Work, Energy and Power

Introduction

In our day-to-day life, we talk about the term work, energy and power. Out of these energy is most important concept, since all living things need energy to maintain life. The concept of work is closely associated with the concept of energy. When we walk or run, we use the energy that we get from the food we eat. The concept of power is also closely associated with that of work. In our daily life, any physical or mental activity is termed as work done. However in physics, the meaning of work is entirely different. In this chapter, we shall discuss detail about these terms.

Work

Work is said to be done by a force on a body if the force applied causes a displacement in the body or object. In other words the condition which must be satisfied for the work to be done are

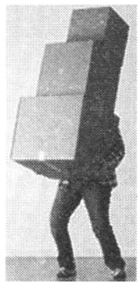
- a force must act on the body and
- the body must be displaced from one position to another position.

Examples: (i) *Work is done, when we hit a football. In this case, when we hit the football, force is applied on the football and the football travels a certain distance before landing on the ground,*
(ii) Work is done when we lift a box through a height. In this case the applied force does work in lifting the box.

Factors on Which Work Done Depends

Work done by a force depends upon the following factors

- The magnitude of the applied force. If a small force is applied on a body, less amount of work is done and vice versa. Thus $W \propto F,$ where F is the magnitude of force applied.
- The distance travelled by the body in the direction of applied force. If a body travels large distance on the application of force, large amount of work is done and vise versa. Thus $W \propto s,$ where s is the magnitude of



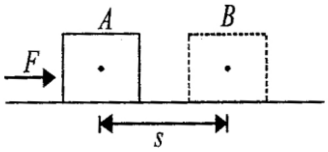
Unit of Work

The S.I. unit of work is joule. One joule work is said to be done on an object when a force of one newton displaces it by one metre along the line of action of the force
1 joule = 1 newton x 1 metre or 1 J = 1 N m
Bigger units of work are kilojoule (kJ), megajoule (MJ) and gigajoule (GJ), i.e.,
1 kilojoule = 10^3 J
1 megajoule = 10^6 J
1 gigajoule = 10^9 J
Work is a scalar quantity, and it has only magnitude but no direction.

Work Done By A Constant Force

- When a constant force is applied in the horizontal direction:
  Let a constant force F be applied on a wooden block placed at position A on the smooth

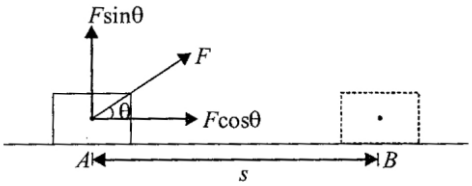
surface as shown in figure. Suppose the block moves in the direction of applied force to the new position B so that its displacement is s. Then, work done by the force is given by



$W = F \times s$ ...(i)

Thus, work done on the block (or any other object) by a constant force is equal to the product of the magnitude of the applied force and the distance travelled by the body.

- **When force is applied at an angle with the horizontal direction:**
  Let a force F be applied on a wooden block at an angle θ with the horizontal direction as shown in figure.
  The component of force F in the horizontal direction $= F\cos\theta$.
  The component of F in the vertical direction $= F\sin\theta$.



Let the block moves horizontally and occupies a new position B so that it travels a distance s horizontally. Since, Fsin6 does not produce displacement in the block in the upward direction, so the only force which displaces the block is $F\sin\theta$. According to the definition of work done,

W = force applied × distance travelled by the body.

or $W = F\cos\theta \times s = FS\cos\theta$ ...(ii)

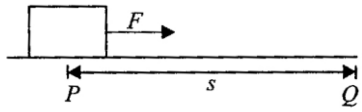
or $W = F \cdot s$ ...(iii)

$F \cdot s$ is read as dot product of F and s.

Thus, work done on a body by a force is defined as the product of the magnitude of the displacement and the force in the direction of the displacement.

- **Positive work done:** If force is acting in the direction of displacement then, the work done is positive. In this case $\theta = 0^o$ i.e., the force F acts in the direction of displacements of the body.

Then



$W = Fs\cos\theta$

i.e., $W = Fs$

$(\because \cos 0^o = 1)$

Example: In a tug of war, the work done by a winning team is positive. The winning team applies a force on the rope in the backward direction and the rope is also displaced in the direction of applied force.

ILLUSTRATION

1. A boy pushes a book by applying a force of 5.0 N. Find the work done by this force in displacing the book through 20 cm along the direction of the push.

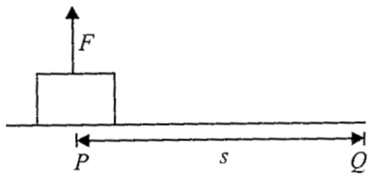
Sol.: Work done is $W = Fs$

$= 5.0\,N \times 20\ cm$

$= 5.0\ N \times 0.2\ m$

$= 1.0\,N\,m = 1.0\,J$

- **Zero work done:** If the force is acting perpendicular to the displacement then work done is zero. In this case $\theta = 90^o$
  i.e., force F acts at right angles to the displacement of the body.



Then $W = F\,s\cos 90$

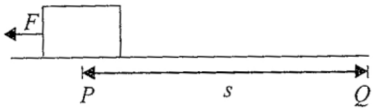
$W = 0$ $(\because \cos 90^o = 0)$

i.e., no work is done by the force.

Example: Work done by the force of gravity on a box lying on the roof of a bus moving with a constant velocity on a straight road is zero. In this case, force of gravity acts vertically downward and the displacement of the box takes place horizontally.

- **Negative work done:** If the force is acting in the direction opposite to displacement then work done is negative. If $\theta = 180^o$
  i.e., force F acts just opposite to the displacement s of the body, then
  $W = Fs\cos 180$

$W = -Fs$ $\quad\quad\quad (\because \cos 180^o = -1)$



Thus work done by force is negative,

Example: In a tug of war, the work done by the losing team is negative. The losing team applies a force on the rope in the backward direction but the rope is displaced in the forward direction.

Do You Know

A weight lifter does work in lifting the weight off the ground, but does not in holding the weight up.

ILLUSTRATION

2. A ball of mass 1 kg thrown upwards reaches a maximum height of 5.0 m. Calculate the work done by the force of gravity during this vertical displacement.

Soln.: The force of gravity on the ball is

$F = mg = 1\ kg \times 9.8\ m\ s^{-2} = 9.8\ N$

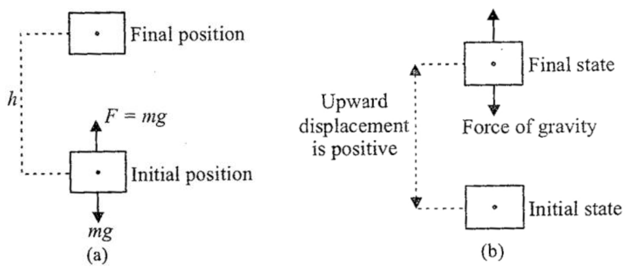
The displacement of the ball is $s = 5.0\ m$.

The force and the displacement are in opposite directions. Hence,

$W = -Fs = -9.8N \times 5.0m = -49\ J$

We can also say that a work of 49 J has been done against the force of gravity.

Work done in lifting a body against gravity



The earth attracts every object (or body) towards it. The force with which the earth attracts a body towards its centre is called its weight. The weight of a body is thus a force acting on it due to the gravitational attraction of the earth. So, if a body is to be lifted up from the surface of the earth, a force equal to the force of gravity (weight) must be applied to the body

Then, the work done in lifting a body through a certain height (h) from the surface of the earth is given by,

Work done in lifting a body = Force of gravity × Height

= Weigh of the body × Vertical distance

or $\quad W = m \times g \times h$

where, m is the mass of the body,

g is the acceleration due to gravity, and

h is the vertical distance through which the body is lifted.

Thus, when a body of mass m is lifted to a height h above the ground, work equal to mgh is done on the body. Since the body is moved against the force of gravity, hence the work $W = mgh$, is commonly called as the work done against the gravity.

ILLUSTRATION

3. A person does work equal to 2500 J in climbing a tree of height 5 m. What is the mass of the person? The value of $g = 9.8\ m\ s^{-2}$.

Soln.: Work done by the person, W = 2500 J

Displacement = Height of the tree, $h = 5\ cm$

$g = 9.8\ m\ s^{-2}$

Let the mass of the person be m.

So,

$W = m \times g \times h$

or $\quad 2500\ J = m \times 9.8\ m\ s^{-2} \times 5\ m$

or $\quad m = \dfrac{2500\,J}{9.8 m s^{-2} \times 5m} = \dfrac{2500\,N\,m}{9.8 m\ s^{-2} \times 5m}$

$= \dfrac{2500\ kg\ m\ s^{-2}\ m}{9.8 \times 5\ m^2 \times s^{-2}}$

$(\because 1\mathrm{N} = 1\ \mathrm{kg\,m\,s^{-2}})$

or $\quad m = \dfrac{2500}{5 \times 9.8} kg = 51\ kg$

Energy

Energy is defined as the capacity to do work and it is measured by the total quantity of work it can do.

When a car runs, the engine of the car generates a force which displaces the car. In other words, work is done by the car. This work is done on the expense of fuel. Fuel provides the energy needed to run the car. The conclusion is that, if there is no source of energy, no work will be done.

Unit of Energy: The S.I. unit of energy is joule (J). The C.G.S. unit of energy is erg. Other unit of energy are electron volt (eV), calorie (cal), kilowatt hour. $1\ \text{eV} = 1.6 \times 10^{-19} J,\ 1\, cal = 4.186\, J$.

Kilowatt hour is the commercial unit of energy.

1 kW h = 1000 W x l h

We know, 1 W = 1 J s^{-1}

1 h = 60 x 60 s = 3600 s

So, one can write

1 kilowatt hour = 1000 W x 1 h = 1000 x 1 J s^{-1} x 3600 s

So, 1 kWh = 3,600,000 J = 3.6 x 10^6 J

Therefore, 1 kilowatt-hour (1 kW h) is equal to 3.6×10^6 joules.

Examples:

(i) A man or a horse does work when they pull a load.

(ii) A moving body can set other bodies into motion when it collides with them.

(iii) Compressed air in a cylinder causes the motion of the piston in it and thus performs work. Our life style demands of energy in various forms. Some forms of energy available naturally or created artificially are as follows:

- **Heat or Thermal Energy:** The energy possessed by a body due to its temperature is known as heat or thermal energy.
- **Chemical Energy:** The energy released in chemical reactions is known as chemical energy.
- **Sound Energy:** The energy of a vibrating body producing sound is known as sound energy.
- **Electrical Energy:** The energy of moving electrons in a conductor connected with a battery is known as electrical energy.
- **Nuclear Energy:** The energy released when two nuclei of light elements combine with each other to form a heavy nucleus or when a heavy nucleus breaks into two light nuclei is known as nuclear energy.
- **Solar Energy:** The energy radiated by the sun is known as solar energy.
- **Mechanical Energy:** The energy possessed by a body because of its speed or position or change in shape is called the mechanical energy. It is the sum of kinetic energy and potential energy of a body. In this chapter our focus will be on mechanical energy.

Do You Know

Wind energy, ocean wave energy, ocean thermal energy, tidal energy, geothermal energy are some natural (non- conventional) sources of energy.

Kinetic Energy

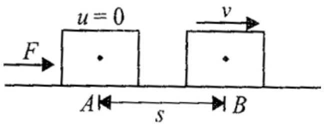
The energy possessed by a body by virtue of its motion is called kinetic energy. So a moving body can do some work due to its kinetic energy. The faster a body is moving, the greater is the its kinetic energy. If a body is at rest, its kinetic energy is zero. Kinetic energy is a scalar quantity.

Examples: (i) ***A high speed bullet, a fast moving cricket ball, a stone thrown with a high speed.***

(ii) ***Flowing wind, and flowing water.***

Expression for Kinetic Energy

Consider a body of mass m lying at rest on a smooth floor. Let a force F be applied on the body so that the body attains a velocity after υ travelling a distance s.



Work done by the force on the body, $W = Fs$ ...(i)

Since the velocity of the body changes from zero to υ, so the body is accelerated. Let a be the acceleration of the body. Then according to Newton's second law of motion.

Substituting the value of $F = ma$ in equation (i), we get

$W = mas$ ...(ii)

Now, using $\upsilon^2 - u^2 = 2as,$ we get

$\upsilon^2 - 0 = 2as$ or $s = \dfrac{\upsilon^2}{2a}$ ...(iii)

Substituting the value of s from equation (iii) in equation (ii), we get

$W = ma \times \dfrac{\upsilon^2}{2a} = \dfrac{1}{2}m\upsilon^2$ ...(iv)

This work done is equal to the kinetic energy of the body.

$\therefore$ Kinetic energy, K.E. $= \dfrac{1}{2}m\upsilon^2$

Thus, K.E. $= \dfrac{1}{2}$ mass of body $\times$ (speed of body)^2

Do You Know

Kinetic energy of a body is always positive. This is because mass can never be negative and square of a real value is always positive.

Relationship between kinetic energy and momentum:

We have,

$$K.E. = \frac{1}{2}m\upsilon^2 = \frac{1}{2}m\upsilon^2 \times \frac{m}{m} = \frac{(m\upsilon)^2}{2m} = \frac{p^2}{2m}$$

$$(\because\ p = m\upsilon) \qquad \therefore \qquad K.E. = \frac{p^2}{2m}$$

ILLUSTRATION

4. A black of mass 2.0 kg slides on a rough surface. At $t = 0$, its speed is 2.0 m/s. It stops after covering a distance of 20 cm because of the friction exerted by the surface on it. Find the work done by friction.

Soln.: The kinetic energy of the ball at $t = 0$ is

$K = \dfrac{1}{2}m\upsilon^2$

$= \dfrac{1}{2}(2.0\ kg) \times (2.0\ m/s)^2 = 4$

When the block comes to res, its kinetic energy becomes zero. This loss of energy takes place because friction does negative work on the block.

Thus, the work done by the friction is (- 4 J).

Work-Energy Theorem

Consider a body or an object of mass m moving with velocity u. Let a force F be applied on the body so that the velocity attained by the body after travelling a distance s is υ.

Work done by the force on the body is given by

$W = Fs$ ...(i)

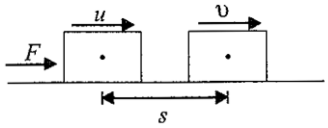
Since velocity of the body changes so the body is accelerated. Let a be the acceleration of the body. Therefore, according to Newton's second law of motion.

$F = ma$ ...(ii)

Using equation (ii) in equation (i), we get

$W = mas$ ...(iii)

Now, using $\upsilon^2 - u^2 = 2as,$ we get



$s = \dfrac{\upsilon^2 - u^2}{2a}$ ...(iv)

Using equation (iv) in equation (iii), we get

$$W = ma\left(\frac{\upsilon^2 - u^2}{2a}\right) = \frac{1}{2}m(\upsilon^2 - u^2)$$

or $W = \dfrac{1}{2}m\upsilon^2 - \dfrac{1}{2}mu^2$

or $W =$ Final K.E. of body – initial K.E. of body

= Change in K.E. of the body.

Thus, work done by a force on a body is equal to the change in kinetic energy of the body.

The expression shows that kinetic energy of a body depends on two factors.

