WORK, POWER & ENERGY

CONTENTS

Work

◈ **Defination :** In our daily life "work" implies an activity resulting in muscular or mental exertion. However, in physics the term 'work' is used in a specific sense involves the displacement of a particle or body under the action of a force. If under the action of a force $\vec{F}$ particle or body is displace by $\vec{S}$. The scalar product of force with displacement is defined as work. Work is a scalar quantity.

$$W = \vec{F}.\vec{S} = FS \cos \theta$$

◆ Another definition of "work is said to be done when the point of application of a force moves. Work done in moving a body is equal to the product of force exerted on the body and the distance moved by the body in the direction of force.

Work = Force × Distance moved in the direction of force.

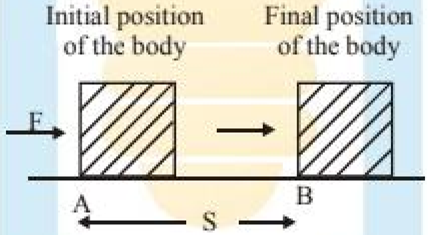
◆ The work done by a force on a body depends on two factors :

(i) Magnitude of the force, and

(ii) Distance through which the body moves (in the direction of force)

◈ **Unit of Work**

When a force of 1 newton moves a body through a distance of 1 metre in its own direction, then the work done is known as 1 joule.



Work = Force × Displacement

1 joule = 1 N × 1 m

or 1 J= 1 Nm (In SI unit)

1 erg= 1 dyne × 1 cm (In CGS unit)

Relationship between joule and erg

1 joule= 1 N × 1 m

= 10^5 dynes × 100 cm

($\because$ 1N = 10^5 dynes, 1 m = 100 cm)

1 joule= 10^7 dynes × cm = 10^7 erg

1 joule= 10^7 erg

Ex.1 How much work is done by a force of 10N in moving an object through a distance of 1 m in the direction of the force ?

Sol. The work done is calculated by using the formula :

$$W = F \times S$$

Here, Force, $F = 10\ N$

And,Distance, $S = 1\ m$

So, Work done, $W = 10 \times 1\ J$

$= 10\ J$

Thus, the work done is 10 joules

Ex.2 Find the work done by a force of 10 N in moving an object through a distance of 2 m.

Sol. Work done= Force × Distance moved

Here, Force = 10 N

Distance moved = 2 m

Work done, $W = 10\ N \times 2\ m$

$= 20$ Joule $= 20\ J$

Work Done Analysis

◈ **Work done when force and displacement are along same line.**

- **Work done by a force :** Work is said to be done by a force if the direction of displacement is the same as the direction of the applied force.
- **Work done against the force :** Work is said to be done against a force if the direction of the displacement is opposite to that of the force.
- **Work done against Gravity :** To lift an object, an applied force has to be equal and opposite to the force of gravity acting on the object. If 'm' is the mass of the object and 'h' is the height through which it is raised, then the upward force

(F) = force of gravity = mg

If 'W' stands for work done, then

$$W = F\ .\ h = mg\ .\ h$$

Thus $W = mgh$

Therefore we can say that, "The amount of work done is equal to the product of weight of the body and the vertical distance through which the body is lifted.

Ex.3 Calculate the work done in pushing a cart, through a distance of 100 m against the force of friction equal to 120 N.

Sol. Force, $F = 120\ N$; Distance, $s = 100\ m$

Using the formula, we have

$$W = Fs = 120\ N \times 100\ m = 12{,}000\ J$$

Ex.4 A body of mass 5 kg is displaced through a distance of 4m under an acceleration of 3 m/s^2. Calculate the work done.

Sol. Given :mass, $m = 5\ kg$

acceleration, $a = 3\ m/s^2$

Force acting on the body is given by

$$F = ma = 5 \times 3 = 15\ N$$

Now, work done is given by

$$W = Fs = 15\ N \times 4\ m = 60\ J$$

Ex.5 Calculate the work done in raising a bucket full of water and weighing 200 kg through a height of 5 m. (Take $g = 9.8\ ms^{-2}$).

Sol. Force of gravity

$mg = 200 \times 9.8 = 1960.0\ N$

$h = 5\ m$

Work done, $W = mgh$

or $W = 1960 \times 5 = 9800\ J$

Ex.6 Calculate the work done in lifting 200 kg of water through a vertical height of 6 metres (Assume $g = 10\ m/s^2$)

Sol. In this case work is being done against gravity in lifting water. Now, the formula for calculating the work done against gravity is:

$W = m \times g \times h$

Here, Mass of water, $m = 200$ kg

Acceleration due to gravity, $g = 10\ m/s^2$

And, Height, $h = 6$ m

Now, putting these values in the above formula, we get :

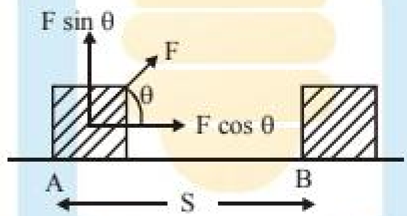
$W = 200 \times 10 \times 6$

$W = 12000\ J$

Thus, the work done is 12000 joules.

◈ **Work done when force and displacement are inclined (Oblique case)**

Consider a force 'F' acting at angle θ to the direction of displacement 's' as shown in fig.

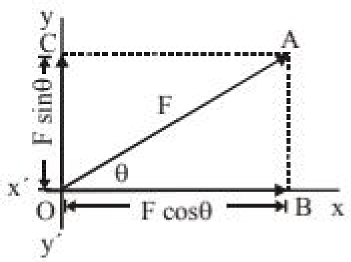


Work done = (component of the force along the direction of motion) × (distance moved)

For this we have to first find the component of the applied force along the direction of the displacement.

◈ **Resolution of a force into two mutually perpendicular components :**

Magnitudes of the Components



◆ Along x-axis :

$$\cos\theta = \frac{\text{base}}{\text{hypotenuse}} = \frac{OB}{OA}$$

$\therefore$ $OB = OA \cos\theta = F.\cos\theta$

$F_x = F\cos\theta$

- Along y-axis :

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{AB}{OA} = \frac{OC}{OA} \; (\because OC = AB)$$

$\therefore$ $OC = OA \,.\, \sin\theta = F\sin\theta$

$F_y = F\sin\theta$

- Work done when force is perpendicular to Displacement

$\theta = 90^\circ$

$W = F.S \times \cos 90^\circ = F.S \times 0 = 0$

Thus no work is done when a force acts at right angle to the displacement.

