UNIT-I

MECHANICS

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DEPT. OF PHYSICS

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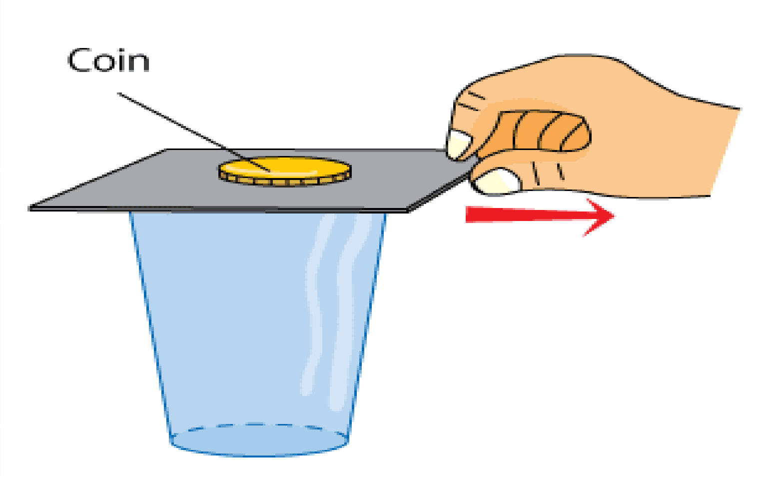
Basic: Mechanics:

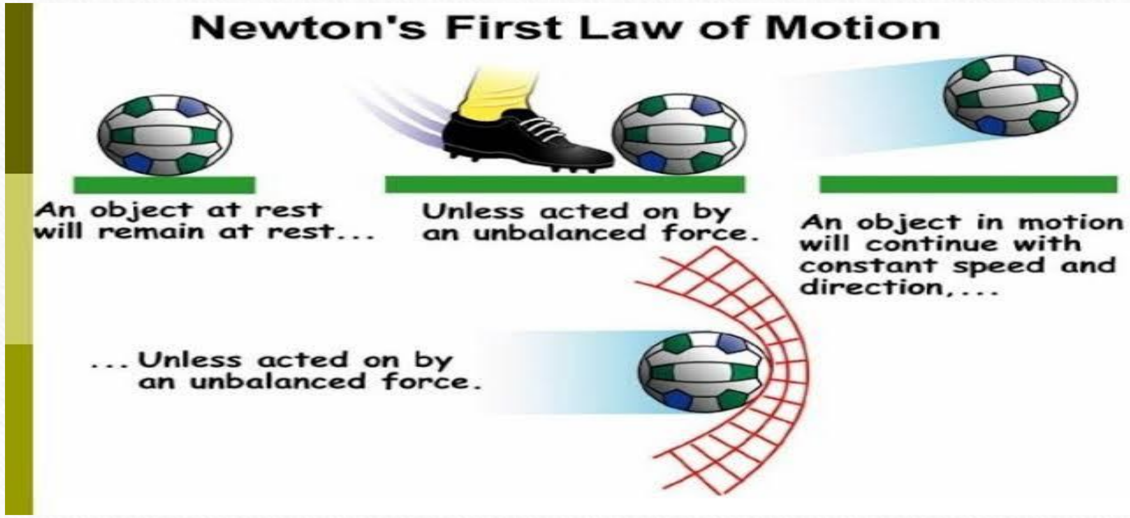
- **Mass:** The amount of matter that body contains
- **Force:** The external egency that changes or tends to change the state of rest or uniform motion of body
- **Inertia:** Inability of material body to change by itself its state of rest or uniform motion
- **Work done:** product of force and displacement in the direction of force
- **Energy:** S Capacity to do work.

Newton’s laws of motion:

- **Newton’s First law of motion:** Every body in this universe, continuous to be in a state of rest or uniform motion in a straight line, unless it is compelled to change that state by forces impressed on it.