(i) Mass $(K.E. \propto m)$

(ii) Velocity $(K.E. \propto \upsilon^2)$

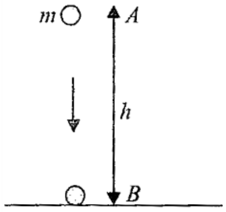
Potential Energy

Energy possessed by a body by virtue of its position, {e.g., height above the ground) or configuration (e.g., shape) is called potential energy.

There are two types of potential energies. These are described below:

- **Gravitational Potential Energy:** The potential energy of a body by virtue of its height above ground level is called gravitational potential energy.

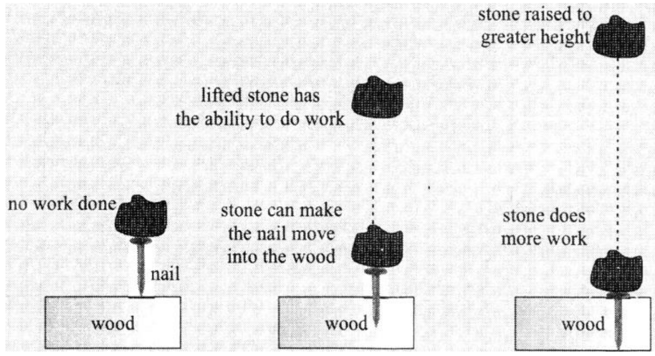
  Example, the energy stored in a body held at a certain height from the ground is gravitational potential energy.



- **Elastic Potential Energy:** The potential energy of a body by virtue of its configuration (or shape) is called elastic potential energy.
  Example, the potential energy stored in the coiled spring of a clock is elastic potential energy.
  Examples: (i) Water stored in an overhead tank possesses gravitational potential energy by virtue of its position (height above ground level).
  (ii) A raised hammer possesses gravitational potential energy by virtue of its height above the ground level.

ACTIVITY CORNER

Fix a nail on a wooden piece. Now keep a stone at the head of a nail as shown in figure. Can the stone drive the nail into the wood? No. Lift the stone through a certain height and drop this stone on the nail fixed on the wooden piece.
It will be observed that the nail moves into the wood. This shows that the stone has acquired some energy. The stone placed at a height has energy in it because of its position at that height. The stone has potential energy. This form of potential energy is called the gravitational potential energy and it is equal to the amount of work done in lifting the stone to that height against the force due to gravity. Now raise the stone to a greater height, and then drop it on the nail. What do you observe?
It will be seen that the nail moves deeper into the wood. So, we can say that the stone raised to a greater height can do more work and hence possesses greater gravitational potential energy.

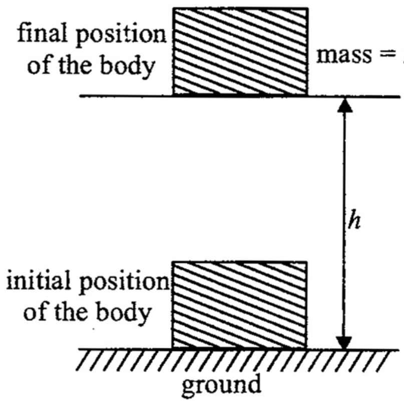


Expression For Gravitational Potential Energy

Suppose a body of mass m is raised to a height h above the surface of the ground as shown figure. The force applied just to overcome the gravitational attraction is

$F = m \times g$ ...(i)

where g = acceleration due to gravity
As the distance moved is in the direction of the forced applied, work is said to be done. The object gains energy equal to the work done on it. Let the work done on the object against gravity be W, so



Work done = Force × Displacement

$W = F \times h$ ...(ii)

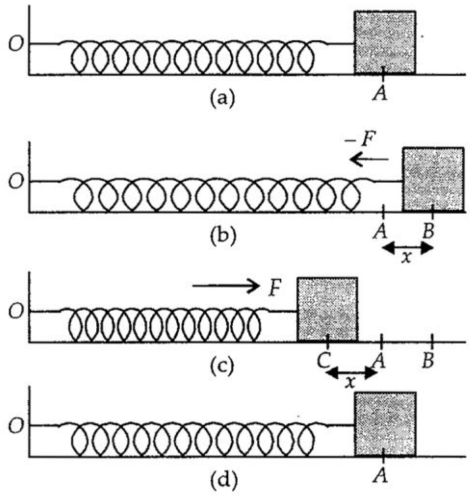
Substituting the value of F from equation (i) in equation (ii), we get

$W = m \times g \times h$

This work gets stored up in the body as gravitational potential energy. Thus,
Work done on the object against gravity
= Gravitational potential energy
Gravitational potential energy $(P.E.) = m \times g \times h$
The expression shows that potential energy depends on
(i) mass m
(ii) height h from ground
(iii) acceleration due to gravity

Potential Energy Of A Spring

Potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.
To calculate it, consider an elastic spring OA of negligible mass. The end O of the spring is fixed to a rigid support and a body of mass m is attached to the free end A. Let the spring be oriented along x-axis and the body of mass m lie on a perfectly frictionless horizontal table as shown in figure.

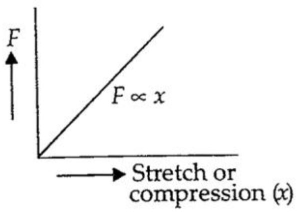


The position of the body A, normal when spring is unstretched is chosed as the origin.
When the spring is compressed or elongated, it is tends to recover its original length, on account of elasticity. The force trying to bring the spring back to its original configuration is called **restoring force or spring force.**
For a small stretch or compression, spring obeys Hook's law, i.e., for a spring.
Restoring Force $\propto$ stretch or compression

$$-F \propto x \qquad \text{...(i)}$$

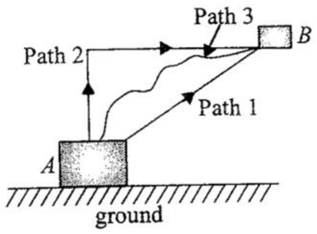
or $\quad -F = kx$

where k is a constant of the spring and is called spring constant.
Equation (i) shows that greater the stretch or compression, greater will be the restoring force and vice-versa as is clear from graph.



Conservative And Non-Conservative Forces

Work done by gravity in moving object from one place to another depends only on the initial and final positions. It does not depends on the path taken. The work done by gravity from A to B is same by path 1, path 2 and path 3. Such forces, the work done by which depends only on the initial and final position and not on the path taken are called conservative forces. The forces in which the work done by which depends on the path taken are called **non-conservative forces**.



ILLUSTRATION

5. An object of mass 12 kg is at a certain height above the ground. If the gravitational potential energy of the object is 480 J, find the height at which the object is with respect to the ground.
$(g = 10\ m\ s^{-2})$

Sol.: Mass of the object $m = 12\,kg$

Acceleration due to gravity $g = 10\ m s^{-2}$

Potential energy of the object, P.E. = 480 J

Height $(h) = ?$

We know P.E. $= m \times g \times h$

Now putting the known values in the above formula, we get

$$480\,J = 12\ kg \times 10\ m\ s^{-2} \times h$$

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

Thus, the object is at a height of 4 m.

Transformation of Energy

Life on the earth depends on the energy received from the sun. Hydrogen nuclei (protons) fuse together to form helium nuclei in the sun's core. In this process, energy of the nuclei is converted into heat energy. This heat energy is absorbed by the atoms at the surface of the sun, and a part of it is converted into light and other radiations. These radiations travel through millions of kilometers of empty space to reach the earth. On receiving radiation from the sun, the land and air get heated. This, as you know, causes wind. This means that heat energy gets converted into kinetic energy. The energy from the sun also heats up the water of oceans.

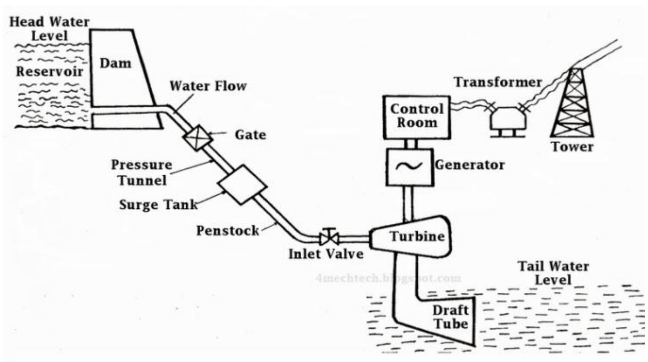
Water evaporates from ocean and rises up to form clouds. This is a case of conversion of kinetic energy into potential energy.

We see many other energy conversion in nature. Snow deposited at high altitudes melts and the water so formed flows down to the seas. In the process, the potential energy of the water is converted into kinetic energy. We convert this kinetic energy of water to electrical energy in hydroelectric power plants.

Plants use sunlight for photosynthesis. In this process, light energy gets converted to chemical energy (as the energy stored in plant food). When plants die, the energy stored in them is not lost. For example, dead plants buried below the earth's surface for millions of years got converted to fuels such as coal, petroleum and gases. These have chemical energy stored in them. When these fuels are burnt, the chemical energy is converted into heat energy.

- **Energy Transformation at Hydroelectric Power House**

At a hydroelectric power house, a dam is built on a river. The river water collects behind the dam to form a reservoir as shown in figure.



Water stored behind the dam has a lot of potential energy but as such this potential energy is of no use to us. If, however, this water is allowed to fall from its great height, the potential energy of water changes into kinetic energy. This kinetic energy of the falling water is used to drive huge water-wheels or turbines which are connected to electricity generators for producing electricity. Thus, at a hydroelectric power house, the potential energy of water is transformed into kinetic energy and then into electrical energy. The transformations of energy taking place at a hydroelectric power house can be written as:

Potential energy $\rightarrow$ Kinetic energy $\rightarrow$ Electrical energy

- **Few artificial devices which convert one form of energy into another are in table:**

	Device	Input energy	Output energy
1.	Fan	Electrical energy	Kinetic energy
2.	Electric lamp	Electrical energy	Light energy
3.	Electrical heaters	Electrical energy	Heat energy
4.	Water pump	Electrical energy	Kinetic energy of impeller to potential energy of water
5.	Cell	Chemical energy	Electrical energy
6.	Microphone	Sound energy	Electrical energy
7.	Rechargeable cell	(a) During discharging Chemical energy (b) During charging	(a) Electrical energy (b) Chemical energy
8.	Loudspeaker	Electrical energy	Sound energy
9.	Elevator moving up	Electrical energy	Potential energy
10.	Television	Electrical energy	Sound energy, light energy
11.	Thermal power plant	Chemical energy of coal	Electrical energy
12.	Car	Chemical energy of petrol/diesel	Mechanical energy
13.	Nuclear power point	Nuclear energy	Electrical energy
14.	Watch	Potential energy of wound spring	K.E. of hands of watch
15.	Generator	Mechanical energy	Electrical energy

Efficiency of a device: In a device, we supply a particular form of energy as input and we get a particular form of energy as output. For example, in an electric heater, we supply electrical energy and get heat energy. The electrical energy is not completely converted into heat energy.

Some energy gets converted into light energy. The percentage of electrical energy converted into heat energy is called the efficiency of the electric heater.

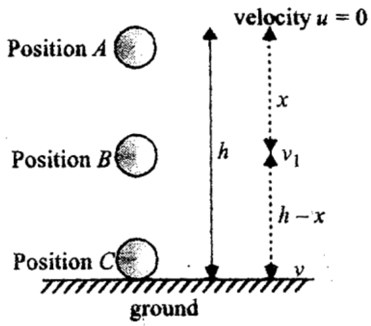
$\therefore$ Efficiency, $\eta = \dfrac{\text{output energy}}{\text{input energy}} = \dfrac{\text{output power}}{\text{input power}}$

Conservation of Energy

According to law of conservation of energy, energy can neither be created nor destroyed, it can be converted from one form to another. The law of conservation of energy holds universally, i.e., it is valid in all situations and for all kinds of transformations.

Verification Of Law Of Conservation Of Energy

Let m be the mass of a body held at a position A and at a height h above the ground.



- **At position A**

Kinetic energy of the body, K.E. = 0
(∵ the body is at rest at A)
Potential energy of the body P.E. $= mgh$
($= mgh$ the body is lifted to a height h)
∴ Total mechanical energy at A, $M.E_A = K.E. + P.E.$
$= 0 + mgh = mgh$
$\therefore \quad M.E_A = mgh$

Let the body be allowed to fall freely under the action of gravity,
In free fall, let the body reach the point B with a velocity υ_1 where
$AB = x$.

- **At position B**

From the equation of motion,
$\upsilon^2 - u^2 = 2as$
$\upsilon_1^2 - 0 = 2gx$
$\upsilon_1^2 = 2gx$ ...(i)
Kinetic energy of the body $K.E. = \frac{1}{2} m\upsilon_1^2$ ...(ii)
Substituting the value of υ_1^2 from equation (i) in equation (ii), we get
$K.E. = \frac{1}{2} m(2gx) = mgx$
Height of the body at B above the ground
$= CB = (h - x)$
Total mechanical energy at $B(M.E_B) = K.E. + P.E.$
$= mgx + mg(h - x)$
$= mgx + mgh - mgx \quad \therefore \quad M.E_B = mgh$

Let the body be allowed to fall freely under gravity, when it strikes the ground at C with a velocity υ.

- **At position C**

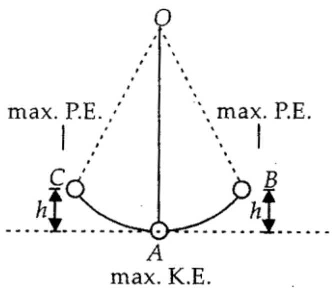
From $\upsilon^2 - u^2 = 2as$
$\upsilon^2 - 0 = 2gh$
$\upsilon^2 = 2gh$ ...(iii)
Kinetic energy of the body, $K.E. = \frac{1}{2} m\upsilon^2$ ...(iv)

Substituting the value of υ^2 from equation (iii) in equation (iv), we get
$K.E. = \frac{1}{2} m(2gh) = mgh$
Potential energy of the body at C, P.E.
$= mgh = mg\ (0) = 0$ (∵ the body is on the ground i.e. $h = 0$)
Total mechanical energy $(M.E_C) = K.E. + P.E. = mgh + 0 = mgh$
$\therefore \quad M.E_C = mgh$
Thus, we find that
$M.E_A = M.E_B = M.E_C = mgh$

Thus, the total mechanical energy (i.e., sum of kinetic energy and potential energy) always remains constant at each point of motion of a body falling freely under gravity and is equal to mgh (initial potential energy at height h).As the body falls, its potential energy decreases and kinetic energy increases. The potential energy changes into kinetic energy. At A, the energy of the body is entirely potential energy and at C, it is entirely kinetic energy.
At B, the energy is partly kinetic and partly potential. Total mechanical energy stays constant (i.e., mgh) throughout. This proves the law of conservation of mechanical energy.

Conservation Of Energy In Case Of A Simple Pendulum

A small metallic ball (called bob) suspended by a light string (thread) from a frictionless, rigid support is called a simple pendulum. When the bob of the pendulum is displaced to B, through a height h, it is given $P.E. = mgh$, where m is mass of the bob. On releasing the bob at B, it moves towards A. P.E. of the bob is being converted into K.E. On reaching A, the entire P.E. has been converted into K.E. The bob, therefore, cannot stop at A. On account of inertia, it overshoots the positions A and reaches C at the same height h above A. The entire K.E. of the bob at A is converted into P.E. at C. The whole process is repeated and the pendulum vibrates about the equilibrium position OA. At extreme positions B and C, the bob is momentarily at rest. Therefore its K.E. = 0. The entire energy at B and C is potential energy. At A, there is no height and hence no potential energy. The entire energy at A is kinetic energy.



