Work and Energy

TALENT & OLYMPIAD

Introduction

In this chapter we shall study about the various concepts of work and energy. All the living organisms needs energy to perform several activities to survive. Work has different meaning in different aspect of life. Scientific notation of the work is that when a force is applied on an object and the object moves through a distance, we can say that work is done. The work done by a force is equivalent to the product of force and displacement of the body in the direction of force.

$$W = F \times D$$

Where, F is the force and D is the displacement of the object.

When the displacement is in the direction of force, it is called positive work and if the displacement is in the opposite direction of the force, it is called **negative work**.

For example:

When we throw a ball in the upward direction, its displacement is in upward direction, whereas the force due to gravity acts in downward direction, hence we can say that work done is negative.

$$W = -F \times D$$

On the other hand, when the ball falls from a certain height both the displacement and the gravitational force acts in downward direction. Here the work done is positive.

$$W = F \times D$$

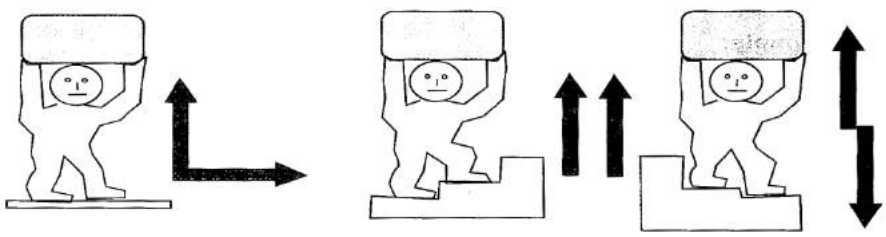
Unit of Work

We know that work is the product of force and displacement. The SI unit of force is **Newton** and that of displacement is **meter**, so the unit of work is **Newton** - meter which is also equal to **joule**.

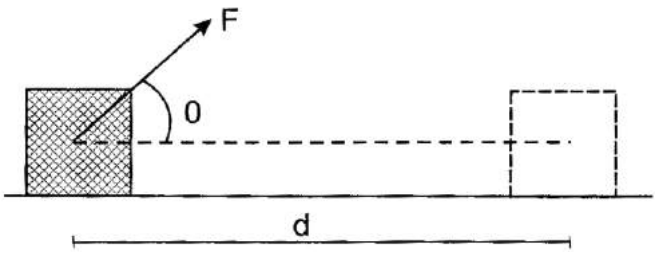
One joule of work is defined as the work done by a force of 1 newton, when it displaces a object by a distance of 1 meter in the direction of force. If the displacement of the object takes place in the direction perpendicular to the direction of force, then work done by the force on the object is zero.

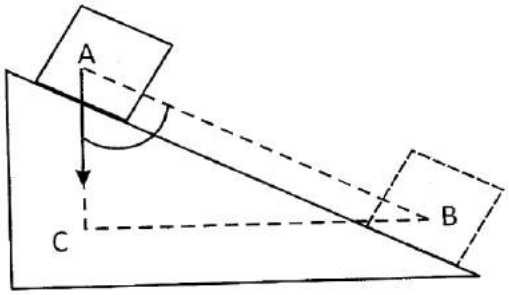
For example:

The work done by the lift moving upward direction or by a potter carrying a load moving on a platform is zero.



When the displacement takes place at an angle to the force. Let us consider an object of mass **'m'** sliding on an inclined surface making an angle ' Q' with the direction of force 'F' acting on the object. Then the work done by the force on the object is given by $\mathbf{W = F \times d \times \cos\theta}$.





Commonly Asked QUESTIONS

A small child pushes a desk using a force of 10 N. Find the work done by this force if the desk is displaced to a distance of 6 meters.

(a) 40 joules
(b) 50 joules
(c) 60 joules
(d) 80 joules
(e) None of these

Answer: (c)

A boy throws a ball in upward direction that reaches a height of 10 m. If the mass of the ball is 980 gm, find the work done by the force of gravity.

