WORK - POWER AND ENERGY 7

WORK:

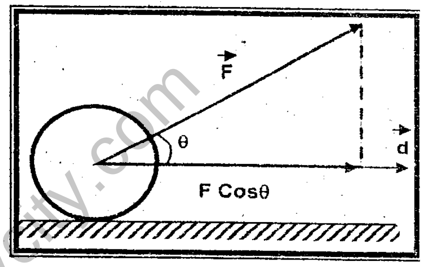
The work done by a constant force is defined as the product of the magnitude of displacement and the magnitude of the component of force in the direction of displacement.

If the force $\vec{F}$ and displacement $\vec{d}$ make an angle θ with each other, then work done is given by.

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

Or $$W = Fd\cos\theta$$

$$\boxed{W = \vec{F} \cdot \vec{d}}$$



This shows that the work is the dot product of force and displacement. It is a scalar quantity.

POSITIVE OR MAXIMUM WORK:

When the angle between $\vec{F}$ and $\vec{d}$ is zero then the work will be positive or maximum.

$W = Fd\cos\theta$

$\theta = 0^\circ$

$W = Fd\cos 0^\circ$

$W = Fd \times 1$ $\quad\because \cos 0^\circ = 1$

$\boxed{W = Fd}$

MINIMUM OR ZERO WORK:

When the angle between $\vec{F}$ and $\vec{d}$ is 90° then the work will be minimum.

$W = Fd\cos\theta$

$\theta = 90^\circ$

$W = Fd\cos 90^\circ$

$W = Fd \times 0$ $\quad\because \cos 90^\circ = 0$

$\boxed{W = 0}$

NEGATIVE WORK:

When the angle between $\vec{F}$ and $\vec{d}$ is 180° then the work will be negative:

$W = Fd\cos\theta$

$\theta = 180^\circ$

$W = Fd\cos 180^\circ$

$W = Fd \times (-1)$ $\quad\because \cos 180^\circ = -1$

$\boxed{W = -Fd}$

Units of Work:

In S.I. system unit of work is Joule and is defined as ***"the work done by a force of 1N in moving a body through a distance of 1m in the direction of force"***. i.e.

$$1J = 1N \times 1m$$

In the physics of molecule and elementary particles, a much smaller unit is used. This unit is known as the electron volt (ev).

$$1\ ev = 1.60 \times 10^{-19}\ J$$

Commonly used multiples of the electron volt are 1 million electron volt

$$1 \text{ million electron volt} = 1\ Mev = 10^{6} ev.$$

The above units are also used for energy.

GRAVITATIONAL FIELD:

The space or region around the earth its force of attraction which can be felt by other bodies, is called ***"GRAVITATIONAL FIELD"***.

CONSERVATIVE FIELD:

The field of force in which work done is independent of the path followed is called a **"CONSERVATIVE FIELD"**.

OR

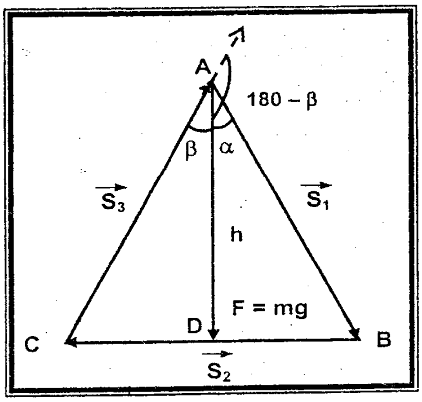
The field in which the total work done along a closed path is zero is called **"CONSERVATIVE FIELD"**.

Gravitational field is conservative field.

GRAVITATIONAL FIELD IS A CONSERVATIVE FIELD:

Consider a body of mass **"m"** at point **"A"** in the gravitational field. The body is moved along a closed path ABCA, as shown in the figure.

