only transformation of energy can take place is the law of conservation of energy.
- **During free fall of body:** K.E + P.E = constant
- **Commercial unit of energy (KW h):** It is the amount of energy consumed when electrical appliances having rating of 1 Kilowatt is used for 1 hour.

$$\begin{aligned} 1 \text{ KW h} &= 1000 \text{ Watt for 1 hr.} \\ &= 1000 \text{ J} \times 60 \times 60\text{s} \\ &= 360{,}00{,}00 \text{ Joule.} \\ 1 \text{ KW h} &= 3.6 \times 10^6 \text{ J} \Rightarrow 1 \text{ unit.} \end{aligned}$$

- **Heat:** It is a form of energy which flows from a region of higher to lower temperature.
- **Sound:** It is a form of energy produced by vibrations which can be detected by our ears.
- **Solar energy:** The energy obtained from Sun is called solar energy.
- **Light energy:** The energy in the form of electromagnetic radiations to which human eye is sensitive and on which our visual awareness of the universe depends.

1. Work

Work is said to be done if :

(*i*) a moving object comes to rest.
(*ii*) a object at rest starts moving.
(*iii*) velocity of an object changes.
(*iv*) Shape of an object changes.

- Work is said to be done when a force produces a motion in the body.
- By applying a force the body must be displaced in the direction of force.
- Work done in moving the body is equal to force and displacement of the body in the direction of force:

$$W = \text{Force} \times \text{displacement}$$
$$W = \vec{F} \times \vec{S}$$

- Work is a scalar quantity but it can be +ve, –ve or zero.
- Unit of work is N–m or Joule.

Joule

When 1 Newton force displaces a body through a distance of 1 metre in its own direction, then work done is said to be 1 J.

- Greater the force, greater is the amount of work done and vice-versa
- Greater the displacement, greater is the amount of work done.
- Work done is positive when the direction of the motion of the body is in the direction of force applied ($\theta = 0°$).
- Work done is negative when the direction of the motion of the body and force applied are opposite to each other ($\theta = 180°$).

- The moon moves around the earth in a circular path. The force of gravitation acts on the moon at right angles to the direction of motion of the moon, i.e. $\theta = 90°$ so work done is zero.

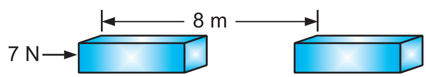
Exercise 11.1

I. Very Short Answer Type Questions (1 Mark)

1. When do we say that work is done? [*NCERT*] **[*CBSE* 2012]**
2. Write an expression for the work done when a force is acting on an object in the direction of its displacement. [*NCERT*]
3. 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 that length of the field? [*NCERT*] **[*CBSE* 2010]**
4. A student is writing a three hours science paper. How much work is done by the student? Give reason for your answer. [*CBSE* 2011]
5. A *coolie* is walking on a railway platform with a load of 30 kg on his head. How much work is done by the *coolie* ? **[*CBSE* 2011]**
6. Calculate the work done when a force of 15 N moves a body by 5 m in its direction. **[*CBSE* 2011]**
7. A bag of cement has a mass of 20 kg. A fork lift raised three bags of cement to 80 cm from the ground on the truck. What is work done by fork lift?
8. Define 1 J of work. [*NCERT*] **[*CBSE* 2012, 11]**

II. Short Answer Type Questions–I (2 Marks)

9. An object thrown at a certain angle with the ground traces in a curved path and falls back to the ground. The initial and final point of the path of the object lies on the same horizontal line. What is the work done by the force of gravity on the object? [*NCERT*]
10. List two essential conditions for work to be done. [*CBSE* 2010, 12]
11. Given below are a few situations, study them and state in which of given cases work is said to be done. Give reason for your answer. **[*CBSE* 2012]**
    (*a*) A person is pushing hard a huge rock but the rock does not move.
    (*b*) A bullock is pulling a cart up to 1 km on the road.
    (*c*) A girl is pulling a trolley for about 2 m distance.
    (*d*) A student standing in the sun for two hours with a heavy bag on his head.
12. A force of 7 N acts on an object. The displacement is, say 8 m, in the direction of the force as shown in the figure. Let us take that a constant force acts on the object through the displacement. What is the work done in this case? [*NCERT*] **[*CBSE* 2011]**



III. Short Answer Type Questions–II (3 Marks)

13. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.
    (*i*) Suma is swimming in a pond.
    (*ii*) A donkey is carrying a load on its back.
    (*iii*) A wind-mill is lifting water from a well.
    (*iv*) A green plant is carrying out photosynthesis.
    (*v*) An engine is pulling a train.
    (*vi*) Food grains are getting dried in the sun.
    (*vii*) A sail boat is moving due to wind energy. [*NCERT*]

14. A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage. ($g = 9.8$ ms^{-2}) [*NCERT*]

Answers 11.1

1. Work is said to be done if by applying the force, the body is displaced.
2. $W = F \times s$
3. $W = F \times s \Rightarrow 140 \text{ N} \times 15 \text{ m} \Rightarrow 2100 \text{ J} \Rightarrow 2.1 \text{ kJ}$
4. No work is done by the student because there is no displacement of the student.
5. Work done is zero because displacement of the *coolie* is at right angle to the force acting on his body due to the load on his head.
6. $W = F \times s$

   $W = 15 \times 5 = 75$ J
7. Total mass = 20 kg × 3 = 60 kg

   $F = mg = 60 \times 9.8 = 588$ N

   $$W = F \times s = 588 \text{ N} \times \frac{80}{100} \text{ m} = 470.4 \text{ J}$$
8. When 1 N force displaces a body by 1m in the direction of force applied then work done is said to be 1 J.
9. $W = mgh$

   Gravitational force and horizontal displacement are perpendicular to each other, $\theta = 90°$

   $\cos 90° = 0 \quad \therefore \quad W = 0$; No work is done.
10. (*i*) It should produce some displacement in the direction of the force applied.

    (*ii*) A force must be applied on the object.
11. (*a*) No work is done because there is no displacement.

    (*b*) Work is done because there is displacement in the direction of force.

    (*c*) Work is done because displacement takes place in the direction of force.

    (*d*) No work is done because there is no displacement of the person.
12. $W = F \times s$

    $W = 7 \text{ N} \times 8 \text{ m}$

    $W = 56$ N m

    $W = 56$ J
13. (*i*) Work is done. (*ii*) No work is done. (*iii*) Work is done.

    (*iv*) No work is done in photosynthesis as there is no force in this process..

    (*v*) Work is done. (*vi*) No work is done. (*vii*) Work is done.
14. $m = 15.0$ kg; $S = 1.5$ m; $W = ?$

    $F = mg = 15 \text{ kg} \times 9.8 \text{ ms}^{-2} = 147.0 \text{ N}$

    $$W = F \times S \Rightarrow 147 \text{ N} \times 1.5 \text{ m} = \frac{147 \times 3}{2} = \frac{441}{2} = 220.5 \text{ J}$$

2. Energy

Energy is the ability or capacity to do work.