The swinging pendulum finally comes to rest due to friction at the support and friction of the air.

ILLUSTRATION

6. A 10 kg ball is thrown upwards with a speed of $5\ m\ s^{-1}$. (a) Find its potential energy when it reaches the highest point (b) Calculate the maximum height it reaches.

Sol.: (a) The kinetic energy of ball is

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}\times(10\,kg)\times(5\ m s^{-2}) = 125\,J$$

At the highest point, the kinetic energy becomes zero, and hence, the entire kinetic energy of 125 J is converted in to potential energy. So the potential energy at the highest point is 125 J. (b) Suppose the ball reaches a maximum height h. its potential energy there will be mgh. Thus,

$$mgh = 125\ J$$

$$\text{or h } = \frac{125\ J}{(10\ kg)\times(9.8\ m s^{-2})} = 1.28\ m$$

Power

The rate at which energy is transferred by an object is called the power delivered by that object, or rate of doing work is power.

If a force does work W in time t, the average power delivered by the force is

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

If the force does work at a constant rate, the average power is the same as the power at any instant during the time the work is being done.

By definition,

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

Therefore, the unit of power depends upon the units of work done, and of the time taken; The

S.I. unit of work done is joule (J), while that of time is second (s).

$$Unit\ of\ power = \frac{Unit\ of\ work}{Unit\ of\ time} = \frac{1\ joule\,(\text{J})}{1\,second\,(s)} = 1\,J\ s^{-1}$$

The unit of $1\ J\ s^{-1}$ is called watt (W). So, the S.I. unit of power is watt (W).

or $1\,W = 1\ J\ s^{-1}$

Thus, when a body works at the rate of 1 J per second, then its power is 1 watt, (W).

Generally, bigger units called kilowatt (kW), megawatt (MW) and gigawatt (gW) are used.

1 kilowatt 1 kW = 1000 watt

or 1 megawatt = 1 MW = 10^6 W

1 gigawatt = 1 GW = 10^9 W

The unit of power in the British engineering system is horse power, denoted by hp.

1 hp = 746 W = 0.746 kW

- To express large quantities of energy, joule is found to be very small and as such an inconvenient unit. For this purpose, a bigger unit of energy, called a kilowatt hour (kW h) is used.

  One kilowatt hour is the amount of energy consumed (or work done) by an agent in one hour working at a constant rate of one kilowatt. Clearly,

$$1\ kW\ h = 1000\ W \times h$$
$$= 1000\ (J\ s^{-1}) \times 3600\ s \qquad (1\,W = 1\ J\ s^{-1})$$
$$= 3600000\,J = 3.6\times10^6\ J$$
$$= 3.6\ MJ$$

A kW h, also called BOTU (Board of Trade Unit) or simply a unit, is used in households, industries and commercial establishments for measuring electric energy consumption. For example, if an electric heater of 1 kW power is used for 2 hours, it consumes 2 kW h or 2 units of electric energy.

ILLUSTRATION

7. A lift is designed to carry a load of 4000 kg through 10 floors of building, average of 6 m per floor, in 10 s. Calculate the power of the lift.

Sol.: Total distance covered by the lift,

$s = 10\times 6\ m = 60\ m$

Time in which this distance is covered, $t = 0\ s$

Force exerted by the lift, $F = 4000\ kg\,wt$

$= 4000\times10\ N \quad (1\,kg\ wt = 10\ N)$

$= 4\times10^4\,N$

Velocity of the lift, $v = \frac{s}{t} = \frac{60\,m}{10\,s} = 6\ m\ s^{-1}$

Power of the lift,

$P = Fv = (4\times10^4\,N)\ (6\ m\ s^{-1})$

$= 24\times10^4\ W = 240\ kW$

Power in Terms of Energy

We know, energy is the ability of a body to do work. Power is the rate of doing work. So, for doing a particular work, an equivalent amount of energy is supplied transferred, so Work done = Energy supplied

So, the rate of energy supplied by a body is called its power,

i.e., $Power = \frac{Energy\,supplied}{Time\,taken} = \frac{E}{t} = \frac{F \times s}{t} = F \times \frac{s}{t} = F \times \upsilon$

where v is the velocity of the body.

Average power is defined as the average amount of work done by a body per unit time,

i.e., $Average\ power = \frac{Average\ amount\ of\ work\ done}{Time\ taken}$

In terms of energy,

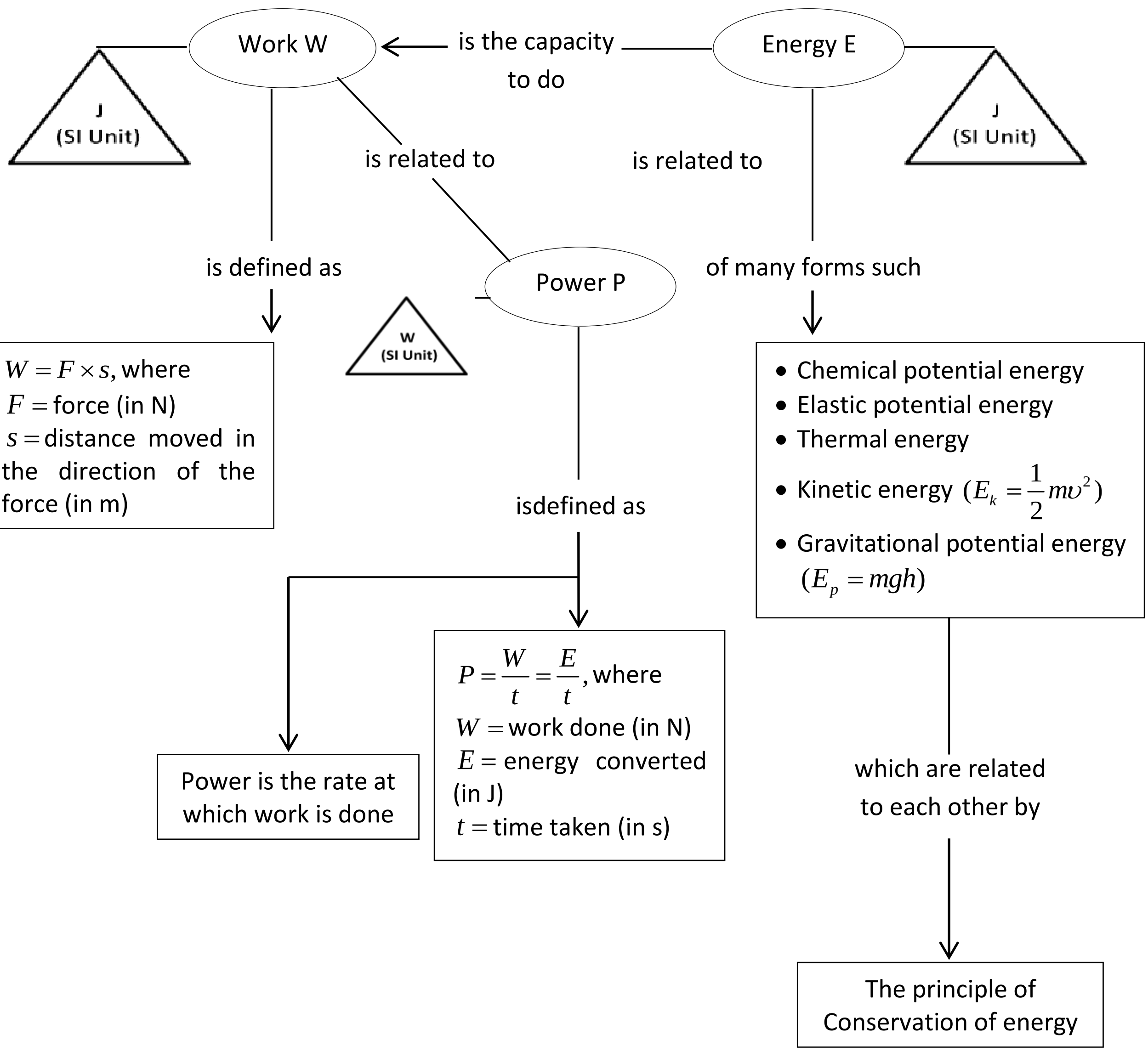
$Average\ power = \frac{Average\ amount\ of\ energy\ supplied}{Time\,taken}$

Since power is the ratio of energy to time, both being scalar quantities, power is also a scalar quantity.

Essential Points

- **Work:** Work is done when a force produces motion.
  Work = Force × Displacement
  i.e., $W = Fs\cos\theta$
  where θ is the angle between the direction of force and displacement.
- S.I. unit of work is joule (J). One joule is defined as the work done in displacing an object in 1 m by applying a force of 1 newton.
- Bigger units of work
  Kilojoule (kJ) = 103 J
  Megajoule (MJ) = 106 J
  Gigajoule (GJ) = 109 J
- When the applied force cause displacement is its own direction, the work done is said to be positive work.
- When a force acting on a body is opposite to the direction of displacement of the body, then the work done is said to be negative.
- When a force acts at right angle to the direction of displacement, then work is done is zero.
- **Energy:** The capacity or ability of a body to do work is called energy.
- The S.I. unit of energy is joule.
- **Mechanical Energy:** The energy possessed by a body due to a displacement caused in it by the application of a force, is called mechanical energy.
- **Kinetic Energy:** The energy possessed by a body by virtue of its motion is called kinetic energy
  Kinetic energy, $K.E. = \frac{1}{2}m\upsilon^2$
- **Potential Energy:** The energy possessed by a body on account of its position or configuration, is called potential energy.
  Potential energy, $P.E. = mgh$
- Mechanical energy is the sum of both potential energy and kinetic energy.
  M.E. = K.E. + P.E.
- The conversion of energy from one form to another is called transformation of energy.
- **Law of Conservation of Energy:** The energy in a system can neither be created nor be destroyed. It may be transformed from one form to another, but total energy of the system remains constant.
- **Power:** The rate of doing work is called power.
  $P = \frac{W}{t}$
  The S.I. unit of power is watt.
  $1W = \frac{1J}{1s} = 1J\,s^{-1}$
- The bigger unit of power are
  (i) Kilowatt $(kW) = 10^3\,W$
  (ii) Megawatt (MW) = 10^6 W
  (iii) Gigawatt (GW) = 10^9 W
- **Commercial unit of Energy:** It is the amount of energy used/produced at a rate of one kilowatt (kW) for one hour.
  $1\,kW\ h = 1\,kW \times 1\,h = 1000\ W \times 3600\,s$
  $= 1000\ J\,s^{-1} \times 3600\ s = 3600000\ J$
  $1\,kW\ h = 3.6 \times 10^6\ J = 3.6\ MJ$
- One kilowatt hour is commonly referred as one unit of electricity.

CONCEPT MAP



SOLVED EXAMPLES

1. Calculate the work required to be done to stop a car of 1500 kg, moving at a velocity of 60 km h^{-1}.

Sol.: Mass of car $(m) = 1.500\ kg$ Initial velocity $(u) = 60\ km\ h^{-1} = 60 \times \frac{5}{18} m\ s^{-1} = 16.67\ m s^{-1}$

Final velocity {v) = 0 m s^{-1}

$\therefore$ Initial kinetic energy

$= \frac{1}{2}mu^2 = \frac{1}{2} \times 1500\ kg \times (16.67\ m\ s^{-1})^2$

$= 2.1 \times 10^5\ J$

Final kinetic energy

$= \frac{1}{2}m\upsilon^2 = \frac{1}{2} \times 1500\ kg \times (0)^2 = 0$

$\therefore$ Work done by the force = Final K.E. - Initial K.E.

$= 0 - 2.1 \times 10^5\ J = -2.1 \times 10^5\ J$

Here, negative work means, the force opposes the motion of the car.

2. A bag of wheat weighs 200 kg. To what height should it be raised so that its potential energy may be 9800 joules? $(g = 9.8\ m s^{-2})$

Sol.: Here, Potential energy, RE. = 9800 J

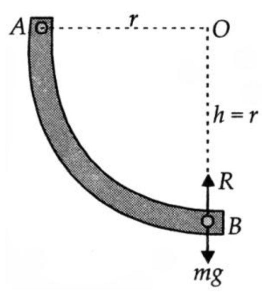
Mass $m = 200\ kg$

Acceleration due to gravity, $g = 9.8\ m\ s^{-2}$
And, Height, $h = ?$
Now, putting these values in the formula:
P.E. $= m \times g \times h$
i.e., $9800 = 200 \times 9.8 \times h$
So, $h = \frac{9800}{200 \times 9.8}$

3. What is the power of a pump which takes 10 seconds to lift 100 kg of water to a water tank situated at a height of 20 m? $(g = 10 m\ s^{-2})$

Sol.: We know that the work done against gravity is given by the formula:
$W = m \times g \times h$ ...(i)
Here, Mass of water, m = 100 kg
Acceleration to gravity, $g = 10\ m\ s^{-2}$
And, Height, h = 20 m
So, putting these values in the above formula, we get:
Work done, $W = 100 \times 10 \times 10$
= 20000 J ...(ii)
And, Time taken, t = 10 s ...(iii)
Now, we have
Power, $P = \frac{W}{t} = \frac{20000}{10}$
= 2000 watts = 2 kW

4. A ball moves along a curved path of radius 5 m as shown in figure, It starts from point A and reaches the point B. Calculate the normal force that acts on the ball at B assuming that there is no friction between the ball and the surface of contact.



Sol.: As it is clear from figure.
RE. of ball at A = K.E. of ball at B
$mgh = \frac{1}{2} m\upsilon^2$
$\upsilon^2 = 2gh = 2gr$
centripetal force on the ball at B
$f = \frac{m\upsilon^2}{r} = \frac{m}{r}(2gr) = 2mg$
If R is normal force of reaction acting on the ball in the upward direction at B, then
$f = R - W$ or
$R = f + W = 2mg + mg = 3mg$

5. A standard car develops 40 h.p. Find the maximum speed the car can attain against a resistance of 20 kg wt. due to air and friction. Given efficiency of the engine is 25%.
1 h.p. = 745 W and g = 10 m s^{-2}?

Sol.: $P = 40\ h.p = 40 \times 746\ watt$
$\upsilon = ?\ F = 20\ kg\ wt. = 20 \times 10\ N$
$\eta = 25\%,\ g = 10\ m\ s^{-2}$
As efficiency, $\eta = \frac{\text{output power}}{\text{input power}}$
$\therefore$ output power = input power $\times \eta = 40 \times 746 \times \frac{25}{100} watt = 7460\ watt$
As output power = force $\times$ velocity $\therefore$ velocity $= \frac{output\ power}{force}$
$\upsilon = \frac{7460}{20 \times 10} = 37.3\ m s^{-1}$

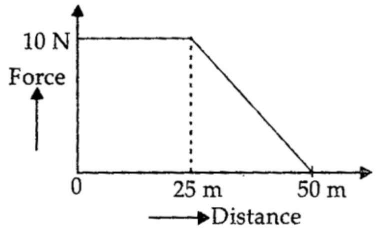
6. A bullet fired into a fixed target loses half of its velocity after penetrating 3 cm. How much further it will penetrate before coming to rest assuming that it faces constant resistance to motion?