Let $\vec{AB} = \vec{S_1}$, $\vec{BC} = \vec{S_2}$ and $\vec{CA} = \vec{S_3}$



Work done in moving the body from A to B

$$W_{A\to B} = \vec{F}.\vec{S_1} = FS_1 \cos\alpha$$

Consider ΔADB

$$\cos\alpha = \frac{AD}{AB}$$

$$\cos\alpha = \frac{h}{s_1}$$

$$W_{A\to B} = Fh$$

But $F = W = mg$

$$\therefore \quad \boxed{W_{A\to B} = mgh}$$

Similarly

Work done in moving the body from B to C

$$W_{B\to C} = \vec{F}\cdot\vec{S_2} = FS_2 \cos 90^\circ = FS_2 \times 0$$

$$\boxed{W_{B\to C} = 0}$$

and work done in moving the body from C to A,

$$W_{C\to A} = \vec{F}\cdot\vec{S_3} = FS_3 \cos(180 - \beta) = FS_3(-\cos\beta) \quad \because \cos(180-\beta) = -\cos\beta$$

$$= -FS_3\cos\beta$$

Consider ΔADC

$$\cos\alpha = \frac{AD}{AC}$$

$$\text{Cos}\,\alpha = \frac{h}{s_3}$$

$$S_3 \text{Cos}\,\alpha = h$$

$$W_{C \to A} = -Fh$$

But $F = W = mg$

$$\boxed{W_{C\to A} = -mgh}$$

The total work done in moving the body along the closed path ABCA is:

$$\begin{aligned} W_{A\to B\to C\to A} &= W_{A\to B} + W_{B\to C} + W_{C\to A} \\ &= mgh + 0 + (-mgh) \\ &= mgh - mgh \\ W_{A\to B\to C\to A} &= 0 \end{aligned}$$

This shows that the total work done in moving a body along a closed path is zero, such a field is called ***conservative field.***

Thus the gravitational field is a conservative field.

The second result i.e. work done in moving a body is independent of the path adopted can be proved by dividing the whole work into two parts i.e.

$$W_{A\to B\to C} + W_{C\to A} = 0 \longrightarrow (1)$$

On the other hand

$$W_{A\to C} + W_{C\to A} = 0 \longrightarrow (2)$$

Comparing eq. (1) and (2)

$$W_{A\to B\to C} + W_{C\to A} = W_{A\to C} + W_{C\to A}$$

$$W_{A\to B\to C} = W_{A\to C}$$

This shows that the work done in moving a body in gravitational field is independent of the path adopted. Thus gravitational field is a ***"conservative field"***.

POWER:

The rate of doing work is called power i.e.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

If "ΔW" is the work done in time "Δt" then average power

$$P_{av} = \frac{\Delta W}{\Delta t}$$

If "Δt" approaches to zero then power will be instantaneous and is given by.

$$P_{ins} = \lim_{\Delta t \to 0} \frac{\Delta W}{\Delta t}$$

If work is done at uniform rate then average and instantaneous power becomes equal and we simply write

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

Power is the dot product of force and velocity:

The average power is given by formula

$$P = \frac{\Delta W}{\Delta t} \longrightarrow (1)$$

If $\vec{F}$ be the force acting on a body through displacement $\Delta\vec{d}$ then work done ΔW is given by:

$$\Delta W = \vec{F} \bullet \Delta\vec{d}$$

Put this value of ΔW in equation (1)

$$P_{av} = \frac{\vec{F} \bullet \Delta\vec{d}}{\Delta t}$$

$$P_{av} = \vec{F} \bullet \frac{\Delta\vec{d}}{\Delta t}$$

But $\frac{\Delta\vec{d}}{\Delta t} = \vec{v}_{av}$ = average velocity.

$$P_{av} = \vec{F} \cdot \vec{v}_{av}$$

If the body is moving with instantaneous velocity $\vec{V}_{ins}$ then instantaneous power is given by.

$$P_{ins} = \vec{F} \bullet \vec{v}_{ins}$$

If the body is moving with constant velocity $\vec{V}$ then power is given as.

$$P = \vec{F} \bullet \vec{v}$$

i.e. power is the dot product of force and velocity. It is a scalar quantity.

Units of Power:

In international system of units, the unit of power is watt and in British engineering system, the unit of power is horse power (hp).

Watt:

When a body does work 1Joule in 1Second, then its power is said to be one watt.

i.e. 1 watt $= \frac{1J}{1S}$

The multiples of watt are:

1 kilo watt (kw) = 1000 watts = 10^3W
1 Mega watt (MW) = 10^6W
1 Giga watt (GW) = 10^9W

Horse Power:

When a body does work 550 ft-lb. in one second, is called its one horse power.

