University of Calcutta
Semester -1
PHYSICS
Paper: PHS-A-CC-1-2-TH (NEW SYLLABUS)

Fundamental of Dynamics : part 1

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1. REVIEW OF NEWTON’S LAW OF MOTION

Review

Newton's First Law:

Objects in motion tend to stay in motion and objects at rest tend to stay at rest unless acted upon by an unbalanced force.

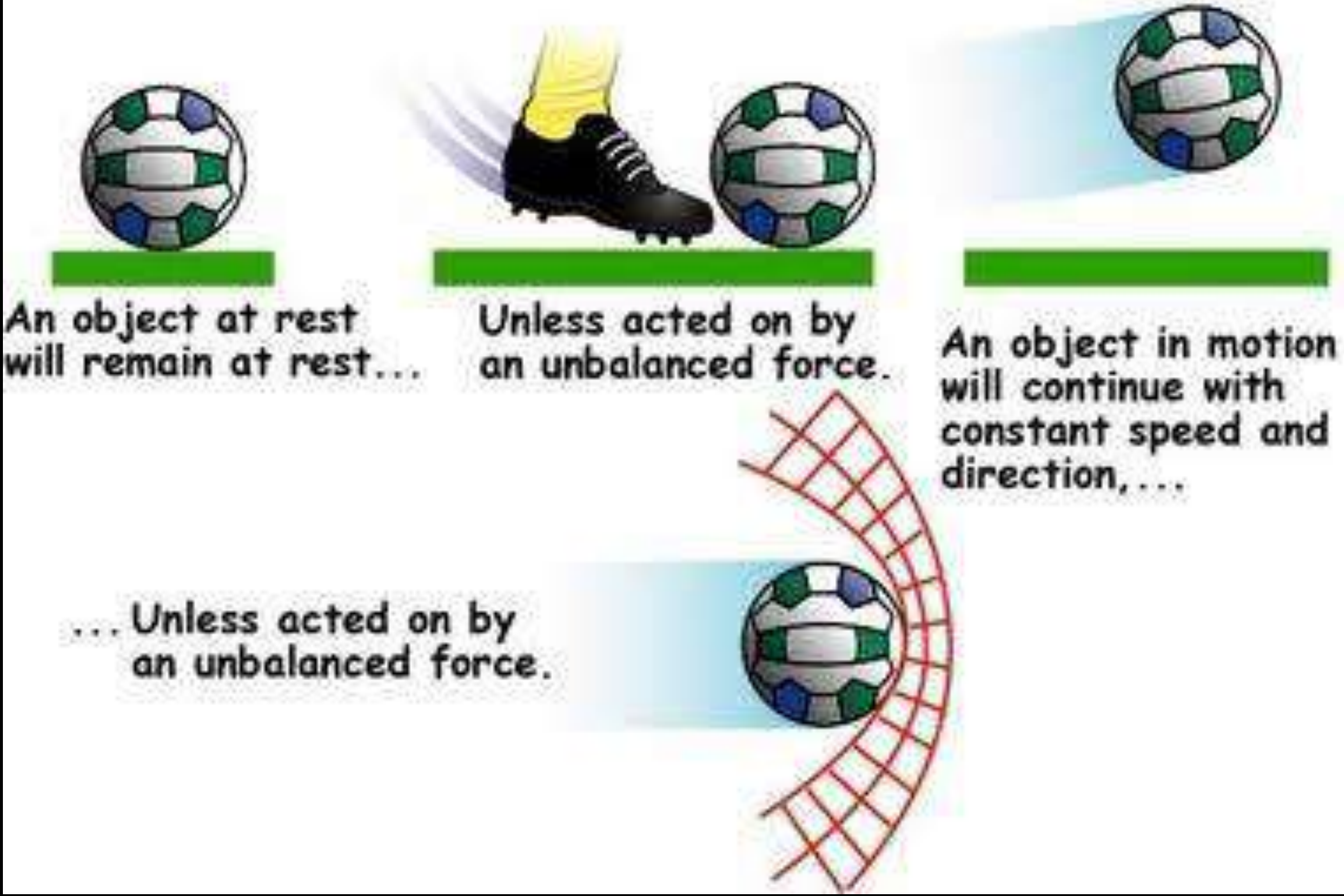
Newton's Second Law:

Force equals mass times acceleration ($F = ma$).