- The amount of energy possessed by a body is equal to the amount of work it can do. A body loses energy in doing work. Body gains energy when work is done on the body.
- Energy is a scalar quantity.
- Its SI unit of energy is Joule and its bigger unit is kilo joule (kJ) (1kJ = 1000 J)
- The energy required to do 1 Joule of work is called 1 Joule energy.

Forms of Energy

Mechanical energy: The energy which is capable to do mechanical work is called mechanical energy. The energy possessed by the body by virtue of its motion as well as its position or change of configuration of the body is called mechanical energy. Mechanical energy is equal to the sum of P.E. and K.E.

$$\text{Mechanical energy} = \text{Kinetic energy} + \text{Potential energy.}$$

Kinetic energy: The energy possessed by the body due to its motion is called kinetic energy e.g. a moving cricket ball, running water, flowing wind, etc.

$$W = F \times s$$

$$F = m \times a$$

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

$$\boxed{s = \frac{v^2 - u^2}{2a}}$$

$$W = ma \times \frac{v^2 - u^2}{2a}$$

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

If $u = 0$ (*i.e.* when the body starts moving from rest)

$$W = \frac{1}{2}mv^2 \quad \text{or} \quad E_k = \frac{1}{2}mv^2$$

where 'm' is the mass of the body, 'v' is its velocity.

Kinetic energy is directly proportional to the mass and to the square of the velocity of a body. If an object is not moving, $E_k = 0$. Its unit is J or kJ.

Potential energy: The energy of a body due to its position or change in its shape is called potential energy, e.g. water stored in a dam, wound up spring of a mechanical watch or a toy car, bent string of bow, etc.

Factors: The work done in lifting a mass m upto a height h

$$\text{W} = mg \times h$$

This work is stored in the force of its potential energy.

$$\therefore \quad \boxed{\text{P.E.} = mgh}$$

'm' is mass of the body, 'g' is acceleration due to gravity and 'h' is its height.

- Greater the stretching, twisting or bending, more the potential energy.
- For ground level, P.E. = 0. Its unit is J or kJ.

Transformation of Energy

The change of one form of energy into another form of energy is called transformation of energy, e.g.

- A stone on a certain height has entire potential energy. It starts moving downwards, potential energy of the stone goes on decreasing whereas kinetic energy goes on increasing. At ground, P.E. = 0 and kinetic energy is maximum. But in between maximum height and ground the body will possess both PE well as KE.
- When matchstick or fuel burns, chemical energy is converted into heat energy and light energy.

- In a battery, chemical energy is converted into electrical energy.
- While recharging a mobile phone, electrical energy is converted into chemical energy.
- In a solar cell (photovoltaic cell), light energy is converted into electrical energy.
- In a wind mill, wind energy is converted into electrical energy.
- At hydroelectric power stations, potential energy of water is converted into kinetic energy and electrical energy.
- All thermal power station uses energy of fuels like coal, LPG gas which is changed into heat energy, which gets further converted into K.E. and electrical energy.
- In crackers, chemical energy is converted into sound energy, heat and light.
- Plants use solar energy to make chemical energy in food by the process of photosynthesis.

Law of Conservation of Energy

The total energy of a system remains constant (conserved) i.e. energy can neither be created nor destroyed, it can be transformed from one form to another.

Although some energy may be lost during the energy conversion but total energy of the system always remain constant.

During free fall:

$$\text{K. E} + \text{P.E.} = \text{Constant}$$

$$\frac{1}{2}mv^2 + mgh = \text{Constant}$$

Power

The rate of doing work is called Power, i.e. the rate of energy consumption.

$$\text{Power} = \frac{\text{Work done}}{t} \quad \text{or} \quad P = \frac{W}{t}$$

'P' is power, 'W' is work done, 't' is time taken

Unit of Power:

$$\frac{\text{1 Joule}}{\text{1 Second}} \Rightarrow 1\ \text{J s}^{-1} \Rightarrow 1\ \text{W (Watt)}$$

$$\text{Average power} = \frac{\text{Total work done or Total energy used}}{\text{Total time taken}}$$

Power of Electrical Gadgets: The power of electrical gadgets will tell how much energy it will consume on per hour basis.

$$1\ \text{kW} = 1000\ \text{Watt} = 1000\ \text{J s}^{-1}$$

Commercial unit of Energy

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

The energy used in one hour at the rate of 1 kW is called kW h.

Exercise 11.2

I. Very Short Answer Type Questions (1 Mark)

1. What is Kinetic energy of an object? [*NCERT*] **[*CBSE* 2011, 12]**
2. Write an expression for the kinetic energy (K.E.) of the object. [*NCERT*]
3. What is Power? [*NCERT*] **[*CBSE* 2011, 12]**
4. Define 1 Watt power. [*NCERT*] **[*CBSE* 2012]**
5. A lamp consumes 1000 J of electrical energy in 10 s. What is its power? [*NCERT*] **[*CBSE* 2012]**

6. Define average power. [*NCERT*] [*CBSE* **2011**]
7. An electric bulb of 60 W is used for 6 hours per day. Calculate the 'units' of energy consumed in one day by the bulb. [*NCERT*]
8. A battery lights a bulb. Describe the energy changes involved in the process. [*NCERT*]
9. What are the various energy transformations that occur when you are riding a bicycle? [*NCERT*]
10. A certain household has consumed 250 units of energy during a month. How much energy is this expressed in joules? [*NCERT*]
11. When a body falls freely towards the earth, then what happens to its total energy? **[***NCERT Exemplar***]**
12. What type of energy is possessed by water stored in a dam?
13. A body is falling from a height 'h'. After it has fallen to a height, $\frac{h}{2}$ what type of energy will be possessed by the body?

II. Short Answer Type Questions–I (2 Marks)

14. An electric motor can lift a weight of 2000 N through a vertical height of 10 m in 20 s. What is the power of this motor?
15. A cell will deliver 3000 J of energy to a 2 W electric motor before the cell gets exhausted. For what period of time will the motor run?
16. An object of mass 15 kg is moving with a uniform velocity of 4 m s^{-1}. What is the kinetic energy possessed by the object? [*NCERT*]
17. Find the energy possessed by an object of mass 10 kg when it is at a height of 6 m above the ground. (Given, $g = 9.8$ m s^{-2}). [*NCERT*]
18. An object of mass 12 kg is at a certain height above the ground. If the potential energy of the object is 480 J, find the height at which the object is with respect to the ground. Given, $g = 10$ m s^{-2}. [*NCERT*]
19. Two girls A and B each of weight 400 N climb up a rope through a height of 8 m. Girl A take 20 s while B takes 50 s to accomplish this task. What is the power expended by each girl? [*NCERT*]
20. 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 value of $g = 10$ m s^{-2}. [*NCERT*]
21. A mass of 10 kg is at the 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. **[HOTS]**
22. The potential energy of a freely falling object decreases progressively. Does it violate the law of conservation of energy? Why? **[HOTS]**
23. Does the transfer of energy takes place when you push a huge rock with all your might and if you fail to move it? Where is the energy you spend going away? **[HOTS]**
24. What is the work done by the force of gravity on a satellite moving around the earth? Justify your answer. [*NCERT*]
25. Can there be any displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher. [*NCERT*] **[HOTS]**
26. 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. [*NCERT*]
27. An electric heater is rated as 1500 W. How much energy does it use in 10 hours? [*NCERT*]
28. Soni says that acceleration in an object could be zero even when several forces are acting on it. Do you agree with her or not? Why? [*NCERT*]
29. Find the energy in kW h consumed in 10 hours by four devices of power 500 W each. [*NCERT*]