(a) -96.04 joules
(b) 96 joules
(c) 98.08 joules
(d) -98 joules
(e) None of these

Answer: (a)

A child pull a block by applying a force of 15 N at an angle of 60°. Find the work done in pulling the block by a distance of 20 meters.

(a) 120 joules
(b) 130 joules

(c) 140 joules (d) 150 joules
(e) None of these
Answer: (d)

Energy

The word energy is used daily in our daily life. In science we give the word a definite and specific meaning. The energy is defined as the ability to do the work. Thus, the unit of energy is same as that of work. That is the unit of energy is joule. 1 joule is the energy required to do the work of 1 joule. The larger unit of energy is kilojoule.

1 kj = 1000 joule

The object which possess energy can exert a force on another object. When this happens, the energy is transferred from the former to the latter. The second object may move as it receives energy and therefore do some work. There are different forms of energy. The different forms of energy includes mechanical energy, heat energy, chemical energy, electrical energy, and light energy. The mechanical energy is of two form: the kinetic energy and the potential energy.

Kinetic Energy

It is defined as the energy possessed by the body, by the virtue of its motion.

Thus, every object in motion possess energy irrespective of the object moving speedly or slowly. We can derive the relation for the kinetic energy. Let us consider an object of mass 'm' moving with a uniform velocity' u'. When a constant force 'F' is applied on the object it is displaced through a distance 'S' in the direction of force. The work done by the force is given by,

W = F x S

Let the work done on the object changes its velocity from 'u' to V which produces an acceleration of 'a', then from third equation of motion we have,

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

Or, $S = \frac{v^2 - u^2}{2a}$

From Newtons second law, we have

F = ma

Therefore, work done is

W=ma $\times$ S

Or, W=max v -u

Or, $W = ma \times \left(\frac{v^2 - u^2}{2a} \right)$

Or, $W = m \times \left(\frac{v^2 - u^2}{2} \right)$

If the object is starting from rest then u=0, hence the work done is given by

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

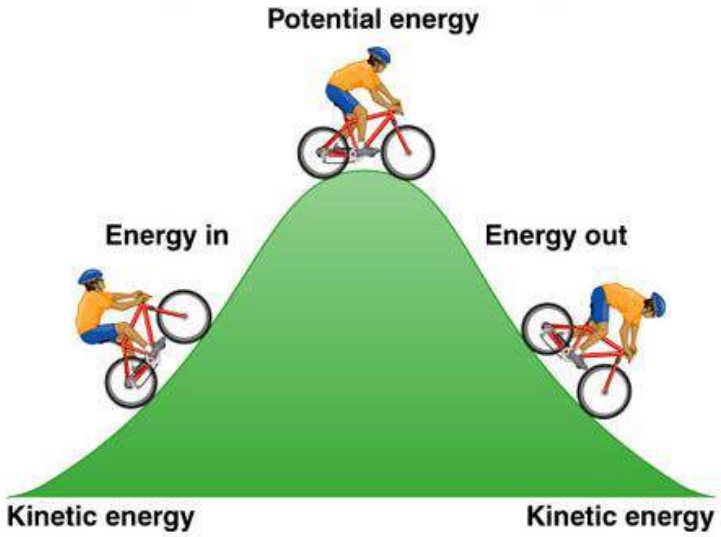
Since this work done is equal to the change in kinetic energy, so the kinetic energy is given by

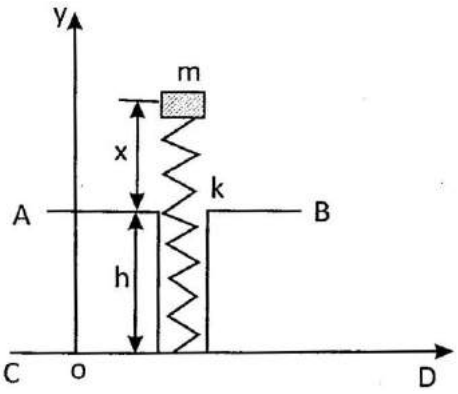
$K.E. = \frac{1}{2} m \times v^2$

Potential Energy

It is defined as the energy possessed by the body, by the virtue of its shape and position.