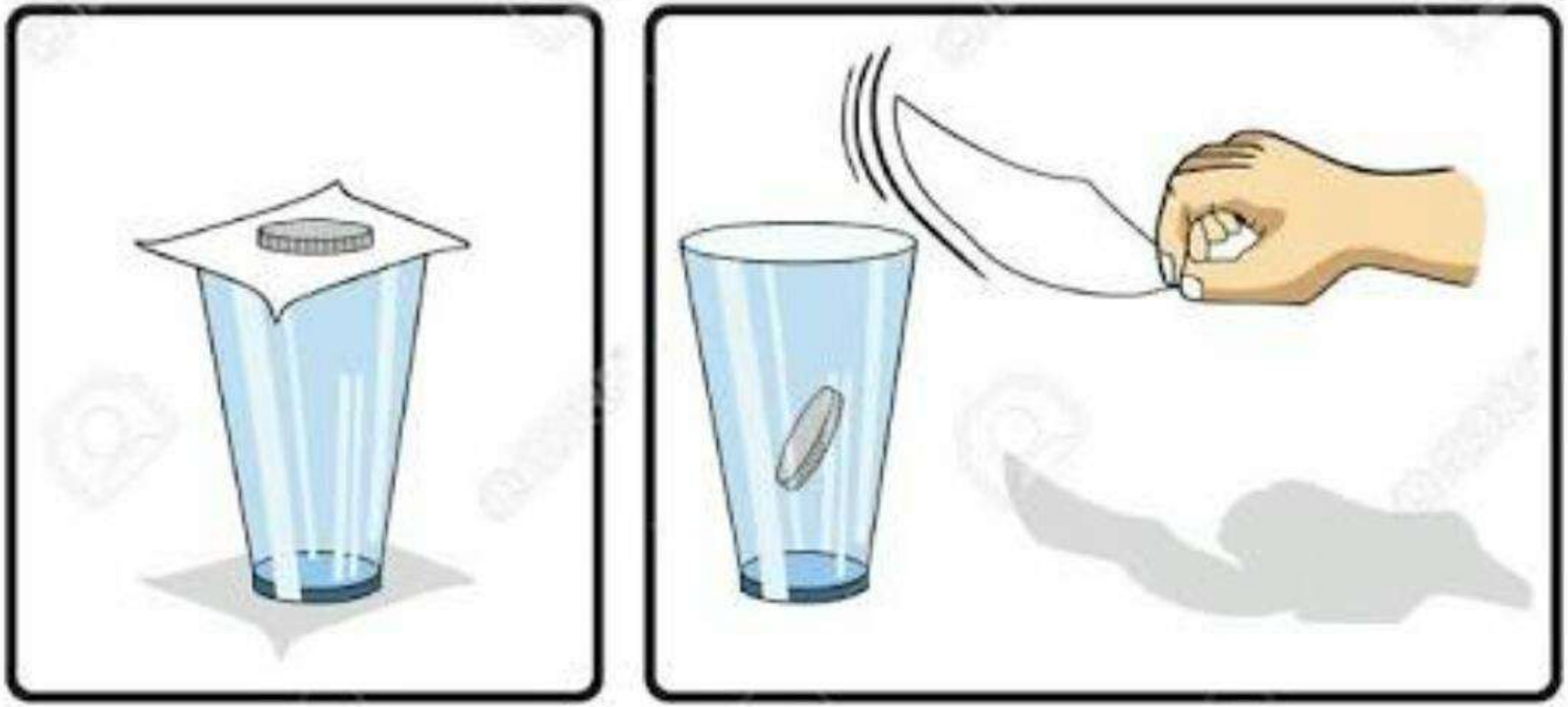
Newton's Third Law:

For every action there is an equal and opposite reaction.

Newton's First Law of Motion



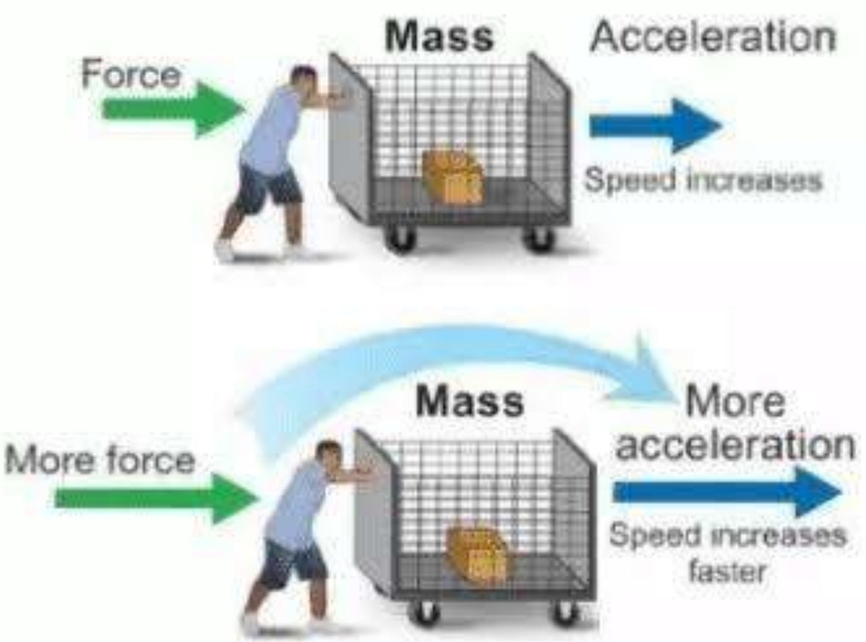
CONCEPT OF INERTIA



When the cardboard is pulled, the coin falls into the glass. This is because the inertia of the coin maintains its state at rest and it falls into the glass due to gravity.

Newton's Second Law

If you apply more force to an object, it accelerates at a higher rate.