30. A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy? [*NCERT*]

31. In case of negative work done, what should be the angle between the force and displacement?

32. An iron sphere of mass 10 kg has the same diameter as an aluminium sphere of mass 3.5 kg. Both spheres are dropped simultaneously from a tower. What type of energy will be equal when both the stones reach at 10 m above the ground? **[HOTS]**

33. Avinash can run at a speed of 8 m s^{-1} against the frictional force of 10 N and Kapil can move with a speed of 3 m s^{-1} against a frictional force of 25 N. Who is more powerful and why? **[HOTS]**

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

35. Compare the power at which each of the following is moving upwards against the force of gravity? (given g = 10 m s^{-2})
   (*i*) a butterfly of mass 1.0 g that flies upward at a rate of 0.5 m s^{-1}.
   (*ii*) a 250 g squirrel climbing up on a tree at a rate of 0.5 m s^{-1}. **[*NCERT Exemplar*] [HOTS]**

36. Identify and state the type of transformation of energy in the following cases:
   (*a*) riding a bicycle (*b*) burning of a cracker **[*CBSE* 2016]**

37. A bag of wheat weighs 49 kg. Calculate the height to which it should be raised such that its potential energy is 980 J. (Take g = 10 m/s^2) **[*CBSE* 2014]**

38. With the help of an example explain the law of conservation of energy. **[*CBSE* 2014]**

39. What will cause greater change in kinetic energy of a body a changing its mass or changing its velocity? **[*CBSE* 2010]**

40. A horse of mass 210 kg and a dog of 25 kg are running at the same speed. Which of the two will possess more kinetic energy? Explain. **[*CBSE* 2011]**

41. A ball is dropped from a height of 10 m. If the energy of the ball is reduced to 40% after striking the ground, how much high can the ball bounces back? (g = 10 m s^{-2}) [*NCERT Exemplar*]

42. The Jog falls in Karnataka state is nearly 20 metres high. 2000 metric tonne of water falls from it in a minute. Calculate the equivalent power if all the energy of water can be utilised? (g = 10 m s^{-2})

43. How many kilograms will a man working at the power of 100 W, be able to lift at a constant speed of 1 m s^{-1} vertically? (g = 10 m s^{-2})

44. What work is to be done in order to increase the velocity of a car from 18 km/h to 90 km/h, if the mass of the car is 2000 kg? [*CBSE* 2011]

III. Short Answer Type Questions–II (3 Marks)

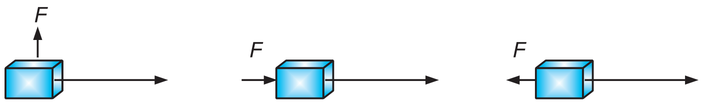
45. What work is to be done in order to increase the velocity of a car from 30 km h^{-1} to 60 km h^{-1} if the mass of the car is 1500 kg? [*NCERT*]

46. 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 by three times? [*NCERT*]

47. 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.

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

49. In each of the following, a force, F is acting on an object of mass, m. The direction of the displacement is from west to east as shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



50. An automobile engine propels a 1000 kg car (A) along a levelled road at a speed of 36 km h^{-1}. Find the power of the engine 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 came 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. [*NCERT Exemplar*]

51. A body of mass 5 kg is thrown vertically upwards with a speed of 10 m s^{-1}. What is its kinetic energy when it is thrown? Find its potential energy when it reaches at the highest point. Also find the maximum height attained by the body. (g = 10 m s^{-2})

52. 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}) [*NCERT Exemplar*]

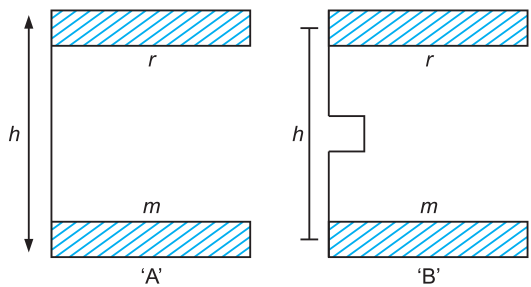
53. If an electric iron of 1200 W is used for 30 minutes everyday, find the electric energy consumed in the month of April.

54. A labourer whose own mass is 50 kg carries a load of an additional 60 kg on his head to the top of a building 15 m high. Find the total work done by him. Also find the work done by him if he carries another additional block of 10 kg to the same height. (take g = 10 m s^{-2}) [*CBSE* 2016]

55. Define potential energy. A hammer of mass 1 kg falls on a nail from a height of 2 m. How much kinetic energy will it have first before hitting the nail? (g = 10 m s^{-2}) [*CBSE* 2016]

56. (*a*) What is meant by potential energy of a body?

(*b*) A body of mass '*m*' is raised to a vertical height '*h*' through different paths A and B. What will be the potential energy of the bodies in the two cases? Give reason for your answer. [*CBSE* 2010]



57. 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}? [*NCERT Exemplar*]

58. Water is falling on the blades of a turbine at a rate of 8×10^2 kg per minute, height of the fall is 50 m. Calculate the power given to the turbine. (g = 10 m s^{-2}) [*CBSE* 2012]

59. An object of mass 5 kg is dropped from the height of 10 m. Find its kinetic energy, when it is half way down. (g = 10 m s^{-2}) [*CBSE* 2012]

IV. Long Answer Type Questions (5 Marks)

60. A large box of mass 50 kg rests on a horizontal floor. A man moves the box by pushing it with a horizontal force of 200 N. The box moves at a constant speed of 0.25 m/s.

(*a*) Calculate the work done on the box at each second by the man.

(*b*) State the rate at which work is done on the box, i.e. power.

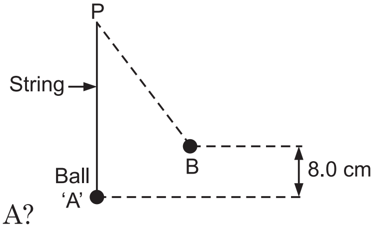
(*c*) State the value of force of friction between the floor and the box. Explain your answer.

61. (*a*) Define the work done by the constant force. Write its SI unit and define the unit.

(*b*) A 3000 kg truck moving at a speed of 72 km/h stops after covering some distance. The force applied by brakes is 24000 N.