DIMENSIONS OF POWER:

The dimensions of power are $\frac{ML^2}{T^3} = ML^2\,T^{-3}$

UNITS OF WORK IN TERMS OF UNIT OF POWER:

Since $\text{Power} = \frac{\text{Work}}{\text{Time}}$

Work = Power x Time

The unit of work in terms of unit of power is ***"kilowatt hour"*** and is defined as the work done in one hour by an agency working at the constant rate of one kilowatt i.e. 1000 j/s.

1kilowatt hour = 1000 watts x 1 hour

$= 1000 \text{ Power } \frac{J}{S} \times 3600\text{ S}$

$= 3600000\text{ J}$

$= 3.6 \times 10^6\text{ J}$

ENERGY:

Energy is the capacity of doing work. There are many forms of energies i.e. mechanical energy, heat energy, chemical energy, nuclear energy, solar energy etc. Energy can be converted from one form to the other.

KINETIC ENERGY:

The energy possessed by the body by virtue of its motion is called kinetic energy (K.E).

Expression for K.E:

Consider a body of mass ***"m"*** which is projected up in the gravitational field with a velocity ***"V"***, after attaining a maximum height ***"h"***, the body comes to rest. The work done by the body against the gravitational force is given by work done by the body = Force x Displacement.

$$\text{Work} = \vec{F} \bullet \vec{h} = Fh \cos\theta$$

But $\theta = 0^\circ$ and $\cos 0^\circ = 1$ also $F = W = mg$.

Work done by the body = $mgh \cos 0^\circ$

$\therefore$ Work done by the body = $mgh \longrightarrow$ **(1)**

"h" can be found by using formula

$$2as = V_f^2 - V_i^2$$

Where
$V_i = v$ = initial velocity of the body.
$V_f = 0$ = final velocity of the body.
$a = -g$
$s = h$ = maximum height attained by the body

$$\therefore \quad 2(-g)h = 0^2 - V_i^2$$
$$-2gh = -V^2$$
$$h = \frac{V^2}{2g}$$

Substituting the value of **"h"** in eq (1),

$$w = mg \times \frac{v^2}{2g}$$
$$= \frac{1}{2}mv^2$$

we get work done by the body = $\frac{1}{2}mv^2$.

This work done is the measure of the K.E of the body.

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

POTENTIAL ENERGY:

When a body is being moved against a field of force, energy is stored in it. This energy called ***"POTENTIAL ENERGY"*** e.g. when a spring is compressed or elongated, work is done on it in the form of ***Elastic Potential Energy***. When a charge is moved against an electrostatic force, work is done on it. This work is stored in the form of ***Electrostatic Potential Energy***.

When a body is moved against gravitational force, work is done on it. This work done is stored in the form of ***GRAVITATIONAL POTENTIAL ENERGY***.

EXPRESSION FOR GRAVITATIONAL POTENTIAL ENERGY:

Consider a body of mass "**m**" which is taken very slowly to small height "**h**" in the gravitational field such that the acceleration of the body is zero. The work done in moving the body is given by:

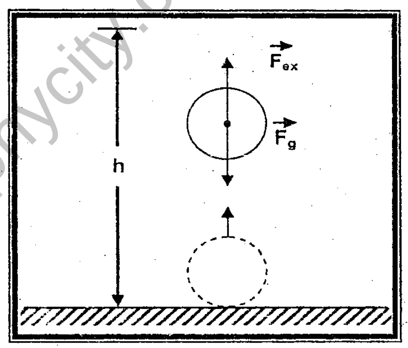
$$\text{Work done} = \vec{F}_{ex} \cdot \vec{h} = F_{ex}\, h \cos\theta$$

Where "$\vec{F}_{ex}$" is the external force applied on the body. Since the external force applied on the body and the displacement are along the same direction, therefore work done by external force "$\mathbf{W_{ex}}$" is given by: $W_{ex} = F_{ex}h$ ---------- ($\because \cos 0^\circ = 1$).