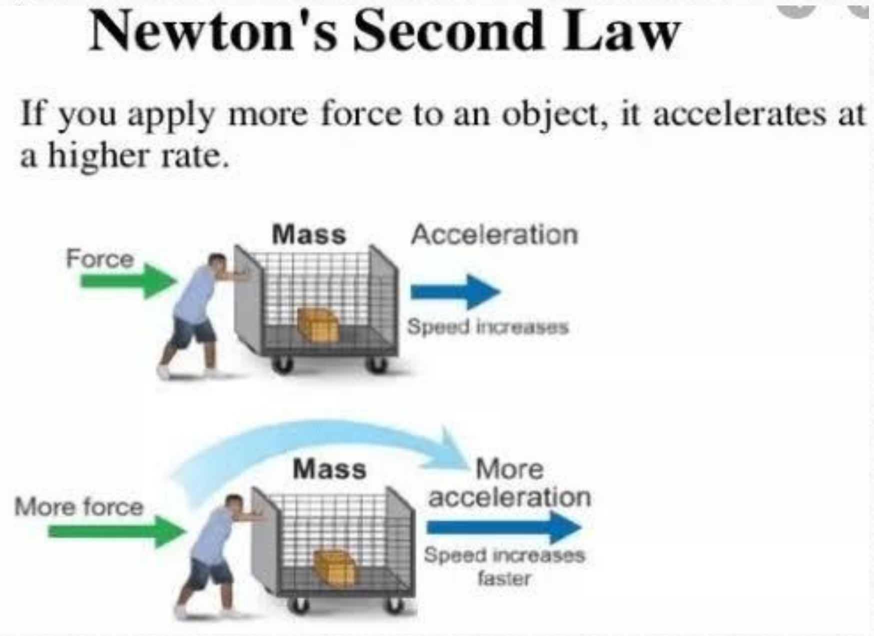
- Also called law of inertia
- Gives definition of force

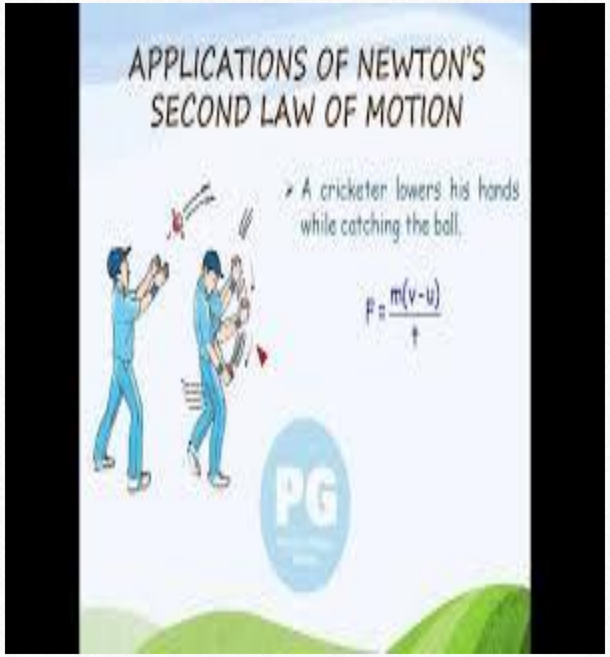


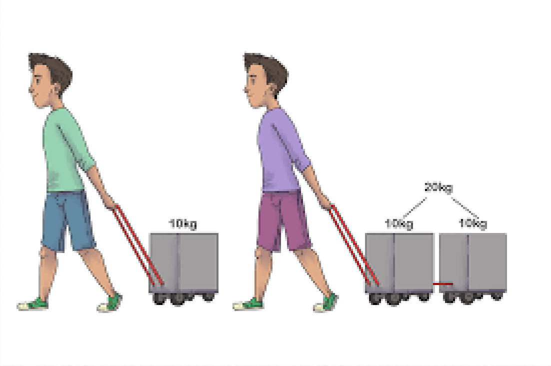


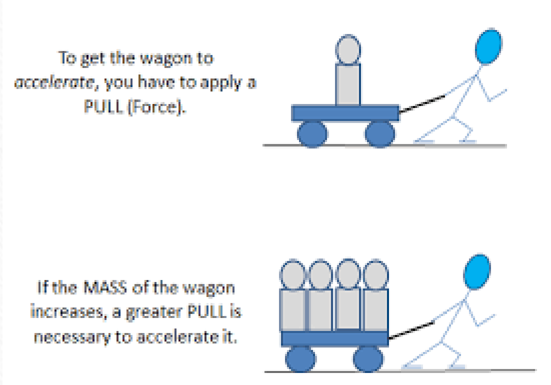
Newton’s second law of motion:

- **STATEMENT:** The rate of change of momentum of a body is directly proportional to impressed force and takes place in the direction of force
- Gives measure of force