Compute the distance covered and work done by this force. [*CBSE* 2016]

62. A simple pendulum is made by hanging a metal ball of mass 100 g from a point 'P', as shown in the figure below:



The ball is pulled to a position B, 8.0 cm vertically above 'A'. Assume g = 10 m s^{-2}

(*a*) Calculate the gain in gravitational energy as the ball moved from A to B.

(*b*) The ball is then released and it swings freely.

(*i*) What will be the kinetic energy of the ball as it reaches A?

(*ii*) Using your answer of *b*(*i*), calculate the speed of the ball as it reaches 'A'. **[HOTS]**

63. A pump lifts 420 kg of water every minute through a vertical height of 30 m. Assume that *g* = 10 N/kg.

(*a*) Calculate the potential energy gained by the water every minute.

(*b*) Explain why the energy is needed to operate the pump for one minute is greater than the value you calculated in (*a*).

(*c*) Calculate the useful power output of the pump.

64. (*a*) Give the SI unit and the commercial unit of electrical energy.

(*b*) Calculate the power of an electric motor that can lift 800 kg of water to store in a tank at a height of 1500 cm in 20 s (g = 10 m s^{-2}).

(c) A lamp consumes 500 J of electrical energy in 20 seconds. What is the power of the lamp? [*CBSE* 2016]

Answers 11.2

1. The energy possessed by a body due to its motion is called its kinetic energy.
2. K. E. = $\frac{1}{2}mv^2$
3. Power is the rate at which energy is consumed.
4. When 1J of energy is consumed in 1 second, then power is said to be equal to 1 W.
5. $P = \frac{E}{t} = \frac{1000\text{ J}}{10\text{ s}} = 100\text{ W}$
6. Average power is the the ratio of the total energy consumed to the total time taken.
7. P = 60 W, t = 6 hour per day.

   Total energy consumed = 60 W × 6 h = 360 W h

   Total energy consumed in kW:

   $$= \frac{360}{1000}\text{ kW h} = 0.36\text{ kW h}$$

   ∴ The energy consumed by the bulb is 0.36 units.
8. In a battery chemical energy is first converted into electrical energy. After that electrical energy is converted into heat energy and light energy in a bulb.
9. Our muscular energy is converted into kinetic energy while riding a bicycle.
10. E = 250 kW h

    E = 250 × 1000 × 60 × 60 s

    E = 900,00,00,00 = 9×10^8 J
11. It remains the constant.
12. Potential energy
13. It will now posses half of its energy as kinetic energy and the other as half as potential energy.

14. $F = 2000 \text{ N}; s = 10 \text{ m}$

$W = \text{F} \times \text{S} \Rightarrow 2000 \text{ N} \times 10 \text{ m} = 20000 \text{ J}$

$P = \frac{W}{T} = \frac{20000 \text{ J}}{20 \text{ s}} = 1000 \text{ W} = 1\text{kW}$

15. $E = 3000 \text{ J}\ ;\ P = 2 \text{ W} = 2 \text{ J s}^{-1}$

$t = \frac{E}{P} = \frac{3000}{2} = 1500 \text{ s} \Rightarrow \frac{1500}{60} = 25 \text{ min.}$

16. $m = 15 \text{ kg}, v = 4 \text{ m s}^{-1}, \text{K.E.} = ?$

$\text{K. E.} = \frac{1}{2} mv^2 = \frac{1}{2} \times 15 \times (4)^2 = \frac{15 \times 16}{2} = 120 \text{ J}$

17. $m = 10 \text{ kg}, h = 6 \text{ m}, g = 9.8 \text{ m s}^{-2}$

$\text{P. E.} = mgh \Rightarrow 10 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 6 \text{ m} \Rightarrow 588 \text{ J}$

18. $m = 12 \text{ kg}, \text{P.E.} = 480 \text{ J}, g = 10 \text{ m s}^{-2}$

$\text{P. E.} = mgh$

$480 \text{ J} = 12 \text{ kg} \times 10 \text{ m s}^{-2} \times h; h = \frac{480}{120} m = 4\, m$

19. Power of Girl A $= \frac{F \times s}{t} = \frac{400 \text{ N} \times 8 \text{ m}}{20 \text{ s}} = 160 \text{ W}$

Power of Girl B $= \frac{F \times s}{t} = \frac{400 \text{ N} \times 8 \text{ m}}{50 \text{ s}} = \frac{3200}{50} = 64 \text{ W}$

20. $m = 50 \text{ kg}, t = 9 \text{ s}$

$h = 15 \text{ cm} \times 45 = 675 \text{ cm} = 6.75 \text{ m}$

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

$P = \frac{mgh}{t} \Rightarrow \frac{50 \times 10 \times 6.75}{9} = 375 \text{ W}$

21. $W = \text{mgh}$

$h = 0;\ \therefore\ W = 0$ ($\because$ Both points 'A' and 'B' are on the same height)

22. No, it does not violate the law of conservation of energy. As the potential energy decreases with decrease in height, to compensate it kinetic energy increases due to increase in the velocity of the object.

The total energy (K. E + P. E) always remains constant at every point.

23. When we push a huge rock, the rock also exerts a huge force on us in accordance with the third law of motion.

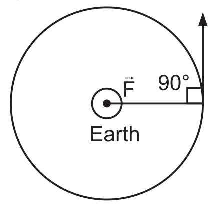
Our energy is spent in overcoming the huge force exerted on us by the huge rock.

24. Satellite moves in a circular path under the force of gravity which acts at 90° to the direction of displacement, so

$\text{W} = F \cos \theta$

$\Rightarrow \text{W} = F \cos 90°$

$\Rightarrow \text{W} = 0$



25. Yes, it is possible. If a body is moving with a constant velocity on a smooth surface, no force is acting on it but the object changes its position, i.e. it undergoes displacement.

26. No, he has not done any work because there is no displacement of the person.

$\text{W} = F \times s;\ \text{W} = 0$ $[\because s = 0]$

27. Total energy consumed = $P \times t$

$= 1500 \text{ W} \times 10 \text{ hours} \Rightarrow 15000 \text{ W h} = 15 \text{ kW h}$

$E = 15 \text{ kW h} \Rightarrow 15 \times 1000 \times 60 \times 60 \text{ J} \Rightarrow 5.4 \times 10^7 \text{ J}$

28. Yes, we agree.

Reason: If the resultant of several forces acting on a body is equal to zero, then

Acceleration, $a = \frac{F}{m} = \frac{0}{m} = 0$

29. Energy $= P \times t$

$= 500 \text{ W} \times 10 \text{ hours} \Rightarrow 5000 \text{ W h} \Rightarrow 5 \text{ kW h}$

Energy consumed by the four devices:

$= 5 \text{ kW h} \times 4 = 20 \text{ kW h}$

30. Kinetic energy is converted into sound energy and heat energy.

31. 180°

$W = F \cos \theta = F \cos 180° = -F = -\text{ve},$

i.e., W is –ve

32. Kinetic energy will be equal.

33. $W_1 = -F \times s = -10 \times 8 = -80 \text{ J s}^{-1}$, $P = 80$ W

$W_2 = -F \times s = -25 \times 3 = -75 \text{ J s}^{-1}$ $P = 75$ W

Therefore, Avinash is more powerful because he is being able to do more work to overcome the frictional force.

