Work And Energy

CLASS-9TH CHAPTER-11

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- Work done on an object is defined as the product of the magnitude of the force acting on the body and the displacement in the direction of the force. **W = F.s**

- If a force acting on a body causes no displacement, the work done is 0. For example, pushing a wall.

- The scientific definition of work is different in many ways from its everyday meaning.

- The definition of work in physics reveals its relationship to energy – whenever work is done, energy is transferred.

- For a work to be done, in a scientific sense, a force must be exerted and there must be displacement in the direction of the force.

- Work is the product of the component of the force in the direction of the displacement and the magnitude of this displacement.

- Mathematically, the above statement is expressed as follows:

$W = (F \cos \theta)\, d = F.\, d$

Where,

- W is the work done by the force.
- F is the force, d is the displacement caused by the force
- θ is the angle between the force vector and the displacement vector

- The dimension of work is the same as that of energy and is given as, [ML2T–2].

Unit of Work

- The SI unit of work is the joule (J), which is defined as the work done by a force of 1 Newton in moving an object through a distance of 1 meter in the direction of the force.

- The work done upon the weight against gravity can be calculated as follows:

- Work Done = (Mass × acceleration due to gravity) × Displacement

$= (25 \times 9.8) \times 2$ J

Factors Affecting Work

Force:

- Force is defined as a push or a pull that can cause any object with a mass to change its velocity and acceleration.
- Force is a vector quantity and has both a magnitude and a direction.
- If the force acting on an object is zero irrespective of the state of the object (dynamic or static) that work done by the force is zero.

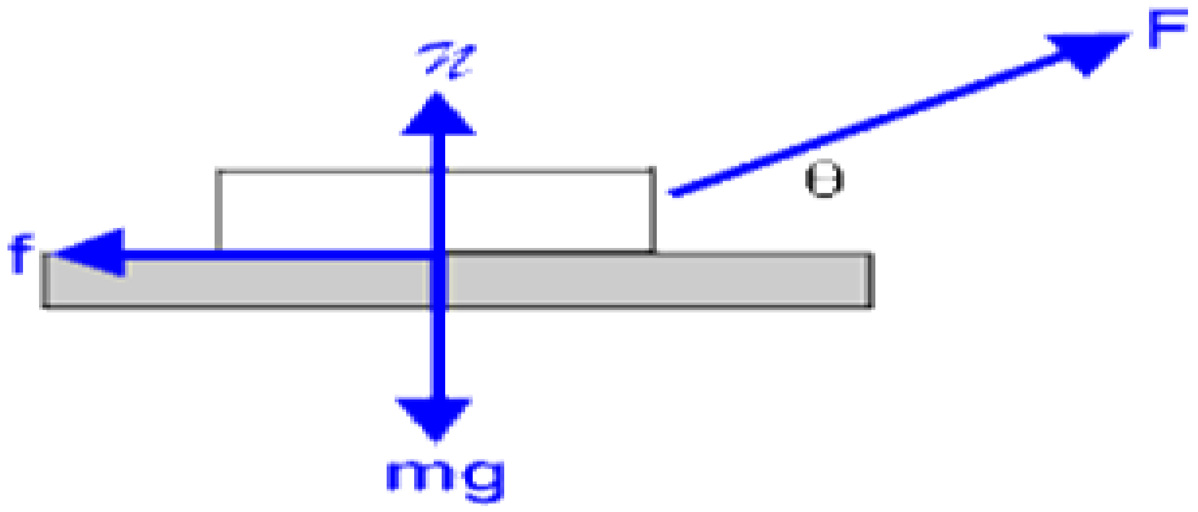
Displacement:

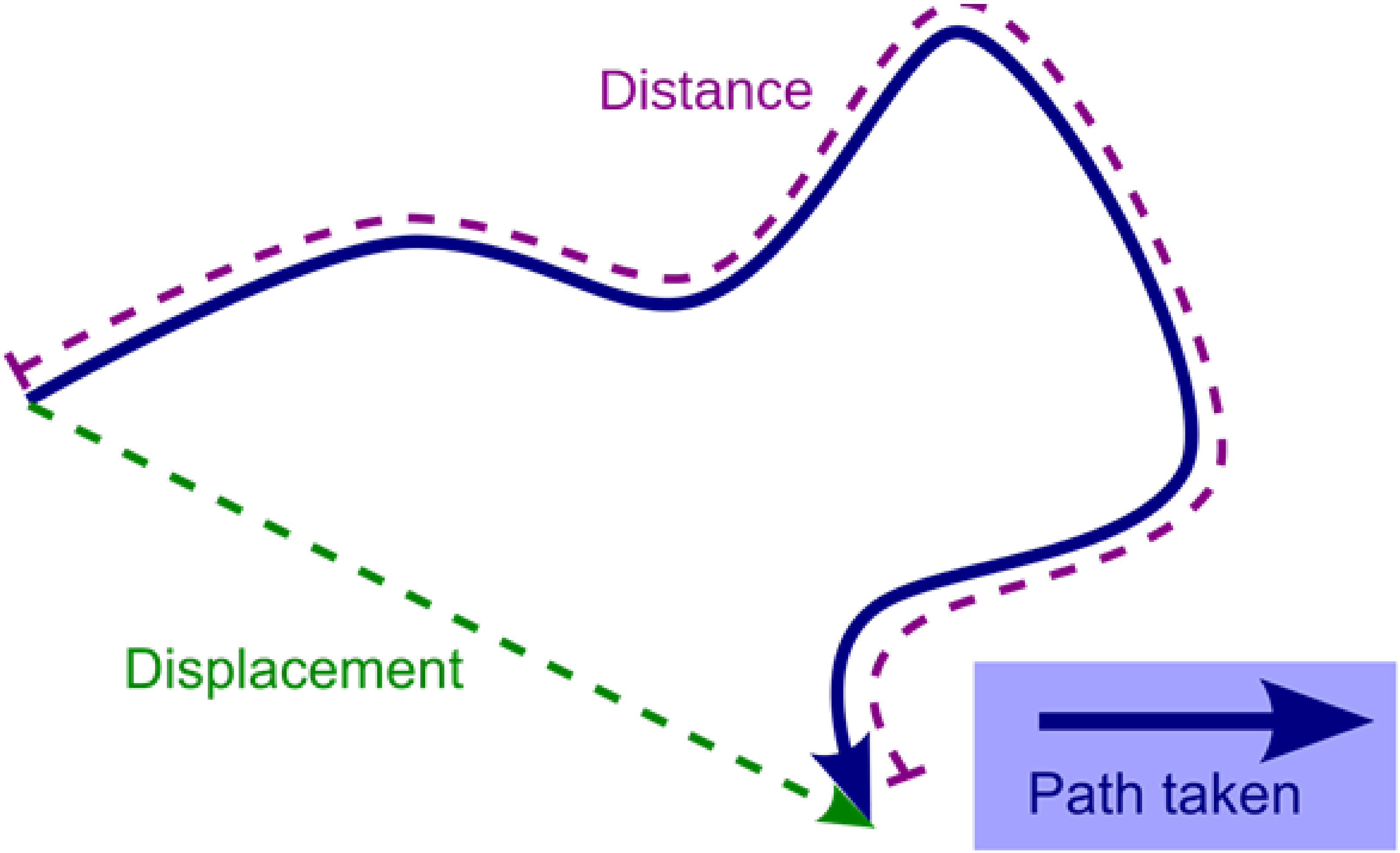
- Displacement is a vector quantity that gives the shortest distance between the initial position and the final position of any object.
- If the resulting displacement in the direction of force, due to force acting on any object is zero, the net work done by that force on that object is zero.
- For e.g., if we push a rigid wall with all our might and still fail to displace it, then we can say no work has been performed by us on the wall.
- The work done by a force on an object can be positive, negative, or zero, depending upon the direction of displacement of the object with respect to the force.