BYJU'S
The Learning App

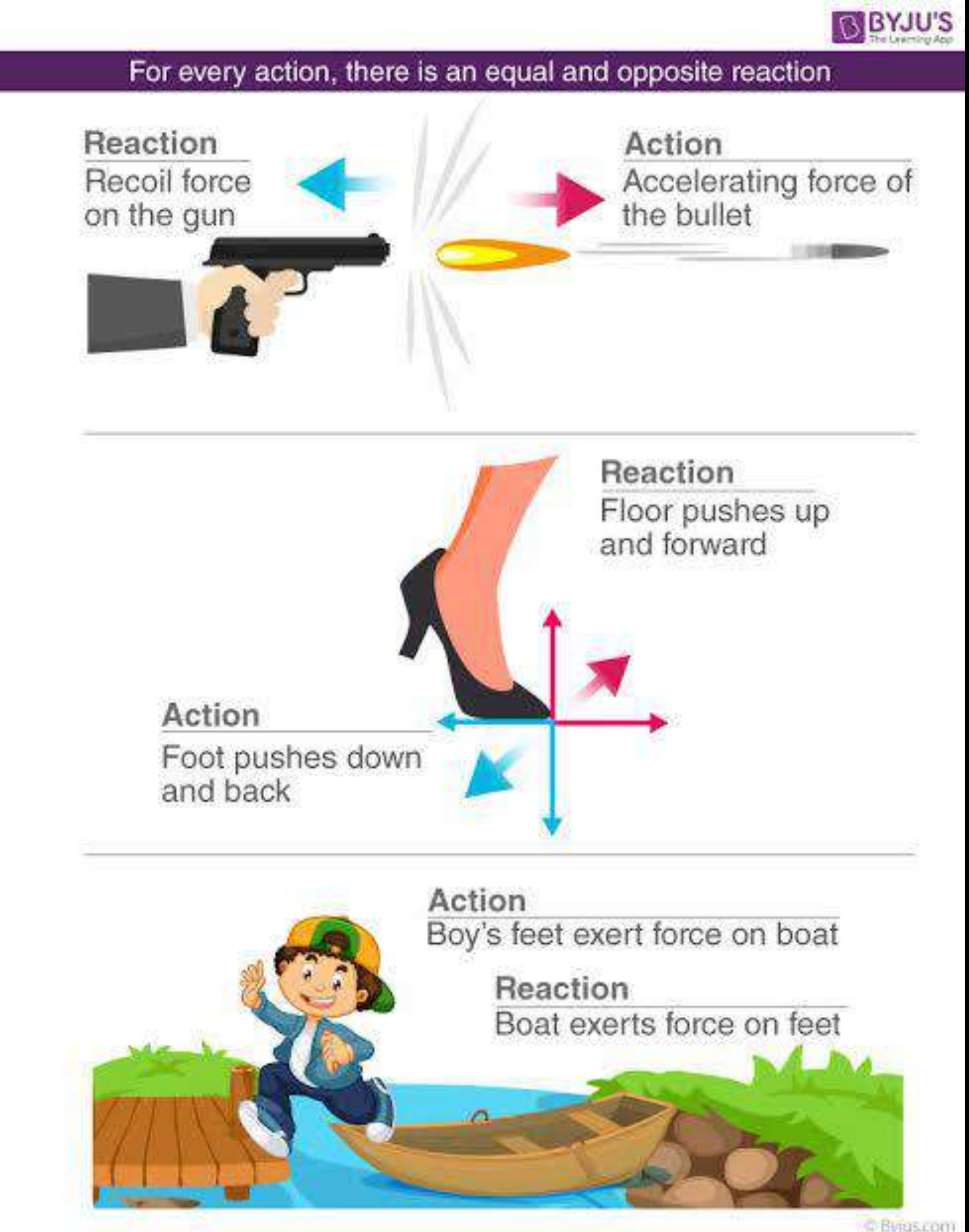
Force = Change of Momentum with change of time