As the acceleration of the body is zero therefore magnitude of external force is equal to that of the force of gravity i.e.

$$F_{ex} = mg$$

$$\therefore \quad W_{ex} = mgh \longrightarrow \mathbf{(1)}$$



Work done "$\vec{W}_g$" by the gravitational force "$\vec{F}_g$" is given by:

$$W_g = \vec{F}_g \cdot \vec{F}$$

$$W_g = F_g h \cos 180^\circ$$

$$W_g = -F_g h$$

$\because$ $\vec{F}_g$ and $\vec{h}$ are in opposite direction

Since $F_g = mg$

$\therefore$ $W_g = -mgh \longrightarrow \mathbf{(2)}$

OR $-W_g = mgh \longrightarrow \mathbf{(3)}$

Comparing eqs. (1) and (3)

$$W_{ex} = -W_g$$

By putting the value of W_g from eq. (2), we get

$$W_{ex} = -W_g = -(-mgh) = mgh$$

This work done on the body by an external force against the gravitational force is stored in it in the form of potential energy and is known as ***gravitational potential energy*** represented by "**Ug**".

$$\therefore \quad Ug = W_{ex} = -W_g = mgh$$

This gravitational potential energy is the relative potential energy of the body with respects to some orbitary zero level.

ABSOLUTE GRAVITATIONAL POTENTIAL ENERGY:

Absolute gravitational potential energy at a point is the amount of work done in moving a body from infinity to that point.

EXPRESSION FOR ABSOLUTE GRAVITATIONAL POTENTIAL ENERGY:

Consider a body of mass **"m"** at point A (0 or 1) in the gravitational field. If the body is lifted to a far off point B (or 'n') in the gravitational field then work done in moving body can not be directly found by using the formula:

Work done = Force x displacement.

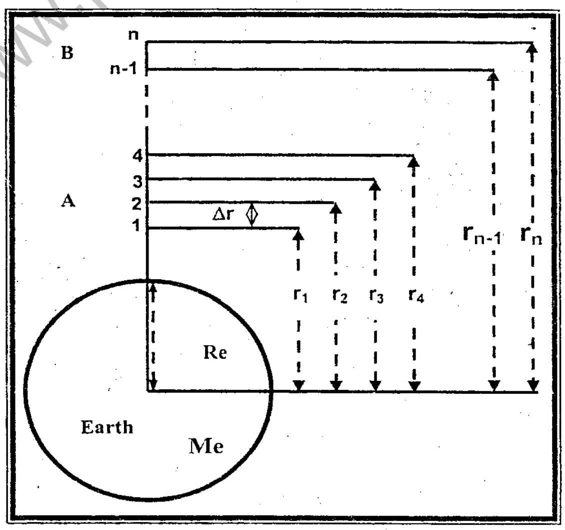
Because the gravitational force will not remain constant for such a large distance.

To overcome the difficulty, divide the distance between A and B into a large number of intervals each of width Δr. Δr is so small that the gravitational force throughout this interval may be assumed to be constant.

If r be the average distance of r_1 and r_2

$$F = \frac{GmM_e}{r^2} \longrightarrow (1)$$

Where G = Gravitational constant
M_e = Mass of earth and
F = Average force from 1 to 2.
and r = Average distance of r_1 and r_2



$$r = \frac{r_1 + r_2}{2}$$

$$r_2 - r_1 = \Delta r$$

$$r_2 = \Delta r + r_1$$

So $$r = \frac{r_1 + \Delta r + r_2}{2}$$

$$r = \frac{2r_1 + \Delta r}{2}$$

$$r^2 = \frac{4r_1^2 + 4r_1\Delta + \Delta r^2}{2}$$

Δr is small, so Δr^2 is negligible

$$r^2 = r_1^2 + r_1\Delta r$$

$$r^2 = r_1^2 + r_1(r_2 - r_1)$$

$$= r_1^2 + r_1 r_2 - r_1^2$$

$$r^2 = r_1 r_2$$

Putting r^2 in (1)

$$F = \frac{GmMe}{r_1 r_2} \longrightarrow (2)$$

Work done in lifting the body from point '1' to '2' given by:

$$W_{1\to 2} = \vec{F}\cdot\vec{\Delta r} = F\Delta r\, \text{Cos}\theta$$

Since $\vec{F}$ and $\vec{\Delta r}$ are along the same direction.