Special Examples :

- When a bob attached to a string is whirled along a circular horizontal path, the force acting on the bob acts towards the centre of the circle and is called as the centripetal force. Since the bob is always displaced perpendicular to this force, thus no work is done in this case.
- Earth revolves around the sun. A satellite moves around the earth. In all these cases, the direction of displacement is always perpendicular to the direction of force (centripetal force) and hence no work is done.
- A person walking on a road with a load on his head actually does no work because the weight of the load (force of gravity) acts vertically downwards, while the motion is horizontal that is perpendicular to the direction of force resulting in no work done. Here, one can ask that if no work is done, then why the person gets tired. It is because the person has to do work in moving his muscles or to work against friction and air resistance.

Important Point :

Work can be positive or negative as θ is acute ($< 90^\circ$) or obtuse ($> 90^\circ$). Positive work means that force (or its component) is parallel to displacement while negative works means that force (or its component) is opposite to displacement . Thus

- When a person lifts a body from the ground, the work done by the (upward) lifting force is positive, but the work done by the (downward) force of gravity is negative.
- Also when a body is pulled on a fixed rough surface, the work done by the pulling force is positive while by frictional force (kinetic) is negative as pulling force is always in the direction while frictional force is opposite to displacement.

Ex.7 A boy pulls a toy cart with a force of 100 N by a string which makes an angle of 60° with the horizontal so as to move the toy cart by a distance horizontally. Calculate the work done.

Sol. GivenF = 100 N, s = 3 m, $\theta = 60^\circ$.

Work done is given by

$W = Fs\cos\theta = 100 \times 2 \times \cos 60^\circ$

$= 100 \times 3 \times \frac{1}{2} = 150 \text{ J} \; (\because \cos 60^\circ = \frac{1}{2})$

Ex.8 An engine does 64,000 J of work by exerting a force of 8,000 N. Calculate the displacement in the direction of force.

Sol. Given W = 64,000 J; F = 8,000 N

Work done is given by W = Fs

or 64000 = 8000 × s

or s = 8 m

Power

◈ **Defination :** Power is defined as the rate of doing work

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \qquad P = \frac{W}{t}$$

In other words, power is the work done per unit time, power is a scalar quantity.

Since W = F.S therefore

$$P = \frac{W}{t} = \frac{F.S}{t} = F \times V = \text{force} \times \text{velocity}$$

◈ **Unit of power :** The S.I. unit of power is watt and it is the rate of doing work at 1 joule per second.

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

1 kilowatt = 1 kW = 1000 W

1 Horse power = 1 H.P. = 746 W

Ex.9 A machine raises a load of 750 N through a height of 15 m in 5s. Calculate :

(i) the work done by the machine.

(ii) the power at which the machine works.

Sol. (i) Work done is given by W = F.s

Here F = 750 N; s = 15 m

∴ W = 750 × 15 = 11250 J

= 11.250 kJ

(ii) Now, power of the machine is given by

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

Heren W = 11250 J; t = 5 s

$$\therefore \text{ Power } P = \frac{11250\text{ J}}{5\text{ s}} = 2250 \text{ W} = 2.250 \text{ kW}$$

Ex.10 A weight lifter lifted a load of 100 kg to a height of 3 m in 10 s. Calculate the following:

(i) amount of work done

(ii) power developed by him

Sol. (i) Work done is given by

W = F . s

Here, F = mg = 100 × 10 = 1000 N

W = 1000 N × 3 m = 3000 joule

(ii) Now, $P = \frac{W}{t}$, where W = 3000 J and t = 10 s

$$\therefore P = \frac{3000\text{ J}}{10\text{ s}} = 300 \text{ W}$$

Ex.11 A water pump raises 60 liters of water through a height of 20 m in 5 s. Calculate the power of the pump. (Given: $g = 10\ m/s^2$, density of water = $1000\ kg/m^3$)

Sol. Work done, $W = F.s$ ...(1)

Here, $F = mg$ ...(2)

But,Mass = volume × density

Volume = 60 liters = $60 \times 10^{-3}\ m^3$

Density = $1000\ kg/m^3$

$\therefore$ Mass , $m = (60 \times 10^{-3}\ m^3) \times (1000\ kg/m^3) = 60\ kg$

$\therefore$ Equation (2) becomes

$F = 60\ kg \times 10\ m/s^2 = 600\ N$

Now, $W = F\ .\ s = 600\ N \times 20\ m = 12000\ J$ $\therefore$ Power $= \frac{W}{t} = \frac{12000\ J}{5\ s} = 2400\ W$

Ex.12 A woman pulls a bucket of water of total mass 5 kg from a well which is 10 m deep in 10 s. Calculate the power used by her.

Sol. Given that m = 5 kg; h = 10 m; t = 10 s

$g = 10\ m/s^2$

Now,$P = \frac{W}{t} = \frac{mgh}{t} = \frac{5 \times 10 \times 10}{10} = 50W$

Energy

- **Defination :** Energy is the ability to do work. The amount of energy possessed by a body is equal to the amount of work it can do when its energy is released. Thus, energy is defined as the capacity of doing work. Energy is a scalar quantity and it exists in various forms.
- **Units of energy :** The units of energy are the same as that of work. In SI system, the unit of energy is joule (J). In CGS system, the unit of energy is erg.

$1\ \text{Joule} = 10^7\ \text{ergs}$

Other units of energy in common use are watt-hour and kilowatt hour.

$$1\ \text{watt-hour} = 1\ \text{watt} \times 1\ \text{hour} = 1\ \text{watt} \times 60 \times 60\ \text{sec} = 3600\ J$$

1 kilowatt-hour (kWh) = 3.6×10^6 Joule

Heat energy is usually measured in calorie or kilocalorie such that

1 calorie = 4.18 J

A very small unit of energy is electron volt(eV).

$1\ eV = 1.6 \times 10^{-19}\ J$

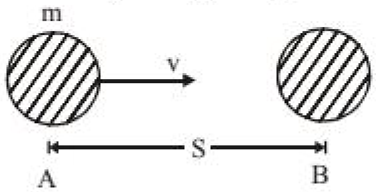
Mechanical Energy

The energy possessed by a body due to its state of rest or state of motion is called mechanical energy. Mechanical energy is of two types–

(A) Kinetic Energy (B) Potential Energy.

- **Kinetic Energy :** The energy of a body due to its motion is called kinetic energy. In other words. The ability of a body to do work by virtue of its motion is called its kinetic energy.

