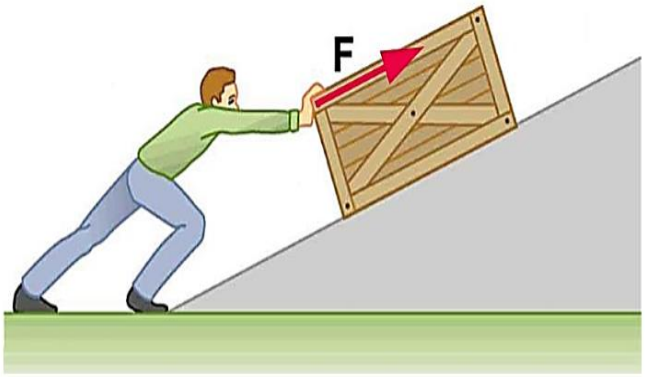
Chapter-3

ENERGY

Work (W)

Work is defined as a force acting upon an object to cause a displacement

It is expressed as the product of force and displacement in the direction of force.



$$W = F \times s$$

Here, W= work done on an object
F = Force on the object
s = Displacement of the object

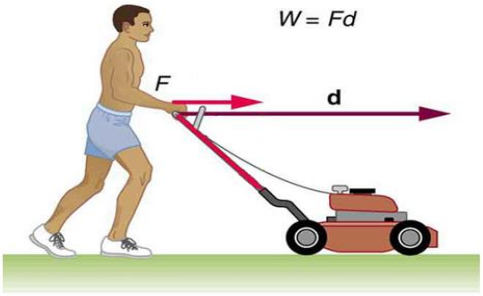
The unit of Work is Newton metre (Nm) or joule (J).
What is 1 Joule Work?

A situation where 1 Newton force is applied on an object that can move the object by a distance of 1m in the direction of the applied force, then 1 joule of work is said to be done.

Sign Conventions for Work Done

- when both the force and the displacement are in the same direction, positive work is done.

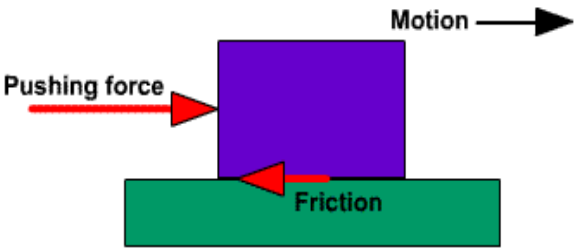
$$W = F \times s$$



- when force acts in a direction opposite to the direction of displacement, the work done is negative.

$$W = -F \times s$$

Angle between force and displacement is 180^{o}.



- If force and displacement are inclined at an angle less than 180°, then work done is given as:

  W= Fs cos θ

  If force and displacement act at an angle of 90° then work done is zero.

Necessary Conditions for Work to be done

Two conditions need to be satisfied for work to be done:

- Force should act on the object.
- Object must be displaced.

Energy

- Energy is ability to do work.
- Energy possessed by an object is the amount of work it can do.
- If an object can do more work, it has more energy and vice versa.

For example; a raised hammer can do work so it has energy and similarly a bomb can do work so it has also energy, a running bike can do work so it has energy, etc.

SI Unit of Energy:

The SI unit of energy is joule and denoted by 'J'.

- Larger unit of energy is kilo joule and is denoted by kJ.
- 1kJ = 1000J
- Energy required to do 1J of work is 1J of energy.
- Another unit of energy is calorie where 1cal =4.2 J

Different forms of Energy:

- **Mechanical Energy** – It is the sum of kinetic and potential energy of an object. Therefore, it is the energy obtained by an object due to motion or by the virtue of its location.

Example, a bicycle climbing a hill possesses kinetic energy as well as potential energy.

- **Heat Energy** – It is the energy obtained by an object due to its temperature. It is also called **Thermal Energy**.

  Example, energy possessed by a hot cup.

- **Chemical Energy** – It is the energy accumulated in the bonds of chemical compounds. Chemical energy is released at the time of chemical reactions.

  Example, energy possessed by natural gas and biomass.

- **Electrical Energy** – It is kind of kinetic energy caused due to the motion of electrons. It depends upon the speed of electrons. As the speed increases so does the electrical energy.

  Example, electricity produced by a battery, lightning at thunderstorms

- **Light Energy** – It is the energy due to light or electromagnetic waves. It is also called as **Radiant Energy** or **Electromagnetic Energy**.

  Example, energy from the sun

- **Nuclear Energy** – It is the energy present in the nucleus of an atom. Nuclear energy releases when the nucleus combines or separate. Therefore, we can say that every atom in this universe comprises of nucleus energy.