- For an object moving in the opposite direction to the direction of force, such as friction acting on an object moving in the forward direction, the work is done due to the force of friction is negative`

- Similarly, an object experiences a zero force when the angle of displacement is perpendicular to the direction of the force.

- Consider an example of a coolie lifting a mass on his head moving at an angle of 90˚ with respect to the force of gravity. Here, the work done by gravity on the object is zero.




Distance
Displacement
Path taken

Energy

- Energy is defined as the ability to do work. Its unit is the same as that of work.

- SI unit of energy or work = Joule (Nm) or Kgm2s−2.

- Energy has different forms: Light, heat, chemical, electrical or mechanical.

Mechanical energy is the sum of:

(i) Kinetic energy (K.E) Kinetic energy is a property of a moving object or particle and depends not only on its motion but also on its mass.

(ii) Potential energy (P.E) Potential energy is the stored energy that depends on the relative position of parts of a system.

- Energy is the fundamental form of living for all living beings.

- There are different forms of energy on this planet. The Sun is considered as the elemental form of energy on the Earth.

- In Physics, energy is considered a quantitative property which can be transferred from an object in order for it to perform work.

- Energy is the ability to do work

Units of Energy

- The International System of Units of measurement of energy is Joule.
- The unit of energy is named after James Prescott Joule.
- Joule is a derived unit and it is equal to the energy expended in applying a force of one newton through a distance of one meter.
- However, energy is also expressed in many other units not part of the SI, such as ergs, calories, British Thermal Units, kilowatt-hours, and kilocalories, which require a conversion factor when expressed in SI units.

Energy Conversion: Transfer and Transform

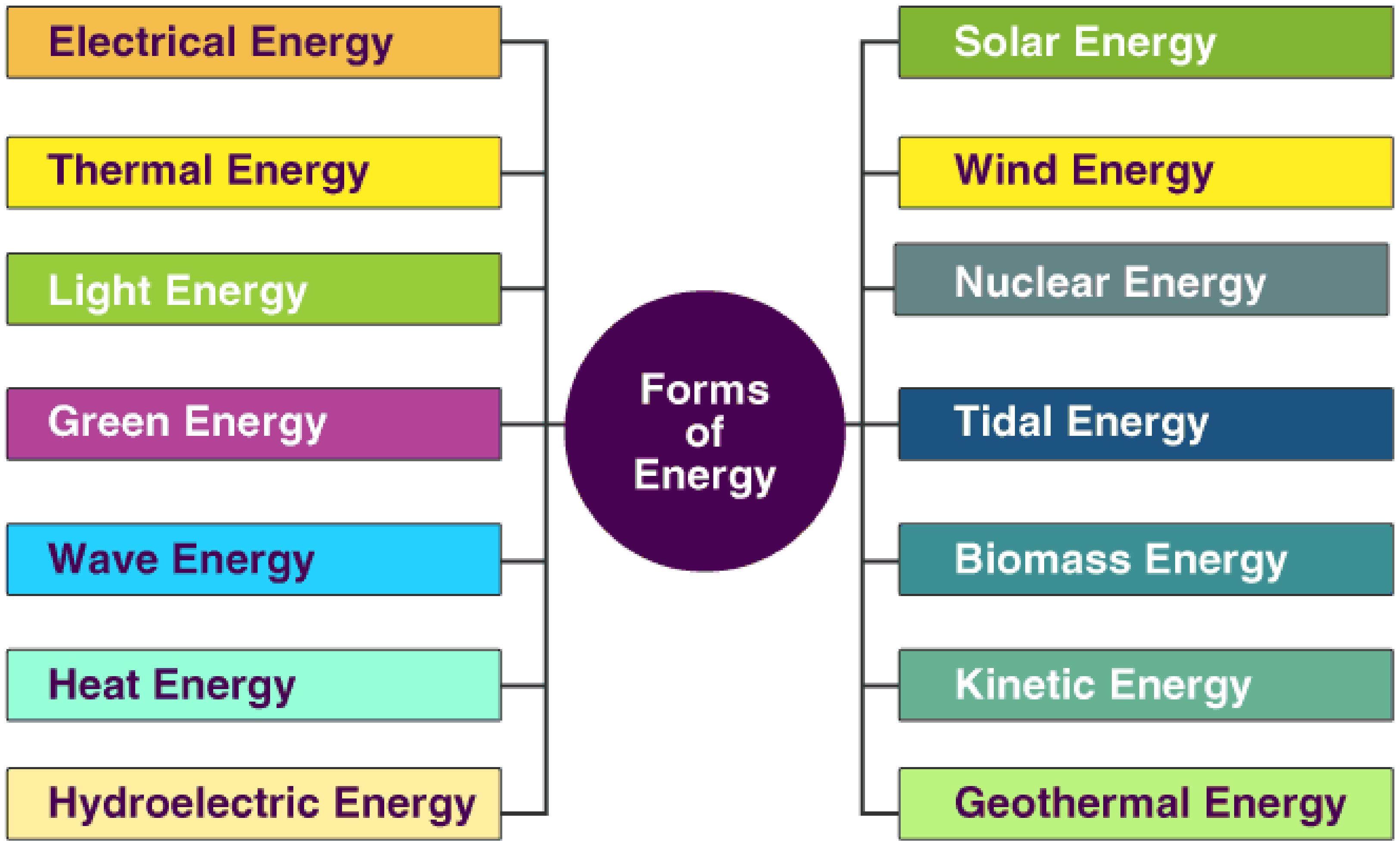
- Energy can be transferred from one form to another, the movement of energy from one location to another is known as energy transfer.