◈ **Expression for Kinetic Energy :** The kinetic energy of a body is measured in terms of the amount of work done by an opposing force that brings the body to rest from its present state of motion.



Suppose a body of mass m is moving with a velocity v and is brought to rest by an opposing force F.

Now retarding force is given by

$$F = ma \quad ...(1)$$

Now using the equation of motion,

$v^2 - u^2 = 2as$, we get

$$0^2 = v^2 - 2as$$

$$\therefore \quad s = \frac{v^2}{2a} \quad ...(2)$$

$\because$ Kinetic energy of the body = work done by the retarding force

or Kinetic energy = force × displacement

$= F \, . \, s ...(3)$

Substituting the value of F from equation (1) and the value of s from equation (2) in equation (3), we get

$$K.E. = ma \times \frac{v^2}{2a} = \frac{1}{2}mv^2$$

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

$$= \frac{1}{2} \times (\text{mass}) \times (\text{velocity})^2$$

Thus, a body of mass m and moving with a velocity v has the capacity of doing work equal to $\frac{1}{2}mv^2$ before it stops.

◈ **Some Important Conclusions :**

(a) The kinetic energy of a body is directly proportional to the mass of the body, and if the mass of a body is doubled, its kinetic energy also gets doubled and if the mass of a body is halved, its kinetic energy also gets halved.

(b) The kinetic energy of a body is directly proportional to the square of velocity of the body (or square of the speed of the body). If the velocity of a body is doubled, its kinetic energy becomes four times, and if the velocity of a body is halved, then its kinetic energy becomes one-fourth.

Ex.13 A bullet of mass 100 gm is fired with a velocity 50 m/s from a gun. Calculate the kinetic energy of the bullet.

Sol. Kinetic energy is given by

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

Here m = 100 gm = 0.1 kg; v = 500 m/s

$$K.E. = \frac{1}{2} \times 0.1 \times (50)^2$$

$$= \frac{1}{2} \times 0.1 \times 50 \times 50 = 125 \text{ J}$$

Ex.14 A 4 kg body is dropped from the top of a building of height 2.5 m. With what velocity will it strike the ground ? What is its kinetic energy when it strikes the ground ? (Takes $g = 9.8\ m/s^2$)

Sol. Velocity of the body with which it strikes the ground can be calculated by using the equation, $v^2 = u^2 + 2gh$

Hereu = 0; $g = 9.8\ m/s^2$; h = 2.5 m

Substituting these values, we get

$$v^2 = 0^2 + 2 \times 9.8 \times 2.5 = 49$$

or $v = 7\ m/s$

Thus, the speed of the body with which it strikes the ground = 7 m/s.

Ex.15 Calculate the velocity of 4 kg mass with kinetic energy of 128 J.

Sol. The formula for kinetic energy is given by

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

HereK.E. = 128 J; m = 4 kg

$$\therefore \quad 128 = \frac{1}{2} \times 4 \times v^2$$

or $v^2 = 64$; or $v = 8\ m/s$

Ex.16 Which would have a greater effect on the kinetic energy of an object, doubling the mass or doubling the velocity ?

Sol. (i) The kinetic energy of a body is directly proportional to its "mass" (m). So, if we double the mass (so that it becomes 2m), then the kinetic energy will also get doubled.

(ii) On the other hand, kinetic energy of a body is directly proportional to the "square of its velocity" (v^2). So, if we double the velocity (so that it becomes 2v), then the kinetic energy will become four times. This is because : $(2v)^2 = 4v^2$.

It is clear from the above discussion that doubling the velocity has a greater effect on the kinetic energy of an object.

◈ Potential Energy

The capacity of a body to do work by virtue of its position is known as gravitational potential energy. Hence possess potential energy due to change in shape, known as elastic potential energy. Thus the energy possessed by a body by virtue of its position or change in shape is known as potential energy. It is obvious that a body may possess energy even when it is not in motion.

◆ Expression for Potential Energy :

Suppose a body of mass m be lifted from the ground to a vertical height h, then the minimum force required to lift the body is equal to the force of gravity, i.e.

$$F = mg$$

This force of gravity acts on the body vertically downwards.

Now, work done in lifting the body to a height h will be

$$\text{Work} = \text{force} \times \text{distance} = mgh$$

This work done is stored as potential energy in the body such that

Potential energy, U = mgh, i.e. gain in potential energy of the body and the earth.

Ex.17 What will be the potential energy of a body of mass 2 kg kept at a height of 10 m ?

Sol. The potential energy is given by

$$U = mgh$$

Here,m = 2 kg; $g = 10\ m/s^2$; h = 10 m

$$\therefore \quad U = 2 \times 10 \times 10 = 200\ J$$

Ex.18 In lifting a mass of 25 kg to a certain height 1250 J energy is utilized. Calculate to what height it has been lifted ? (Take $g = 10\ m/s^2$)

Sol. In lifting a mass through a height h the work done is given by

$$U = mgh$$

Here, $U = 1250\ J;\ g = 10\ m/s^2;\ m = 25\ kg$

$\therefore \quad 1250 = 25 \times 10 \times h$

or $\quad h = 5\ m$

Transformation of Energy

◈ **Defination :** The change of one form of energy into another form of energy is known as transformation of energy.

A body is released from a height then the potential energy of the body is gradually transformed (or changed) into kinetic energy. When a body is thrown upwards, the kinetic energy of body is gradually transformed (or changed) into potential energy.

◈ **Different Forms of Energy**

- **Heat energy :** Burning of fuels like diesel or petrol in vehicles provides heat energy to do work.
- **Electrical energy :** Electric motors are used in home, industry and even for driving electric trains.
- **Light energy :** When light energy falls on light-meter used in photography, it causes its pointer to move across a scale.
- **Sound energy :** Sound energy causes a thin plate of microphone diaphragm to vibrate.
- **Chemical energy :** Chemical energy is the source of energy in our food and it provides us energy to move the various objects.
- **Nuclear Energy :** The energy in the nucleus of an atom is used to produce heat energy which in turn is used to generate electrical power.

Device used	Energy tranformation	
	From	to
Steam engine	Heat	Mechanical
Electric fan	Electrical	Mechanical
Electric lamp	Electrical	Light and Heat
Electric heater	Electrical	Heat
Microphone	Sound	Electrical
Solar cell	Solar heat	Electrical
Photo-cell	Light	Electrical
Car engine	Chemical	Heat, Mechanical
Electric cell/batteries	Chemical	Electrical

◈ **Energy from the Sun (or Solar Energy)**

The sun is a big store-house of energy. The sun's energy is produced by the nuclear reactions going on inside it all the time. All of our energy comes or has come from the sun. The sun's energy (or solar energy) gets transformed into many other forms of energy which are useful to us.