When an object is raised to a certain height its energy increases. This is because of work done on the object against gravity, when it is being raised to a certain height. The energy possessed in such object is called the **gravitational potential energy**.





Let us consider an object of mass **'m'** raised to a height of **'h'** from the surface of ground. The force required to raise the object to a height **'h'** is equal to the weight of the object 'mg', where g is the acceleration due to gravity. Thus, the work done is given by

Work = force x displacement = mg x h = mgh

Hence the potential energy is equal to, P.E. = mgh

The potential energy has many uses such as generation of hydroelectricity.

The SI unit of potential energy is joule (J).

It is a **scalar quantity**.

Commonly Asked QUESTIONS

Find the energy possessed by a ball of mass 550 gm rolling on the surface with a speed of 25 m/sec.

(a) 120.896 joules
(b) 132.875 joules
(c) 171.875 joules
(d) 150.965 joules
(e) None of these

Answer: (c)

An object of mass 2 kg is raised to a height of 0.102 meters. Find the energy required to raise the object to the height.

(a) 2.5892 joules
(b) 1.9992 joules
(c) 1.7175 joules
(d) 1.5065 joules
(e) None of these

Answer: (b)

Calculate the work done in lifting an object of mass 0.5 kg to a height of 1.5 meters from the ground.

(a) 8.02 joules
(b) 6.28 joules
(c) 7.98 joules
(d) 7.35 joules
(e) None of these

Answer: (d)

A batsman hits the ball of mass 250 gm with his bat and the ball leaves the bat with the speed of 10 m/s. Find the work done by the bat on the ball.

(a) 10.25 joules
(b) 9.75 joules
(c) 12.5 joules
(d) 8.35 joules
(e) None of these

Answer: (c)

A ball of mass 1 kg is thrown upward with a speed of 10 m/s. Find the potential energy of the ball when it reaches the highest point.

(a) 50 joules
(b) 25 joules
(c) 75 joules
(d) 90 joules
(e) None of these

Answer: (a)

Relation between Kinetic Energy and Momentum

The kinetic energy and momentum (p) are related to each other.

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

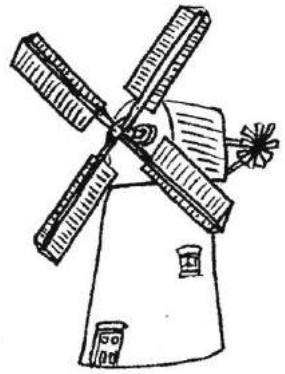
But, $p = mv$

$$K.E. = \frac{1}{2}m\left(\frac{p}{m}\right)^2 \quad K.E. = \frac{p^2}{2m}$$

Transformation of energy

The change of one form of energy into another is called transformation of energy. When a body falls from a certain height, its potential energy changes into kinetic energy.

- **Wind Energy → Electricity → Light + Heat**



Illustrative EXAMPLE

(1) A stone when is released from a height, the potential energy of the stone is gradually changed into kinetic energy and reverse happens when the stone is thrown upward.
On the other hand, when a body is thrown up, its kinetic energy gradually changes into potential energy.
(2) At a hydroelectric power house, the potential energy of water is transformed into kinetic energy and then into electrical energy.
(3) At a thermal power station, the chemical energy of coal is converted into heat energy which is further converted into electrical energy.
(4) Heat energy is converted into kinetic energy by the steam engine.

The Law of Conservation of Energy

According to the law of conservation of energy. **Energy can neither be created nor destroyed, only it can be transformed from one form to another**. But the total energy of the entire system always remains constant.