- Following are the four ways through which energy can be transferred:

- Mechanically – By the action of force
- Electrically – Electrically
- By Radiation – By Light waves or Sound waves
- By Heating – By conduction, convection, or radiation

- The process which results in the energy changing from one form to another is known as energy transformation.

- While energy can be transformed or transferred, the total amount of energy does not change – this is called energy conservation.


Forms of Energy
Electrical Energy
Thermal Energy
Light Energy
Green Energy
Wave Energy
Heat Energy
Hydroelectric Energy
Solar Energy
Wind Energy
Nuclear Energy
Tidal Energy
Biomass Energy
Kinetic Energy
Geothermal Energy

Kinetic Energy

- Objects in motion possess energy and can do work. This energy is called Kinetic Energy.

F = ma.

- Also W = F.s

⇒ From the 2nd equation of motion v2−u2=2as,

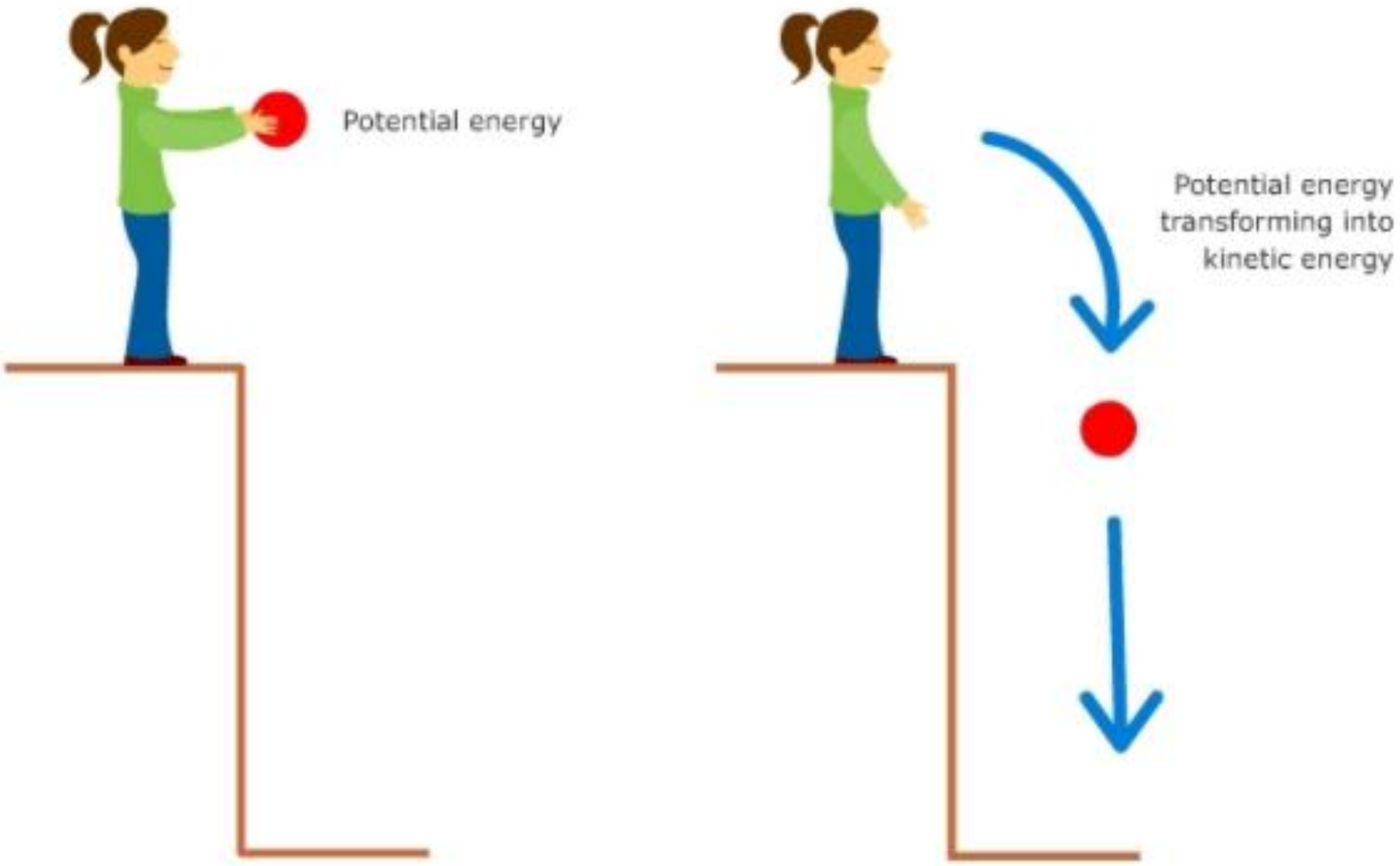
⇒ we get s = v2−u22a ⇒ Substituting equation for work done by a moving body,

⇒ we get W =m.a * v2−u22a

Or

⇒ Kinetic Energy = K.E= 12 mv2 (taking initial velocity u=0)

- When two identical bodies are in motion, the body with a higher velocity has more K.E.


Potential energy
Potential energy
transforming into
kinetic energy

- Kinetic energy is the energy associated with the object’s motion.
- Objects in motion are capable of causing a change or are capable of doing work.
- A wrecking ball in motion is used to do work such as demolition of buildings, stones, etc.
- Even a slow-moving wrecking ball is capable of causing a lot of damage to another object such as an empty house.
- However, a wrecking ball that is not in motion, does not do any work.
- Another example of kinetic energy is the energy associated with the constant, random bouncing of atoms or molecules.

- This is also known as thermal energy. The average thermal energy of a group of molecules is what we call temperature, and when thermal energy is being transferred between two objects, it’s known as heat.

- Kinetic energy is determined by the given formula K.E=12mv2

- Factors affecting kinetic energy

Mass
Velocity
Momentum

- **Potential** Energy is the energy stored in an object or system of objects. Potential energy has the ability to transform into a more obvious form of kinetic energy.