Difference form : $F = \dfrac{m_1 V_1 - m_0 V_0}{t_1 - t_0}$

With constrant mass : $F = m \dfrac{V_1 - V_0}{t_1 - t_0}$

Force = mass x acceleration

t = time | X = location | m = mass | V = velocity



Newton's third law

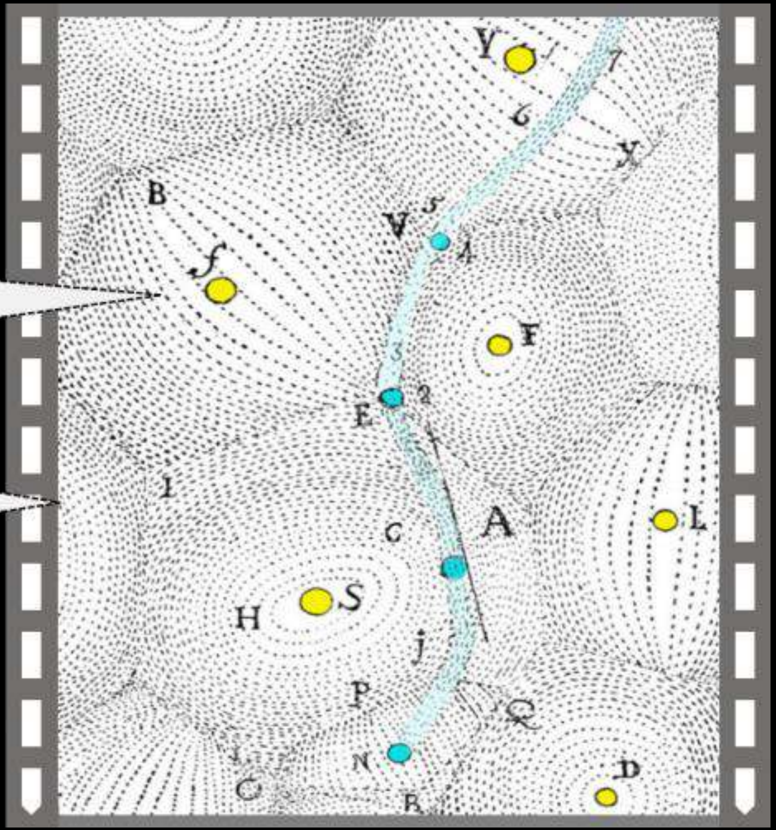
$$\vec{F}_{12} = -\vec{F}_{21}$$

F_{ab}: Force exerted by object a on object b

MECHANISTIC VIEW OF THE UNIVERSE

All matter anywhere in the universe obeys the same set of laws.

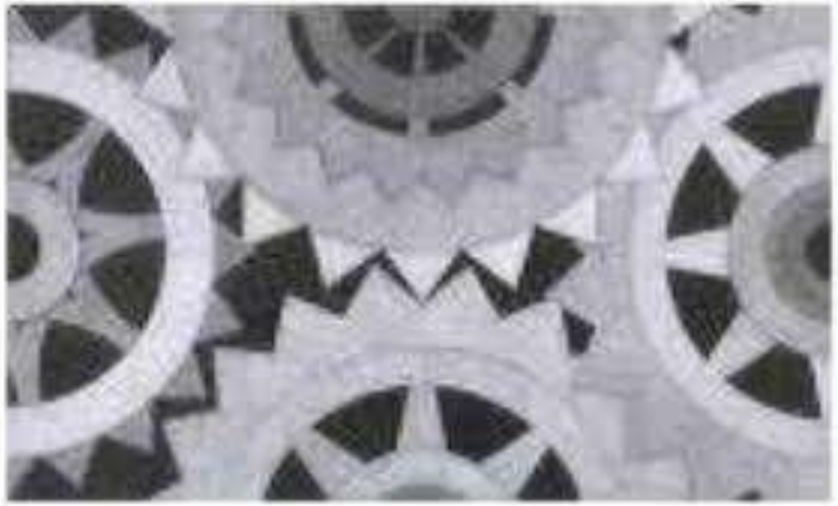
The universe is extended *indefinitely*.



