Force, Work, Power and Energy

- **Second law of motion**
    - The second law of motion says, when a force F is subjected to a body of mass m, an acceleration a is gained by the body in the direction of the force and the magnitude of acceleration is directly proportional to the F and inversely proportional to the m.
    - Rate of change of momentum $\propto$ Applied unbalanced force
    - Direction of change in momentum is the same as the direction of unbalanced force

      $F = ma$

      Unit of force is Newton

      $1\ \text{N} = 1\ \text{kg} \times 1\ \text{m} / \text{s}^2$

Rigid body motions

- Linear or translation motion
- Rotational motion

Torque

Torque (τ) = Force (F) × Perpendicular distance (d)

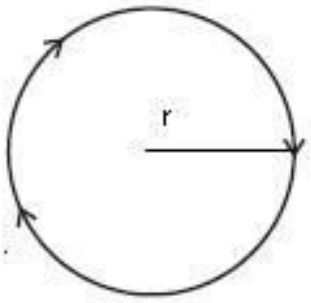
Couple: A pair of parallel forces, which are equal and opposite and are not acting along the same line, forms a couple. These two equal and opposite forces always act at two different points. Such couple is always needed to produced a rotation.

- S.I. Unit of torque is Nm.
- Principle of moments
  Clockwise moment = Anticlockwise moment

Centre of Gravity of some regular objects

Object	Position of Centre of Gravity
1. Rod	Mid point of rod
2. Circular Disc	Geometric centre
3. Solid or hollow Sphere	Geometric centre of sphere
4. Solid or hollow Cylinder	Mid point on the axis of cylinder
5. Solid Cone	At a height h/4 from the base, on its axis
6. Hollow Cone	At height h/3 from the base, on its axis
7. Circular Ring	Centre of ring
8. Triangular Lamina	The point of intersection of medians
9. Parallelogram, rectangular lamina	The point of intersection of the diagonals

- Circular motion: A body is said to be in circular motion when it rotates about a fix point.



speed = v, radius = r,
time to complete 1 rotation = T

$v = 2\pi r/T$

- Uniform circular motion: If the speed of rotation is constant, then the circular motion is uniform.

- **Condition for scientifically work to be done**
  - There must be a displacement
  - Displacement of an object must be in the direction of applied force

- **Work done** by a constant force is defined as

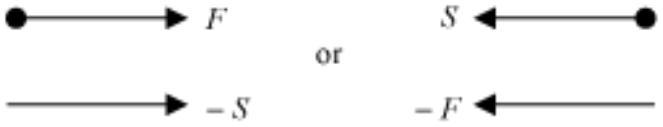
  Work = Force × Displacement [along the direction of force]

  $W = F \times s$ [Unit – Joule, 1 J = 1 N-m]

  - Work done against gravity = Weight × Height = mgh

  - **Condition for the Negative Work done**

    Force and displacement must be in opposite direction



- **Conditions for no work done**
  - No displacement (e.g. a boy pushes the wall)
  - Displacement occurs perpendicularly to the applied force(e.g. in case of circular motion, there is no work done by the centripetal force)

- Work-Energy Relationship:
  - The ability to do work is called energy.
  - Energy of the body is equal to the amount of work it can do when its energy is released.
  - A Body possessing energy is only capable of doing work.

Power: It is defined as rate of doing work.

$$P = \frac{W}{t}\left(\text{Unit - Watt, } 1W = \frac{1J}{1s}\right)$$

1Horse Power = 746Watts

For electric appliances,

power = voltage × current

Energy consumed in time t = Power × time.

Power is also defined as the product of force and average speed.

P=F×v

- **Energy** : Capacity to do work is called energy.
- There are various form of energy e.g. heat energy, mechanical energy, nuclear energy, light energy etc.
- **Mechanical Energy:** It is caused by the motion or the position and configuration of the object.
- **Kinetic energy:** A body possesses kinetic energy by virtue of its motion.

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

- **Proof**

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

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

$W = ma \times \frac{v^2 - u^2}{2a}$

$= \frac{1}{2} m\left(v^2 - u^2\right)$

$= \frac{1}{2} mv^2 [\text{when u} = 0]$

The kinetic energy of the wind is used in windmills to generate electricity.

Relationship between kinetic energy and momentum

K.E. =12pm2p2 =2mK=2mK (where K =Kinetic energy)

- **Potential energy:** A body possesses potential energy by virtue of its configuration or position.

- **Gravitational potential energy**

  PE = *mgh* [*h* = height of object from the earth surface]

  - **Elastic potential energy**

    $U = \frac{1}{2}kx^2$ [Where x = compression or elongation in the spring]

- **Law of conservation of energy**
  - The total amount of energy in a system always remains constant.

$$mgh + \frac{1}{2}mv^2 = \text{constant}$$

Energy: Unit – Joule

- **Kinetic energy** (because of motion): It depends on the mass and the speed of the body. Kinetic energy = $\frac{1}{2}mv^2$
- **Potential energy** (Because of position and shape of the body). Potential energy = *mgh* [gravitational potential energy; *h* = height, *g* = acceleration due to gravity]
- **Mechanical energy**: A body is said to have mechanical energy if it possesses either kinetic energy or potential energy or both.
- **Various forms of energy are** Chemical energy, Sound energy, Light energy, heat energy, magnetic energy, and muscular energy.
- Grease and other lubricating substances are used to minimize the energy loss due to the friction.
- **Energy Chain:** The sun's energy reaches us through a series of conversions which is called energy chain i.e the interconversion of energy from one form to various other forms.
- **Conservation of energy:** It states that energy cannot be created or destroyed. It can only be transformed from one form to another.