- Potential energy is determined by the given formula
- Potential Energy=m×g×h

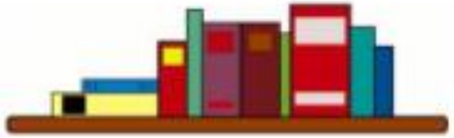
- Both potential energy and kinetic energy form mechanical energy.

- Mechanical energy is determined by the following formula
- Mechanical Energy=12mv2+mgh

Three types of potential energy:

Gravitational

Energy potential that comes from and object's height and weight



Chemical

Energy potential comes from the atoms it contains and the chemical reactions that take place within the object

Elastic

Energy potential an object being compressed or stretched

Potential Energy

- Energy can get stored in an object when work is done on it.

- For example, stretching a rubber string. The energy that is possessed by a body by virtue of its configuration or change in position is known as **Potential Energy.**

- The potential energy of an object at a height.

- When an object is raised to a certain height, work is done against gravity to change its position. This energy is stored as Potential Energy.

$\Rightarrow W = F.s$

$\Rightarrow F = ma$

- In the case of increasing the height, $F = mg$
- Therefore , W (P.E) $= mgh$

$\Rightarrow \Delta PE = mg(h_{final} - h_{initial})$

Work-energy theorem

The work-energy theorem states that the net work done by a moving body can be calculated by finding the change in KE.

⇒ W net = KE final − KE initial

⇒ Wnet= 12 m[v2−u2]

Relation between work done and energy. Now we will see the theorem that relates them. According to this theorem, the net work done on a body is equal to change in kinetic energy of the body. This is known as Work-Energy Theorem. It can be represented as

$K_f – K_i = W$

Where K_f = Final kinetic energy

K_i = Initial kinetic energy

W = net work done

So the above equation follows the law of conservation of energy according to which we can only transfer energy from one form to another.

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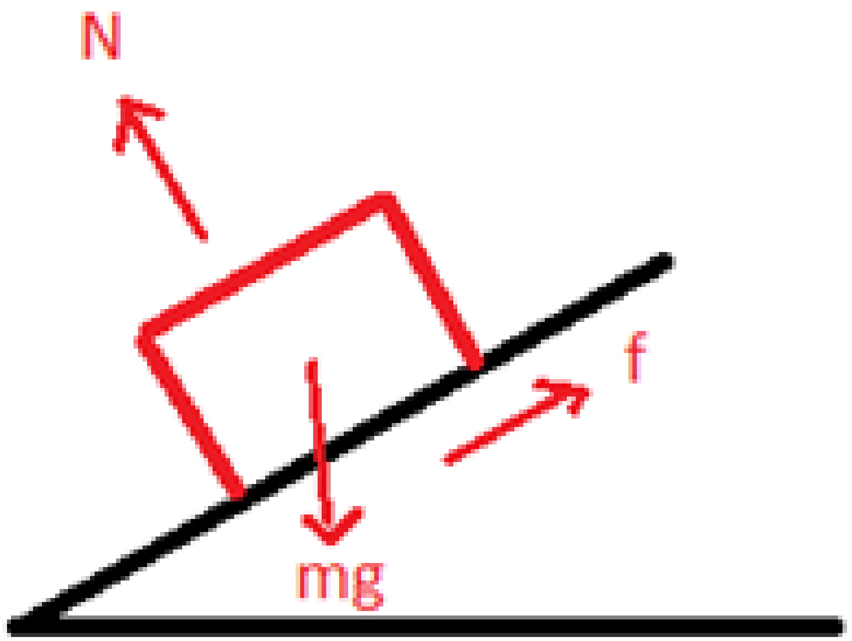
- Also here the work done is the work done by all forces acting on the body like gravity, friction, external force etc. For example, consider the following figure,



According to Work energy theorem

Work done by all the forces = Change in Kinetic Energy

$W_g + W_N + W_f = K_f - K_i$

Where W_g = work done by gravity

W_N = work done by a normal force

W_f = work done by friction

K_f = final kinetic energy

K_i = initial kinetic energy

Work done by a constant force

A constant force will produce constant acceleration. Let the acceleration be ‘a’.