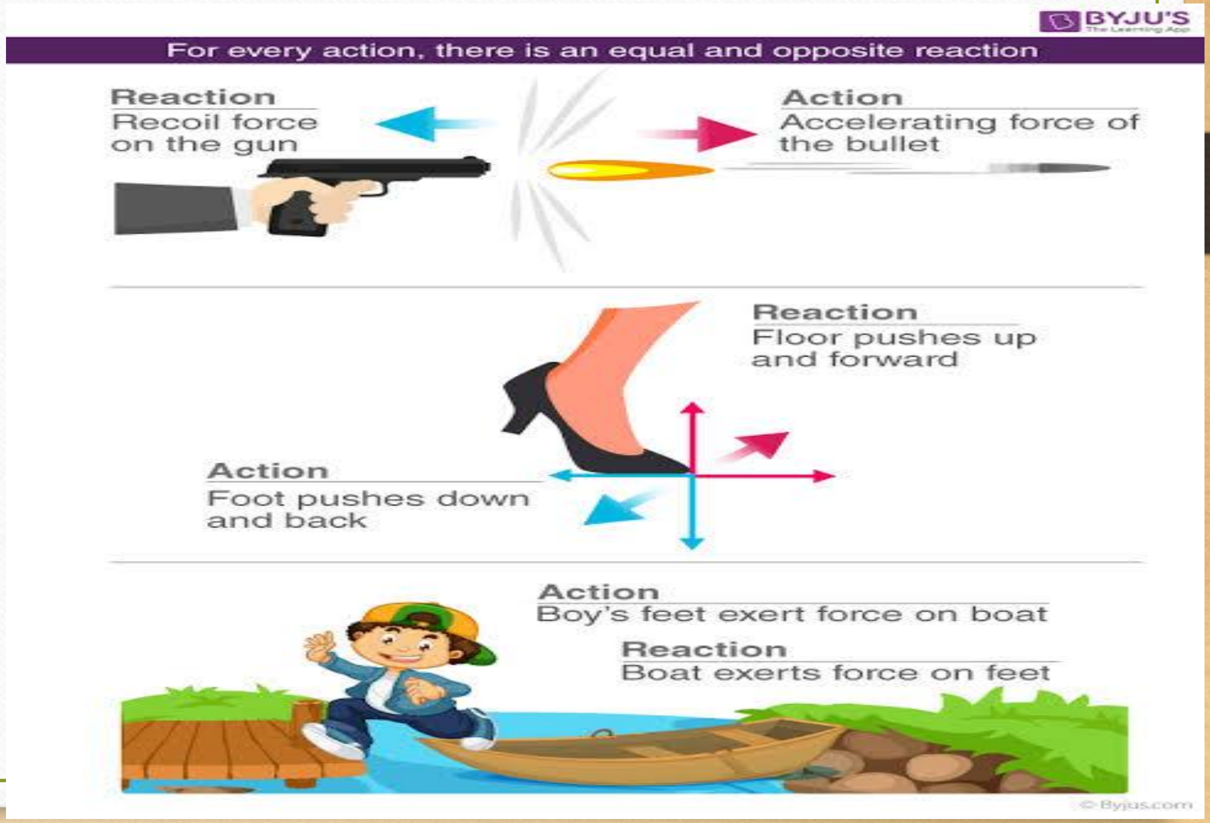






Newton's third law of motion:

- **STATEMENT: To an every action there is always an equal and opposite reaction**
- **Specifies the property of force**



NEWTON'S LAW OF GRAVITY:

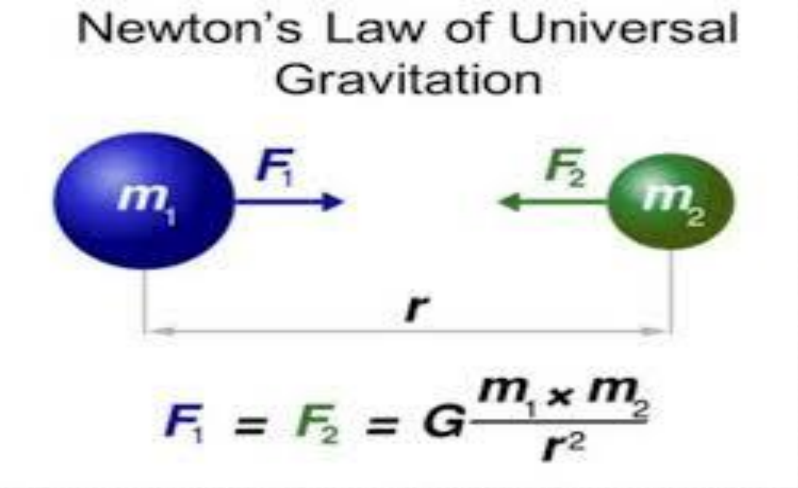
- **STATEMENT:** **Every particle of matter in the universe attract every other particle of matter with a force which is directly proportional to product of their masses and inversely proportional to square of distance between them**