  Example, uranium is a radioactive metal capable of producing nuclear energy in nuclear power plants

- **Sound Energy** – It is the energy produced by a substance as it vibrates. This energy flows through the substance in the form of sound waves.

  Example-music instruments produce sound energy

- **Magnetic Energy** –a magnet can attract an iron nail from a distance and thus the force exerted by the magnet causes the nail to move towards the magnet. This energy is called magnetic energy.

  Example-Electro magnet to lift iron, to separate magnetic and nonmagnetic substances

TWO FORMS OF MECHANICAL ENERGY

Mechanical energy has two forms

- Potential energy
- Kinetic energy

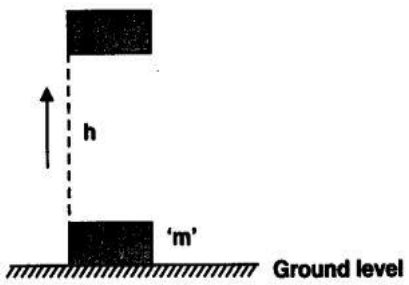
Potential Energy:

It is the energy possessed by an object due to its position or change in its shape.

Force acting on a body or system can change its Potential Energy.

Potential energy is denoted by letter U.

All bodies fall towards the earth with a constant acceleration known as acceleration due to gravity.



Expression for Potential Energy

The potential energy (E_p) is equal to the work done over an object of mass 'm' to raise it by a height 'h'.

Thus, $E_p = mgh$, where g = acceleration due to gravity

For example:

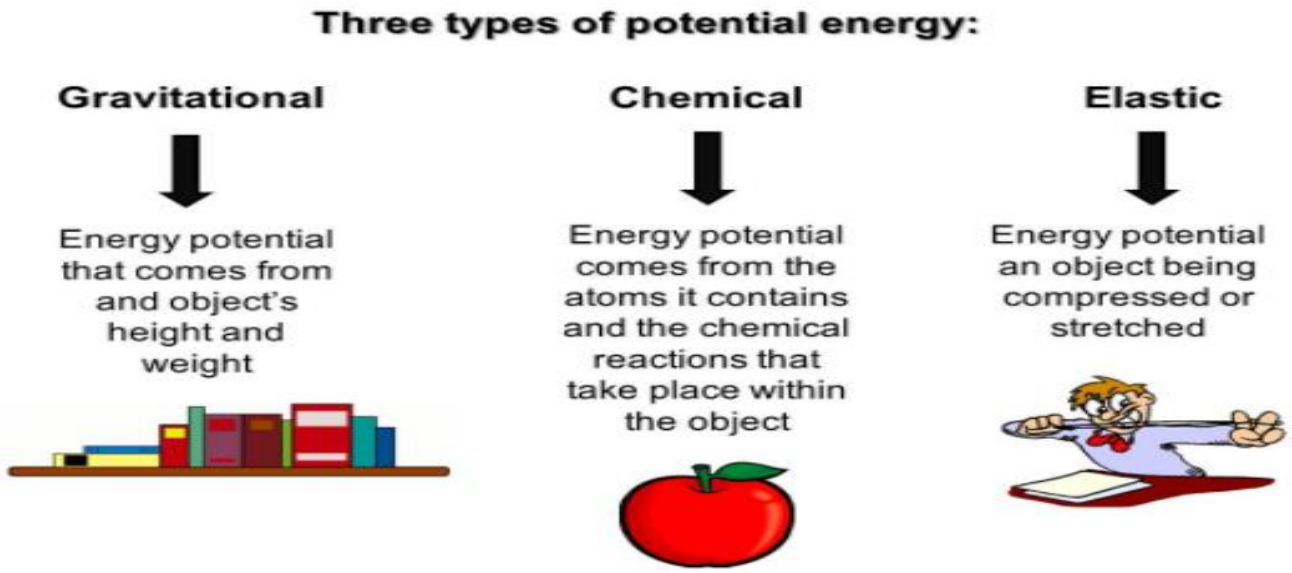
- In bow the stretched band can do work as when the stretched band is released the arrow starts moving so we can say that stretched band has energy.

In this case, energy possessed by the stretched band is due to change in shape.

- The block on ground can't do work. The block at high position can do work so it has energy.