From equation of motion,

$v2 = u2 + 2as$

$2as = v2 – u2$

Multiplying both side with mass ‘m’

$(ma).s = (mv2–mu2)2$

$F.s = (mv2–mu2)2$

Comparing the above equation we get,

Work done by force (F) = F.s

Where ‘s’ is the displacement of the body.

Work done by Non-Uniform Force

Now the equation,

$W = F.ds$

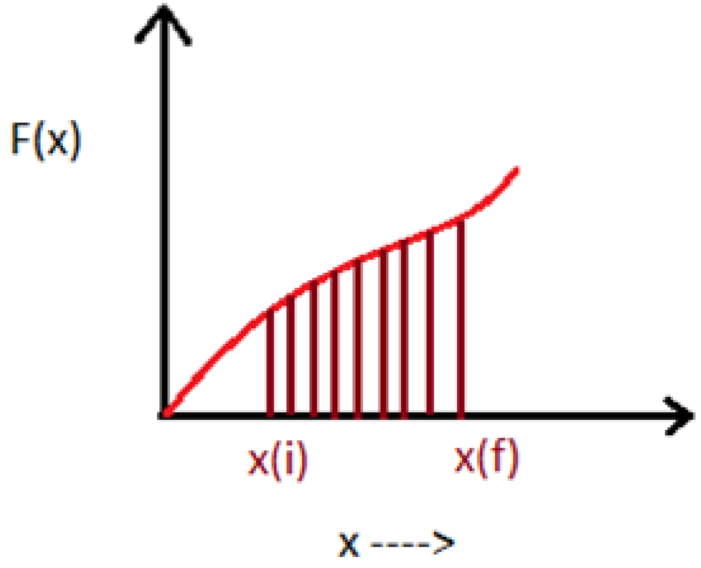
- This is only valid when force remains constant throughout the displacement. Suppose we have a force represented below,

- For these kinds of forces, force remains constant for a very small displacement and then integrate that from initial position to final position.

W = ∫xfxiF(x)dx

- This is work done by a variable force. A graphical approach to this would be finding the area between F(x) and x from xi to xf .

- The shaded portion represents the work done by force F(x).



Law of Conservation of Energy

Law of conservation of energy states that energy can neither be created nor destroyed, but can be transferred from one form to another. The total energy before and after the transformation remains constant.