Sol.: Using law of conservation of total energy
$\frac{1}{2} mu^2 = \frac{1}{2} m\left(\frac{u}{2}\right)^2 + F \times 3$
or $\frac{3}{4}\left(\frac{1}{2} mu^2\right) = F \times 3$ ...(i)
$\frac{1}{2} mu^2 = F \times s$
Put equation (ii) in (i)
or $\frac{3}{4} = \frac{3}{s}$ or $s = 4\ cm$
$\therefore$ Further distance travelled $= 4 - 3 = 1\ cm$

7. Water falls from a height of 60 m at the rate of 15 kg s^{-1} to operate a turbine. The losses due to frictional forces are 10% of energy. How much power is generated by the turbine?

Sol.: Here, h = 60 m, m = 15 kg s^{-1}
Loss of energy = 10%, g = 10 m s^{-2}
Power generated $= mgh/t$
$= 15 \times 10 \times 60 = 9000\ watt$
Useful power $= \frac{(100 - 10)}{100} \times 9000 = 8100\ watt = 8.1 \text{kW}$

8. A body of mass 5 kg is acted upon by a variable force. The force varies with the distance covered by the body as shown in figure. What is the speed of the body when it has covered 25 m? Assume that the body starts from rest.



Sol.: Here, $m = 5\ kg, \upsilon = ?, s = 25\ m, u = 0$

From figure, F = 10 N

$a = \frac{F}{m},\ a = \frac{10}{5} = 2 m s^{-2}$

As $\upsilon^2 - u^2 = 2as$

$\upsilon^2 = u^2 + 2as = 0 + 2 \times 2 \times 25 = 100$

9. A tube well pumps out 2400 kg of water per minute. If water is coming out with a velocity of 3 m s^{-1}, what is the power of the pump? How much work is done, if the pump runs for 10 hours?

Sol.: Mass of water pumped out/sec

$m = \frac{2400}{60} = 40\ kg$

velocity $= \upsilon = 3\ m\ s^{-1}$

Power $= \frac{\text{energy}}{\text{time}} = \frac{\frac{1}{2} m\upsilon^2}{t} = \frac{\frac{1}{2} \times 40 \times 3^2}{1} = 180\ W$

As work = power × time

$W = 180 \times 10 \times 60 \times 60 = 6.48 \times 10^6\ J$

10. An automobile is moving at 100 km/h and is exerting a force of 400 kg f. What horse power must the engine develop if 20% of the power developed is wasted?

Sol.: Here, v = 100 km h^{-1}

$= \frac{100 \times 1000}{60 \times 60} m s^{-1} = \frac{250}{9} m\ s^{-1}$

$F = 400\ kg\ \ f = 400 \times 9.8\ N$

$P_{output} = F \times \upsilon = 400 \times 9.8 \times \frac{250}{9} watt$

As $\eta = \frac{P_{output}}{P_{input}}$ $\therefore$

$P_{input} = \frac{P_{output}}{\eta} = \frac{400 \times 9.8 \times 250}{9 \times 80 / 100} watt$

As $1\ h.p = 746\ W$

$P_{input} = \frac{9.8 \times 10^6}{72 \times 746} h.p = 182.45\ h.p$

11. The turbine pits at the Niagra falls are 50 m deep. The average horse power developed is 5000, the efficiency being 85%. How much water passes through the turbines per minute?

Given 1 h.p. = 746 W and g = 10 m s^{-2}.

Sol.: Here, depth/ h = 50 m

Average power developed $= 5000\ h.p = 5000 \times 746\ watt = 37.3 \times 10^5\ J\ s^{-1}$

Efficiency = 85%

Mass of water, $m = ?\ t = 1\ \text{min} = 60 s$.

Power generated $= \frac{100}{85} \times$ average power developed $= \frac{100}{85} \times 37.3 \times 10^5\ J\ s^{-1}$

$\therefore$ Total work done by falling water in 1 min.

$= \frac{100}{85} \times 37.3 \times 10^5 \times 60\ \ joule$

$W = 26.32 \times 10^7$.

As $W = mgh$

$\therefore$ $m = \frac{W}{gh} = \frac{26.32 \times 10^7}{10 \times 50} = 5.27 \times 10^5 kg$

12. A body of mass 1.0 kg initially at rest is moved by a horizontal force of 0.5 N on a smooth frictionless table. Calculate the work done by the force in 10 s and show that this is equal to the change in kinetic energy of the body.

Sol.: Here, m = 1.0 kg, u = 0, F = 0.5 N, t = 10 s

$a = F / \text{m} = \frac{0.5}{1.0} = 0.5 m s^{-2}$

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

$s = 0 + \frac{1}{2} \times 0.5 (10)^2 = 25 \text{m}$

Work done $= F \times s = 0.5 \times 25 = 12.5$ joule

From $\upsilon = u + at = 0 + 0.5 \times 10 = 5\ m\ s^{-1}$

Change in $K.E. = \frac{1}{2} m(\upsilon^2 - u^2)$

$= \frac{1}{2} \times 1.0 (5^2 - 0) = 12.5$ joule

13. A rocket of mass 3×10^6 kg takes off from a launching pad and acquires a vertical velocity of 1 $km\ s^{-1}$ and an altitude of 25 km. Calculate its (a) potential energy (b) kinetic energy.

Sol.: Here, mass of the rocket, $m = 3 \times 10^6\ kg$

velocity acquired by the rocket, $\upsilon = 1\ km\ s^{-1} = 1000 = m\ s^{-1}$

height attained by the rocket, $h = 25\ km = 25000\ m$

(a) Potential energy of the rocket, $E_p = mgh = (3 \times 10^6\ kg)\ (10\ m\ s^{-2})\ (25000\ \text{m})$

$= 7.5 \times 10^{11}\ J$

(b) Kinetic energy of the rocket,

$$E_k = \frac{1}{2}m\upsilon^2 = \frac{1}{2}(3\times10^6\ kg)\ (1000\ m\,s^{-1}) = 1.5\times10^{12}\ J$$

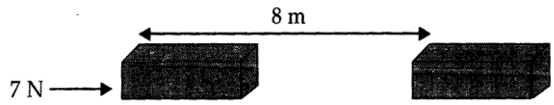
14. The mass of a ball A is double the mass of another ball B. The ball A moves at half the speed of the ball B. Calculate the ratio of the kinetic energy of A to the kinetic energy of B.

Sol.: mass of ball $A = 2m$, mass of ball $B = m$
velocity of ball $A = \upsilon$, , velocity of ball $B = 2\upsilon$

$$\frac{\text{Kinetic energy of ball A}}{\text{Kinetic energy of ball B}} = \frac{\frac{1}{2}(2m)\upsilon^2}{\frac{1}{2}m(2\upsilon)^2} = \frac{m\upsilon^2}{2m\upsilon^2} = \frac{1}{2} = 1:2$$

NCERT SECTION

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



Ans.: Force, *F = 7* N
Displacement, s = 8 m
Then, Work done $= 7N\times 8m = 56Nm = 56J$

2. When do we say that work is done?

Ans.: Work is done by a force on an object if a force acts on the object and the object is displaced from its original position.

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

Ans.: If F is the constant force acting in the direction of displacement *s,* then work done by the force, *i.e.,*
$W = F\times s = Fs.$

4. Define 1 J of work.

Ans.: The amount of work done when a force of 1 N moves a body through a distance of 1 m in the direction of the force is called 1 joule.

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.: Here, F = 140 N; *s* = 15 m.
Work done in ploughing the field,
$W = F\times s = (140N)\times(15cm) = 2100J$

6. What is the kinetic energy of an object?

Ans.: Kinetic energy of an object is the energy possessed by it due to its motion. In fact, kinetic energy of an object moving with a certain velocity is equal to the work done to make it acquire that velocity.

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

Ans.: Kinetic energy of an object, *i.e.,* $K.E. = \frac{1}{2}m\upsilon^2$

where *m* = mass of the object and
v = uniform velocity of the object

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

Ans.: K.E. of an object = 25 J
K.E. of the object with doubled velocity

$$= \frac{1}{2}\times m(2\upsilon)^2 = 4\times\left(\frac{1}{2}m\upsilon^2\right) = 4\times 25J = 100J$$

K.E. of the object with tripled velocity

$$= \frac{1}{2}\times m(3\upsilon)^2 = 9\times\left(\frac{1}{2}m\upsilon^2\right) = 9\times 25J = 225J$$

9. What is power?

Ans.: The rate of doing work is called power. Thus,

Power $(P) = \dfrac{Total\ work\ done\,(W)}{Time\,taken\,(t)}$ or $P = \dfrac{W}{t}$

Power may also be defined as the amount of work done in one unit of time.

10. Define 1 watt of power.

Ans.: Power of an object is said to be 1 W if it does 1 joule of work in 1 s, *i.e.,*

$$1\,watt(W) = \frac{1\,joule(J)}{1\sec ond\,(s)} = 1J\,s^{-1}$$

In other words, we say that power is 1 W when the rate of consumption of energy is $1J\,s^{-1}$.

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

Ans.: Energy consumed = 1000 J
So, Time = 10 s
Power

$$= \frac{Energy\ consumed}{Time} = \frac{1000\,J}{10\,s} = 100J\,s^{-1} = 100W$$

$(\because 1J\,s^{-1} = 1W)$

12. Define average power .

Ans.: Average power $= \dfrac{Total\ energy\ consumed}{Toal\ time\,taken}$

The concept of average power is useful when the power of an agent varies with time and it does work at different rates during different intervals of time.

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'.

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

Ans.: (a) Suma is doing work. She is applying force to move horizontally.

(b) Donkey is not doing any work. Here, the displacement and the force are at 90°.

(c) Work is done by the windmill. The water is lifted against force of gravity.

(d) No work is done by a green plant during photosynthesis.

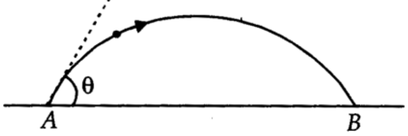
(e) The engine applies a pulling force on the train, and the train moves in the direction of this force. Therefore, engine is doing work.

(f) During drying of food grains in the sun no work is done.

(g) Work is done by the air. The sailboat moves in the direction of the force exerted by wind.

14. 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.: Since initial and the final positions on the path of the object thrown at a certain angle to the ground lie on the some horizontal plane, the displacement of the object is in the horizontal direction. The force of gravity on the object acts vertically downwards, so no work is said to be done.



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

Ans.: A battery converts chemical energy into electrical energy. This electrical energy is converted into light energy as the bulb is lighted up, *i.e.,* the sequence of energy changes is as follows:

Chemical energy $\rightarrow$ Electrical energy $\rightarrow$ Light energy.

16. 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.

Ans.: Mass of the object, *m* = 20 kg

Total work done by the force = Change in the kinetic energy of the object

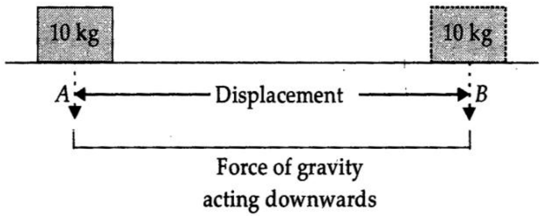
$$=\frac{1}{2}\times m\times\Delta(\upsilon)^2=\frac{1}{2}\times m\times\left(\upsilon_f^2-\upsilon_i^2\right)$$

$$=\frac{1}{2}\times 20kg\times[(2\,m\,s^{-1})^2-(5\,m\,s^{-1})^2]=10\,kg\times(-21\,m^2s^{-2})$$

$$=-210\,kg\,m^2\,s^{-2}=-210\,J$$

The force will do work equivalent to 210 J. Here the direction of force is opposite to the direction of motion.

17. 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.: Here, the mass of 10 kg is moved horizontally from point A to B. The force of gravity acts vertically downwards. Thus, the mass moves in a direction at right angle to the force of gravity.

So,

Work done on the object by the force of gravity

$$=FS\cos\theta=FS\cos90^o=0(\because\cos90=0)$$

Therefore, no work is done by the force of gravity on the object.

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

Ans.: As the potential energy of the freely falling object decreases, its kinetic energy increases on account of an increase in its velocity. The sum total of the potential energy and the kinetic energy of the object during its free fall remains the same, *i.e.,* the total mechanical energy (potential energy + kinetic energy) remains constant. Thus, the law of conservation of energy is not violated.

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

Ans.: The muscular energy of the cyclist is converted into kinetic energy (rotational) of the pedals of the bicycle which is transferred to its wheels. The kinetic energy of the rotation of the wheels is converted into the kinetic energy of the bicycle and the cyclist.

20. 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.: No transfer of energy takes place when we push a huge rock unsuccessfully.
The energy is spent for the physical activity of muscles.

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

Ans.: Energy consumed $= 250$ units

$= 250 \times 1000\text{Wh} = 250 \times (1000 \text{ W})(3600 \text{ s})$

$= 250 \times 1000 \times 3600\text{Ws}$

$= 900 \times 10^6 = 9 \times 10^8 \text{J}$

$(\because 1\text{W} = 1\text{Js}^{-1})$

22. 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.: Potential energy of the object $= m \times g \times h$

$= 40\,kg \times 10\,m s^{-2} \times 5m$

$= 40 \times 10 \times 5 \text{kg}\,\text{m}\,\text{s}^{-2}\text{m} = 2000.\text{J}$

Let υ be the velocity of the object at half the height *i.e.,* after travelling 2.5 m.

Then $\upsilon^2 - u^2 = 2as$

$\upsilon^2 - 0^2 = 2 \times 10\,m s^{-2} \times 2.5m = 50 m^2 s^{-2}$

So, $\upsilon^2 = 50\ m^2 s^{-2}$

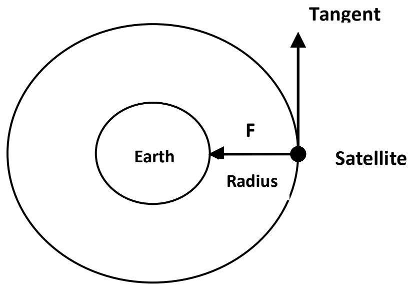
Then, Kinetic energy

$= \frac{1}{2} m\upsilon^2 = \frac{1}{2} \times 40kg\ kg \times 50 m^2 s^{-2}$

$(\because 1J = 1kg\,m^2 s^{-2}) = 1000\text{J}$

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

Ans.: When a satellite moves around the earth, its displacement in a short interval is along the tangent to the circular path of the satellite. The gravitational force (F) acting on the satellite due to the earth is along Since a tangent is always perpendicular to the radius, the displacement and the force are perpendicular to each other. There is no displacement of the satellite in the direction of the force, *i.e.,* 5=0. Thus, work done by the force of gravity on the satellite is zero as $W = F \times S = 0$.



24. 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.

Ans.: Yes. In the absence of any force on the object, *i.e.* $F = 0$, $ma = 0$ (as F = *ma).* Since $m \neq 0, a = 0$. In such a case, the object is either at rest or in a state of uniform motion in a straight line. In the latter case, there is a displacement of the object without any force acting on it.

25. 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.: The person holding a bundle of hay on his head gets tired as he experiences muscular fatigue.
This fatigue is due to conversion of chemical energy into thermal energy by the muscular effort.
The person has done no work as his effort causes no displacement of the bundle over his head, *i.e., S* = 0.