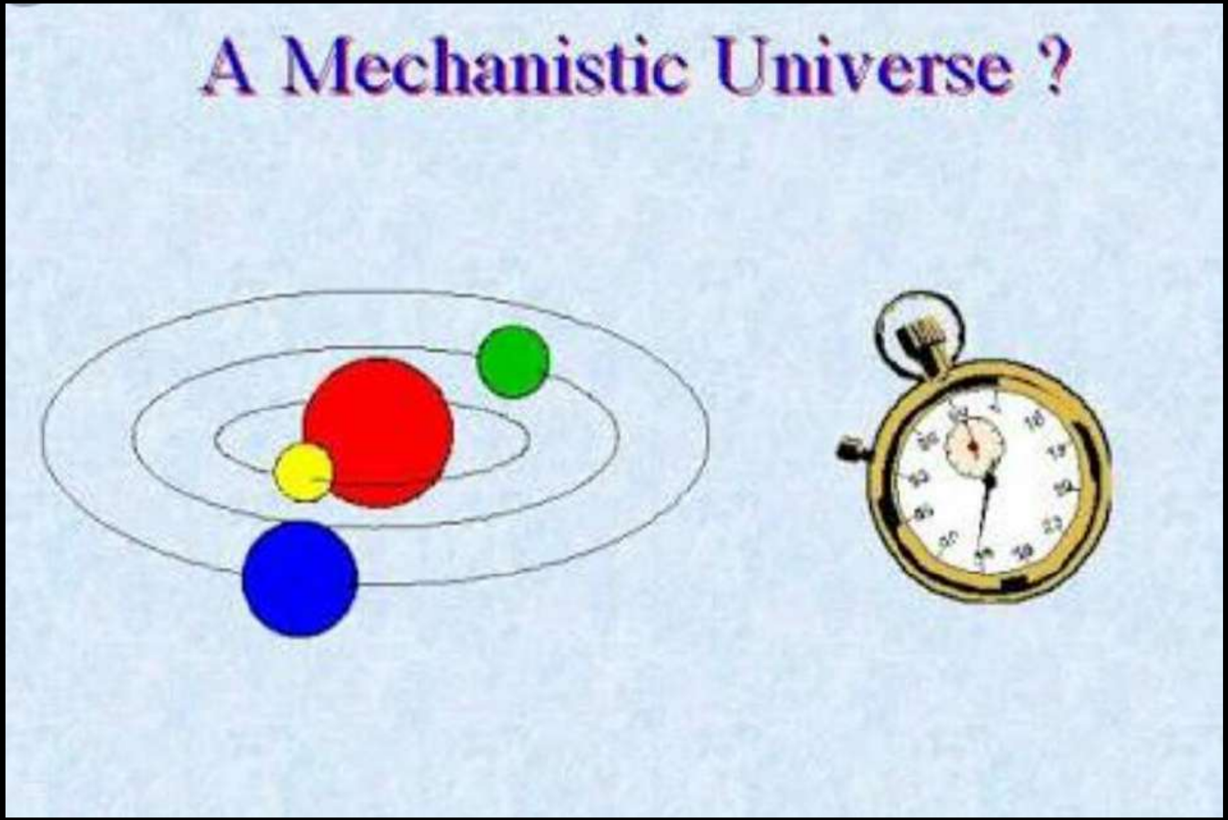
mechanistic theory

the assumption that psychological processes and behaviors ultimately can be understood in the same way that mechanical or physiological processes are understood. Its explanations of human behavior are based on the model or metaphor of a machine and invoke mechanical causality, reducing complex psychological phenomena to simpler physical phenomena. Also called **mechanistic approach**.

"The mechanistic way"



Then the "mechanistic way" was the new view of studying the nature: it was called "mechanistic" because the nature was considered like a big "machine" and each natural phenomenon like an its "mechanism", of whom it was not searched the aim anymore, but **how it happens**.

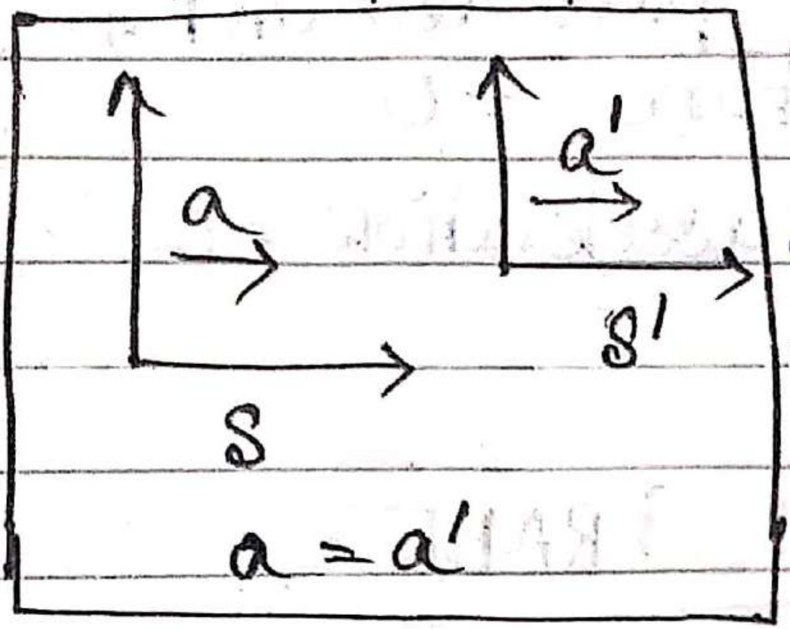


Newtonian physics and the general shift toward a mechanistic explanation of the natural world initially offered not a threat, but the promise of a deeper understanding of the inner workings of a cosmos linked directly to the very mind and nature of God.

Newton treated the motions of the stars and planets as problems in mechanics, governed by the same laws that govern motions on Earth. He described the force of gravity mathematically.

The solar system contains many bodies, and the calculation of the orbit of any planet or satellite is not simply a matter of its gravitational attraction to the body around which it orbits. In addition, other bodies have smaller, but not negligible, effects (called "perturbations"). For example, the Sun alters the Moon's motion around the Earth, and Jupiter and Saturn modify the motions of each other about the Sun.

Concept of Inertial Frame :-



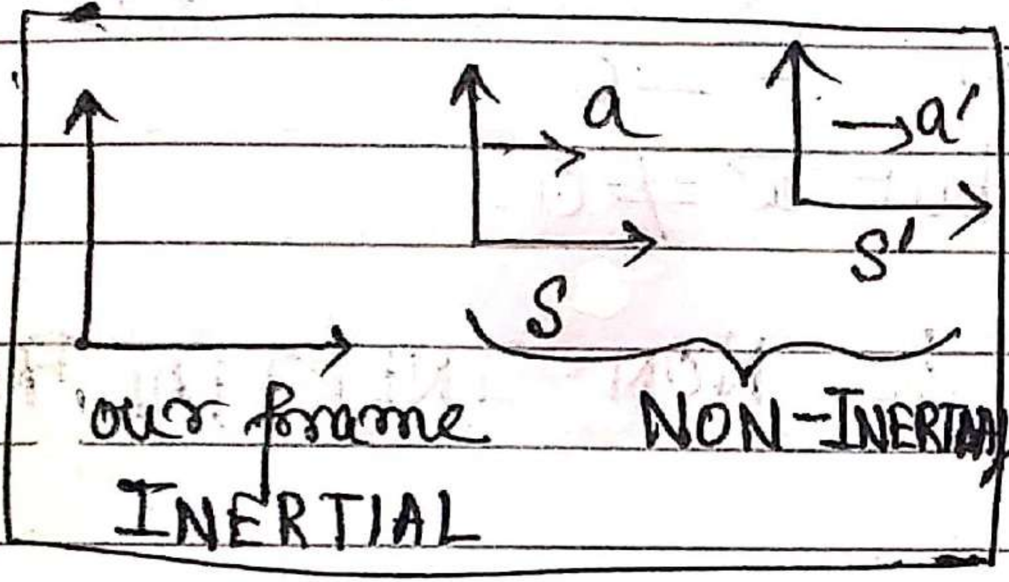
Let us consider two frames S & S' moving with respect to each other.