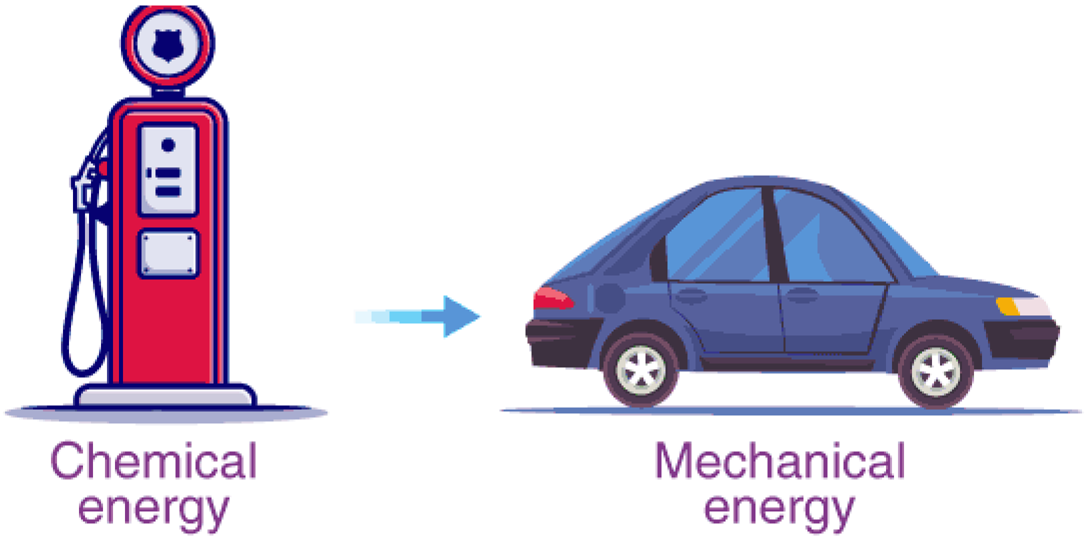
Total energy = KE + PE

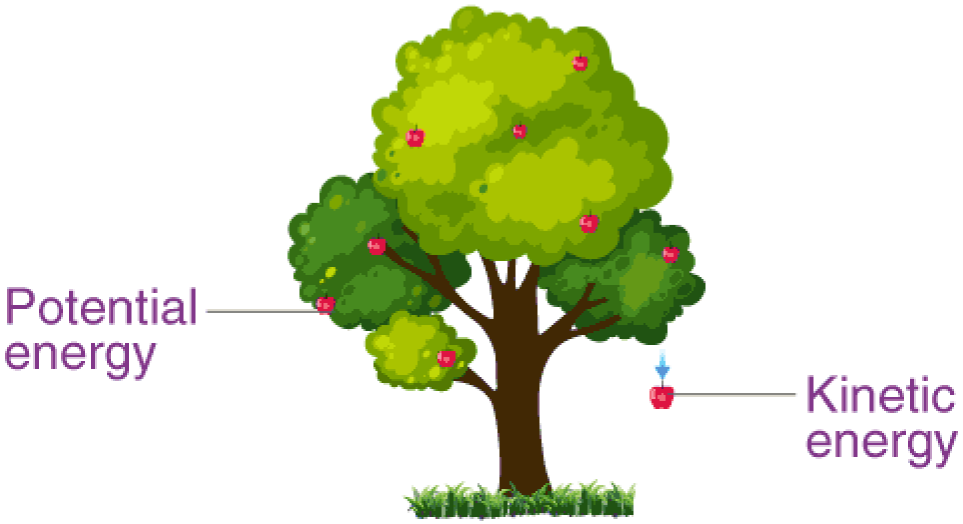
For example: consider a ball falling freely from a height. At height h, it has only PE = mgh.

By the time it is about to hit the ground, it has a velocity and therefore has KE= 12 mv2.
Therefore, energy gets transferred from PE to KE, while the total energy remains the same.

- The law of conservation of energy states that energy can neither be created nor be destroyed.
- Although, it may be transformed from one form to another.
- If you take all forms of energy into account, the total energy of an isolated system always remains constant.
- All the forms of energy follow the law of conservation of energy. In brief, the law of conservation of energy states that

In a closed system, i.e., a system that is isolated from its surroundings, the total energy of the system is conserved.


Chemical energy
Mechanical energy


Potential energy
Kinetic energy

- So in an isolated system such as the universe, if there is a loss of energy in some part of it, there must be a gain of an equal amount of energy in some other part of the universe.

- Although this principle cannot be proved, there is no known example of a violation of the principle of conservation of energy.

- The amount of energy in any system is determined by the following equation:

$$U_T = U_i + W + Q$$

- UT is the total energy of a system
- Ui is the initial energy of a system
- Q is the heat added or removed from the system
- W is the work done by or on the system

- The change in the internal energy of the system is determined using the equation

$$\Delta U = W + Q$$

Power

The rate of doing work or the rate of transfer of energy is called power. It is denoted by P

⇒ P = Wt

SI unit is Watt (Js−1).

Average power = Total energy consumed/Total time taken

The commercial unit of power is kWh i.e. energy used in 1 hour at 1000 Joules/second.
1kWh=3.6×106J

THANKYOU….