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r2}$$

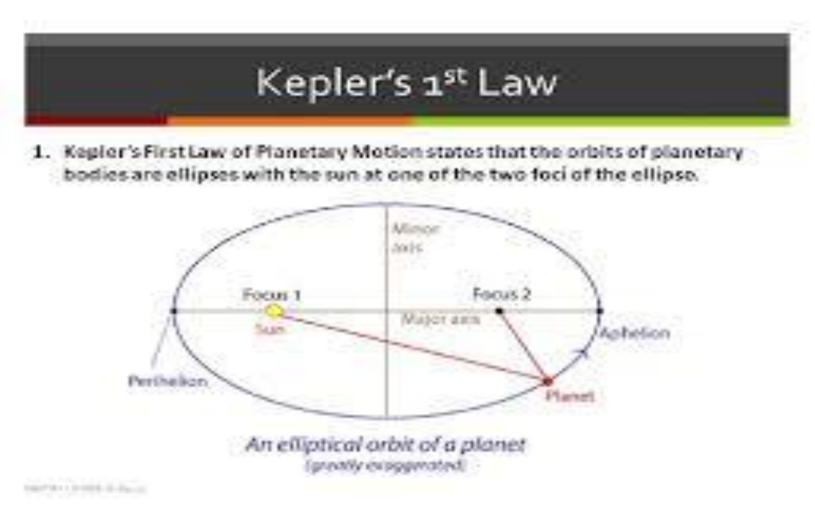
$$F \propto \frac{m1m2}{r2}$$

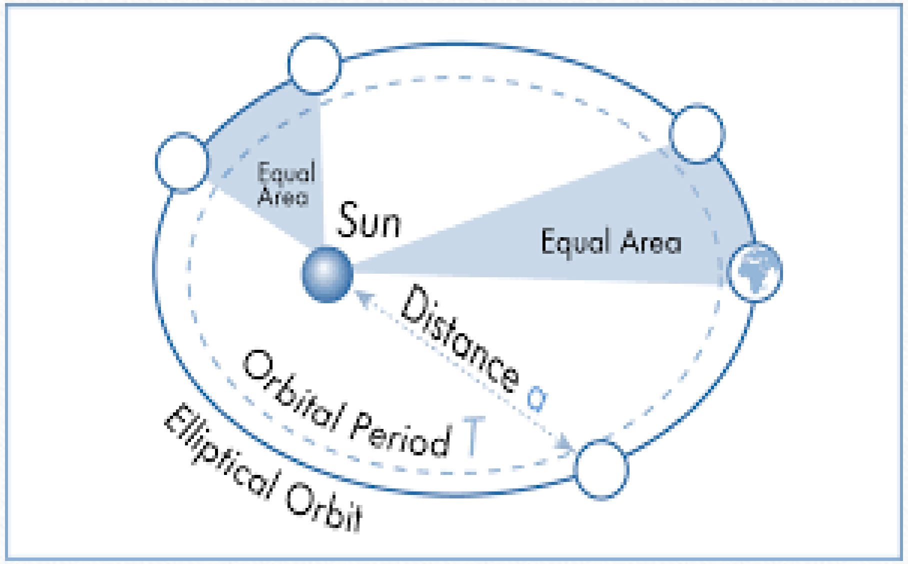
$$F = G\frac{m1m2}{r2}$$



KEPLER'S LAWS OF PLANETARY MOTION:

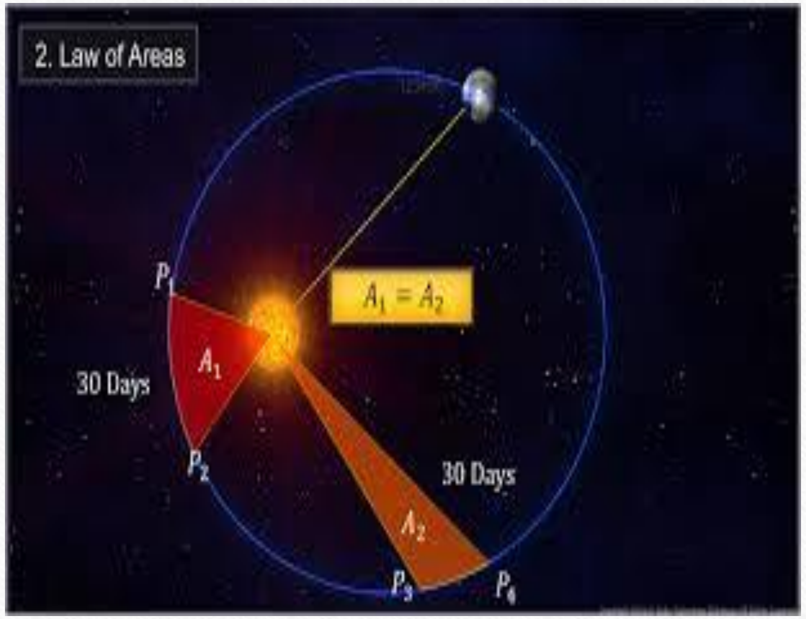
- **Kepler's First Law of planetary motion (Law of orbit):**
- **STATEMENT:** Every planet revolves around the Sun in an elliptical orbit where sun is situated at one of foci of ellipse.

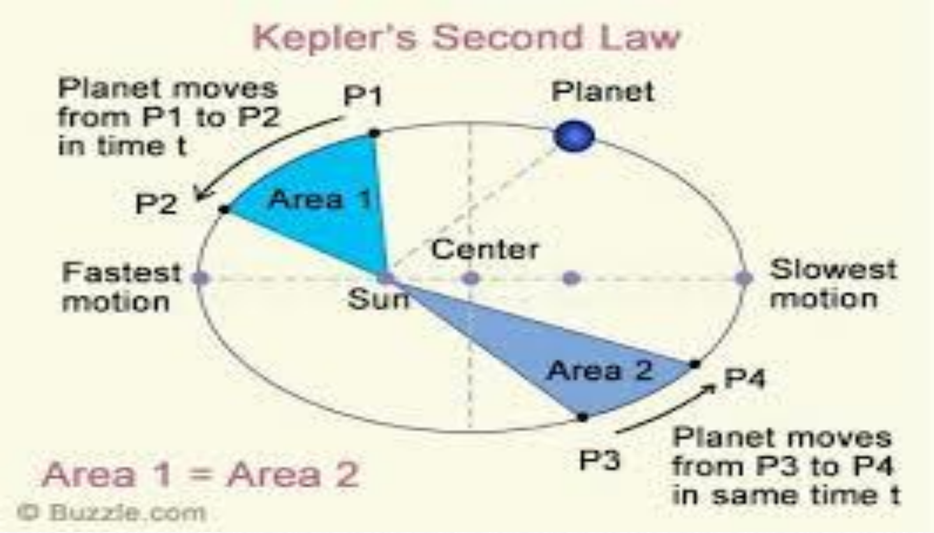




KEPLER'S LAWS OF PLANETARY MOTION:

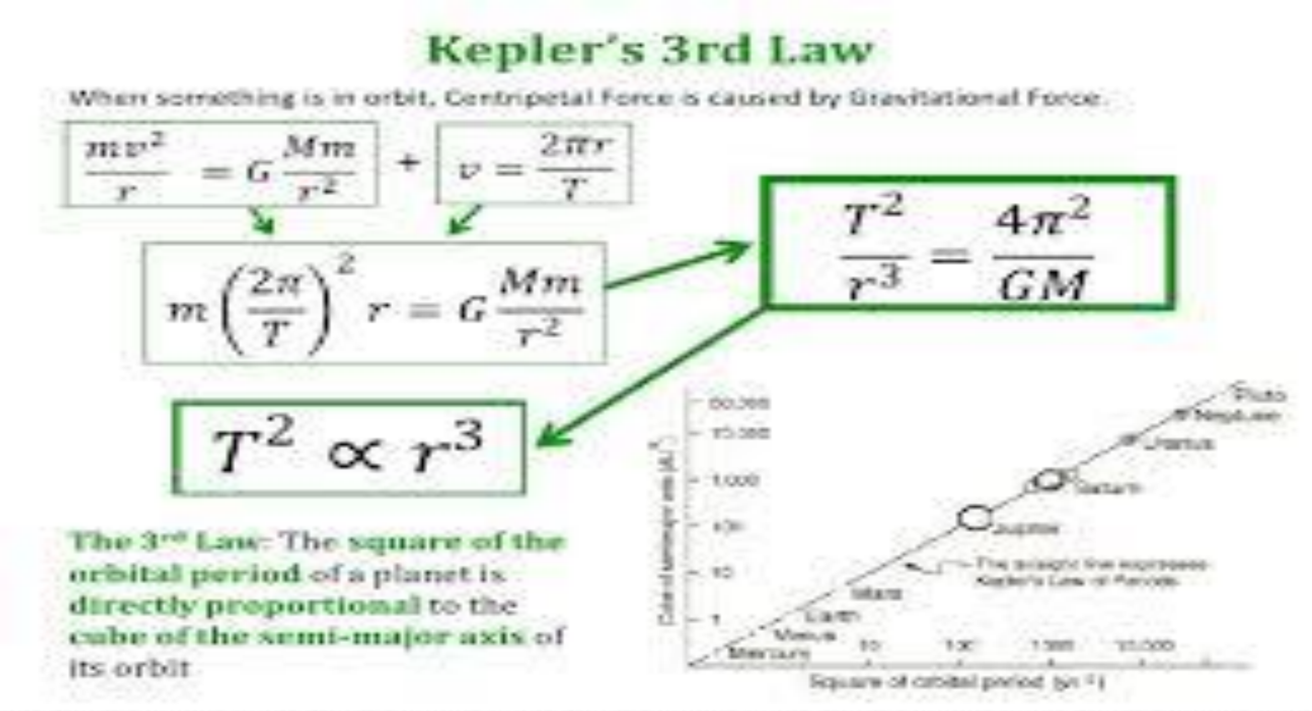
- **Kepler's Second law of Motion (Law of equal areas):**
- STATEMENT :Line joining sun and planet sweeps out equal areas in equal interval of time i.e. Areal velocity of planet is constant.





KEPLER'S LAWS OF PLANETARY MOTION:

- **Kepler's Third law of Motion (Harmonic Law):**
- STATEMENT :The square of period of revolution of planet around the sun is directly proportional to cube of semi-major axis of ellipse

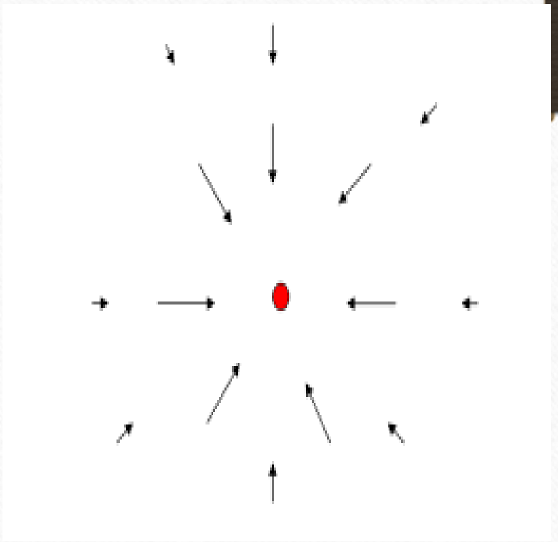


GRAVITATIONAL FIELD AND INTENSITY:

- Space around a body, within which its gravitational attraction is experienced
- Intensity at a point is force experienced by unit mass placed in a field.
- OR Rate of change of gravitational potential

- If gravitational field at a point is E, the force acting on a mass m is
- F=m E
- E= F/m

Also the gravitational field is the negative gradient of gravitational potential $E = -\frac{dV}{dx}$