a = acceleration of S-frame

a' = " " S' "

If a = a' ⟹ no relative acceleration of S' frame with respect to S-frame

• Now the question is : How can you realize these accelerations of two frame?



To realize these accelerath a & a' of S & S' frame respectively, our frame should be another frame with respect to S & S' frames.

Now we can realize accelerath

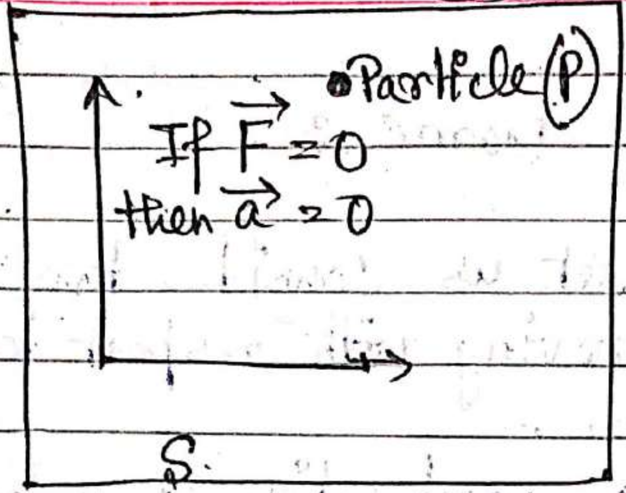
- Now the question is : A frame is INERTIAL or NON INERTIAL

(1) A frame is INERTIAL or NON-INERTIAL — that is exclusively tested by if you have a particle and you look at that particle from this frame

(2) You find that there is no force on the particle i.e. zero force on the particle

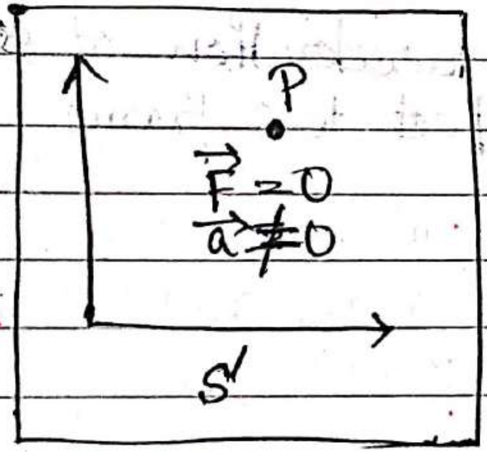
(3) There is no acceleration of the particle

— That frame is INERTIAL



Let S = frame where P is a particle. On P, Force = 0 then acceleration = 0

S is <u>INERTIAL FRAME</u>.



Let S' = frame where particle P is accelerating without applying any force.

i.e. $\vec{F} = 0$

but $\vec{a} \neq 0$,

— Then S' is NON-INERTIAL FRAME

INERTIAL FRAME

1). In this frame, external Force = 0, accel = 0.

2). So the particle either will stay at rest or remain in uniform motion or velocity

3). Newton's law holds true in this frame.

CONCEPT OF MASS

Inertial mass is a mass parameter giving the inertial resistance to acceleration of the body when responding to all types of force. Gravitational mass is determined by the strength of the gravitational force experienced by the body when in the gravitational field *g*.