(a) Transformation of Sun's Energy into wind energy.

(b) Transformation of Sun's Energy into electrical energy.

(c) Transformation of Sun's Energy into food energy.

(d) Transformation of Sun's Energy into energy of fossil fuels.

Law of Conservation of Energy

- **This law states that :** "Energy can neither be destroyed nor created. It can simply be transformed from one form to another." It may also be stated as : "The sum total of all the forms of energy in the universe remains constant."
- Sometimes we come across certain situations in which we start doubting the validity of the law of conservation of energy. For instance, in the case of a body falling freely from a height, the body strikes the ground and its velocity reduces to zero. It means that both its kinetic and potential energies are zero whereas at places above the ground their sum total was not zero. It appears that the law fails here but this is not true. In fact when the body hits the ground, through its kinetic energy reduces to zero but we notice that on the ground, heat sound and sometimes light are produced. We know that sound, heat and light are different forms of energies. If we take into account energies of all the forms, it can be proved that the total energy of the system still remains constant.
- Truly speaking the law of conservation of energy is valid if one includes all forms of energy available in the universe.

◈ Einsten's Mass Energy Relation :

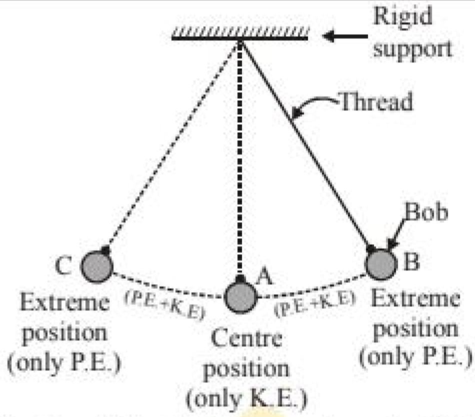
Till the beginning of this century, the scientists believed that matter and energy are two different entities. It was also believed that like energy, the total mass of the universe is also conserved and this statement is known as Law of conservation of mass. A German scientist Einstein, however, showed that matter and energy are the two definite aspects (or manifestations) of the same thing and they are inter-convertible. The transformation of mass into energy takes place according to the famous Enistein's relation,

$$E = m \cdot c^2$$

This equation is known as mass energy relation. Here 'E' is the energy obtained when mass 'm' is completely converted into energy and 'c' is the velocity of light and is equal to 3×10^8 m/s. The large magnitude of 'c' suggests that a huge amount of energy is obtained from complete conversion of a small amount of matter. So, while considering the validity of the law of conservation of energy, we have not to distinguish between mass and energy. Hence the above discussion shows that the law of Conservation of Energy is a Universal law.

◈ A swinging simple pendulum is an example of conservation of energy :

This is because a swinging simple pendulum is a body whose energy can either be potential or kinetic, or a mixture of potential and kinetic, but its total energy at any instant of time remains the same.



- When the pendulum bob is at position B, it has only potential energy (but no kinetic energy).
- As the bob starts moving down from position B to position A, its potential energy goes on decreasing but its kinetic energy goes on increasing.
- When the bob reaches the centre position A, it has only kinetic energy (but no potential energy).
- As the bob goes from position A towards position C, its kinetic energy goes on decreasing but its potential energy goes on increasing.
- On reaching the extreme position C, the bob stops for a very small instant of time. So at position C, the bob has only potential energy (but no kinetic energy).

Miscellaneous Examples :

Ex.19 A car weighing 1200 kg and travelling at a speed of 20 m/s stops at a distance of 40 m retarding uniformly. Calculate the force exerted by the brakes. Also calculate the work done by the brakes.

Sol. In order to calculate the force applied by the brakes, we first calculate the retardation.

Initial speed, u = 20 m/s; final speed,

v = 0, distance covered, s = 90 m

Using the equation, $v^2 = u^2 + 2as$, we get $0^2 = (20)^2 + 2 \times a \times 40$

or $80a = -400$

or $a = -5\ m/s^2$

Force exerted by the brakes is given by

$F = ma$

Herem = 1200 kg; $a = -5\ m/s^2$

$\therefore\ F = 1200 \times (-5) = -6000\ N$

The negative sign shows that it is a retarding force. Now, the work done by the brakes is given by

$W = Fs$

Here F = 6000 N; s = 40 m

$\therefore\ W = 6000 \times 40\ J = 240000\ J$

$= 2.4 \times 10^5\ J$

$\therefore$ Work done by the brakes $= 2.4 \times 10^5\ J$

Ex.20 A horse applying a force of 800 N in pulling a cart with a constant speed of 20 m/s. Calculate the power at which horse is working.

Sol. Power, P is given by force × velocity, i.e.

$P = F\ .\ v$

Here $F = 800\ N;\ v = 20\ m/s$

$\therefore\ P = 800 \times 20 = 16000$ watt

$= 16$ kW

Ex.21 A boy keeps on his palm a mass of 0.5 kg. He lifts the palm vertically by a distance of 0.5 m. Calculate the amount of work done. Use $g = 9.8\ m/s^2$.

Sol. Work done, W = F . s

Here, force F of gravity applied to lift the mass, is given by

$$F = mg$$
$$= (0.5\ kg) \times (9.8\ m/s^2)$$
$$= 4.9\ N$$

and $s = 0.5\ m$

Therefore, $W = (4.9)\ .\ (0.5m) = 2.45\ J.$

Ex.22 A truck of mass 2500 kg is stopped by a force of 1000 N. It stops at a distance of 320 m. What is the amount of work done ? Is the work done by the force or against the force?

Sol. Here the force, F = 1000 N

Displacement, s = 320 m

$\therefore$ Work done, W = F . s

$$= (1000N)\ .\ (320\ m)$$
$$= 320000\ J$$

In this case, the force acts opposite to the direction of displacement. So the work is done against the force.

Ex.23 Which would have greater effect on the kinetic energy of an object, doubling the mass or doubling the velocity ?

Sol. The expression for kinetic energy is,

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

(i) When m is doubled, that is $m \rightarrow 2m$,

$$E'_k \text{ becomes } = \frac{1}{2}(2m)\ v^2 = 2\left(\frac{1}{2}mv^2\right) = 2E_k$$

(ii) When v is doubled i.e. $v \rightarrow 2v$

$$E_k'' \text{ becomes } = \frac{1}{2}m(2v)^2$$
$$= \frac{1}{2}m(4v^2) = 4\left(\frac{1}{2}mv^2\right) = 4\ E_k.$$

Therefore, doubling v has a greater effect on the kinetic energy of an object than doubling the mass.