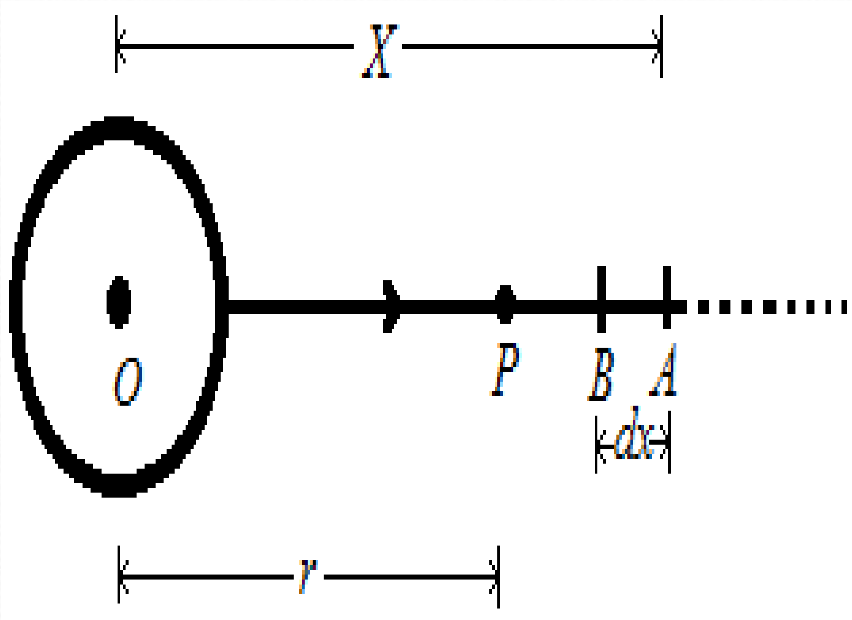


GRAVITATIONAL POTENTIAL:

- Amount of work done in moving unit mass from the point to infinity against the gravitational force of attraction.
- Measure of energy in a field at a point compared to infinite distance away
- Zero of potential at infinity
- Consider body of mass m.
- P is point at a distance r
- The gravitational intensity at P

$$E = \frac{F}{m} = \frac{GM}{r^2}$$

- Scalar quantity



GRAVITATIONAL POTENTIAL AT A POINT:

- $E = -\frac{dV}{dr}$
- $dV = \left(\frac{-GM}{r^2}\right) dr$
- Integrating between limits infinity and r,
- $\int dV = \int_r^\infty \left(\frac{-GM}{r^2}\right) dr = \left[\frac{GM}{r}\right] = \left[\frac{GM}{\infty} - \frac{GM}{r}\right]$
- $V = -\frac{GM}{r}$
- The gravitational potential at a point due to a point mass
- $V = -\frac{GM}{r}$

GRAVITATIONAL POTENTIAL ENERGY:

- Gravitational potential energy at a point is the work done to move a mass from infinity to that point.
- The gravitational potential energy is product of mass of body and gravitational potential at that point. $Potential\ Energy = m\left(-\frac{GM}{r}\right)$
- Gravitational Potential Energy depends upon
- 1) Mass of heavy body M
- 2) Distance between two masses r
- At infinity it is maximum and zero. At all other points it is negative

CONSERVATION LAWS:

- Familiar conservation laws: Energy, linear momentum, Angular momentum, charge etc
- Advantages:

- 1) Understanding symmetry in the universe
- 2) Powerful tool for solving problems
- 3) Not depends on details of trajectory and forces involved.
- 4) Enables the consequences of equation of motion
- 5) Involved in Physics of elementary particles
- 6) predicted new elementary particles
- 7) tackling in new and not understood problems
- 8) Prediction of certainty that particular phenomena will not ocuurs

WORK:

Consider particle p moving along a curve AB under the action of variable force F.

r -position vector of particle

F displaces the particle through distance dr

Infinitesimal small amount of work done dW is

dW = F. dr

If particle moved from point A with position vector r1

to point B when position vector r2

Total work done by force on particle

$$W = \int_A^B F.dr = \int_{r_1}^{r_2} F.dr \qquad (1)$$

F makes angle θ with tangent to the path at any point

$$W = \int_A^B F\ Cos\theta\ dr \quad (2)$$

Cont…..

- F and θ may changes from point to point
- The integral form of equation along path AB (line integral)
- $\int_A^B F.dr = \int_A^B F\ Cos\ \theta\ dr$ Cosθ is components of force along path
- **Work done:** Line integral of tangential components of force and taken over actual line of motion.

- If F remains constant and displacement r is along straight line then
- $W = \int_A^B f.dr = F.r = F\ cos\theta\ r$ (3)
- Work: Product of components of force along the displacement and distance moved by the particle
- If F_x, F_y $and\ F_z\ are\ rectangular\ components\ of\ F\ and\ dr = dx\,\vec{\imath} + dy\,\vec{\jmath} + dz\,\vec{k}$
  $W = \int_A^B (F_X\vec{\imath} + F_y\vec{\jmath} + F_z\vec{k}).(dx\,\vec{\imath} + dy\,\vec{\jmath} + dz\,\vec{k})$
- $W = \int_A^B (F_x dx + F_y dy + F_z\, dz)$ (4)