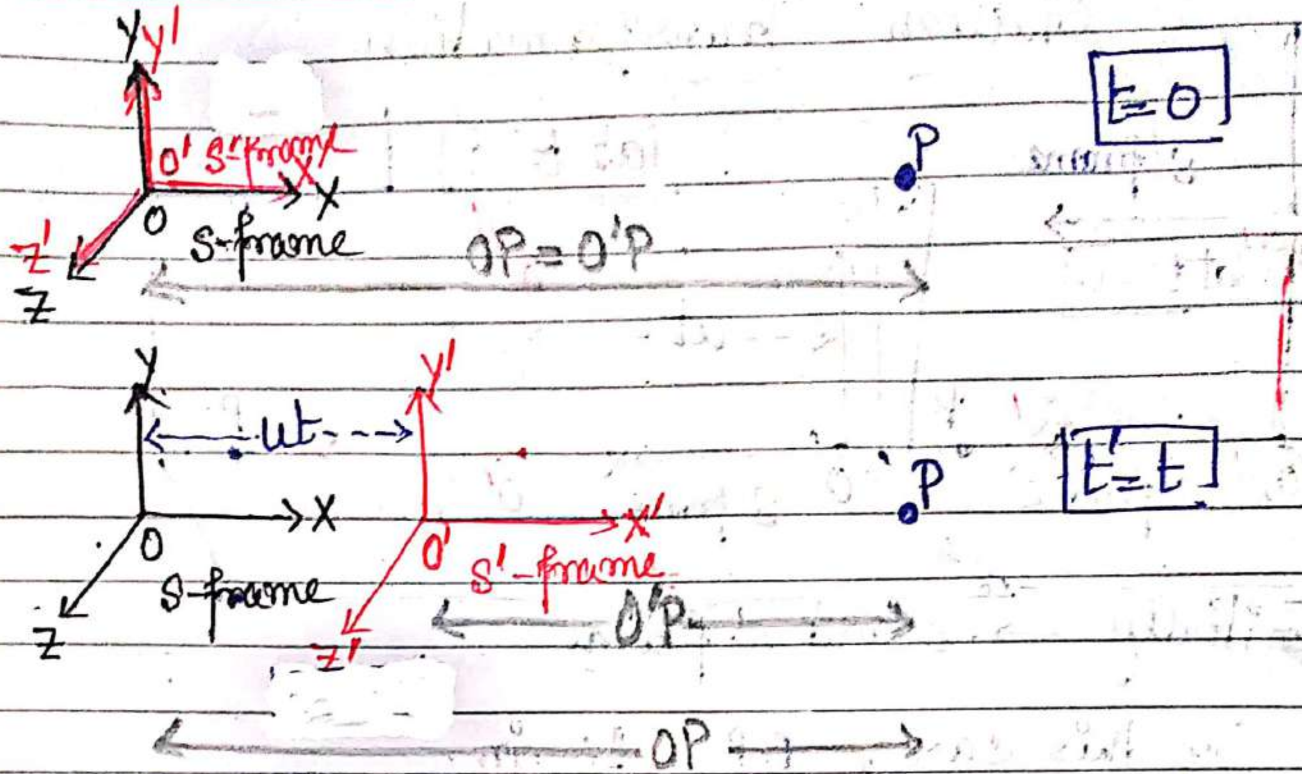
Inertial mass

$$F = ma$$

Gravitational mass

$$F = G\frac{m_1 m_2}{r^2}$$

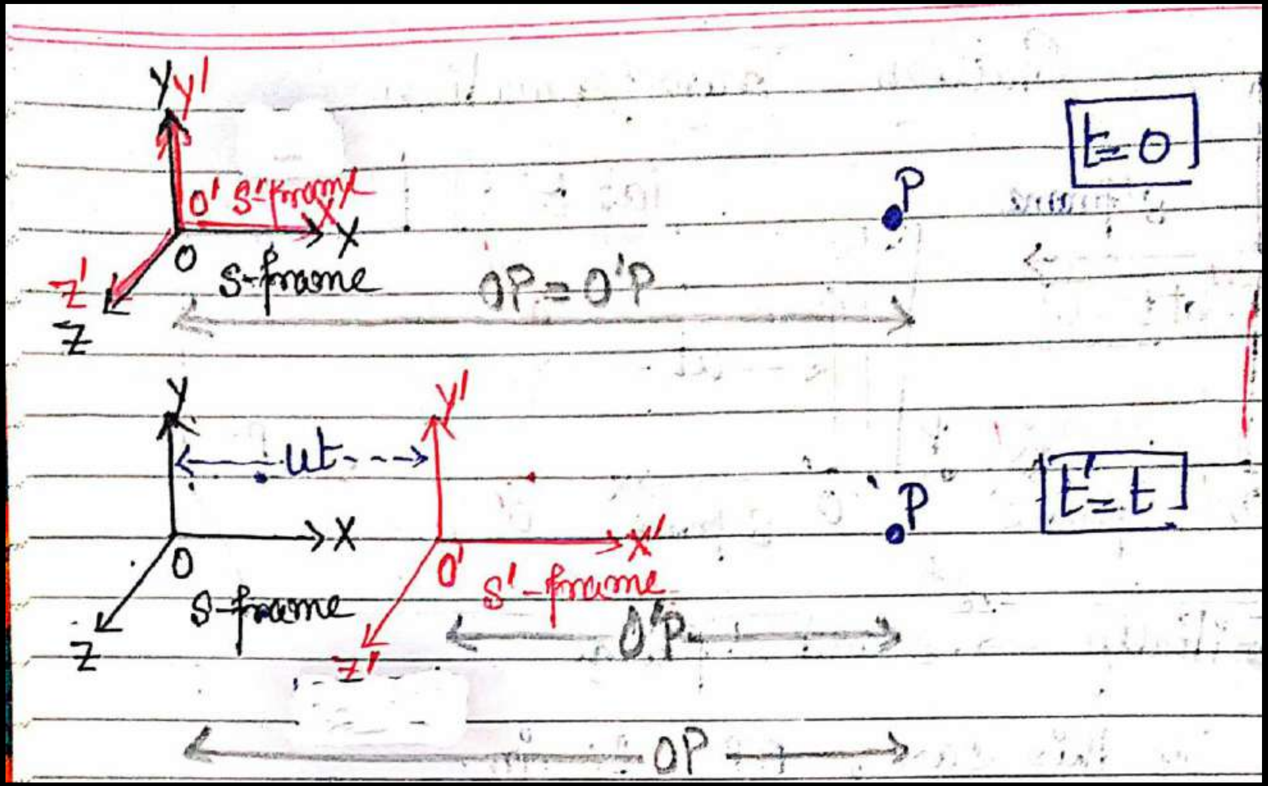
Coordinate Transformation



1) Initially, the frames S & S' just overlap to each other such that their co-ordinates OX, OY, OZ & O'X', O'Y', O'Z' are coincide to each other.

