ENERGY -

Energy is the capability (or Capacity) of doing work.

The object which does work, loses energy.
The object on which work is done, it gains energy.

UNITS OF ENERGY -

Energy is Capacity of doing work. Unit of energy is same as that of work.

SI unit of energy = 1 Joule (J)

One Joule (1 J) of energy is the energy required to do 1 Joule of work.

Larger Units -

1 Kilo Joule = 1 KJ
= 1000 J = 10^3 J

1 mega Joule = 1 MJ
= 1000 KJ = 10^6 J

Smaller Units

1 millijoule = 1 mJ
= 10^{-3} J

1 microjoule = 1 μJ
= 10^{-6} J

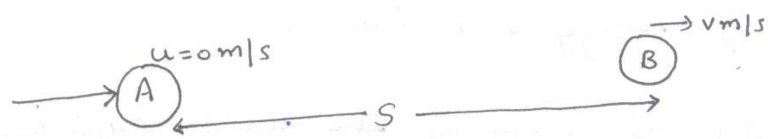
Mechanical energy
- Kinetic Energy (KE)
- Potential energy (PE)

KINETIC ENERGY -

The energy possessed by an object by virtue of its motion.

K.E of a moving object depends on its velocity.
Higher the velocity, greater the Kinetic energy of a moving object.

DERIVATION OF KINETIC ENERGY -



Let us consider a body of mass m.
Initial velocity = 0
final velocity = V
displacement = S

Using IIIrd eqn. of motion,

$$V^2 - u^2 = 2as$$
$$v^2 - 0^2 = 2as$$
$$v^2 = 2as$$
$$a = \frac{v^2}{2s}$$

Work done by body, $W = F \times S$

Using Newton's Second Law of motion,

$$F = ma$$
$$= m\left(\frac{v^2}{2s}\right)$$

Work done $= W = Fs$

$$= \left(m \times \frac{v^2}{2s}\right) s$$

$$= \frac{mv^2}{2} = \frac{1}{2} mv^2$$

This work done on object is kinetic energy acquired by the moving object.

$$E_K = \frac{1}{2} mv^2$$

NOTE –

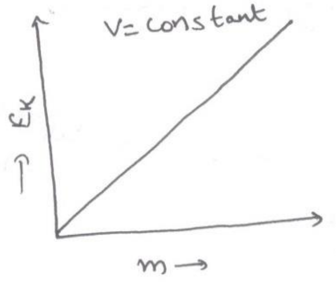
$$E_K = \frac{1}{2} mv^2$$

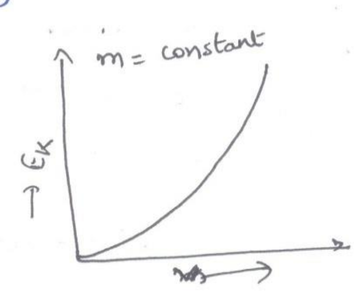
1) K.E of an object is directly proportional to mass.

$$E_K \propto \text{mass}$$

2) K.E of an object is directly proportional to the square of magnitude of its velocity.

$$E_K \propto (\text{velocity})^2$$





K.E only has magnitude and no direction. Hence, K.E is a Scalar quantity.

RELATION BETWEEN KINETIC ENERGY AND MOMENTUM -

Momentum, $P = mv$

Kinetic energy, $E_K = \frac{1}{2} mv^2$

$$P^2 = m^2 v^2$$

$$\frac{P^2}{E_K} = \frac{m^2 v^2}{\frac{1}{2} m v^2}$$

$$\frac{P^2}{E_K} = 2m$$

$$E_K = \frac{P^2}{2m}$$

$$\boxed{P = \sqrt{2mE_K}}$$

WORK ENERGY THEOREM -

The work done by a force applied on the object is equal to change in kinetic energies of that object.

$$V^2 - u^2 = 2as \longrightarrow \text{IIIrd eqn. of motion}$$

$$a = \frac{V^2 - u^2}{2s}$$

$$F = ma \longrightarrow \text{Newton's IInd law of motion}$$

$$F = m\left(\frac{V^2 - u^2}{2s}\right)$$

$$W = F s$$
$$= m\left(\frac{v^2 - u^2}{2s}\right) \times s = \frac{mv^2}{2} - \frac{mu^2}{2}$$
$$W = E_K(\text{final}) - E_K(\text{initial})$$

NOTE -

If work is done by a force on an object, then its Kinetic energy increases.

If work is done by the moving object, then its Kinetic energy decreases.

POTENTIAL ENERGY -

Energy possessed by an object by virtue of its position or configuration.

The energy transferred to the object is stored as its potential energy if it is not used to cause a change in the velocity of the object.

eg: Water stored in overhead tank.

A wound spring of a toy car has P.E due to change in its shape.

SI unit of Potential Energy -

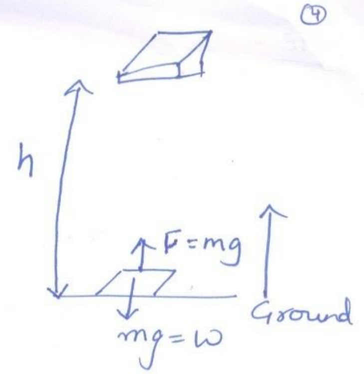
Potential Energy is a scalar quantity.
SI unit of potential energy is Joule (J).