34. As per the law of conservation of energy:

$mg_1h_1 = mg_2h_2$

$m \times g_1 \times 0.4 = m \times \frac{g_1}{2} \times h_2$

$\boxed{h_2 = 0.8 \text{ m}}$

The height of the jump will be 0.8 m at planet 'A'.

35. (*a*) P = F × $v = mgv$

$\Rightarrow$ Power of butterfly

$= 10^{-3} \text{ kg} \times 10 \times 0.5 = 5 \times 10^{-3} = 0.005$ Watt

(*b*) Power of squirrel $= 250 \times 10^{-3} \text{ kg} \times 10 \times 0.5 = 1.25$ Watt.

Therefore, power of squirrel is more than that of butterfly.

36. (*a*) Muscular energy into Kinetic energy.

(*b*) Chemical energy into sound and heat energy.

37. P.E = mgh

$980 \text{ J} = 49 \text{ kg} \times 10 \text{ m s}^{-2} \times h$

$h = \frac{980 \text{ J}}{490 \text{ kg m s}^{-2}} = 2 \text{ m}$

38. When a body is dropped from a height its potential energy is maximum at the time of drop, but its K.E is zero. With the decrease in its height its P.E decreases and K.E increases. Finally when it reaches the ground P.E becomes zero and K.E is maximum. Total energy remains the same throughout the process. This illustrates the law of conservation of energy.

K.E + P.E = Constant

39. Change in velocity will cause greater change in K.E, because K.E $\propto v^2$.

40. The horse will have more kinetic energy because it has more mass. ($\because$ K.E $\propto$ m)

41. P.E $= mgh = \text{m} \times 10 \times 10 = 100 \cdot \text{m J (100 m) J}$

Energy of ball on striking the ground

$$= 100 \cdot \text{m} - \frac{40}{100}\text{m} = 60 \cdot \text{m}$$

Now $mgh = 60 \cdot \text{m}$

$m \times 10 \times h = 60$ m

$10\, h = 60$ m

$\Rightarrow \quad h = 6$ m

42. Power $= \frac{mgh}{t} = \frac{2000 \times 10^3 \text{ kg} \times 10 \times 20 \text{ m}}{60 \text{ s}}$ [1 metric ton = 10^3 kg]

$$= \frac{20}{3} \times 10^6 = 6.66 \times 10^6 \text{ Watt} = 6.66 \times 10^3 \text{ kW}$$

43. $\text{P} = \frac{mgh}{t}$

$$100 \text{ W} = \frac{m \times 10 \times 1}{1 \text{s}}$$

$$\text{m} = \frac{100}{10} = 10 \text{ kg}$$

44. Initial velocity $= \frac{18 \times 1000 \text{ m}}{60 \times 60 \text{ s}} = 5 \text{ m s}^{-1}$

Final velocity $= \frac{90 \times 1000 \text{ m}}{60 \times 60 \text{ s}} = 25 \text{ m s}^{-1}$

$$\text{W} = \frac{1}{2}\text{m}(v^2 - u^2) \Rightarrow \frac{1}{2} \times 2000 \text{ kg} \times ((25)^2 - (5)^2)$$

$$\text{W} = \frac{1}{2} \times 2000 \times 600 = 600{,}000 \text{ J} = 6 \times 10^5 \text{ J} \Rightarrow 600 \text{ kJ}$$

45. $W = ?;\ v_1 = 30 \text{ km h}^{-1};\ v_2 = 60 \text{ km h}^{-1};\ m = 1500$ kg

$$v_1 = \frac{30 \times 1000}{60 \times 60} = \frac{500}{60} \Rightarrow \frac{25}{3} \text{ m s}^{-1};\ v_1^2 = \frac{25}{3} \times \frac{25}{3} = \frac{625}{9} \text{ m s}^{-1}$$

$$v_2 = \frac{60 \times 1000}{60 \times 60} = \frac{50}{3};\quad v_2^2 = \frac{50}{3} \times \frac{50}{3} = \frac{2500}{9} \text{ m s}^{-1}$$

Initial K. E. $= \frac{1}{2} \times m \times v_1^2 = \frac{1}{2} \times 1500 \times \frac{625}{9} = 52083.33$ J

Final K. E. $= \frac{1}{2} \times m \times v_2^2 = \frac{1}{2} \times 1500 \times \frac{2500}{9} = 208333.33$ J

Work done = Change in K.E. = 156250 J = 156.250 kJ

46. $\text{K. E.}_1 = \frac{1}{2} mv^2;\ \text{K. E.}_2 = \frac{1}{2} \times m \times (2v)^2;\ \text{K. E.}_3 = \frac{1}{2} \times (3v)^2 = \frac{1}{2} \times 9v^2$

$$\text{K. E.} = \frac{1}{2} \times m \times 4v^2$$

K. E. will become four times, i.e. 4 × 25 = 100 J

K.E. will become nine times, i.e. 9 × 25 = 225 J

47. $m = 20$ kg

Work done = Change in K. E.

Initial K.E. = $\frac{1}{2} m v_1^2 = \frac{1}{2} \times 20 \text{ kg} \times 25 \text{ m}^2 \text{ s}^{-2} = 250$ J

Final K. E. = $\frac{1}{2} m v_2^2 = \frac{1}{2} \times 20 \text{ kg} \times 4 \text{ m}^2 \text{ s}^{-2} = 40$ J

Change in K. E. = 40 J – 250 J = – 210 J

W = – 210 J

48. $m = 1500$ kg; $v = 60$ km/h

$$v = \frac{60 \times 1000}{60 \times 60} \text{ m s}^{-1} = \frac{50}{3} = 16.66 \text{ m s}^{-1}$$

Work done = Change in K.E. = $\frac{1}{2} m v_1^2 - \frac{1}{2} m v_2^2$ ($\because$ Car is at rest initially, $v_1 = 0$)

$$= 0 - \frac{1}{2} m v_2^2 - \frac{1}{2} \times 1500 \times \left(\frac{50}{3}\right)^2 = -\frac{1}{2} \times \frac{1500 \times 2500}{9}$$

= – 208333.33 J = –208.333 kJ

49. **Case I:** W = $F \cos \theta = F \cos 90° = F \times 0 = 0$

Case II: W = $F \cos \theta = F \cos 0 = F \times 1 = F$

(Positive work), $\because \cos \theta = 1$

Case III: W = $F \cos \theta = F \cos 180°$

$= F \times (-1) = -F$

(Negative work), $\because \cos 180° = -1$

50. $m = 1000$ kg

$u = 36 \text{ km/hour} = \frac{36 \times 1000}{60 \times 60} = 10 \text{ ms}^{-1}$

Power = Force × Velocity

= 100 N × 10 ms^{-1} = 1000 Watts

= 1 kW

If 'm' is mass of car 'A', v_A is velocity of car 'A', 'm' is mass of car 'B', v_B is velocity of car 'B'.