- If number of forces F1,F2 and F3 are acting on particle so that resultant force on particle is F= F1+F2+F3
- Work done on particle
- $W = \int_A^B F.dr = \int_A^B (F_1 + F_2 + F_3 + \cdots.)dr$
- $W = \int_A^B F_1\, dr + \int_A^B F_2 dr + \cdots..$
- Sum of work done by each force

POWER:

- Rate of doing work
- P=dW/dt
- If F is instantaneous force acting on the particle then
- Instantaneous power is
- $P = \frac{dW}{dt} = \frac{F\,.dr}{dt} = F.v$
- Average Power during time interval t is
- $P_{av} = \frac{W}{t}$

KINETIC ENERGY-WORK ENERGY THEOREM:

- Statement: Work done on a particle is equal to change in its kinetic energy
- Energy is capacity of doing work
- Measured as amount of work which it can do in the position in which it is
- Energy due to motion is kinetic energy

- According to Newtons second law of motion F=ma
- $F = m.\frac{dv}{dt}$ where $\frac{dv}{dt}$ is acceleration produced in particle
- Amount of work done on a particle when moves from A point to B
- $W = \int_A^B F.dr = m\int_A^B \frac{dv}{dt}.dr$ (1)
- Now $dr = \frac{dr}{dt.}.dt = v.dt$
- $\frac{dv}{dt}.dr = \left(\frac{dv}{dt}.v\right)dt = \frac{d}{dt}\left(\frac{1}{2}v.v\right)dt = d\left(\frac{v^2}{2}\right)$
- $\therefore W = \frac{m}{2}\int_A^B d(v^2) = \frac{m}{2}[v_B^2 - v_A^2]$
-

- Where v_A and v_B speeds of particle at A and B
- $W = \int_A^B F.dr = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2$ =Change in kinetic energy

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Thus Work done on particle only depends on initial and final speed of particle and independent upon nature of force and path followed by particle.

CONSERVATION OF ENERGY FOR A PARTICLE : ENERGY FUNCTION:

- Work done by a force on a particle of mass m will
- $W = \int_1^2 F.dr = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = U_1 - U_2$ =change in kinetic energy
- Equation expresses that in a conservative force field if KE of particle increases in moving from one point to another then, its potential energy decreases
- $\frac{1}{2}mv_1^2 + U_1 = \frac{1}{2}mv_2^2 + U_2$
- $K_1 + U_1 = K_2 + U_2$
- **Law of conservation of energy**
- Sum of KE and PE of particle remains constant at any point of conservative force field
- The quantity E=K+U Called **ENERGY FUNCTION**

MOTION OF BODY NEAR THE SURFACE OF THE EARTH:

- Body of mass m situated at height h in rest above surface
- PE is 0 at surface
- Let the x direction be normal to the surface and directed upward

- If body start to fall at any instant at height x above surface,
- The work done by gravitational force –mg on body
- $W = \int_h^x (-mg)dx = -mg(x-h) = mg(h-x)$
- Work done will increases body's K.E.
- $W = \frac{1}{2}mv^2 \quad \therefore Initial\ velocity = 0$
- $\therefore \frac{1}{2}mv^2 = mg(h-x)$
- $\therefore mgh = \frac{1}{2}mv^2 + mgx$
- P.E. at x is mgx,

- **TE at Height "h" above surface**
- Initially body has only PE and no KE
- Initial TE=KE+PE=0+mgh= **mgh**
- **TE at Surface (x=0)**
- PE at surface =0, KE at surface= $\frac{1}{2}mv^2$
- TE at surface $\frac{1}{2}mv^2$ =**mgh**
- **TE at any Height "x"**
- PE at height "x"=mgx and KE at height "x" $= \frac{1}{2}mv^2$
- TE at any height "x"= $mgh = \frac{1}{2}mv^2 + mgx$=**mgh**
- **∴ TE of freely falling body remains constant through out its motion**

NON-CONSERVATIVE FORCE:

- **Non-conservative force :** Work done by force, which moves particle between two points depends upon path between those points.
- Frictional and viscous forces are non conservative forces.
- For non-conservative force work done around the closed path not zero and particle loses its KE along path.
- For conservative force, KE+ PE= E=Constant
- ΔKE+ ΔPE=0= ΔE
- $W_c = -\Delta$PE Negative increase in PE
- In addition to conservative force nonconservative force due to friction
- If W_f work done by frictional and Wc by conservative forces
- W_f +Wc= ΔKE But Wc= - ΔPE
- ΔKE+ ΔPE= W_f
- When frictional forces acts on particle total mechanical energy is not constant