$\therefore \quad \theta = 0^\circ$ and $\text{Cos } 0^\circ = 1$

$\therefore \quad W_{1\to 2} = F\Delta r$

By putting the values of **"Δr"** and **"F"** from eqs. **(1)** and **(2)**, we get.

$$W_{1\to 2} = \frac{GmM_e}{r_1\, r_2}(r_2 - r_1) = GmM_e\left(\frac{r_2 - r_1}{r_1\, r_2}\right)$$

$$= GmM_e\left(\frac{r_2}{r_1\, r_2} - \frac{r_1}{r_1\, r_2}\right)$$

$$\therefore \quad W_{1\to 2} = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Similarly the work done in lifting the body from point 2 to 3, 3 to 4 --- and (n - 1) to n is given by:

$$W_{2\to 3} = GmM_e\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$$

$$W_{3\to 4} = GmM_e\left(\frac{1}{r_3} - \frac{1}{r_4}\right)$$

$$W_{(n-1)\to n} = GM_e\left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

The total work done in lifting the body from point '1' to 'n' is given by:

$$W = W_{1\to 2} + W_{2\to 3} + W_{3\to 4} + \text{--------}\ W_{(n-1)\to n}$$

OR

$$W = GmM_e\left[\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_3} - \frac{1}{r_4} + \ldots\ldots\ldots\ldots\frac{1}{r_{n-1}} - \frac{1}{r_n}\right]$$

$$W = GmM_e\left[\frac{1}{r_1} - \frac{1}{r_n}\right]$$

This work done is stored in the body as potential energy.

Thus P.E of the body at B with respect to point A

$$P.E = GmM_e\left[\frac{1}{r_1} - \frac{1}{r_n}\right]$$

The P.E of the body at point A with respect to point B is

$$\Delta U = -W$$

OR $\Delta U = -GmM_e\left[\frac{1}{r_1}-\frac{1}{r_n}\right]$

If the point **"B"** lies at infinity then $r_n = \propto$ and $\frac{1}{\propto} = 0$

$$\therefore \quad \Delta U = -GmM_e\left(\frac{1}{r_1}\right)$$

This P.E of the body at point **"A"** is called ***ABSOLUTE POTENTIAL ENERGY***

$$\Delta U = (P.E)_{abs}$$

$$\therefore \quad \boxed{(P.E)_{abs} = -\frac{GmM_e}{r_1}}$$

If **"R_e"** be the radius of the earth then the absolute potential energy of the body at the surface of the earth is given by:

$$\boxed{(P.E)_{abs} = -\frac{GmM_e}{R_e}}$$

ABSOLUTE POTENTIAL ENERGY AT CERTAIN HEIGHT:

The absolute potential energy of the body at a height **"h"** ($h \ll Re$) above the surface of the earth is given by:

$$(P.E)_{abs} = -\frac{GmM_e}{R_e+h} = \frac{-GmM_e}{R_e(1+\frac{h}{R_e})}$$

$$= -\frac{GmM_e}{R_e}\left(1+\frac{h}{R_e}\right)^{-1}$$

Using Binomial theorem, we can write

$$\left(1+\frac{h}{R_e}\right)^{-1} = 1+\frac{(-1)}{1!}\frac{h}{R_e}+\frac{(-1)(-2)}{2!}\left(\frac{h}{R_e}\right)^2+\ldots\ldots$$

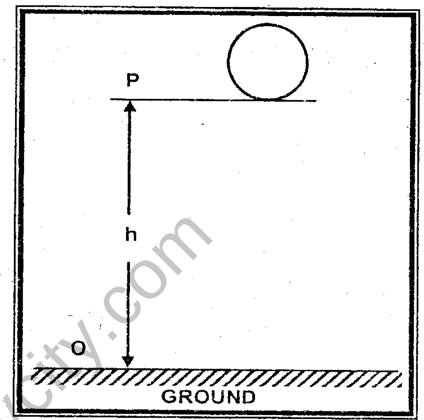
$$= 1-\frac{h}{R_e}+\left(\frac{h}{R_e}\right)^2+\ldots\ldots$$

Since $h \ll Re$. Therefore we can neglect the terms containing the higher powers of $\frac{h}{R_e}$.

$$\therefore \quad \left(1+\frac{h}{R_e}\right)^{-1} = 1-\frac{h}{R_e}$$

Thus $(P.E)_{abs} = -\frac{GmM_e}{R_e}\left(1-\frac{h}{R_e}\right)$

WORK – ENERGY EQUATION
OR
INTER-CONVERSION OF POTENTIAL AND KINETIC ENERGY



Consider a body of mass ***"m"*** placed at a point P which is at a height ***"h"*** from the ground. The body possesses a gravitational potential energy equal to ***"mgh"*** with respect to the ground while its kinetic energy is zero because its velocity is zero.

