Lecture - I

Mechanics of a single particle

- **Mechanics:** Science of motion of material bodies

  - Kinematics

    The motion of material bodies in terms of quantities such as DISPLACEMENT, VELOCITY etc.

    eg $$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$$

    $$\vec{v} = \vec{u} + \vec{a}t$$

    (basically a geometrical description)

  - Dynamics
    - It is mostly related to force.
    - Study of equation of motion.

    eg $$F = G\frac{mM}{r^2}$$

- Now what are classical mechanics, Quantum mechanics etc?

- In this course we shall study dynamics of particles -

- So now the Question –

  what is a particle ?

  any examples ? (Earth compared the Sun)

- How to study the dynamics of Particles ?

— NEWTON'S LAWS

① "EVERY BODY CONTINUES TO BE IN ITS STATE OF REST OR OF UNIFORM MOTION IN A STRAIGHT LINE UNLESS IT IS COMPELLED TO CHANGE THAT STATE BY EXTERNAL FORCES ACTING ON IT."

② "THE TIME RATE OF CHANGE OF MOMENTUM OF A PARTICLE IS PROPORTIONAL TO THE EXTERNAL FORCE AND IS IN THE DIRECTION OF THE FORCE."

③ "TO EVERY ACTION, THERE IS ALWAYS AN EQUAL AND OPPOSITE REACTION."

Inertia ?

Force ?

- Second law: meaning of Force

Force → Change of momentum/time

$(\vec{p} = m \times \vec{v})$

So, $\vec{F} \propto \frac{d\vec{p}}{dt}$

$$F = k \frac{d\vec{p}}{dt}$$

$$= k \frac{d}{dt}(m\vec{v})$$

$$= k m \left(\frac{d\vec{v}}{dt}\right)$$

$\Rightarrow \vec{F} = k m \vec{a}$

k ↳ constant of proportionality

$\vec{F} \Rightarrow$ (1 kg mass) → (1 m/s^2 accl^n)

↳ 1 N Force

$1 = k \times 1 \times 1$

$k = 1$ unit

$$\boxed{\vec{F} = m\vec{a}}$$

(2)

- From 2nd law, when $\vec{F} = 0$, $m\vec{a} = 0$

$\frac{d}{dt}(m\vec{v}) = 0$

$\boxed{m\vec{v} = \text{const.}}$

- What if there are more forces present in the system?

— If more forces are present, $F_1, F_2 \ldots F_N$, acting on the particle, then the total effect in motion produced by these forces can be looked upon as produced by a single force

— Principle of superposition.

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \ldots + \vec{F}_N \quad \text{(vector sum)}$$

- What about the third law now?

  - applis to two isolated particles exerting forces on each other. (When ext. forces are absent.)

  - Action and reaction. = mutual interaction.
  - $\vec{F}_1 = -\vec{F}_2$

- Where can we apply these laws?

?

- Example – to measure masses.

= $\vec{F} = m\vec{a}$ to measure mass.

= Let the same force $\vec{F}$ action on m_1 and m_2 produces accln $\vec{a}_1$ and $\vec{a}_2$.

$$m_1 \vec{a}_1 = m_2 \vec{a}_2$$

Numerically

$$m_1 a_1 = m_2 a_2$$

$$\Rightarrow \frac{m_1}{m_2} = \frac{a_2}{a_1}$$

↳ consider m_2 to be unit mass $m_2 = 1\ kg$

measure a_2 and a_1

In this way you can measure the mass of m_1.

- masses measured in this way are called

Inertial mass

– Gravitational mass.

$\vec{W} = m\vec{g}$ → accl^n due to gravity ($9.8\ m/s^2$)

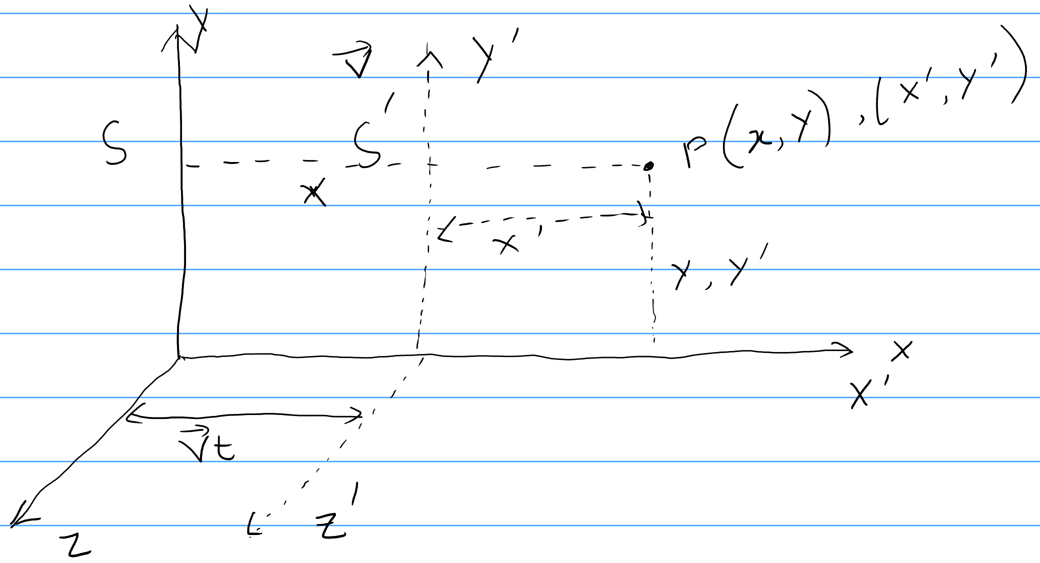
↳ m: gravitational mass

Inertial mass ~ gravitational mass (10^{10})

Weak equivalence principle.

- Inertial frame of reference:

Coordinate system.



- How are these coordinates related?

 - By Galilean transformation eq^{n}s.

$$x' = x - vt \quad \text{— (1)}$$

$$y' = y$$

$$z' = z$$

$$t' = t$$

- How to check the validity of Newtons laws in this system?

(1) $\Rightarrow$ $x' = x - vt$

$$\frac{dx'}{dt} = \frac{dx}{dt} - v$$

$$\frac{d^2x'}{dt^2} = \frac{d^2x}{dt} \quad //$$

$$m\frac{d^2x'}{dt^2} = m\frac{d^2x}{dt^2}$$

$$\Rightarrow m\vec{a} = m\vec{a}$$

$\#$ Newton's laws are same in all inertial reference frames.