Power

The rate of doing work is called power.

$$(P) = \frac{\text{work done (W)}}{\text{time taken (t)}} = \text{or } P = \frac{W}{t}$$

❖ Power is expressed in watt (W). When a body performs work at the rate of 1 J per second, its power is 1 W. Power is a scalar quantity.

❖ Horse power is another unit of power.

1 hp = 746 W

= 0.746 kW

Commercial Unit of Energy

The unit joule is too small and hence is inconvenient to express large quantities of energy. So, we use a bigger unit of energy called kilowatt hour (kW h).

1 kW h = 1 kW × 1 h

= 1000 W × 3600 s

= 3600000 J

1 kW = 3.6 × 10^6 J

Which one of the following is the commercial unit of energy?

(a) Joules (b) Watt

(c) KW (d) KWh

(e) None of these

Answer: (d)

One kilowatt hour is equal to:

(a) $36\times10^6\ J$ (b) $136\times10^6\ J$

(c) $3.6\times10^6\ J$ (d) $1.36\times10^6\ J$

(e) None of these

Answer: (c)

One horse power is equal to:

(a) 746 watt (b) 74.6 watt

(c) 7.46 watt (d) 746 kw

(e) None of these

Answer: (a)

Work done by a string when a stone is tied to it and whriled in a circle is:

(a) Positive (b) Negative

(c) Zero (d) All of these

(e) None of these

Answer: (c)

SUMMARY

- Work is said to be done if the force applied on the object cause displacement.
- The capacity to do the work is called energy.
- The energy possessed by the object by the virtue of its motion is called kinetic energy.
- The energy possessed by the body by the virtue of its shape and position is called potential energy.
- The commercial unit of power is KWh.

Self Evaluation TEST

Duration 10 Minutes

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1. When the force applied and the displacement of the body are inclined at 90° with each other, the work done is:

(a) Infinite
(b) Maximum
(c) Zero
(d) Unity
(e) None of these

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2. Two bullets P and Q, masses 10g and 20 g, are moving in the same direction towards a target with velocities of 20 m/s and 10 m/s respectively. Which one of the bullets will pierce a greater distance through the target?

(a) P
(b) Q
(c) Both are correct
(d) both are incorrect
(e) None of these

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3. In the SI system, the unit of P.E. is:

(a) Erg
(b) Newton
(c) Dyne
(d) Joule
(e) None of these

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4. Two unequal masses possess the same momentum, then the kinetic energy of the heavier mass is _____ the kinetic energy of the lighter mass.

(a) More
(b) Less
(c) Equal
(d) Insufficient data
(e) None of these

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5. If the speed of a motor car becomes six times then the kinetic energy becomes:

(a) 6 times
(b) 12 times
(c) 24 times
(d) 36 times
(e) None of these

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6. If a body rolls down a inclined plane then it possesses only:

(a) Kinetic energy
(b) Potential energy
(c) Both
(d) Neither

(e) None of these

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7. In which one of the following situation the potential energy of the spring will be minimum?

(a) Compressed (b) Extended
(c) In its original shape (d) Neither
(e) None of these

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8. What happens to the kinetic energy of the body if its velocity is doubled?

(a) Remains same (b) Becomes double
(c) Becomes four times (d) Becomes half
(e) None of these

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9. When a stone is thrown upward with a certain speed then its kinetic energy at the highest point is:

(a) Maximum (b) Minimum
(c) Insufficient data (d) Zero
(e) None of these

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10. An electric bulb of 100 watt is used for 8 hour daily. Find the energy consumption in the month of March.

(a) 24.8 kwh (b) 0.248 kwh
(c) 2.48 kwh (d) 248 kwh
(e) None of these

Answers – Self Evaluation Test																					
1.	C	**2.**	A	**3.**	D	**4.**	A	**5.**	D	**6.**	C	**7.**	C	**8.**	C	**9.**	D	**10.**	A		