Ex.24 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 30º with the horizontal, calculate the work done in pulling the load upto a distance of 3 m. What is the increase in potential energy of the block ? Use $g = 10\ m\ .s^{-2}$. Neglect work done against friction.

Sol. The weight of the block, mg acts vertically downward.

The component of the weight parallel to the slope is mg sin 30º. So the driving force for pulling the block up is

$F = mg \sin \theta$

$= (20 \text{ kg})\ (10 \text{ m/s}^2)\ (\sin 30^o)$

$= 20 \times 10 \times 0.5 \text{ N} = 100 \text{ N}.$

Given the distance through which load is pulled, s = 3m.

Work done, $W = F \,.\, s$

$= (100 \text{ N}).\ (3 \text{ m})$

$= 300 \text{ J}$

Ex.25 Two bodies of equal masses move with uniform velocity v and 3v respectively. Find the ratio of their kinetic energies.

Sol. In this problem, the masses of the bodies are equal, so let the mass of each body be m. We will now write down the expression for the kinetic energies of both the bodies separately.

(i) Mass of first body = m

Velocity of first body = v

So, K.E. of first body $= \frac{1}{2}mv^2$ ...(1)

(ii) Mass of second body = m

Velocity of second body = 3v

So, K.E. of second body $= \frac{1}{2}m(3v)^2$

$= \frac{1}{2}m \times 9v^2$

$= \frac{9}{2}mv^2$ ...(2)

Now, to find out the ratio of kinetic energies of the two bodies, we should divide equation (1) by equation (2), so that :

$$\frac{\text{K.E. of first body}}{\text{K.E. of second body}} = \frac{\frac{1}{2}mv^2}{\frac{9}{2}mv^2}$$

or $$\frac{\text{K.E. of first body}}{\text{K.E. of second body}} = \frac{1}{9} \quad ...(3)$$

Thus, the ratio of the kinetic energies is 1 : 9. We can also write down the equation (3) as follows :

K.E. of second body = 9 × K.E. of first body

That is, the kinetic energy of second body is 9 times the kinetic energy of the first body. It is clear from this example that when the velocity (or speed) of a body is "tripled" (from v to 3v), then its kinetic energy becomes "nine times".

EXERCISE - 1

VERY SHORT ANSWER-TYPE QUESTIONS

Q.1 Is work a scalar or a vector quantity ?

Q.2 What name is given to the product of force and distance ?

Q.3 Give the units of work in SI system and in CGS system.

Q.4 What is the work done, when the displacement of a body is perpendicular to the direction of force acting on it ?

Q.5 Give the SI unit of power.

Q.6 What is the relationship between watt and horse power ?

Q.7 Define the term watt.

Q.8 What are the units of work and energy ?

Q.9 A cell converts one form of energy into another. Name the two forms.

Q.10 Name the device which converts electrical energy into mechanical energy.

Q.11 Is energy a scalar quantity or a vector quantity ?

Q.12 What are the two different forms of mechanical energy ?

Q.13 How much work is done when a body of mass m is raised to a height h above the ground ?

Q.14 How much work is done when a force of 1 N moves a body through a distance of 1 m in its own direction ?

Q.15 What is the power of a body which is doing work at the rate of one joule per second ?

SHORT ANSWER-TYPE QUESTIONS

Q.16 Moment of force and work done by a force both possess same unit, i.e. Nm, then what is the difference between them ? Which one of them is a vector ?

Q.17 Write the formula for the work done on a body when the force is applied at an angle θ with the direction of motion of the body.

Q.18 A satellite revolves around the earth in a circular orbit. Calculate the work done by the force of gravity ?

Q.19 In which of the following case the work done by a force will be maximum : when the angle between the direction of force and direction of motion is 0º or 90º ?

Q.20 State two situations in which a body moves with uniform speed and force acts on the body but work done on the body by the force acting is zero.

Q.21 Define the terms "work" and "power". Give their units.

Q.22 What do you understand by the kinetic energy of a body ? Deduce the formula for kinetic energy.

Q.23 On what factors does the kinetic energy of a body depend ?

/

Q.24 What is the difference between potential energy and kinetic energy ?

Q.25 When a ball is thrown vertically upwards, its velocity goes on decreasing. What happens toits potential energy as its velocity becomes zero ?

Q.26 State whether the following objects possess potential energy, kinetic energy or both ?

(i) A flying aeroplane
(ii) A stretched spring
(iii) A rotating ceiling fan
(iv) A man climbing upstairs
(v) A stone placed on the roof
(vi) A running car
(vii)Water stored in a dam

Q.27 What do you understand by the term "transformation of energy" ? Explain with an example.

Q.28 A car of mass 1000 kg moving with a speed of 10 m/s stops after moving a distance of 8 m after applying the brakes. Calculate the force applied by the brakes and work done by the brakes.

Q.29 A car is being driven by a force of 2.5×10^{10}N. Travelling at a constant speed of 5 m/s, it takes 2 minutes to reach a certain place. Calculate the work done.

Q.30 How much is the mass of a man if he has to do 2500 joules of work in climbing a tree 5 m tal ?

Q.31 A boy weighing 40 kg carries a box weighing 20 kg to the top of a building 15 high in 25 seconds. Calculate the power. ($g = 10\ m/s^2$)

Q.32 A man weighing 500 N carried a load of 100 N up a flight of stairs 4 m high in 5 seconds. What is the power ?

Q.33 On a level road, a car weighing 1000 kg is slowed down for 20 m/s to 10 m/s by applying brakes. Caculate the work done by the brakes.

Q.34 An athlete weighing 60 kg makes a high jump of 1.8 m. Determine the following :

(i) kinetic energy at the highest point.

(ii) potential energy at the highest point.

Q.35 If an electric bulb of 100 W is light up for 2 hrs, how much electrical energy will be consumed ?

Q.36 A ball of mass 1 kg slows down from a speed of 5 m/s to that of 3 m/s. Calculate the change in kinetic energy of the ball.

Q.37 A person weighing 800 N carries a packet from the base camp B to point A of a hill at a height of 1200 m. The weight of the packet is 200 N. Calculate the following :

(i) How much work he does against gravity ?

(ii) What is the potential energy of the packet at if it assumed to be zero at B ?

Q.38 A man weighing 600 N carries a load of 100 N up a flight of stairs 4 m high in 5 s. Calculate the power.