An object simultaneously possess potential energy as well as Kinetic energy and Sum of these energies is called the total mechanical energy.

Kinds of potential energy -

- **Gravitational Potential Energy (GPE)**
  GPE at a point above ground is defined as work done in raising it from ground to that point against gravity.
- **Elastic Potential energy**
  PE due to configuration of object (change in shape / or size)

GRAVITATIONAL POTENTIAL ENERGY -



Consider an object of mass m.
Let it be raised to a height h from ground.

A force is reqd. to raise the object and this minimum force reqd. to raise is against gravity and it is the weight of object.

Force applied on object,

$$F = mg \quad \text{(vertically upward)}$$

Work done against gravity is ⇒

$$\text{Work}, W = \text{Force} \times \text{displacement}$$
$$= F \times h$$
$$= mg \times h$$
$$= mgh$$

This work done is stored as gravitational potential energy.

$$E_p = mgh$$

NOTE -

(i) $E_p \propto m$

If mass is doubled, pot. energy is also doubled.

(ii) $E_p \propto h$

If object is taken to greater height, then Pot. energy is also proportionally greater.

If h is negative then E_p is also negative.

eg: If stone is initially lying at ground level is pushed downward (into pond) then its pot. energy is negative.

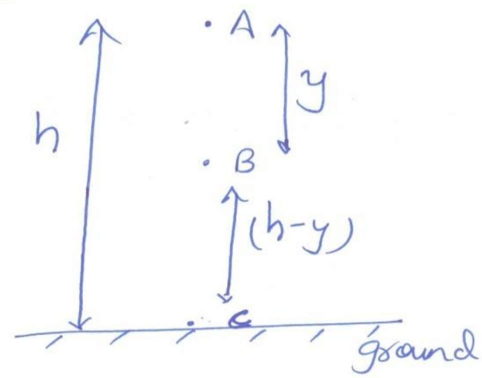
Work done by / against gravity is independent of path.

Work done in both cases = mgh ~~with~~ which is independent of path followed.

LAW OF CONSERVATION OF ENERGY -

Energy can neither be created nor be destroyed but it can be converted from one form to another.

Total energy must remain constant before and after transformation.



Proof -

At A,

$E_p = mgh$

Body is at rest, so K.E ⇒

$E_K = 0$

Total energy at A is,

$E_A = E_p + E_K = mgh + 0 = mgh$

At B,

Ht. from ground is $(h-y)$.

Velocity at B is V_B.

Use eqn. $v^2 - u^2 = 2as$

$(V_B)^2 - (V_A)^2 = 2gy$

$(V_B)^2 - 0 = 2gy$

$V_B^2 = 2gy$

Grav. Pot. Energy at position B,

$$(E_P)_B = mg(h-y)$$

K.E , $(E_K)_B = \frac{1}{2} m (V_B)^2$

$$= \frac{1}{2} m (2gy)$$

$$= mgy$$

Total Energy at B,

$$E_B = (E_P)_B + (E_K)_B$$

$$= mg(h-y) + mgy$$

$$= mgh$$

At position C,

Object falls to ground with a vertical height (distance) h.

Let velocity ⇒ V_C

$$V^2 - U^2 = 2as$$

$$V_C^2 - V_A^2 = 2gh$$

but $V_A = 0$

$$V_C^2 - 0 = 2gh$$

$$V_C^2 = 2gh$$

Grav. Pot. Energy at c,

$$(E_K)_c = \frac{1}{2} m v_c^2$$
$$= \frac{1}{2} m(2gh)$$
$$= mgh$$

Total energy at c,

$$E_c = (E_P)_c + (E_K)_c$$
$$= 0 + mgh = mgh$$

Hence, we conclude that sum of pot. energy and Kinetic energy of object remains constant ~~at~~ at all the position during its free fall.

POWER -

A person doing work in less time is Considered more Stronger whereas, a person doing equal work in longer time is weaker.

Rate of doing work is defined as Power.

It is also defined as rate of transfer of energy.

$$\text{Power, } P = \frac{\text{Work}}{\text{time}}$$

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

Total Work done by a machine is called as energy supplied by machine.

$$\text{Power} = \frac{\text{Energy Supplied}}{\text{Total time}}$$

$$P = \frac{E}{T}$$

Average Power = $\frac{\text{Total Work}}{\text{Total time}}$

$= \frac{\text{Total energy Consumed / Supplied}}{\text{Total time taken}}$

NOTE - Power has only magnitude hence, it is a Scalar quantity.

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

$= \frac{\text{Force} \times \text{displacement}}{\text{Time}}$

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

but, $\frac{s}{t} = v$ (velocity of object)

$$P = F \times v$$

UNITS OF POWER

$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ Second}}$

$$1 W = 1 J/s$$

Bigger units,

$$1\ KW = 1000 W = 1000\ J/S$$

$$1\ MW = 1000\ KW = 10^6 w = 10^6 J/s$$

Power of Machines,

$$1 \text{ Horsepower } (1hp) = 746 W$$

COMMERCIAL UNIT OF ENERGY -

1 Kilowatt hour = 1 KWh

Energy consumed is 1KWh if an appliance of 1 KW power is operated for a period of 1 hour.

$$1\ KWh = 1000\ W \times 1\ hour$$

$$= 1000\ W \times (60 \times 60) s$$

$$= 3.6 \times 10^6\ Ws$$

$$= 3.6 \times 10^6\ J$$