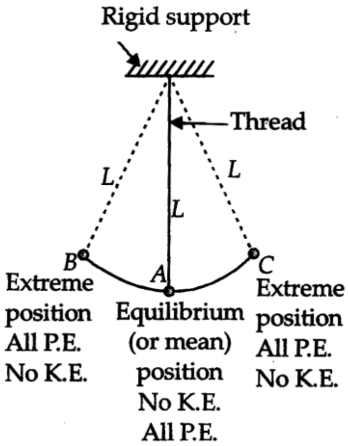
26. An electric heater is rated 1500 W. How much energy does it use in 10 hours?

Ans.: Here, power of the electric heater, P=1500 W
Time for which it is used, *t* = 10 h
Energy used by the electric heater, *i.e.,*
$W = P \times t = 1500W \times 10h = 1500Wh = 15kW\,h = 15$ units
Energy consumed

$= 15 \times Wh \times \frac{3.6 \times 10^6 J}{1k\,Wh} (\because 1kWh = 3.6 \times 10^6 J)$

27. 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.: A small metallic ball (called bob) suspended by a light string (thread) from a frictionless, rigid support is called a simple pendulum. A simple pendulum is shown in figure alongside. The bob of a simple pendulum swings from one extreme position to the other through its mean position.. The bob is at its highest position at the extreme positions and at lowest at its mean position,



The energy changes which occur during the motion of the bob are shown in figure given alongside. So, when a pendulum swings to and fro, its energy changes constantly in the following sequence.

Extreme right position All P.E.	→	Mean position No P.E.	→	Extreme Left position ALL P.E.	→	Mean position No P.E.	→	Extreme right position All P.E.

28. 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.: Initial kinetic energy of the object, $K.E_i = \frac{1}{2}m\upsilon^2$ When the object comes to rest, final kinetic energy of the object, Change in kinetic energy $= \frac{1}{2}m\upsilon^2 - 0 = \frac{1}{2}m\upsilon^2$

Work done on the object = change in its kinetic energy $= \frac{1}{2}m\upsilon^2$

29. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km h^{-1}?

Ans.: Here, mass of the car, $m = 1500\text{kg}$

Initial velocity of the car, $u = 60\,km\,h^{-1} = \frac{60\times1000m}{60\times60s} = \frac{50}{3}m\,s^{-1}$

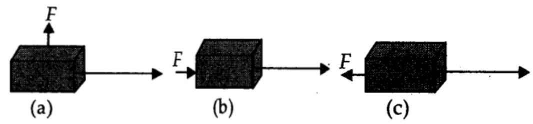
Initial kinetic energy of the car, $K.E._i = \frac{1}{2}mu^2$

$= \frac{1}{2}(1500kg)\left(\frac{50}{3}m\,s^{-1}\right)^2 = 20833.3J$

Final kinetic energy of the car, $K.E._f = \frac{1}{2}m\upsilon^2 = 0$

Change kinetic energy of the car $= K.E._f - K.E._i = -208333.3J$

30. The sign of minus indicates that the work is being done against the moving car. 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.: (a) Here, the force acts at right angle to the displacement. So, work done by the force =0

(b) Here, the direction of displacement is the same as that of the force. So, work done by the force = + ve

(c) Here, the body moves in a direction opposite to the direction of the force. So, work done by the force = - ve

31. 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.: The acceleration of an object can be zero even if several forces are acting on it provided the resultant force (F) is zero. As $F = 0, ma = 0$ and accordingly $a = 0 (as\, m \neq 0)$.

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

Ans.: Power of each device = 500 W
Number of devices = 4
Duration of use = 10 h
Total energy consumed = 4 x 500 W x 10 h
= 20000 Wh = 20 kW h

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

Ans.: When a freely falling body eventually stops on reaching the ground, its kinetic energy appears in the from of:
(i) heat (the body and the ground become warmer due to collision).
(ii) sound (produced due to collision of the body with the ground).

(iii) potential energy of configuration of the body and the ground (the body may be deformed and the ground may be depressed at the place of collision).

This process in which the kinetic energy of a freely falling body is lost in an unproductive chain of energy changes is called dissipation of energy.

NCERT EXEMPLAR PROBLEMS-SOLUTIONS

Multiple Choice Questions (MCQs)

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)** Since, total energy of the system is always conserved, so when a body falls freely towards the earth, then its total energy remains constant i.e., the sum of the potential energy and kinetic energy of the body would be same at all points.

2. A car is accelerated on a leveled 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)** Potential energy of the car don't change and kinetic energy changes by as follows

Let, initial velocity = u

$\therefore$ Kinetic energy $K_1 = \frac{1}{2}mu^2$

Given, after sometime velocity become 4 times of its initial velocity i.e., final velocity (v} = 4u Now, put v = 4u, in Eq. (i), we get

$\therefore$ Kinetic energy $= \frac{1}{2}m(4u)^2$

$$= \frac{1}{2}m16u^2$$

$$K_2 = 16\frac{1}{2}mu^2$$

From Eq. (i), $K_2 = 16K_1$

So in this process, the kinetic energy of car becomes 16 times that of initial energy.

3. In case of negative work, + the angle between the force and displacement is

(a) 0 (b) 45^o

(c) 90^o (d) 180^o

Ans. **(a)** Work done $W = F.d\cos\theta$

$\therefore$ Work done at $\theta = 0^o, W = F.d\cos 0^o$

$(\because \cos 0^o = 1)$

$\Rightarrow$ W = F. d

For angle $\theta = 0^o$

Work done is positive,- so it is not true. .

(b) We know that work done, $W = F.d\cos\theta$

$\therefore$ Work done at $\theta = 45^o$

$W = F.d\cos 45^o$ $\left(\because 45^o = \frac{1}{\sqrt{2}}\right)$

$W = \frac{F.d}{\sqrt{2}}$ For angle $\theta = 45^o$, work done is positive, so it is not true.

(c) We know that work done, $W = F.d\cos\theta$

$\therefore$ Work done at $\theta = 90^o$ $W = F.d\cos\theta$

$(\because \cos 90^o = 0)$

$$W = 0$$

So, it is not true.

(d) Work done at $\theta = 180^o$, $W = F.d\cos\theta$

$(\because \cos 180^o = -1)$

$$W = -F.d$$

For negative work, the angle between the force and displacement should be 180^o. (i.e., force and displacement are anti parallel to each other) So, it is true.

4. 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. When they are 10 m above the ground, they have the same

(a) acceleration (b) momenta

(c) potential energy (d) kinetic energy

Ans. **(a)** When both spheres are dropped simultaneously from a tower, they have same acceleration. Because, during free fall acceleration of body becomes equals to $(g = 9.8 m/s^2)$ and 'g' depends on mass of earth and radius of earth i.e., $\left(i.e., g = \frac{GM_e}{R_e^2}\right)$

5. A girl is carrying a school bag of 3 kg mass on her back and moves 200 m on a leveled road. The work done against the gravitational force will be $(g = 10 ms^{-2})$

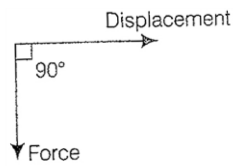
(a) 6×10^3 J (b) 6 J

(c) 0.6 J (d)zero

Ans. **(d)** We know that, work done $= F\cdot d\cos\theta$

Force on school bag makes an angle 90° from the road.

i.e., $\theta = 90^o$



$W = F \cdot d \cos 90^o$

$(\because \cos 90^o = 0^o)$

$W = 0$

Hence, work done against the gravitational force is 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)** We know that, joule, newton metre and kilowatt hour are the units of energy and the kilowatt is the unit of power.

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)** We know that, $W = F \cdot d \cos\theta$

Here, F = force applied on the object, d = displacement and θ is angle between force and displacement. So, the work done on an object does not depend upon the 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 is stored energy or the energy of position, so water stored in a dam possesses potential energy.

9. A body is falling from a height h, After it has fallen a height $\frac{h}{2}$, 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)** As we know that when a body is at height h, it has total energy = KE+ PE and at height 'h', velocity of body is zero. (m)

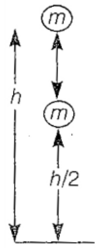
So, KE = 0 and PE = mgh

So, total energy = mgh + 0 = mgh

Now, at height $\frac{h}{2}$

Its, $PE = mg\frac{h}{2} = \frac{mgh}{2}$

Now at height $\frac{h}{2}$ And $KE = \frac{1}{2}mv^2$ ...(i)



Where, velocity can be determined by equation of motion $v^2 = u^2 + 2gh$

($\therefore$ All v, g, h are in same direction)

[As u = 0 at highest point]

So, $v^2 = \frac{2gh}{2} \Rightarrow v = \sqrt{gh}$

So, $KE = \frac{1}{2}m \times (\sqrt{gh})^2 = \frac{mgh}{2}$ ...(ii)

So, from Eqs. (i) and (ii) body at $\left(\frac{h}{2}\right)$ possesses half potential energy and half kinetic energy.

SHORT ANSWER TYPE 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?

Thinking Process

Firstly we use the formula of kinetic energy i.e., $K = \frac{1}{2}mv^2$, and further use the given condition $v_1 = v$ and $v_2 = 3v$ to find kinetic energy and to get the required ratio.

Ans. Given $v_1 = v$ and $v_2 = 3v$

$\because$ Kinetic energy of rocket $(K) = \frac{1}{2}mv^2$

The ratio of two kinetic energies, $\frac{K_1}{K_2} = \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2}$

$\frac{K_1}{K_2} = \frac{v_1^2}{v_2^2} (put\, v_2 = 3v \,\text{and}\, v_1 = v)$

we get $\frac{v^2}{(3v)^2} = \frac{v^2}{9v^2} \Rightarrow \frac{K_1}{K_2} = \frac{1}{9}$

Thus, the ratio of two kinetic energies $K_1 : K_2 = 1:9$

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

Ans. Given, force applied by Avinash = 10N

Speed of Avinash $=8ms^{-1}$

$\therefore$ Power of Avinash $=F\cdot v=10\times 8=80W$

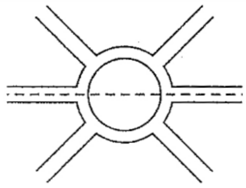
Now, force applied by Kapil = 25 N

Speed of Kapil $=3ms^{-1}$

$\therefore$ Power of Kapil $=F\cdot v=25\times 3=75W$

Since, Avinash has more power (80 - 75) = 5 W than Kapil. So, Avinash is more powerful.

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 of radius 100 m as shown in figure. However, he moves on the circular path for one and half cycle and then he moves forward up to 2.0 km. calculate the work done by him.



Ans. Given, force applied by boy against friction=5N

Displacement on the circular path = One cycle + Half cycled = 0 + Half cycle

= 0 + Diameter of circular path

($\therefore$ Displacement depends on initial and final point)

= 0 + 2 r = 0 + 2 x 100 [$\because$ r = 100 m]

= 0 + 200 = 200 m

$\therefore$ Total displacements = 1.5 km+200m+ 2.0km

= 1.5 x 1000 + 200+2x 1000km

(1 km= 1000m) = 3700 m

Work done by boy $=F\cdot s\cos\theta$

$=5\times 3700\times\cos 0=18500\,\text{J}$ $\begin{bmatrix}\because \theta=0^o\\ \therefore \cos 0^o=1\end{bmatrix}$

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

Ans. Since, mechanical energy is the sum of kinetic energy and potential energy, And as given that, momentum of the body is zero, it means velocity of the body is zero, so it has kinetic energy equals to zero. But it may have potential energy.

So, even if the momentum of the body is zero, it may have mechanical energy.

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

Ans. Since, mechanical energy = potential energy + kinetic energy If mechanical energy = 0

So, PE + KE= 0

$\Rightarrow$ PE = - KE

So, we can say that body may have momentum, in case mechanical energy is zero.

15. 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, $g=10ms^{-2}$]

Ans. Given, power of a motor

$=2kW=2\times 1000W=2000W$

$[\because 1kW=1000W]$

Power, $P=\dfrac{\text{Energy}}{\text{Time}}$

By putting the values, $P=\dfrac{mgh}{t}$

[m = mass of water]

$$2000=\frac{m\times 10\times 10}{60}$$

[Here h = 10 m and t = 1 min = 30 s]

$$m=\frac{2000\times 60}{10\times 10}$$

$$m=1200kg$$

16. 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. It is given that weight of person on the earth = w (i.e., w = mg)

And as he can jump upto height $(h_1=0.4m)$

So, potential energy at this point $=mgh=mg\times .04$ ...(i)

And it is given that weight of the person on the other planet $=\dfrac{w}{2}$

And if he could jump to height (hg) its potential energy would be $\dfrac{w}{2}h_2=\dfrac{mg}{2}h_2$ ...(ii)

Since, he applied same amount of effort in both the cases to lift his body, so its potential energy will be same.

And from Eqs. (i) and (ii) $0.4=\dfrac{mg}{2}h_2$

$\Rightarrow$ $h_2=0.4\times 2=0.8m$

17. 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 an object of mass m moving with a uniform velocity u.

Let, it now be displaced through a distance s, when a constant force F acts on it in the direction of its displacement.

From the third equation of motion,

$$v^2 = u^2 + 2as$$

$$\Rightarrow \qquad v^2 - u^2 = 2as$$

$$\Rightarrow \qquad s = \frac{v^2 - u^2}{2a} \qquad \text{....(i)}$$

We know that, work done by F is

$W = Fs\cos\theta$ (since, force and displacement are in same direction so $(\theta = 0)$ $= ma \cdot s$

$[\because F = ma] \qquad = ma \times \left(\frac{v^2 - u^2}{2a}\right)$ [From Eq. (i)]

$W = \frac{1}{2}m(v^2 - u^2)$ If the object is starting from its stationary position i.e., u=0, from Eq. (II),

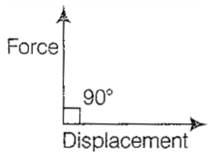
we get $W = \frac{1}{2}mv^2$

It is clear that the work done is equal to the change in the kinetic energy of an object.

18. 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, when force acts in a direction perpendicular to the direction of displacement.



e.g., earth revolves around the sun under gravitational force of sun on earth, but no work is done by the sun, though earth has centripetal acceleration.

19. 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? $[g = 10\,ms^{-2}]$

Ans. If the energy of the ball reduces by 40% after striking the ground, then remaining energy of the ball will be 60% of initial energy.

Let initial energy of the body of mass (m) at height (h) is (mgh).

According to the question, mgh' = 60% of mgh

[given, h = 10 m and $g = 10\,ms^{-2}$]

$$h' = 60\% \times h = \frac{60}{100} \times 10 = 6m$$

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

Thinking Process

Here, for finding the energy of 30 days, firstly find the energy of one day by using the formula, Energy = Power x Time and then multiply that energy by 30, to get required energy.