Q.39 Water is falling on the blades of a turbine at the rate of 6×10^3 kg/min. The height of the fall is 10 m. Calculate the power of the motor to be used.

Q.40 An electri motor drives a machine which lifts a mass of 2 kg through a height of 6 m, in 4 s at a constant speed. Assume $g = 9.8\ N\ kg^{-1}$ and calculate (i) the amount of work done and (ii) the power of the machine to lift the mass of 2 kg.

LONG ANSWER-TYPE QUESTIONS

Q.41 Define the term work. What are the quantities on which the amount of work done depends ? How are they related to work ? What is the condition for a force to do work on a body?

Q.42 Write the formula for work done on a body when the body moves at an angle to the direction of force. Give the meaning of each symbol used. What will happen to the work done if angle θ between the direction of force and motion of the body is increased gradually? Will it increase, decrease or remain constant ?

Q.43 Write an expresssion for the kinetic energy of a body of mass m moving with a velocity v. Explain by an example what is meant by potential energy. Write down the expression for graviational potential energy of a body of mass m placed at a height h above the surface of the earth.

Q.44 How can you explain the oscillation of a simple pendulum on the basis of conservation of energy ?

FILL IN THE BLANKS

Q.45 Work is measured as the product of .... and ....

Q.46 Kilowatt hour is the unit of ....

Q.47 A man pushes a rigid wall by applying a force of 500 N. The work done is.............

Q.48 A car weighing 1000 kg and travelling at a speed of 30 m/s stops at a distance of 50 m. Work done by the brakes is ....

Q.49 1 joule = ... ergs.

Q.50 3 electron volt = ... joule

Q.51 The kinetic energy of a body is the energy by virtue of its ....

Q.52 The potential energy of a body is the energy by virtue of its ....

Q.53 A particle is moving along the circumference of a circle with a uniform speed, the work done is ....

TRUE/FALSE-TYPE QUESTIONS

Q.54 Amount of work done depends upon the displacement produced by the body.

Q.55 A person carrying a load on his head walking on road does no work.

Q.56 Horse power is a largest unit for power.

Q.57 At the extreme positions of a pendulum, energy of a bob is partly potential and partly kinetic.

Q.58 1 horse power is equal to 746 kJ.

Q.59 Kinetic energy of body is directly proportional to square of momentum of body.

Q60 Conservation of energy is failed when some mass is converted into energy.

Q.61 Potential energy is possed by a watch when it is wond up ?

Q.62 Steam engine is converted mechanical energy to heat energy.

Q.63 The sun's energy is produced by the nuclear reaction.

SINGLE CORRECT ANSWER TYPE QUESTIONS

Q.64 No work is done when
(A) A box is pushed along a horizontal floor
(B) there is no component of force parallel to the direction of motion
(C) there is no component of force perpendicular to the direction of motin
(D) A nail is plugged into a wooden board

Q.65 A load is carried through a distance of 10 m in the following different ways. In which case the work done is minimum ?
(A) When pushed over smooth rollers
(B) When pushed along a plane horizontal surface
(C) When pushed along an inclined plane
(D) When lifted vertically upward

Q.66 A load is carried through a distance of 10 m in the following different ways. In which case the work done is maximum ?
(A) When pushed over smooth rollers
(B) When pushed along a plane horizontal surface
(C) When pushed along an inclined plane
(D) When lifted vertically upward

Q.67 A body at rest can have–
(A) speed (B) velocity
(C) momentum (D) energy

Q.68 When a body is projected into space, there is an increase in its–

(A) mass (B) momentum

(C) kinetic energy (D) potential energy

Q.69 A simple pendulum is oscillating. At any point of the path, the sum of kinetic energy and potential energy of the bob is–

(A) zero (B) maximum

(C) constant (D) variable

Q.70 Two bodies of same masses are moving with velocities v and 3v. The ratio of their kinetic energy is–

(A) 1 : 1 (B) 1 : 3 (C) 1 : 9 (D) 3 : 1

Q.71 Potential energy of a compressed spring–

(A) increases (B) decreases

(C) remains unchanged (D) disappears

Q.72 The work done in one complete revolution of moon around the earth is eaual to–

(A) gravitational force × diameter of the orbit of moon

(B) gravitational force × circumference of the orbit of moon

(C) centripetal force × radius of the orbit

(D) zero

Q.73 During oscillations of a simple pendulum, at the extreme position, potential energy of the bob is maximum–

(A) at the mean position

(B) at the extreme position

(C) midway between mean and the extreme position

(D) nowhere

Q.74 A 1 kg mass has a kinetic energy of a Joule. Its speed is–

(A) 0.5 m/s (B) 1 m/s (C) 1.4 m/s (D) 2 m/s

Q.75 When the speed of a moving object is doubled, then–

(A) weight is doubled

(B) potential energy is doubled

(C) kinetic energy is doubled

(D) kinetic energy becomes four times

Q.76 An iron sphere of mass 50 kg and an aluminium sphere of mass 17.5 kg of the same volumes are dropped simultaneously from the top of a tower. When they have reached a distance of 5 m, they have the same–

(A) momentum (B) acceleration

(C) potential energy (D) kinetic energy

Q.77 Two bodies A and B of equal masses are kept at heights of h and 3h respectively. The ratio of their potential energies is–

(A) 1 :1 (B) 1 : 3 (C) 1 : 9 (D) 3 : 1

Q.78 The expression for the work done by a force 'F' when displacement 's' takes place along it, is given by–

(A) F/s (B) F + s (C) F . s (D) s/F

Q.79 An object has a mass of 1 kg. It has a potential energy of 1 joule relative to ground when it is at a height of–

(A) 1 m (B) (1/9.8) m
(C) 0.32 m (D) 9.8 m

Q.80 A 2 kg metallic sphere and a paper sphere of mass 200 g, are dropped simultaneously from a cliff. When they are 10 m from the ground, they have the same–

(A) Potential energy (B) Kinetic energy
(C) momentum (D) velocity

Q.81 The S.I. unit of energy is :

(A) joule (B) newton
(C) joule per second (D) newton per metre

Q.82 When the speed of a scooter becomes half, its K.E. becomes–

(A) two times (B) four times
(C) eight times (D) one-fourth

Q.83 A body is falling freely under gravity–

(A) both is K.E. and P.E. are increasing
(B) its K.E. decreasing but P.E. is increasing
(C) both its K.E. and P.E. are decreasing
(D) its K.E. increasing and P.E. decreasing