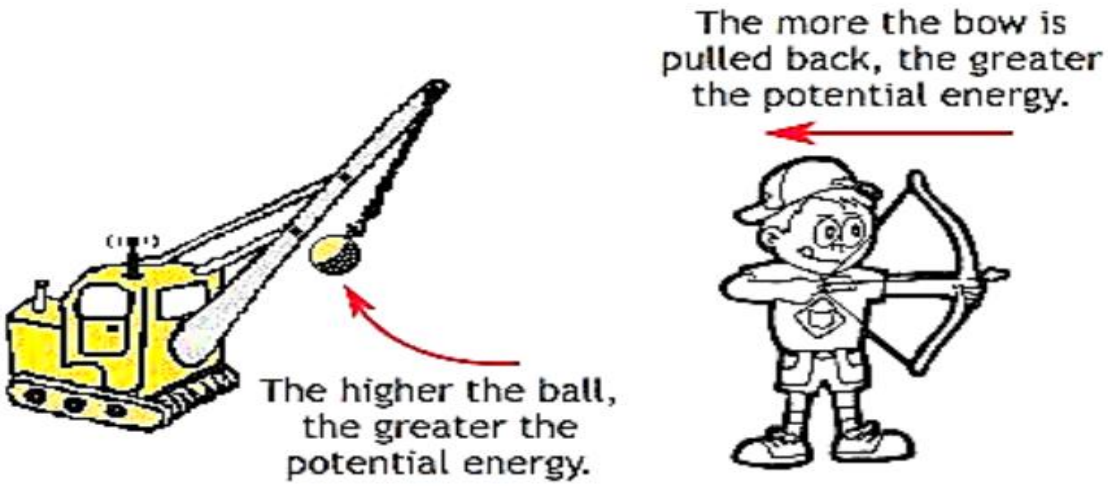
In this case, energy possessed by the block is due to its position.

On the basis of position and change in shape of object, potential energy is of two type:



Gravitational Potential Energy: It is the energy possessed by a body due to its position above the ground.

If an object is at greater height, it has more potential energy.



Elastic Potential Energy: It is the energy possessed by a body due to its change in shape.

Potential Energy (P.E.) = mgh

Here,

m = mass of body

g= 9.8 m/s^2

h= height of object from ground

Factors affecting the potential energy placed at a height

The potential energy of a body in the raised position depends up on following two factors

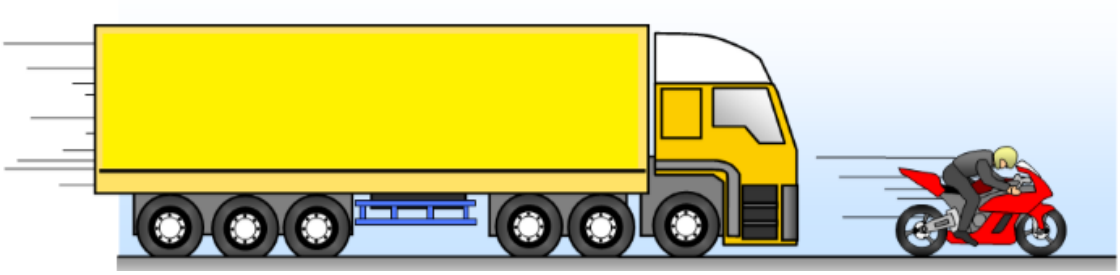
The mass of the body: greater the mass of the body, greater is the potential energy of the body

Its height above the ground: Higher the height of the body, greater is its potential energy

Kinetic Energy:

- It is the energy possessed by an object due to its motion.
- Anything moving is said to have kinetic energy.
- Body moving with greater velocity would possess greater K.E in comparison of the body moving with slower velocity
- **Kinetic energy** of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity.

For example; here the bike is moving so it has kinetic energy



Kinetic energy (K.E.) = $1/2mv^2$

Here,

m = Mass of object;

v = Speed of object;

- If two objects have same velocity but different masses, then object which have more mass possesses more kinetic energy.
- Similarly, more speed means more kinetic energy and vice versa.

Factors affecting the kinetic energy of a moving body

The kinetic energy of a moving body depends up on following two factors

The mass of the body: greater the mass of the body, higher is kinetic energy

The speed of the body: more the speed of the body, more is its kinetic energy

Transformation of Energy

Energy can transform from one form to another. For example; when a body falls from a height to ground potential energy transforms to kinetic energy.

Energy transformation in gadgets:

- In fan, electrical energy is transformed into kinetic energy.
- In bulb, electrical energy is transformed into heat energy then finally into light energy.
- In riding a bicycle, chemical energy is transformed into muscular then into kinetic energy etc.

Energy transformation in Nature:

- During photosynthesis, light energy is transformed into chemical energy;
- During rain, potential energy is transformed into kinetic energy;
- During striking of clouds, kinetic energy is transformed into light and sound energy etc.