Ans. Given, power of electric iron = 1200 W

Time (r) = 30 min = 30 x 60s = 1800s

We know that, $\quad \text{power} = \frac{\text{energy}}{\text{time}}$

$$1200 = \frac{E}{30 \times 60}$$

$E = 1200 \times 30 \times 60 = 21.6 \times 10^5\,\text{J}$

Energy used in one day $= 21.6 \times 10^5\,\text{J}$

$\therefore$ Energy used in 30 days

$= 21.6 \times 10^5 \times 30 = 6.4 \times 10^7\,\text{J}$

LONG ANSWER TYPE QUESTIONS

21. 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. Suppose m_1 and m_2 are masses of a light and a heavy objects, respectively. As we know

kinetic energy $(K) = \frac{1}{2}mv^2$

[v = velocity of objects] ...(i)

and movement (p) = mv ...(ii)

Multiplying and dividing with m in Eqs. (i)

So, $K = \frac{1}{2}\frac{mv^2 \times}{m} \Rightarrow K = \frac{1}{2}\frac{(mv)^2}{m}$ as form Eqs (ii) $\qquad (p = mv)$

So, $\qquad K = \frac{p^2}{2m}$

We have, $\qquad$ kinetic energy, $K = \frac{p^2}{2m}$

$\because$ Momentum is same for light and heavy body

So, $\qquad$ kinetic energy, $K \propto \frac{p^2}{m}$

Thus, kinetic energy is inversely proportional to the mass.

So, lighter body has larger kinetic energy.

22. An automobile engine propels a 1000 kg car A along a leveled road at a speed of 36 kmh^{-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, mass of car (A) = 1000 kg

Mass of car 6 =1000 kg

Force applied by car A = 100 N

(V_A) Speed of car

$\left[\because 1km/h = \frac{5}{18} m/s\right]$

$(A) = 36\,kmh^{-1} = 36 \times \frac{5}{18} = 10\,ms^{-1}$

$\therefore$ Power of car $(A), P_A = F \cdot V_A = 100 \times 10 = 1000W$

[F = force exerted by the car $\underline{A}$ against friction]

Again, for car (A) Newton's law, F = ma

$100 = 1000 \times a \Rightarrow a = \frac{100}{1000}$

$a = \frac{1}{10} ms^{-2}$

Velocity of car A after travelling 200 m is given by

From third equation of motion, $v^2 = u^2 + 2as$

[for car A here, $u = 10ms^{-1}, s = 200m$]

$v^2 = (10)^2 + 2 \times \frac{1}{10} \times 200$

$v^2 = 100 + 40 = 140$

$v = \sqrt{140} = 11.8ms^{-1}$

According to the question, after moving of 200 m, the speed of car A, $u_1 = 11.8ms^{-1}$ Just after the collision, the final speed of car $A, v_1 = 0$ before collision, the initial speed of car $B, v_2 = 0$ From conservation of linear momentum, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

[Let just after the collision, the speed of the car B is v_2] $m_1 \times 11.8 + m_2 \times 0 = m_1 \times 0 + m_2 \times v_2$

$11.8m_1 = m_2v_2$ $\qquad [As \because m_1 = m_2]$

$11.8m_1 = m_1v_2$

$\Rightarrow \qquad v_2 = 11.8ms^{-1}$

23. A girl having mass of 35 kg sits on a trolley of mass 5 kg. The trolley is given an initial velocity of $4ms^{-1}$ by appling 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?

Thinking Process

To find the value of acceleration (a) by using third equation of motion i.e., $v^2 = u^2 + 2as$ and, then putting this value in w = mass to get required work.

Ans. Given, $u = 4m/s, v = 0$ and $s = 16m$

From the third equation of motion

[$\because$ for retardation, the acceleration is negative i.e., $a = -a$] $v^2 = u^2 - 2as$

$(0)^2 = (4)^2 - 2a \times 16$

$0 = 16 - 32a$

$a = \frac{16}{32} = 0.5ms^{-2}$

u = inital velocity, v = final velocity, a = acceleration and s == displacement

(a) Total mass = 35 + 5 = 40 kg

Work is done on the trolley $W = F \cdot d = mas$

$[\because F = ma]$

$= 40 \times 0.5 \times 16 = 320\text{J}$

(b) Mass of girl m= 35 kg

Work done by the girl

$W = F \cdot d = mas = 35 \times 0.5 \times 16 = 280\text{J}$

24. 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? [given = 10 ms^{-2}].

Ans. Given, m = 250 kg, height (h) = 1 m and acceleration due to gravity $g = 10ms^{-2}$

(a) Work done by the man in lifting the box

W = Potential energy of box

W = mgh

W = 250 x 1 x 10 = 2500 J

(b) Work done is zero in holding a box, because displacement is zero.

(c) In holding the box, the energy of man loses. Due to loss of energy he felt tired.

25. 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? $[g = 10ms^{-2}]$

Ans. (i) Power is defined as the rate of doing work or the rate of transfer of energy. The unit of power is watt or kilowatt. [1 kW= 10OOW]

(ii) Kilowatt is the unit of power while kilowatt hour is bigger unit of energy

kWh = 1000 x 3600 $\Rightarrow$ 1 kilowatt hour $= 3.6 \times 10^6\text{J}$

(iii) Given, mass of water = 2000 tonnes

$[\because 1\text{tonne} = 1000kg]$

$\therefore$ Mass of water $= 2000 \times 1000 = 2 \times 10^6 kg$

We know that, power $= \frac{\text{energy}}{\text{time}}$

$P = \frac{mgh}{t}$ $[\because energy = mgh]$

$P = \frac{2\times10^6 \times 10 \times 20}{60}$

[given, h = 20 m and g = 10 ms^{-2}]

$P = 6.67\times10^6$ W This power can be utilized.

26. 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 ms^{-1} vertically? $[g = 10 ms^{-2}]$

Ans. (i) The power delivered to a body can also expressed in term of the force F applied to the body and the velocity v of the body

$\text{Power}(P) = \frac{\text{work}}{\text{time}} \Rightarrow P = \frac{F\cdot s}{t}$

where F = Force, S = displacement and t = time P = F - v

$[\because W = F\cdot s]$

$\left(\because v\frac{s}{t}\right)$ [v = velocity of the body]

Given, power $(P) = 100W, v = 1ms^{-2}$ and $g = 10ms^{-2}$ We know that, power (P) = F.v

$\Rightarrow$ $P = mg.v$

$100 = mg\cdot v$ $[\because F = mg]$

$100 = m\times10\times1 \Rightarrow m = \frac{100}{10}$

$\Rightarrow$ $m = 10kg$

Therefore, man working at the power of 100 W can lift 10 kg.

27. 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 speed of 20 ms^{-1}?

Ans. (i) One watt is the power of a body which does work at the rate of 1 J/s.

$1watt = 1\frac{\text{joule}}{\text{second}}$

(ii) 1 kilowatt =1000 watt = 1000 J/s

(iii) Given, m =150 kg,

P = 500 W and v = 20 ms^{-1}

A car engine 150 kg develops 500 watt for each kg.

So, total power = 150 x 500 = 75000 W

We have, Power = Force x speed

75000 = Force x 20

Force, $F = \frac{75000}{20} = 3750N$

28. Compare the power at which each of the following is moving upwards against the force of gravity? [given, $g = 10ms^{-2}$]

(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 upon a tree at a rate of 0.5 ms^{-1} .

Thinking Process

Firstly we find the power by using the formula P = mg - v in both parts and then comparing both powers.

Ans. (i) Given, mass of butterfly $= 1.0g = \frac{1}{1000}kg$

$[\because 1kg = 1000g]$

$g = 10ms^{-2}$ and speed $= 0.5ms^{-1}$

Power = Force x Speed $[\because Force(f) = mg]$

P = mgv

$P = \frac{1}{1000}\times10\times0.5$

$\Rightarrow$ $P = \frac{1}{200}W$

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

$[\because 1kg = 1000g]$

and speed $= 0.5\text{ms}^{-1}$

$\therefore$ Power = Force x speed [Force, F = mg]

$P = mg\times v$

$P = \frac{250}{1000}\times10\times0.5 = \frac{250}{200}W$

$\therefore$ $P = \frac{250}{200}W$

Therefore, squirrel has more power than butterfly.

EXERCISE

Multiple Choice Questions

1. No work is done when

(a) a nail is plugged into a wooden board

(b) a box is pushed along a horizontal floor

(c) there is no component of force parallel to the direction of motion

(d) there is no component of force normal to the direction of force

2. 1 kW h is equal to

(a) 3.6 J (b) 3.6 KJ

(c) 3.6 MJ (d) 36 J

3. A body of mass 1 kg has a kinetic energy of

$1J$ when its speed is

(a) $0.45 ms^{-1}$ (b) $1\, ms^{-1}$

(c) $1.4 ms^{-1}$ (d) $4.4\, ms^{-1}$

4. The unit of work is joule. The other physical quantity that has same unit is

(a) Power (b) Velocity

(c) Energy (d) Force

5. In which case work is not done

(a) a girl swimming in a pond

(b) windmill lifting water from a well

(c) a standing man holding a suit case in his hand

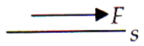
(d) a sail boat moving in the direction of wind.

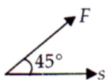
6. An electric motor creates a tension of 4500 N in hoisting a cable and reels it at a rate of $2m^{s-1}$. The power of the motor is

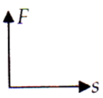
(a) 25 $25kW$ (b) $9kW$

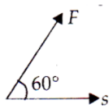
(c) $225kW$ (d) $90kW$

7. In which of the following cases is work done maximum

(a) 

(b) 

(c) 

(d) 

8. The work done by a weight of 1 kg mass when it moves up through 1 m is

(a) $10J$ (b) $-10J$

(c) $0.1J$ (d) $-0.1J$

9. A man carries a suitcase in his hand climbs up the stairs. The work done by the man is

(a) Positive (b) negative

(c) zero (d) none of the above

10. A total of 4900 joules were consumed in lifting a 50 kg mass. The mass was raised to a height of

(a) 10 m (b) 960 m

(c) 98 m (d) 245,000 m

11. The work done in holding 15 kg suitcase while waiting for a bus for 45 minutes is

(a) $675J$ (b) $40500J$

(c) $4500J$ (d) zero

12. If Rahul has done the same amount of work in less time compared to Rohan then

(a) Rahul has more power

(b) Rohan has more power

(c) both Rahul and Rohan have equal power

(d) Rahul has more energy than Rohan

13. Which of the following is not an example of potential energy?

(a) water stored in a dam

(b) a stretched bow and arrow system

(c) a dog chasing a hare

(d) a stone lying on the top of a roof

14. Chlorophyll in plants converts light energy into

(a) heat energy (b) chemical energy

(c) mechanical energy (d) electric energy

15. In a factory due to a sudden strike the work usually done in a day took a longer time. Then

(a) power increases (b) power decreases

(c) energy increases (d) energy decreases

16. When the momentum of a body is increased by 100%, its K.E. increases by

(a) 100% (b) 200%

(c) 300% (d) 400%

17. A person pulls a body on a horizontal surface by applying a force of 5.0 N at an angle of 30° with the horizontal. Find the work done by this force in displacing the body through 2.0 m.

(a) $5\sqrt{3}\ J$ (b) $6\sqrt{2}\ J$

(c) $7\sqrt{3}\ J$ (d) $4\sqrt{3}\ J$

18. A certain household consumes 250 units of electric energy in a month. The energy consumed in mega joule is

(a) $900MJ$ (b) $750KJ$

(c) $2250MJ$ (d) $1750KJ$

19. The power of a pump which takes 10 s to lift 100 kg of water tank situated at a height of 20 m is

(a) $2\times10^4 W$ (b) $2\times10^3 W$

(c) $200W$ (d) $1kW$

20. When the speed of a particle is doubled, the ratio of its kinetic energy to its momentum

(a) remains the same

(b) gets doubled

(c) becomes half

(d) becomes four times

21. When you compress a coil spring you do work on it. The elastic potential energy

(a) increases

(b) decreases

(c) disappears

(d) remains unchanged

22. An iron sphere of mass 30 kg has the same diameter as an aluminum sphere whose mass is 10.5 kg. The spheres are dropped simultaneously from a cliff. When they are 10 m from the ground, they have the same

(a) acceleration (b) momentum

(c) potential energy (d) kinetic energy

23. Two boys A and B lift 100 bricks through the same height in 5 minutes and 6 minutes respectively.
(a) A has more power than B
(b) B has more power than A
(c) both have same power
(d) none of the above

24. A rocket rises up vertically. What happens to its potential energy?
(a) it increases
(b) it initially increases then decreases
(c) it initially decreases then increases
(d) it increases, till it becomes maximum

25. 1 watt is equal to
(a) $J\,s^{-1}$ (b) $J\,s$
(c) $J\,s^{-2}$ (d) $N\,s^{-2}$

26. In an electric flashlight the chemical energy of the cell is
(a) converted into heat energy only
(b) converted into light energy only
(c) converted first into light and then heat energy
(d) converted first into heat and then light energy

27. The speed of a particle is doubled. Its kinetic energy
(a) remains the same
(b) becomes two times
(c) becomes half
(d) becomes four times

28. A body of mass 2 kg is projected vertically upwards with a speed of 3 ms^{-1}. The maximum gravitational potential energy of the body is
(a) $18J$ (b) $4.5J$
(c) $9J$ (d) $2.25J$

29. A student carries a bag weighing 5 kg from the ground floor to his class on the first floor that is 2 m high. The work done by the boy is
(a) $1J$ (b) $10J$
(c) $100J$ (d) $1000J$

30. An engine develops a power of 10 kW. How much time will it take to lift a mass of 200 kg to a height of 40 m? $(g = 10\,m s^{-2})$
(a) $4s$ (b) $5s$
(c) $8s$ (d) $10s$

31. When a force retards the motion of a body, The work done is
(a) positive (b) zero
(c) negative (d) undefined

32. The work done is zero if
(a) The body shows displacement in the opposite direction of the force applied.
(b) The body shows displacement in the same direction as that of the force applied.
(c) The body shows a displacement in perpendicular direction to the force applied.
(d) The body moves obliquely to the direction of the force applied.