Q.84 The value of 'g' on moon is 1/6 th the value of 'g' on the earth. A man can jump 1.5 m high on the Earth. Height upto which he can jump on Moon is–

(A) 0.25 m (B) 3 m (C) 6 m (D) 9 m

Q.85 While a force of 6 N is acting on a body, the body moves through a distance of 2 m at right angles to the direction of the force. The work done by the force is–

(A) 12 J (B) 3 J (C) zero (D) 24 J

Q.86 One kWh equals–

(A) 3.6×10^3 J (B) 3.6×10^4 kJ
(C) 3.6×10^6 J (D) 3.6×10 J

Q.87 Two bodies of masses 10 g and 40 g possess equal kinetic energies. The ratio of their moment are–

(A) 1 : 2 (B) 1 : 4 (C) 1 : 8 (D) 1 : 16

Q.88 A wound watch spring has–

(A) mechanical potential energy stored in it

(B) mechanical kinetic energy stored in it

(C) electrical energy stored in it

(D) no energy stored in it

ONE OR MORE THAN ONE CORRECT ANSWER TYPE QUESTIONS

Q.89 If force is always perpendicular to motion–

(A) KE remains constant

(B) work done = 0

(C) speed is constant

(D) velocity is constant

Q.90 Work done by force of friction–

(A) can be zero (B) can be positive

(C) can be negative (D) any of the above

Q.91 When work done by force of gravity is negative–

(A) KE increases (B) KE decreases

(C) PE increases (D) PE stays constant

Q.92 When two particles collide and stick together–

(A) energy is conserved

(B) work is negative

(C) KE is conserved

(D) ME is conserved

Q.93 When you carry a body from floor and keep it on table, work done does not depend on–

(A) time taken in doing so

(B) path chosen

(C) weight of the body

(D) height of the table

Q.94 When work done on a particle is positive–

(A) KE remains constant

(B) Momentum increases

(C) KE decreases

(D) KE increases

Q.95 KE of a particle increases continuously with time when–

(A) resultant force on the particle must be paralled to the velocity at all instants

(B) the resultant force on the particle must be at an angle less than 90º all the time

(C) magnitude of its linear momentum is increasing continuously

(D) its height above the ground must decreases continously

Q.96 A heavy stone is thrown from a cliff of height h in a given direction. The speed with which it hits the ground–

(A) must be larger than the speed of projection

(B) must be independent of speed of projection

(C) must depend on the speed of projection

(D) may be smaller than the speed of projection.

Q.97 No work is done by a force on an object if –

(A) Object is stationary but point of application of force moves on the object

(B) Object moves in such a way that the point of application of force remains fixed

(C) Force is always perpendicular to its velocity

(D) Force is always perpendicular to its acceleration

MATCH THE COLUMN

Q.98

	Column-I		Column-II
(A)	1 calorie	(P)	746 W
(B)	1 kWh	(Q)	1.9×10^{-19} J
(C)	1 eV	(R)	4.2 J
(D)	1 H.P	(S)	3.6×10^{6} J

Q.99 **Colum-I** **Column-II**

(A) Stopping distance (P) Force × displacement

(B) Efficiency (Q) Force × velocity

(C) Power (R) $\frac{\text{Kinetic energy}}{\text{Stopping force}}$

(D) Work (S) $\frac{\text{Output energy}}{\text{Input energy}}$

ASSERTION-REASON-TYPE QUESTIONS

The following questions consist of two statements each printed as Assertion & Reason. While answering these you are to choose any one of the following four responses.

(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.

(B) If both Assertion & Reason are true but the Reason is not a correct explanation of the Assertion.

(C) If Assertion is true but Reason is false.

(D) If Reason is true but Assertion is false.

Q.100 **Assertion :** When a body is moving uniformly in a circle, its momentum goes on changing, but its K.E. remains constant.

Reason : $\vec{p} = m\vec{v}$, K.E. = 1/2 mv^2. In circular motion, $\vec{v}$ changes, v^2 does not.

Q.101 **Assertion :** Two bodies of different masses have same kinetic energies. Their momenta are in the direct ratio of their masses.

Reason : p = mv

Q.102 **Assertion :** Kilowatt hour is the unit of electric power.

Reason : Watt hour has units of energy.

Q.103 **Assertion :** Mass and energy are not conserved separately, but are conserved as a single entity called 'mass-energy'.

Reason : This is because one can be obtained at the cost of the other as per Einstein equation $E = mc^2$.

Q.104 **Assertion :** No work is done when an electron completes a circular orbit around the nucleus of an atom.

Reason : Work done by a centripetal force is always zero.

Q.105 **Assertion :** Time taken by a body to complete a given work has nothing to do with energy of the body.

Reason : Because power of a body is the rate of doing work.

EXERCISE - 2

SINGLE CORRECT ANSWER TYPE QUESTIONS

Q.1 An object a moving horizontally with kinetic energy of 800 J experiences a constant opposing force of 100 N while moving from a to b (where ab = 2m). The energy of particle at b is–

(A) 700 J (B) 400 J
(C) 600 J (D) 300 J

Q.2 A water pump driven by petrol raises water at a rate of 0.5 m^3/min. from a depth of 30 m. If the pump is 70% efficient, the power developed by the engine is–
(A) 1750 W (B) 2450 W
(C) 3500 W (D) 7000 W

Q.3 The energy required to accelerate a car from 10 m/s to 20 m/s is n times the energy required to accelerate the same from rest to 10 m/s, where n is–
(A) 1 (B) 4
(C) 2 (D) 3

Q.4 The four engine airplane developes a total of 30,000 hp., when its velocity is 240 m/s. The force which the engine exerts is–
(A) 3×10^4 N (B) 9.3×10^4 N
(C) 7.2×10^5 N (D) 2500 N

Q.5 A body is under the action of two equal and opposite forces, each of 3 N. The body is displaced by 2m. The work done is–
(A) + 6 J (B) – 6 J
(C) 0 (D) none of these

Q.6 The work done on a body does not depend upon :
(A) force applied
(B) displacement
(C) initial velocity of body
(D) angle at which force is inclined to the displacement

Q.7 Tape recorder records the sound in the form of–
(A) electrical energy
(B) magnetic field on the tape
(C) variable resistance on the tape
(D) sound wave held on the tape

Q.8 You lift a suit-case from the floor and keep it on the table. The work done by you on the suitcase depends on–
(A) the path taken by the suitcase
(B) your weight
(C) the weight of the suitcase
(D) the time taken by you in doing so

Q.9 Once a choice is made regarding zero potential energy reference state, the changes in potential energy–

(A) are same

(B) are different

(C) depend strictly on the choice of the zero of potential

(D) become indeterminate

Q.10 A 12 HP motor has to be operated 8 hours/day. How much will it cost at the rate of 50 paise/ kWh in 10 days ?