P.E. of the body at P = mgh

K.E. of the body at P = 0

Total energy of body at P = K.E.+ P.E. = 0 + mgh

Total energy at P = mgh $\longrightarrow$ (1)

If the body is allowed to fall freely under the action of gravity then its potential energy will go on decreasing while its kinetic energy will go on increasing because the velocity of the body is increasing.

If there is no force of friction acting on the body then this P.E is converted to K.E of the body.

When the body reaches just above the ground, its potential energy is nearly zero while its K.E is maximum i.e.

If "v" be the velocity of the just before hitting the ground then K.E. of the body = $\frac{1}{2}mv^2$.

The velocity of the body can be found by formula:

$$2gh = Vf^2 - Vi^2$$

Where Vi = initial velocity at 'P' = 0

Vf = final velocity at O = v

$\therefore$ $2gh = V^2$

$\therefore$ $V^2 = 2gh$

$\therefore$ K.E at O = $\frac{1}{2}m \text{ X } 2gh = mgh$

P.E at O (near the ground) = 0

Total energy of the body at 'O'= K.E + P.E

= mgh + o

= mgh $\longrightarrow$ (2)

From Eq. (1) and Eq. (2)

$\boxed{\text{Loss of P.E = Gain in K.E}}$

IN THE PRESENCE OF FORCE OF FRICTION:

If there is some force of friction *"f"* acting on the body then a fraction of its P.E is lost in doing work against the frictional force while remaining energy is converted into the K.E.

i.e. Loss of P.E = Gain of K.E + Work done against friction

OR Gain of K.E = Loss of P.E – Work done against friction

But Loss of P.E = mgh

Work done against friction = fh.

$\therefore$ $\boxed{\textbf{Gain of K.E} = mgh - fh}$

The above equation is termed ***"Work–Energy Equation"***

LAW OF CONSERVATION OF ENERGY:

According to this law, ***"Energy can neither be created nor is it destroyed. It can only be transformed from one form to another. A loss in one form of energy is accompanied by an equal increase in the other forms of energy. The total energy remains constant"***.

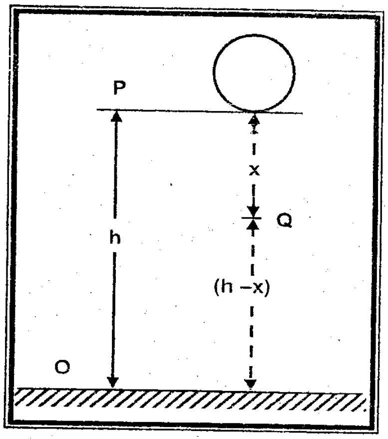
According to Einstein's mass energy relation:

$E = mc^2$, energy can be converted into mass and mass can be converted to energy. ***PAIR PRODUCTION*** is the example of conversion of energy into mass.

On the other hand ***NUCLEAR FISSION*** and ***FUSION*** are examples of conversion of mass into energy.

PROOF OF THE LAW OF CONSERVATION OF ENERGY:

Consider a body of mass **"m"** placed at a point **"P"** which is at a height **"h"** from the ground.



P.E. of the body at P = mgh

K.E of the body at P = 0

Total energy of body at P = K.E + P.E = 0 + mgh

Total energy at P = mgh $\longrightarrow$ **(1)**

If the body is allowed to fall freely under the action of gravity then its P.E will go on decreasing while its K.E will go on increasing.

Just before hitting the ground the P.E of the body will be minimum or zero while K.E of the body will be maximum. If **"v"** be the velocity of the body just before hitting the ground then K.E of the body = $\frac{1}{2}mv^2$.

The velocity of the body can be found by formula:

$$2gh = V_f^2 - V_i^2$$

Where V_i = initial velocity at 'P' = 0

V_f = final velocity at O = v

$\therefore$ $2gh = V^2 - 0^2$

$\therefore$ $V^2 = 2gh$

$\therefore$ K.E at O $= \frac{1}{2}m \times 2gh = mgh$

P.E at O (near the ground) = 0

Total energy of the body at 'O' = K.E + P.E

= mgh + o

= mgh $\longrightarrow$ (2)

Let at any instant the point Q which is at a distance *"x"* from P.