33. A nail becomes hot when hammered in a plank
(a) the potential energy of hammer changes into heat energy
(b) the kinetic energy of the hammer changes into heat energy
(c) the force of friction changes into heat energy
(d) none of the above

34. What should be the angle between the force and displacement for maximum work?
(a) 0° (b) 30°
(c) 60° (d) 90°

35. Two bodies have their masses $m_1 / m_2 = 3$ and their kinetic energies $\frac{K.E_1}{K.E_2} = \frac{1}{3}$ The ratio their velocities are
(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 2 : 3

36. A locomotive exerts a force of 7500 N and Pulls a train by 1.5 km. The work done by the locomotive in mega joule is
(a) 12.25 MJ (b) 11.25 MJ
(c) 10.75 MJ (d) 11.50 MJ

37. An object of mass m is moving with a constant velocity v. The work done on the object to bring it to rest is
(a) $m\upsilon^2$ (b) $\frac{1}{2}m\upsilon^2$
(c) $m\upsilon$ (d) $\frac{m^2\upsilon}{2}$

38. If force and displacement of the particle (in direction of force) are doubled. Work should be
(a) doubled (b) 4 times
(c) halved (d) 1/4 times

39. Which of the following statements is correct regarding the relation between centripetal force and radius of the circular path?
(a) The work done by the centripetal force increases if the radius of the path is increased
(b) The work done by the centripetal force decreases by decreasing the radius
(c) The work done by the centripetal force increases by decreasing the radius

(d) The work done is always zero

40. A body rolls down on an inclined plane, it has
(a) only kinetic energy
(b) only potential energy
(c) both kinetic energy and potential energy
(d) neither kinetic energy nor potential energy

41. In which of the following case is the potential energy of a spring minimum?
(a) When it is compressed
(b) When it is extended
(c) When it is at its natural length
(d) When it is at its natural length but is kept at a height h above the ground

42. The work done by the weight of a 1 kg mass while it moves up through 1 m is
(a) $9.8J$ (b) $-9.8J$
(c) $\frac{1}{9.8}J$ (d) $-\frac{1}{9.8}J$

43. A photocell converts light energy into
(a) photon energy (b) electrical energy
(c) magnetic energy (d) heat energy

44. A particle of mass 100 g moves at a speed of $1ms^{-1}$. Its kinetic energy
(a) $50J$ (b) $5J$
(c) $0.5J$ (d) $0.05J$

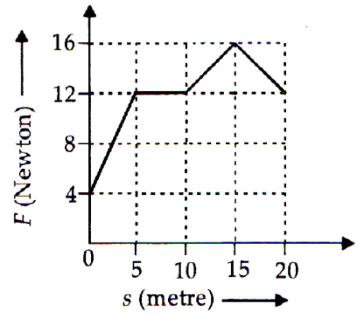
45. A uniform force of 4 N acts on a body of mass 8 kg for a distance of 2.0 m. The K.E. acquired by the body is
(a) $8J$ (b) $64J$
(c) $4J$ (d) $16J$

46. A car weighing 500 kg working against resistance of 500 N, accelerates from rest to $20m\ s^{-1}$ in 100 m.
(a) $1.0\times10^5 J$
(b) $1.5\times10^5 J$
(c) 1.05 x 105 $1.05\times10^5 J$ J
(d) Data is insufficient

47. A man of weight 60 kg wt. takes a body of Mass 15 kg at a height 10 m on a building in 3 minutes.
The efficiency of man is
(a) 10% (b) 20%
(c) 30% (d) 40%

48. A boy has four options to move a body through 3 m as indicated. In which case is maximum work done?
(a) Push over an inclined plane
(b) lift vertically upwards
(c) Push over smooth rollers
(d) Push on a plane horizontal surface

49. Figure shows the frictional force versus displacement for a particle in motion. The loss of kinetic energy (work done against friction) in travelling over $s=0$ to $s=20$ m will be



(a) $18J$ (b) $160J$
(c) $240J$ (d) $24J$

50. A boy pulls up a bucket of water from a well 80 m deep. If the mass of the bucket along with water is 20 kg, the amount of work done by he boy is
(a) 16, 0000 J (b) 20, 000 J
(c) 16,000 J (d) 20, 0000 J

51. Work done is always
(a) scalar quantity (b) vector quantity
(c) positive (d) negative

52. A hammer of mass 1 kg falls freely on a nail from a height of 1 m. The kinetic energy of hammer, just before hitting the nail is $[g=10ms^{-2}]$
(a) $1J$ (b) $5J$ (c) $10J$ (d) $4J$

53. An object of mass 1 kg has a potential energy of 1 joule relative to the ground when it is at a height of
(a) 0.102 m (b) 1 m
(c) 9.8 m (d) 32 m

54. A 1 kg mass has a kinetic energy of 1 joule when its speed is
(a) $0.45ms^{-1}$ (b) $1ms^{-1}$
(c) $1.4ms^{-1}$ (d) $4.4ms^{-1}$

55. A body is allowed to roll down a hill/ it will have
(a) only K.E. (b) only RE
(c) both (a) and (b) (d) data is insufficient

56. An object of mass 40 kg is raised to a height of 8 m above the ground. The gain in potential energy by the object $(g=10ms^{-2})$
(a) $200J$ (b) $3200J$
(c) $1500J$ (d) $1000J$

57. The speed of a motor bike decreases by 4 times Its kinetic energy will decrease by
(a) four times (b) eight times
(c) sixteen times (d) thirty two times

58. Energy possessed by a body on account of its motion is called
(a) mechanical energy (b) potential energy
(c) kinetic energy (d) magnetic energy

59. A stone is placed on the .top of a building of height h. Its potential energy is directly proportional to its
(a) mass
(b) height
(c) acceleration due to gravity
(d) all the above

60. When the speed of a particle is increased 3 times, its kinetic energy
(a) increases 3 times (b) remains same
(c) increases 9 times (d) decreases to 1/3

61. In which case work is done
(a) a green plant carrying out photosynthesis
(b) a porter standing at a place and carry heavy load on his head
(c) drying of food grains in sun
(d) a trolley rolling down a slope

62. The work done by an electric drill rated 50 W in 30 s is
(a) $1200\,J$ (b) $600\,J$
(c) $900\,J$ (d) $1500\,J$

63. A stone is thrown up vertically. What happens to its P.E. during its motion during its upward journey?
(a) Decreases
(b) Increase till it becomes maximum
(c) First decreases and then increases
(d) First increases and then decreases

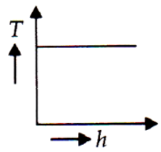
64. A body falling from a height of 10 m rebounds from a hard floor. It loses 20% of energy in the impact. What is the height to which it would rise after the impact?
(a) $7m$ (b) $5m$
(c) $8m$ (d) $6m$

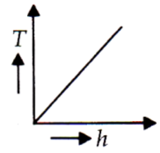
65. A lorry and a car with the same kinetic energy are brought to rest by the application of brakes which provide equal retarding forces. Which of them will come to rest in a shorter distance?
(a) Lorry (b) Car
(c) Both will stop at the same distance
(d) None of these

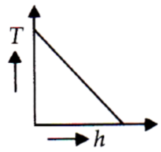
66. The units N s are equivalent to
(a) J (b) $kg\,m\,s^{-1}$
(c) $kg\,m\,s^{-2}$ (d) $N\,m\,s^{-1}$

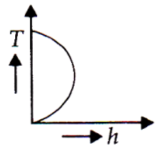
67. One kilowatt is approximately equal to
(a) 1.30 h.p (b) 1.56 h.p
(c) 2.50 h.p (d) 1.83 h.p

68. Which of the following graph best represents the total energy (T) of a freely falling body and its height (h) above the ground?

(a) 

(b) 

(c) 

(d) 

69. Watt sec represents the unit of
(a) energy (b) power
(c) force (d) none of these

70. When the time taken to complete a given amount of work increases, then
(a) power increases
(b) energy increases
(c) power decreases
(d) energy decreases

71. The momentum of a body is doubled. What is the percentage increase in kinetic energy?
(a) 500% (b) 300%
(c) 200% (d) 600%

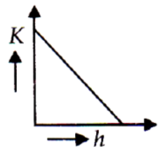
72. In a hydroelectric dam the potential energy of water directly changes to
(a) electric energy only
(b) kinetic energy only
(c) first kinetic energy and then electric energy
(d) first electric energy and then kinetic energy

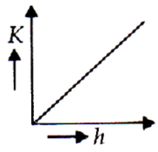
73. If a body is raised through height h on the surface of earth and the energy spent is E, then for the same amount of energy the body on the' surface of moon will rise through the height of
(a) $2h$ (b) $6h$
(c) $4h$ (d) $12h$

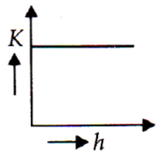
74. Asha lift a doll from the floor and places it on a table. If the weight of the doll is known, what else does one need to know in order to calculate the work Asha has done on the doll?
(a) The time required (b) Mass of the ball
(c) Height of the table
(d) Cost of the doll or the table

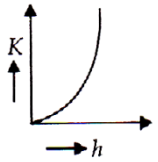
75. The moon revolves around the earth because the earth exerts a radial force on the moon. Does the earth perform work on the moon?
(a) No
(b) Yes, always
(c) Yes, sometimes
(d) cannot be decided

76. Which of the following graph best represents the kinetic energy (K.E) of a freely falling body and its height h above the ground?

(a) 

(b) 

(c) 

(d) 

77. One joule work is said to be done when a force of one Newton acts through a distance of

(a) $1cm$ (b) $1mm$
(c) $1m$ (d) $1km$

78. A rocket rises up in the air due to the force generated by the fuel. The work done by the

(a) fuel is negative work and that of force of gravity is positive work
(b) fuel is positive work and that of force of gravity is negative work
(c) both fuel and force of gravity do positive work
(d) both fuel and force of gravity do negative work.

79. A ball is thrown upward from a point, reaches to the highest point Q

(a) kinetic energy at P is equal to kinetic energy Q
(b) potential energy at P is equal to kinetic energy at Q
(c) kinetic energy at P equal to potential energy at Q
(d) potential energy at P is equal to potential energy at Q

80. A boy lifts a book of known weight from the surface of a table and then keeps it back. To calculate the work done, he needs to know

(a) the mass of the book
(b) the height
(c) the cost of the book
(d) the time taken by him

81. A steam engine has an efficiency of 20%. It is given an energy of 1000 cal. per minute. What is the actual work done by it in joule and in calories?

(a) $100cal, 800J$ (b) $200cal, 873J$
(c) $10cal, 80J$ (d) $100cal, 100J$

82. A stretched spring possesses

(a) kinetic energy
(b) elastic potential energy
(c) electrical energy
(d) magnetic energy

83. The mass of a ball A is twice the mass of another ball B. The ball A moves at half the speed of the ball B. The ratio of the kinetic energy of A to that of B is

(a) $\frac{3}{2}$ (b) $\frac{1}{2}$
(c) $\frac{5}{2}$ (d) $\frac{4}{2}$

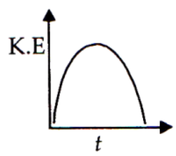
84. The kinetic energy of an object of mass m, moving with a velocity of $5ms^{-1}$ is $25J$. If the velocity is increased by three times, the kinetic energy is

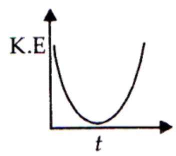
(a) $100J$ (b) $225J$
(c) $400J$ (d) $180J$

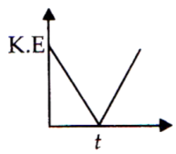
85. A rocket of mass $3\times10^{6}\,kg$ takes off from a launching pad and acquires a vertical velocity of 1 kms^{-1} at an altitude of 25 km. The potential energy of the rocket is $(g=10ms^{-2})$

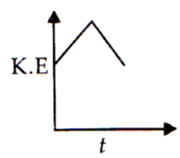
(a) $7.5\times10^{11}J$
(b) $2.5\times10^{11}J$
(c) $7.5\times10^{10}J$
(d) $5.5\times10^{11}J$

86. A cricket ball is projected vertically upward such that it returns back to the thrower. The Variation in kinetic energy with time is best represented by

(a) 

(b) 

(c) 

(d) 

87. The work done by a body is directly proportional to

(a) force acting on the body
(b) displacement produced in the body
(c) mass of the body
(d) both (a) and (b)

88. A large box is taken to a height of 8 m, when energy spent is $64,000J$. The mass of the box is $(g=10ms^{-2})$

(a) 400 kg (b) 800 kg
(c) 700 kg (d) 1600 kg

89. Which one of the following is not the measure of energy
(a) $kW\,h$ (b) erg
(c) $W\,s$ (d) $J\,s$

90. An aeroplane flying at a height of 20,000 m at a speed of 300 km h^{-1} has
(a) only potential energy
(b) only kinetic energy
(c) both, potential and kinetic energy
(d) none of the above

FILL IN THE BLANKS

1. A stone is tied to a string and whirled in a circular path. The work done by the stone is
2. When a torch is switched on, the............ energy of the batteries is converted into heat energy and then light energy.
3. Water stored in an overhead tank possesses .... energy.
4. The negative work means that the............. opposes the motion of the body.
5. When a body moves in a circular path, work done on it is ....
6. Kilowatt hour is the unit of.............
7. Power is a............. quantity.
8. 1 hp is equal to............. kW.
9. A body can have.............without momentum.
10. 1 kg mass has a K.E. of 1 J when its speed is
11. Efficiency is the ratio of output power to the
12. 1 erg is............. joule.
13. Heat energy is present in a body in the form of............. of constituent particles.
14. A compressed spring has............. potential energy than the potential energy which it has at the natural length.
15. Chemical energy of petrol or diesel is transformed in to .... energy to run automobiles.
16. If velocity of a body is twice of previous velocity, then kinetic energy will become .... times.
17. If the K.E. of a body is increased by 300%, its momentum will increase by ....
18. If the angle between force F and displacement is 60°, then the work done is .... If you apply 1 J of energy to lift a book 0.5 kg, it will rise up to .... m

TRUE OR FALSE

1. When a body falls, its kinetic energy remains constant.
2. Work and energy have different units.
3. The potential energy of a spring increases when it is extended and decreases when it is compressed.
4. When negative work is done by external forces on a system, the energy of the system decreases.
5. When an aeroplane takes off, the work done by its weight is positive.
6. In an electromagnet, electric energy changes in to magnetic energy.
7. One kilowatt hour is commonly referred as one unit of electricity.
8. Kinetic energy is the energy possessed by a body by virtue of its position.
9. A rubber band has more potential energy when wrapped around a packet than when it was lying unused.
10. Energy can neither be created, nor be transferred.
11. A force does no work, if it produces no motion.
12. The unit of work is watt.
13. When a body falls on the ground and stops, The principle of conservation of energy is violated.
14. Energy stored in the spring of a watch is Kinetic energy.
15. Work done by centripetal force is zero.
16. When an arrow is released from a bow, potential energy changes in the kinetic energy.
17. In order to get maximum work, the angle between force and displacement should be 90°.
18. Work done by a force depends upon how fast work is done.

Matrix Match Type

In this section each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in Column-I have to be matched with statements (p, a, r, s) in Column-II.

1. **Column-I** **Column-II**

Column-I	Column-II
(A) Kinetic energy	(p) mgh
(B) Power	(q) $\frac{1}{2}m\upsilon^2$
(C) Potential energy	(r) $m\upsilon$
(D) Momentum	(s) W/t

2. **Column-I** **Column-II**

Column-I	Column-II
(A) Potential energy to sound energy	(p) A cracker bursts
(B) Chemical energy to heat, light and sound energy	(q) A duster falling from a table.
(C) Kinetic energy to sound energy shaken.	(r) A container filled with marbles is
(D) Kinetic energy to heat energy	(s) Rubbing of hands

3. **Column-I** **Column-II**

Column-I	Column-II
(A) Joule	(p) Power
(B) Watt	(q) 1 h.p
(C) $1KWh$	(r) Energy
(D) $746W$	(s) $3.6\times10^6 J$

4. **Column-I** **Column-II**

Column-I	Column-II
(A) Mass of 1 kg, pulled through 1 m horizontally, force applied 8 N	(p) Work done $=0$
(B) Suitcase on head, person moves upstairs	(q)Workdone$=mgh\,J$
(C) No component of force in the direction of motion	(r) $Fs\cos\theta$
(D) Work done	(s) Work done$=8]$

5. **Column I** **Column II**

Column I	Column II
(A) Force	(p) $kg\,m^2s^{-2}$
(B) Work	(q) $kg\,m\,s^{-2}$
(C) Momentum	(r) $kg\,m^2s^{-3}$
(D) Power	(s) $kg\,m\,s^{-2}$

ASSERTION & REASON QUESTIONS

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as

(a) If both assertion and reason are true and reason is the correct explanation of assertion

(b) If both assertion and reason are true but reason is not the correct explanation of assertion

(c) If assertion is true but reason is false

(d) If assertion is false but reason is true.