Then, as per law of conservation of momentum.

$m \times u_A + m \times 0 = m \times 0 + m \times v_B$

$m \times u_A = m \times v_A$

$u_A = v_B = 10 \text{ m s}^{-1}$

51. K.E = $\frac{1}{2} m v^2 \Rightarrow \frac{1}{2} \times 5 \text{ kg} \times (10 \text{ m s}^{-1})^2 = 250$ J

At the highest point, K.E = 0 $\because v = 0$

Loss in kinetic energy = Gain is potential energy = 250 J

P.E = mgh

250 J = 5 kg × 10 m s^{-1} × h

$$h = \frac{250}{50} \text{ m} = 5 \text{ m}$$

52. $p = 2$ kW = 2000 W

$h = 10$ m, m = ?, g = 10 m s^{-2}

Potential energy $= mgh$

$$\text{Power} = \frac{\text{Work done}}{\text{time}} \quad \frac{\text{P.E}}{\text{time}}$$

$$\Rightarrow \; 2000 = \frac{m \times 10 \times 10}{t}; \; \frac{m}{t} = \frac{2000}{100} \;\Rightarrow\; 20 \text{ kg/s}$$

Mass of water lifted is 2 kg/s

Mass of water lifted per minute = 20 × 60 = 1200 kg/min

53. Total energy consumed per day $= 1200 \text{ W} \times \frac{30}{60} = 600 \text{ W h} = 0.6 \text{ kW h}$.

Total energy consumed per month = 0.6 kW h × 30

= 18 KW h = 18 units

54. Work done = P.E = mgh

$= (50 + 60) \text{ kg} \times 15 \times 10 \text{ m s}^{-2} \;\Rightarrow\; 110 \times 15 \times 10 = 16500 \text{ J}$

= 16.5 kJ

$w = \text{P.E} \;\Rightarrow\; \text{mgh} \;\Rightarrow\; 120 \times 15 \times 10$

= 180,00 J = 18 kJ

55. Potential energy is the energy due to the position of a body.

P = mgh

$= 1 \text{ kg} \times 2 \times 1.0 \text{ m s}^{-2} = 20 \text{ J}$

K.E will be equal to the P.E = 20 J

56. (*a*) The energy due to the position of a body is called its potential energy.

(*b*) Potential energy of both the bodies 'A' and 'B' will be the same (P.E. = mgh) because the height of both the paths is same. Potential energy depends upon the height and not on the path.

57. $$P = \frac{W}{t} \;\Rightarrow\; P = \frac{F \times s}{t}$$

$$150 \text{ kg} \times 500 \text{ W} = \frac{F \times 20}{1 \text{ second}} \qquad [\because P = 500 \text{ W per kg}]$$

$$F = \frac{500 \times 150}{20} \;\Rightarrow\; 25 \times 150 = 3750 \text{ N}$$

58. $$P = \frac{m \times g \times h}{t} = \frac{8 \times 10^2 \text{ kg} \times 10 \times 50 \text{ m}}{60 \text{ s}}$$

$$= \frac{40}{6} \times 10^3 \;\Rightarrow\; 6.67 \times 10^3 \text{ Watt} = 6.67 \text{ kW}$$

59. $m = 5$ kg, g = 10 m s^{-2}, $h = 10$ m, $\frac{h}{2} = 5$ m

P.E = $mgh \;\Rightarrow\; 5 \text{ kg} \times 10 \text{ m s}^{-2} \times 5 \;\Rightarrow\; 250 \text{ J}$

At $\frac{h}{2}$, loss of P.E. = Gain in K.E. = 250 J

60. (*a*) Work done per second = 200 N × 0.25 ⇒ 50 J

(*b*) Power = 50 J × 1 s = 50 W

(*c*) Friction = 200 N

Since the speed is constant, there is no acceleration. Therefore, the resultant of the forces acting on the box is zero.

Therefore, force of friction between the floor and the box is equal and opposite to the applied force, i.e. 200 N.

61. (*a*) Work done by a constant force is defined as the product of force and distance (displacement) covered by the body. Its S.I unit is Joule.

1 Joule is the work done when 1 Newton force displaces the body by 1 m.

(*b*)

$$u = 72 \text{ km/hr}$$

$$u = \frac{72 \times 1000}{60 \times 60} = 20 \text{ m s}^{-1}$$

$$F = ma$$

$$-24000 \text{ N} = 3000 \text{ kg} \times a$$

$$a = -8 \text{ m s}^{-2}$$

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

$$0 - (20 \times 20) = 2 \times (-8) \times s$$

$$s = \frac{-400}{-16} = 25 \text{ m}$$

$$W = F \times s = 2400 \text{ N} \times 25 \text{ m}$$

$$W = 500{,}000 \text{ J}$$

$$W = 500 \text{ kJ}$$

62. (*a*) Gain in gravitational potential energy $= mgh = \frac{100}{1000} \times 10 \times \frac{8}{100} = 0.080$ J

(*b*) (*i*) As the ball reaches 'A', gravitational potential energy at B gets converted to kinetic energy of the ball.

Therefore K.E. of the ball = 0.080 J

(*ii*) $\text{K.E.} = \frac{1}{2} mv^2 \; ; \quad v^2 = \frac{2 \text{ KE}}{m}$

$$v = \sqrt{\frac{2 \text{ KE}}{m}} \Rightarrow \sqrt{\frac{2 \times 0.080}{0.1 \text{ kg}}} \Rightarrow \sqrt{1.6} = 1.27 \text{ m s}^{-1}$$

63. (*a*) Potential energy $= mgh$

$$= 420 \text{ kg} \times 10 \text{ N/kg} \times 30 \text{ m} \Rightarrow 126000 \text{ J} = 126 \text{ kJ}$$

(*b*) Energy needed to operate the pump is greater than from the calculated value because some energy is used up to overcome the frictional forces while operating the pump.

(*c*) Power output $= \frac{\text{Energy}}{t} = \frac{126000 \text{ J}}{60 \text{ s}}$

$$= 2100 \text{ W} = 2.1 \text{ kW}$$

64. (*a*) Watt (W) is the S.I unit of energy and kW h is the commercial unit of energy.

(*b*) $W = m \times g \times h = 800 \text{ kg} \times 10 \times \frac{1500}{100} = 8000 \times 15 = 120{,}000 \text{ J}$

$$P = \frac{W}{t} = \frac{120{,}000}{20} = 6000 \text{ Watt} = 6 \text{ kW}$$

(*c*) $P = \frac{\text{Energy}}{\text{time}} = \frac{500 \text{ J}}{20 \text{ s}} = 25$ Watt.

VALUE BASED QUESTIONS

1. Rahul and his younger brother Rohan went to see Dussehra fair. Rohan purchased a bow and arrow there and tried to aim but, the arrow fell on the ground just below him. Rahul told him to stretch the string and then release it. Rohan did the same and was able to release the arrow to a good distance.