(A) Rs. 350/- (B) Rs. 358/-

(C) Rs. 375/- (D) Rs. 397/-

Q.11 An engine developes 10 kW of power. How much time wil it take to lift a mass of 200 kg to a height of 40 m ($g = 10\ m/s^2$)

(A) 4s (B) 5 s

(C) 8 s (D) 10 s

Q.12 1amu mass is equal to–

(A) 1 J (B) 931 eV

(C) 931 MeV (D) 931 meV

Q.13 Water is falling from the top of a high water fall. On falling–

(A) it evaporates

(B) it freezes

(C) its mass increases

(D) it gets slightly warmed up

Q.14 A body is acted upon by a force, which is inversely proportional to the distance covered (x). The work done will be proportional to–

(A) x (B) $x^{1/2}$

(C) x^2 (D) none of these

Q.15 A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to–

(A) $t^{1/2}$ (B) $t^{3/4}$ (C) $t^{3/2}$ (D) t^2

Q.16 A car of mass 1000 kg moves at a constant speed of 20 m/sec up an incline. Assume that the θ = 1/20 where θ is the angle of the inclined to the horizontal. Take $g = 10\ m/s^2$. Find the power developed by the engine–

(A) 14 kW (B) 4 kW

(C) 10 kW (D) 28 kW

Q.17 What is the shape of the graph between the square of speed and kinetic energy of a body ?

(A) straight line (B) hyperbola

(C) parabola (D) exponential

Q.18 Force F applied on a body moves it through a distance along F. Energy spent is–
(A) $F \times s$ (B) F/s
(C) Fs^2 (D) F/s^2

Q.19 The slope of potential energy versus position graph represents–
(A) force (B) work
(C) power (D) momentum

PASSAGE BASED QUESTIONS

Passage - I

Two physicists, both of mass 50 kg, climb up identical ropes suspended from the ceiling of a gymnasium. The ropes are 15 meters long. Physicist 1 reaches the top twice as quickly as physicist 2 does. After physicist 2 also reaches the top, they argue about who did more work against gravity:

Physicist 1

"I did more work fighting gravity, because I was overcoming gravity more quickly. Your climb was lazier, and therefore, you did less work."

Physicist 2

"No way. I did more work fighting gravity, because I spent *more time* climbing the rope. Since we both ended up at the same height, but I spent more time getting there, I had to work harder."

Q.20. Which physicist, if either, did more work against gravity while climbing from the floor to the ceiling ?
(A) Physicist 1 did more work.
(B) Physicist 2 did more work.
(C) Both physicists did the same positive work.
(D) Neither physicist did any work.

Q.21 Physicist 1 climbed her rope in 30 seconds. What average power did she exert fighting gravity?
(A) 25 watts (B) 250 watts
(C) 1500 watts (D) 15,000 watts

Q.22 Physicist 2 started at rest from the floor and ended at rest near the ceiling. Which of the following best expresses the net energy transfer during this process?
(A) Chemical to kinetic
(B) Chemical to potential
(C) Kinetic to chemical
(D) Kinetic to potential

Q.23 Physicist 2 now lets go of the rope and falls onto a heavily-padded cushion, safely coming to rest. During this process, the energy transfer is best described as:
(A) Potential to kinetic to chemical
(B) Potential to kinetic to heat
(C) Kinetic to potential to chemical
(D) Kinetic to potential to heat

Q.24 When physicist 2 has fallen one third of the way from the ceiling to the floor, her kinetic energy is approximately:

(A) 10 joules (B) 250 joules

(C) 1000 joules (D) 2500 joules

Passage - II

Work done is the scalar product of force and displacement. Power is defined as the rate of doing work. A power is the scalar product of force and velocity.

Energy is the ability to do work. Energy can nither be destroyed nor created. It can simply be transformed from one form to another.

Q.25 A block of mass 5 kg is being raised vertically upwards by the help of string attached to it. It rises with an acceleration of 2 m/s^2. The work done by tension in the string if block rises by 2.5 m–

(A) 125J (B) 147.5 J

(C) 193.4 J (D) – 87.5 J

Q.26 $W = FS \cos \theta$ is applicable for–

(A) only constant force

(B) only time varying force

(C) any force

(D) neither for constant nor for variable force

Q.27 A pump is required to lift 1000 kg of water per minute from a well 20 m deep and eject it at the rate of 20 m/s. What horse power engine is required for the purpose of lifting water–

(A) Nearly 9 (B) Nearly 2

(C) Nearly 16 (D) Nearly 25

Q.28 A man of mass 50 kg jumps a height of 1.2 m. His potential energy is–

(A) 60 joules (B) 6 joules

(C) 600 joules (D) 6000 joules

Q.29 In 10 sec, a body of 6 kg mass is dragged 8 metres with uniform velocity across a floor by a steady force of 20 N. The kinetic energy of the body is–

(A) 2.92 joule (B) 0.92 joule

(C) 1.92 joule (D) 19.2 joule

ONE OR MORE THAN ONE CORRECT ANSWER TYPE QUESTIONS

Q.30 The total work done on a particle is equal to the change in its kinetic energy–
(A) always
(B) only if the forces acting on it are conservative
(C) only if gravitational force alone acts on it
(D) only if elastic force alone acts on it.

Q.31 A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. If follows that–
(A) its velocity is constant
(B) its acceleration is constant
(C) its kinetic energy is constant
(D) it moves in a circular path

Q.32 You lift a suitcase from the floor and keep it on a table. The wrok done by you on the suitcase does not depend on–
(A) the path taken by the suitcase
(B) the time taken by you in doing so
(C) the weight of the suitcase
(D) your weight

Q.33 No work is done by a force on an object if–
(A) the force is always perpendicular to its velocity
(B) the force is always perpendicular to its acceleration
(C) the object is stationary but the point of application of the force moves on the object
(D) the object moves in such a way that the point of application of the force remains fixed

Q.34 The kinetic energy of a particle continuously increases with time–
(A) The resultant force on the particle must be parallel to the velocity at all instants
(B) The resultant force on the particle must be at an angle less than 90º all the time
(C) Its height above the ground level must continuously decrease
(D) The magnitude of its linear momentum is increasing continuously