1. **Assertion:** A crane P lifts a car up to a certain height in 1 min. Another crane Q lifts the same car up to the same height in 2 min. Then crane P consumes two times more fuel than crane Q.

   Reason: Crane P supplies two times more power than crane Q.

2. **Assertion:** The kinetic energy, with any reference, must be positive.

   Reason: It is because, in the expression for kinetic energy, the velocity appears with power 2 and mass is a scalar quantity.

3. **Assertion:** The rate of doing work is called power.

   Reason: Power is a scalar quantity.

4. **Assertion:** Two bodies of equal masses moves with the uniform velocities υ and 3υ respectively.

   Reason: The ratio of their kinetic energy be 1 : 4.

5. **Assertion:** Work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed between the two points.

   Reason: Gravitational forces are conservative forces.

6. **Assertion:** According to law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy.

   Reason: Mechanical energy is not a conserved quantity.

7. **Assertion:** The kinetic energy of a body is quadrupled, when its velocity is doubled.

   Reason: Kinetic energy is proportional to square of velocity.

8. **Assertion:** Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.

   Reason: Potential energy of a stretched or compressed spring, is directly proportional to square of extension or compression.

9. **Assertion:** The work done during a round trip is always zero.

   Reason: No force is required to move a body in its round trip.

10. **Assertion:** The change in kinetic energy of a particle is equal to the work done on it by the net force.

    Reason: Change in kinetic energy of particle is equal to the work done only in case of a system of one particle.

11. **Assertion:** Soft steel can be made red hot by continued hammering on it, but hard steel cannot.
Reason: Energy transfer in case of soft Iron is large as in hard steel.

12. **Assertion:** When the force retards the motion of a body, the work done is zero.
Reason: Work done depends on angle between force and displacement.

13. **Assertion:** The power of a pump which raises 100 kg of water in 10 sec to a height of 100 m is 10 kW.
Reason: The practical unit of power is horse power.

14. **Assertion:** A light body and heavy body have same momentum. Then they also have same kinetic energy.
Reason: Kinetic energy depend on mass of the body.

15. **Assertion:** A spring has potential energy, both when it is compressed or stretched.
Reason: In compressing or stretching, work is done on the spring against the restoring force.

PASSAGE

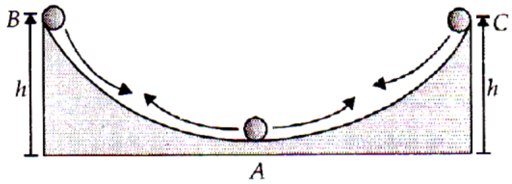
PASSAGE 1: An elevator weighing 500 kg is to be lifted up at a constant velocity of $0.4 ms^{-1}$. For this purpose a motor of required horse power is used.

1. The power of motor is
(a) 1940 W (b) 1950 W
(c) 1960 W (d) 1970 W
2. The acceleration of elevator in case of upward motion is
(a) $9.8 ms^{-2}$ (b) $-9.8 ms^{-2}$
(c) $8.9 ms^{-2}$ (d) $-8.9 ms^{-2}$
3. The power of motor in h.p. is
(a) 2.33 (b) 2.43
(c) 2.53 (d) 2.63

PASSAGE 2: A force is said to be non- conservative if work done by or against the force in moving a body from one position to another, depends on the path followed between these two positions.

1. Which among the following is not a non-conservative force
(a) frictional force (b) induction force
(c) gravitational force (d) none of the above
2. If a body is moved from a position A to Another position B on a rough table, work done against frictional force depends on
(a) position of A and B
(b) length of path between A and B
(c) both (a) and (b)
(d) none of these

PASSAGE 3: Figure shows a watch glass embedded in clay. A tiny spherical ball is placed at the edge B at a height h above the centre A.



1. The kinetic energy of ball, when it reaches at point is
(a) zero (b) maximum
(c) minimum (d) can't say
2. The ball comes to rest because of
(a) frictional force (b) gravitational force
(c) both (a) and (b) (d) none of these
3. The energy possessed by ball at point C is
(a) potential energy (b) kinetic energy
(c) both potential and kinetic energy
(d) heat energy

SUBJECTIVE PROBLEMS

VERY SHORT ANSWER TYPE QUESTIONS

1. Define 1 joule of work.
2. When a body falls freely, its potential energy is converted into kinetic energy. But when the freely falling body reaches the ground, it comes to rest. What happens to the kinetic energy of the body when it stops on reaching the ground?
3. Name two types of potential energy.
4. A student makes the following statement: "The acceleration in an object can be zero even when several forces are acting on the object." Do you agree with the statement? If yes, why?
5. Convert 1 kW h into joules.
6. What is gravitational potential energy?
7. In a tug of war, one team wins and the other team loses. Which team does positive work and which one does negative work? Justify your answer.
8. Aman does 60 J of work in 6 seconds. Calculate the power

9. What is the commercial unit of energy? Define it.

10. When an arrow is released from a stretched bow and arrow, the arrow moves in air. From where the arrow receives kinetic energy?

11. The kinetic energy of a body is 10 J. What will be its new kinetic energy when its speed becomes double?

12. Draw a graph showing the variation of kinetic energy, potential energy and total energy during the motion of a freely falling body.

13. Mention a situation in which an object gets displaced in the absence of a force acting on it.

14. How is energy transferred in the following cases?
(a) When a rubber band is stretched.
(b) When a stretched rubber band is released.

15. A boy and a girl do the same work in 5 minutes and 10 minutes respectively. Which of these two has more power and why?

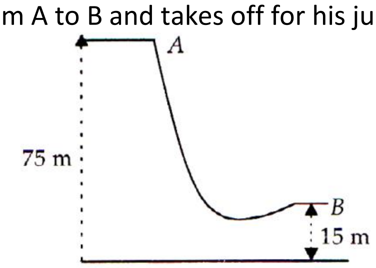
SHORT ANSWER TYPE QUESTIONS

1. The mass of body A is less than that of body both the bodies have equal momentum. Which of the two will have more kinetic energy?

2. A force acts on a body of mass 10 kg. If the velocity of the body change from $5\,ms^{-1}$ to $3\,ms^{-1}$, then what is the work done by the force on the body?

3. What should be the power of an engine required to lift 90 metric tonnes of coal per hour from a mine whose depth is 200 m?

4. The diagram given below shows a ski jump. A skier weighing 60 kg f stands at A. He moves from A to B and takes off for his jump at B.



(a) Calculate the change in the gravitational potential energy of the skier between A and B.
(b) If 75% of the energy in part (a) becomes kinetic energy at B, calculate the speed at which the skier arrives at B.

5. When a constant force is applied to a body moving with constant acceleration, is the power of the force constant? If not, how would force have to vary with speed for the power to be constant?

6. A nail becomes warm when it is hammered into a plank. Explain why?

7. Ram weighs 40 kg and takes 60 seconds to climb a hill 50 m high. Shyam also weighs 40 kg and takes 50 seconds to climb the same hill. Who is more powerful? (g = 10 m s^{-2}).

8. Calculate the work done in lifting 200 kg of water through a vertical height of 6 metres (Assume $g = 10\,ms^{-2}$)

9. A child pulls a toy car through a distance of 10 metres on a horizontal floor. The string Held in child's hand makes an angle of 60° with the horizontal surface. If the force applied by the child be 10 N, calculate the work done by the child in pulling the toy car.

10. Relation between position and time of a Particle under a constant force is given as $x = (t-3)^2$ where x is in meter and t is in sec. Find out work done by force in first 6 seconds.

11. A car of mass 1200 kg travelling at 72 km hr^{-1} is brought to rest in 80 metres. Find the average braking force on the car. What has happened to the original kinetic energy?

12. An electric lamp of 100 W is used for 5 hours per day. Calculate the units of energy consumed by lamp in one day.

13. A body of mass 10 kg is kept at a height 10 m from the ground, when it is released, after sometime its kinetic energy becomes 450 joule. What be the potential energy of the body at that instant.

14. A pump is required to lift 1000 kg of water per minute from a well 12 m deep and eject it with a speed of 20 m s^{-1}. How much work is done per minute in lifting the water and what must be, the power output of the pump?

15. A pendulum, swimming back and forth, rises at the end of its swing to a position 15 cm higher than its lowest point. How fast is it going at the lowest point?

LONG ANSWER TYPE QUESTIONS

1. A mass 10 kg is released from a height of 40 m above the surface of the earth. Calculate its mechanical energy when it is at 20 m, above the surface of the earth. (Take $g = 10\,ms^{-2}$)

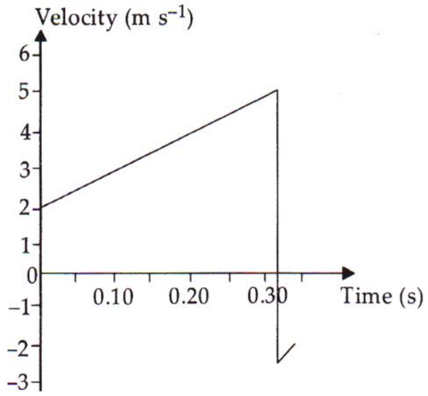
2. A body A of mass 3.0 kg and a body B of mass 10 kg are dropped simultaneously from a height of 14.9 m. Calculate (a) their moment, (b) their potential energies, and (c) their kinetic energies when they are 10 m above the ground.

3. A truck and a car having equal kinetic energies are stopped by applying equal retarding forces. What is the relation of distances covered by them before stopping.

4. If an electric bulb of 100 watt is lighted for 2 hours daily, how much electrical energy would be consumed per day? Also find the cost if cost per unit is Rs. 2.

5. A running man has half the kinetic energy that a boy of half his mass has. The man speeds up by $10 m s^{-2}$ and then has the same kinetic energy as the boy. What were the original speeds of the man and boy?

6. A ball is thrown down from a certain height and allowed to fall downward. Figure shows how the velocity of the ball varies with time t. Air resistance may be ignored. The ball has mass 0.23 kg and leaves the thrower's hand at $t = 0$. It hits the ground at $t = 0.320 s$ and rebounds with 50% of the Speed with which it hit the ground.



(a) State the maximum velocity of the ball.
(b) how that the acceleration of free fall is $10 m s^{-2}$.
(c) Determine the velocity of the ball just after it rebounds.
(d) Calculate the loss of kinetic energy of the ball as it hits the ground and rebounds.

7. A block of 20 kg mass is pulled up a slope by, applying a force acting parallel to the slope. If the slope makes an angle of 30° with the horizontal, calculate the work done in pulling the load up a distance of 3.0 m. What is the increase in potential energy of the block? Assume that the force of friction is zero- Take $g = 10 N kg^{-1}$.

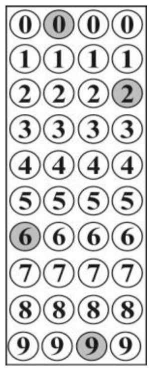
8. A bullet moving with a velocity of $300 m s^{-1}$ is just able to pierce a block of wood 2.0 cm thick. What would be its velocity if it is required to pierce a block of wood (same type) 18 cm thick?

9. The heart does 1.5 J of work in each heart beat. How many times per minute does it beat if its power is 2 W?

10. How much work should be done on a bicycle of mass 20 kg to increase its speed from $2 m s^{-1}$ to $55 m s^{-1}$? (Ignore air resistance and friction).

INTEGER ANSWER TYPE

This section contains 5 questions.
The answer to each of the questions is a single digit integer, ranging from 0 to9.
If the correct answers to question numbers X, Y, Z and W (say) are 6, 0, 9 and 2 respectively, then the correct darkening of bubbles will look like the following.



2. A bullet is fired normally on an immovable wooden plank. It loses 25% of its momentum in penetrating a thickness of 3.5 cm. Find the total thickness penetrated by the bullet.

3. An engine develops 10 kW of power. How much time will it take to lift a mass of 200 kg to a height of 40 m $(g = 10 m s^{-2})$

4. A block of mass 2 kg collides with a horizontal massless spring of force constant $2 M m^{-1}$. The block compresses the spring 4 m from the rest position. What is the speed of the block at the instant of collision?

5. A bullet loses $\frac{1^{th}}{10}$ of its speed in passing through a wooden plank. Find the least number of such planks required to stop the bullet.

6. A wooden block of mass 0.9 kg is suspended from the ceiling of a room by thin wires. A bullet of mass 0.1 kg moving horizontally with a speed of $100\,ms^{-1}$ strikes the block and sticks to it. What is the height to which the block rises? (Take g $g = 10\,ms^{-2}$)

ANSWER – KEY

Multiple Choice Questions

1. C	**2.** C	**3.** C	**4.** C	**5.** C	**6.** B	**7.** A
8. B	**9.** A	**10.** A	**11.** D	**12.** A	**13.** C	**14.** B
15. B	**16.** C	**17.** A	**18.** A	**19.** B	**20.** B	**21.** A
22. A	**23.** A	**24.** D	**25.** A	**26.** D	**27.** D	**28.** C
29. C	**30.** C	**31.** C	**32.** C	**33.** B	**34.** A	**35.** C
36. B	**37.** B	**38.** B	**39.** D	**40.** C	**41.** C	**42.** B
43. B	**44.** D	**45.** A	**46.** B	**47.** B	**48.** B	**49.** C
50. C	**51.** A	**52.** C	**53.** A	**54.** C	**55.** C	**56.** B
57. C	**58.** C	**59.** D	**60.** C	**61.** D	**62.** D	**63.** B
64. C	**65.** C	**66.** B	**67.** A	**68.** A	**69.** A	**70.** B
71. B	**72.** C	**73.** B	**74.** C	**75.** A	**76.** B	**77.** C
78. B	**79.** C	**80.** B	**81.** B	**82.** B	**83.** B	**84.** B
85. A	**86.** C	**87.** D	**88.** B	**89.** D	**90.** C	

Fill in the Blanks

1. Zero	**2.** Chemical
3. Potential	**4.** Force
5. Zero	**6.** Energy
7. Scalar	**8.** 0.746
9. Energy	**10.** 1.4 m s^{-1}
11. Input power	**12.** 10^{-7}
13. Kinetic Energy	**14.** More
15. Mechanical	**16.** 4
17. 100%	**18.** $\frac{Fs}{2}$
19. 0.2	

True or False

1. False	**2.** False
3. False	**4.** True
5. False	**6.** True
7. True	**8.** False
9. True	**10.** False
11. True	**12.** False
13. False	**14.** False
15. True	**16.** True
17. False	**18.** False

Matrix Match Type

1. A→q; B→s; C→p; D→r
2. A→q; B→p; C→r; D→s
3. A→r; B→p; C→s; D→q
4. A→s; B→q; C→p; D→r
5. A→s; B→p; C→q; D→r

Assertion and Reason Type

1. A	**2.** A	**3.** B	**4.** C	**5.** A	**6.** C	**7.** A
8. D	**9.** C	**10.** C	**11.** C	**12.** D	**13.** B	**14.** D
15. A						

Passage Comprehension

Passage : 1

1. C	**2.** B	**3.** D

Passage : 2

1. C	**2.** C

Passage : 3

1. B	**2.** A	**3.** A

Integer Answer Type

1. 8	**2.** 8	**3.** 4	**4.** 5	**5.** 5