(*i*) What type of energy is possessed by the stretched string?

(*ii*) How did the arrow gain kinetic energy?

(*iii*) What characteristic values of Rahul and Rohan did you notice? [*DOE*]

2. Rohan has replaced all the normal bulbs and tubelights of his house with LED bulbs. He was told by a shopkeeper, initially it cost more but it has long term benefits.

(*i*) What values are associated with Rohan?

(*ii*) What is meant by LED?

(*iii*) What is the advantage of using LED's?

Answers

1. (*i*) Potential energy

(*ii*) Potential energy gets converted into kinetic energy when the arrow was released.

(*iii*) Rahul and Rohan share their knowledge and learn from each other. They have sound knowledge of physics and its application in daily life.

2. (*i*) He is saving electricity which is very valuable.

(*ii*) Light emitting diode

(*iii*) These bulbs consume less power and electricity bills are thus reduced. It will save money and valuable resources.

IMPORTANT FORMULAE

1. $W = F \times d$ where 'W' is the work done, 'F' is force applied and '*d*' is the displacement.

2. $W = F \times d \cos \theta$

When $\theta = 0°$, $\cos 0° = 1$, $W = F_d$, maximum work

When $\theta = 90°$, $\cos 90° = 0$, $W = 0$, zero work

When $\theta = 180°$, $\cos 180° = -1$, $W = -F_d$, negative work

3. $W = F \times d = mg \times h$ [*m* is mass, '*h*' is height, 'g' is acceleation due to gravity]

$E_p = mgh$, where 'E_p' is potential energy

4. $\boxed{W = \frac{1}{2} m (v^2 - u^2)}$ '*v*' is final velocity, '*u*' is initial velocity.

5. $E_k = \frac{1}{2} mv^2$ (E_k is kinetic energy), '*v*' is velocity

6. Mechanical energy $= E_k + E_p$

7. $P = \frac{W}{t} = \frac{\text{work done}}{\text{time}}$

8. Average power $= \frac{\text{Total energy consumed}}{\text{Total time taken}}$

9. 1 kW h = 1kw × 1h = 1000 W × 3600 s

1 kW h = 3.6×10^6 J [kW h is the commerical unit of Energy]

IMPORTANT NUMERICAL PROBLEMS

Q1. Calculate the work done when a force of 15 N moves a body by 5 m in its direction.

Sol. $W = F \times d = 15 \text{ N} \times 5 \text{ m} = 75 \text{ J}$

Q2. A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.

Sol. $m = 15$ kg, $h = 1.5$ m, g = 9.8 m s^{-2}

W = mgh = 15 kg × 9.8 ms^{-1} × 1.5 m = 220.50 J

Q3. A ball of mass 2 kg is dropped from a height. What is the work done by its weight in 2 seconds after the ball is dropped?

Sol. $m = 2$ kg, g = 9.8 m s^{-2}, $u = 0$, $t = 2$s

$v = u + gt$

$v = 0 + 9.8 \times 2 = 19.6$ m s^{-1}

$$W = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \text{ kg} \times (19.6)^2 = 384.16 \text{ J}$$

Q4. A bag of wheat weighs 60 kg. Find the height to which it is lifted so that its potential energy is 3000 J. (g = 10 m s^{-2})

Sol. $m = 60$ kg, $h = ?$, $E_p = 3000$ J, g = 10 m s^{-2}

W = E_p = mgh

$$h = \frac{W}{mg} = \frac{3000 \text{ J}}{60 \text{ kg} \times 10 \text{ m s}^{-2}} = 5 \text{ m}$$

Q5. A body of mass 2 kg is thrown up with a speed of 25 m s^{-1}. Find its maximum potential energy.

Sol. $m = 2$ kg, $v = 25$ m/s, $E_p = ?$, g = 9.8 m s^{-2}

$\because$ $v^2 = u^2 - 2gh$ [$\because$ $v = 0$, at the highest point]

$(0)^2 = (25)^2 - 2 \times 9.8 \times h$

$$h = \frac{625}{2 \times 9.8}$$

$$\text{Maximum } E_p = mgh = 2 \times 9.8 \times \frac{625}{2 \times 9.8} \Rightarrow 625 \text{ J}$$

Q6. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/hour?

Sol. $$\text{Work done} = \text{K.E} = \frac{1}{2} mv^2 = \frac{1}{2} \times 1500 \text{ kg} \times \left(\frac{60 \times 10^3 \text{ m}}{60 \times 60}\right)^2$$

$$\text{Work done} = \frac{1}{2} \times 1500 \times \frac{50}{3} \times \frac{50}{3} = \frac{375}{18} \times 10^4 = 20.83 \times 10^4 \text{ J}$$

$$W = 2.083 \times 10^5 \text{ J} = 2.083 \times 10^2 \text{ kJ} = 208.3 \text{ kJ}$$

Q7. A man of mass 60 kg runs up a flight of 30 steps in 40 s. If each step is 20 cm high, calculate its power. [g = 10 m s^{-2}]

Sol. $m = 60$ kg, Total height = 30 × 20 cm = 600 cm = 6 m, $t = 40$ s

P = ?

$$P = \frac{W}{t} = \frac{mgh}{t} = \frac{60 \text{ kg} \times 10 \times 6 \text{ m}}{40} = 90 \text{ Watt.}$$

Q8. 16 bulbs of 40 W are used for 6 hours a day along with one bulb of 100 W for 2 hours. Calculate the unit of energy consumed in 30 days.

Sol. Energy = Power × time

= P × (No. of days) × (No. of hours) × Number of bulbs

Energy consumed by 40 W bulb = 16 × 40 × 30 × 6

= 16 × 12 × 6 × 100 = 16 × 72 × 100

= 115200 W = 115.2 kW h

Energy consumed by 100 W bulb = $1 \times 100 \times 2 \times 30 = 6$ kW h

Total energy consumed = $115.2 + 6 = 121.2$ kW h

Q9. Water is falling on the blades of a turbine at the rate of 8×10^2 kg per minute, height of the fall is 50 m. Calculate the power given to the turbine. ($g = 10 \text{ m s}^{-2}$)

Sol. $m = 8 \times 10^2$ kg, $h = 50$, $g = 10 \text{ ms}^{-2}$, $t = 1$ min $= 60$ s

$$P = \frac{W}{t} = \frac{mgh}{t} = \frac{8 \times 10^2 \text{kg} \times 10 \text{m s}^{-2} \times 50 \text{m}}{60}$$

$$P = 6.67 \times 10^3 \text{ W} = 6.67 \text{ kW}.$$

Q10. A force of 10 N acts on a body of 2 kg for 3 seconds. Find the kinetic energy acquired by the body in 3 seconds.