If V' be the velocity of the body at point 'Q' Then:

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

$$\text{P.E at Q} = mg(h-x) = mgh - mgx$$

V' can be found by formula:

$$2gh = V_f^2 = V_i^2$$

where $V_i = 0$, $V_f = V'$ and $h = x$

$\therefore$ $2gx = (V')^2 - 0^2$

$= (V')^2 = 2gx$

$\therefore$ K.E at Q $= \frac{1}{2}m \times 2gx = mgx$

Total energy at Q = K.E + P.E

= mgx + mgh − mgx

Total energy at Q = mgh $\longrightarrow$ (3)

From equations **(1)**, **(2)**, and **(3)** it can be seen that the total energy of the body remains constant every where provided there is no force of friction involved during the motion of the body.

If there is some force of friction acting on the body then a fraction of P.E is lost in doing work against the force of friction, Thus,

Total energy = K.E + P.E + Loss of energy or work done against force of friction.

Examples of Conservation of Energy:

1. When we switch on an electric bulb, we supply electrical energy to it which is converted into heat and light energies. i.e.

   Electrical Energy = Heat energy + Light energy

2. Fossil fuels e.g. coal and petrol is stores of chemical energy. When they burn, chemical energy is converted into heat energy i.e.

   Chemical Energy = Heat energy + Losses

3. The heat energy present in the steam boiler can be used to drive a steam engine. Here heat energy is converted into kinetic (mechanical energy), i.e.

   Heat Energy = Mechanical energy + Losses

4. In rubbing our hands we do mechanical work which produces heat, i.e

   Mechanical Energy = Heat energy + Losses

VARIOUS SOURCES OF ENERGY:

1. Wind Energy (Wind Power):

The source of this energy is wind. This energy is used in running flour mills. It can also be used for various purposes e.g. for sailing boats, for rotating wheel.

2. Hydro Electricity (Water Power):

The source of this energy is water at some height. To store this water at height, various dams are constructed. This water is also used to derive electrical generation. The electricity thus produced is used for various purposes.

3. Fossil Fuel:

Fossil fuels are remains of plants and animals which died millions of years ago. The fuel can be liquid, gaseous or solid. Coal is being used by man since long as a source of energy. Fossil fuel is used for running machines, for driving the engines etc.

4. Nuclear Energy:

The nuclear energy is produced due to the fission of a heavy nucleus. If fission reaction occurs in a controlled manner (in a reactor), the nuclear energy thus produced is used for the production of electrical power. This energy is usually more economical and not polluting. If the fission reaction is uncontrolled, the enormous energy produced in the form of heat causes heavy destruction.

Fusion reaction if uncontrolled can cause much more destruction than caused by fission reaction. On the other hand controlled fusion reaction may generate enormous amount of energy for useful purposes.

5. Geothermal Energy:

Geothermal energy is the earth's natural heat, which is conducted out from the interior of the earth's surface at a rate of 1.5μ cal/cm^2, and over a time interval of a year, this flux to the entire surface is 1020 calories.

Geothermal power is used in two ways. One involves the piping of steam from naturally occurring reservoirs of steam deep in the earth and using that steam to turn turbines to generate electricity. The other way involves the tapping into very hot water which is some times found deep in the earth, and using the steam from the water to run the turbines.

6. Solar Energy:

The source of energy most easily available to us is sunlight. Our lives absolutely depend upon it. Mirrors and lenses have been used to concentrate the energy of the sun's rays into small spots. Every year the earth absorbs about 4×10^{17} Kwh of solar energy. If we could utilize only 0.1 percent of the incident energy, that would be more than enough to satisfy the entire world's energy requirements. The most practical way to utilize this energy is to allow it to vapourize water into steam, which can then be used to derive turbines to produce electricity. The voltage produced by a single solar cell is very small. In order to get a large voltage, a number of solar cells are connected in series forming a panel of solar cells. This solar panel provides the electrical power directly from the sunlight. Nickel-Cadmium batteries, according to our requirements, are connected in series with solar panels in machine to store this energy. Then, these batteries can be used to supply power to our electrical appliances.

7. Tidal Energy:

The water rises along coasts due to gravitational pull of the moon on water twice daily forming tides. This back and forth surging of water can be turned in narrow tunnels and used for power generation.