2) Now S'-frame starts to move with respect to S along +ve x-dirn with uniform velocity u.

A SIMPLE PROBLEM



1) Initially → S and S'-frame

In this case, OP = 10m
O'P = 10m

2). Let S'-frame starts to move with velocity u along +x direction
u = 2m/sec
& t = 3 sec.

Then in 3 sec, the distance travelled by S'-frame } = $u \times t$
$= 2 \times 3$
= 6m.

3). The distance of the point P from S-frame } = OP
= 10m

4). Now, the distance of the point P from S'-frame which is moving with uniform vel u along +x dir^n } = O'P
= (10−6) m
= 4 m.

Here OP = x = 10m
O'P = x' = 4m
ut = 6m.

$\therefore$ $x' = x - ut$

GALILEAN TRANSFORMATION

Then, the coordinates of a particle w.r.t. the S' frame at any time t will be

$$x' = x - ut \quad \cdots (12.1)$$

$$y' = y \quad \cdots (12.2)$$

$$\text{and} \quad z' = z \quad \cdots (12.3)$$

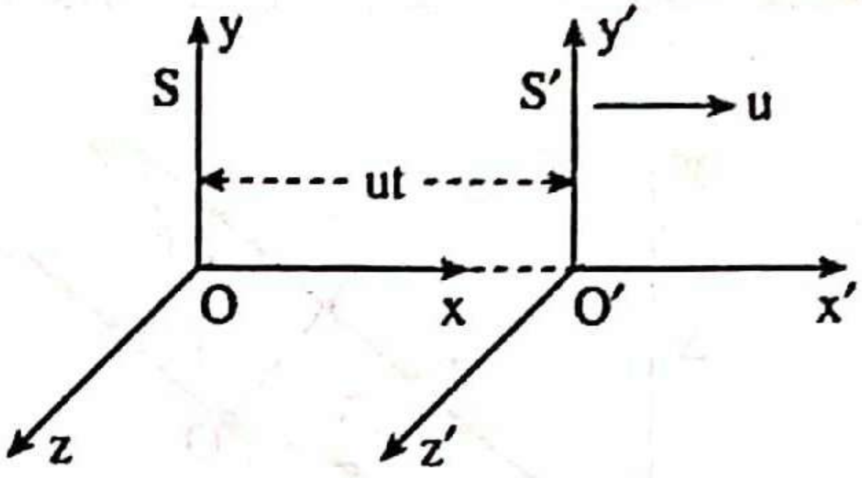


FIG. 12.1

Since time remains same in both the S and S' frames, above equations are supplemented by the equation of transformation of time

$$t' = t \quad \cdots (12.4)$$

These transformations are known as ***Galilean transformations.***

The inverse Galilean transformations are:

$$\left.\begin{aligned} x &= x' + ut \\ y &= y \\ z &= z' \\ t &= t' \end{aligned}\right\} \qquad \cdots (12.5)$$

INVARIANCE OF LENGTH

Suppose, there is a rod of length L in S frame with end coordinates x_1 and x_2. Then

$$L = x_2 - x_1 \qquad \cdots (12.6)$$

If at the same time, the end coordinates of the rod in S' frame are x_1' and x_2', then

$$L' = x_2' - x_1' \qquad \cdots (12.7)$$

From Eqn (12.1), for any time t

$$x_2' - x_1' = x_2 - x_1$$

Hence

$$L' = L \qquad \cdots (12.8)$$

Therefore, the length or distance between two points is invariant under Galilean transformation.

VELOCITU AND ACCELERATION ARE INVARIANT

The relations between velocity components in the two frames are obtained by differentiating Eqns (12.1)-(12.3) w.r.t. time:

$$\left.\begin{aligned} v_{x'} &= v_x - u \\ v_{y'} &= v_y \\ v_{z'} &= v_z \end{aligned}\right\} \quad \cdots (12.9)$$

A further differentiation w.r.t. time yields the acceleration components in the two frames:

$$\left.\begin{aligned} a_{x'} &= a_x \\ a_{y'} &= a_y \\ a_{z'} &= a_z \end{aligned}\right\} \quad \cdots (12.10)$$

Hence, according to Galilean transformations, the accelerations of a particle relative to the frames are equal.

ASSUMPTIONS

Thus, Galilean transformations are based on two assumptions:

(1) There exists a universal time t which is the same in all reference frames.

(2) The distance between two points in all inertial systems is the same.