Sol. F = 10 N, $m = 2$ kg, $t = 3$ s

$$a = \frac{F}{m} = \frac{10 \text{ N}}{2 \text{ kg}} = 5 \text{ m s}^{-2}$$

$u = 0$

$v = u + at$

$v = 0 + at = 5 \text{ m s}^{-2} \times 3 \text{ s} = 15 \text{ m s}^{-1}$

$$\text{K.E} = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \text{ kg} \times (15 \text{ m s}^{-1})^2 = 225 \text{ J}.$$

Q11. An object of mass 5 kg is dropped from a height of 10 m. Find its kinetic energy when it is halfway down. ($g = 9.8 \text{ m s}^{-2}$)

Sol. $m = 5$ kg, $h = 10$ m, $g = 9.8 \text{ m s}^{-2}$

W = mgh = $5 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 10 \text{ m} = 490$ J

At halfway, loss in P.E. = $\frac{490 \text{ J}}{2} = 245$ J

Loss in potential energy = Gain in Kinetic energy = 245 J.

Q12. A body of mass 5 kg is thrown vertically upwards with a speed of 10 m s^{-1}. What is its kinetic energy when it is thrown? Find the potential energy when it reaches the highest point. Also find the maximum height attained by the body. ($g = 10 \text{ m s}^{-2}$)

Sol. $m = 5$ kg, $v = 10 \text{ m s}^{-1}$

$$\text{K.E} = \frac{1}{2} mv^2 = \frac{1}{2} \times 5 \text{ kg} \times (10 \text{ m s}^{-1})^2 = 250 \text{ J}$$

At the highest point, $v = 0$ $\therefore$ K.E = 0

Loss in kinetic energy = Gain in potential energy = 250 J

$$h = \frac{\text{P.E}}{mg} = \frac{250 \text{J}}{5 \text{ kg} \times 10 \text{ ms}^{-2}} = 5 \text{ m}$$

Q13. A body of mass 25 g has a momentum of 0.40 kg m/s. Find its kinetic energy.

Sol. $m = 25 \, g = \frac{25}{1000}$ kg, $p = 0.40 \text{ kg m s}^{-1}$.

$p = mv$

$$0.40 \text{ kg ms}^{-1} = \frac{25}{1000} \text{kg} \times v$$

$$v = \frac{400}{25} = 16 \text{ m s}^{-1}$$

$$\text{K.E.} = \frac{1}{2} \times m \times v^2 = \frac{1}{2} \times \frac{25}{1000} \times 16 \times 16 = 3.2 \text{ J}$$

or $$\text{K.E.} = \frac{p^2}{2\text{m}} = \frac{0.40 \times 0.40}{2 \times 0.025} = 3.2 \text{ J}$$

Q14. How much work is to be done to increase the velocity of a car from 18 km/h to 90 km/h if mass of the car is 2000 kg?

Sol. $m = 2000$ kg, $u = 18 \text{ km/h} = \frac{18 \times 1000}{60 \times 60} = 5 \text{ m s}^{-1}$

$$v = 90 \text{ km/h} = \frac{90 \times 1000}{60 \times 60} = 25 \text{ m s}^{-1}$$

$$\text{W} = \frac{1}{2} \times m \times (v^2 - u^2) = \frac{1}{2} \times 2000 \text{ kg } [(25)^2 - (5)^2]$$

$$= \frac{1}{2} \times 2000 \times (625 - 25) = \frac{1}{2} \times 2000 \times 600 = 6 \times 10^5 \text{ J} = 600 \text{ kJ}$$

Q15. A car weighing 1200 kg is uniformly accelerated from rest and covers a distance of 40 m in 5 seconds. Calculate the work, the car engine had to do during this time.

Sol. $m = 1200$ kg, $s = 40$ m, $t = 5$ s, $u = 0$

$$s = ut + \frac{1}{2} at^2$$

$$s = 0 + \frac{1}{2} \times a \times t^2$$

$$a = \frac{2\text{S}}{t^2} = \frac{2 \times 40 \text{ m}}{5 \times 5} = \frac{80}{25} = 3.2 \text{ m s}^{-2}$$

$$\text{W} = \text{F} \times s = ma \times s = 1200 \text{ kg} \times 3.2 \times 40 \text{ m} \qquad [\because \text{F} = \text{ma}]$$

$$\text{W} = 153600 \text{ J} = 153.6 \text{ kJ}$$

COMMON ERRORS

Errors	Corrections
• When work required to stop the car is to be calculated children do not understand that the final velocity will be zero.	☞ Final velocity will be zero. $v = 0$ ∵ car will stop and will come to rest.
• Children forget the number of devices or bulbs while calculating the energy consumption.	☞ E = P × t × No. of devices and not E = P × t.
• If a person is holding a weight at a height of 0.5 m, students use this formula W = Force × displacement = mgh.	☞ Work done will be zero, because there is no displacement of the person or weight.
• Children do not convert velocity given in km/hour into m s^{-1}.	☞ It should be converted by multiplying with 1000 and dividing by 60 × 60. This should be done because SI unit of velocity is m/s
• Children convert hours into minutes or seconds while calculating energy consumption.	☞ Commercial unit of energy consumption is kW h, so time is to be taken in hours and not in minutes or seconds.

REVISION CHART

WORK

Work done is defined as the product of magnitude of force and displacement covered by an object in the direction of the applied force.

$W = F \times s$

- If displacement = 0, W = 0
- It is a scalar quantity.
- It can be +ve or –ve or zero.
- Greater the force or displacement, greater is the amount of work done.
- SI unit of work = J or N m
- **Joule** is equal to the work done where 1N force moves a body through a distance 1 metre in its own direction.

ENERGY

Energy is defined as the capability or ability to do work.

A body loses energy in doing work and gains energy when work is done on it.

Energy is a scalar quantity.

S.I unit = Joule

Its commercial unit = kW h

1 kJ = 1000 J

1 kWh = 3.6×10^6 J

POWER

Power is defined as the rate of doing work or the rate of transfer of energy.

$$P = \frac{W}{t} = \frac{F.S}{t}$$

$$P = F.V$$

SI unit = Watt or J s^{-1}

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

1 kW = 1000 Watt (W) = 1000 J s^{-1}

FORMS OF ENERGY

Kinetic Energy: Energy possessed by the body due to its motion, e.g. blowing wind.

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

It is directly proportional to the mass and square of velocity of a body.

Potential Energy: Energy possessed by an object due to its position or change in shape.

$$E_p = mgh$$

Greater the stretching, twisting or bending, falling from height, more is the P.E, e.g. water stored in a dam.

Mechanical Energy: Energy possessed by a body due to its motion as well as its position.

$$M.E = K.E + P.E$$

LAW OF CONSERVATION OF ENERGY

It states that energy can neither be created nor destroyed.

It can be transformed from one form to another. The total energy of a system remains constant.

K.E + P.E. = constant

Sum of KE & PE of an object is its total mechanical energy.

Examples: In a battery, chemical energy is converted into electrical energy.

At hydroelectric power stations, P.E. of water is converted to K.E. and electric energy. Plants uses solar energy to make chemical energy in the form of food during the process of photosynthesis