Law of Conservation of Energy

Law of conservation of energy says that

" Energy can neither be created nor destroyed, but can be converted from one form into another. When energy changes from one form to another, total amount of energy remains constant or conserved ".

For example:

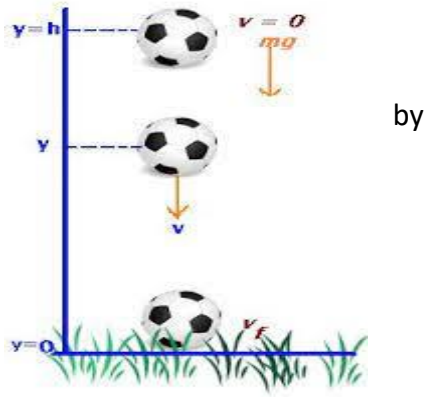
In an iron the electrical energy required to run it is 100J (say), then this energy is converted into heat energy and the energy still remains 100J only its form gets converted not its amount.

Energy conservation for a falling body:

- Let's suppose a ball of mass 1 kg is kept at a distance 4m from ground.

  Potential energy of ball = mgh= (1)(10)(4) = 40 J

- As ball moves down, potential energy decreases. But by conservation of energy, total energy should be constant. It means kinetic energy would increase.
- Kinetic energy (K.E.) = $1/2\ mv^2$



Initially velocity is zero, so

K.E. = 0

But as ball moves down, velocity is increasing and thus kinetic energy would increase.

- Thus we can say potential energy is transforming to kinetic energy and total mechanical energy is constant.

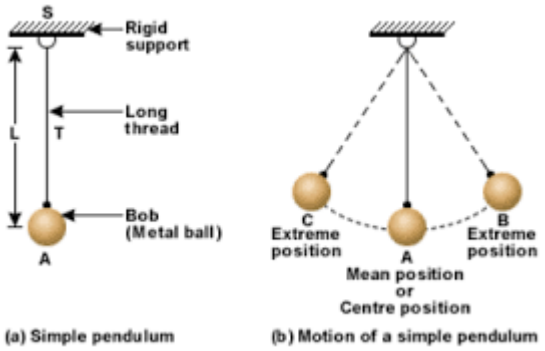
P.E. + K.E. = Mechanical energy = constant

- When the ball finally hits the ground, it comes to rest and its P.E. and K.E. both are zero.
- 40 J kinetic energy is converted to sound and heat energy.
- Sound is produced on hitting and ground gets a bit heated.

Energy Conservation in Pendulum:

We know as pendulum oscillates, its height changes.

- At point A, ball has kinetic energy and no potential energy.
- When pendulum slowly rise, K.E. decreases and P.E. increases. At point B, ball has potential energy and no kinetic energy.
- While going from B to A, P.E changes to K.E. At point A, K.E. becomes maximum and P.E energy becomes zero.



- While going from A to C, K.E changes to P.E. At point C, ball has potential energy and no kinetic energy.
- While going from C to A, P.E changes to K.E.

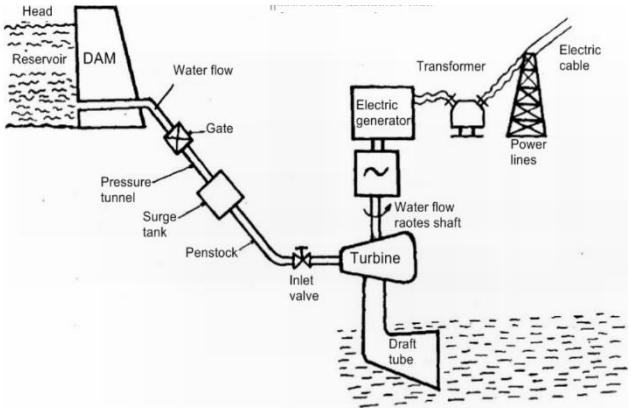
When pendulum stops, both P.E. and K.E. becomes zero and entire energy is converted into sound and heat energy.

Thus an oscillating pendulum also verifies law of conservation of energy.

Hydro-power Plants

In hydro-power plants, kinetic energy of the flowing water or the potential energy of the water at height is used to turn the turbine and generate electricity.

To produce hydel electricity, high-rise dams are constructed on the river to obstruct the flow of water and thereby collect water in larger reservoirs. The water level rises and in this process the kinetic energy of flowing water gets transformed into potential energy. The water from the high level in the dam is carried through pipes, to the turbine, at the bottom of the dam



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