Lecture-2

MECHANICS

The branch of physics which deals with motion and effect of force on a body is called mechanics

Force is an external cause that changes or tends to change the state of rest or motion of a body.

Forces affect Motion

- A ***force*** is a ***push or a pull*** that changes an object's motion.
- This means that forces make objects ***speed up, slow down,*** or ***change direction.***
- Forces also ***transfer energy*** from one object to another object like when you hit a ball with a bat.
- The SI unit used to measure force is the ***newton***. ***(N).***

◈ **One newton** is the amount of force needed to accelerate a **1 kg** mass by **1 m/sec^2**.

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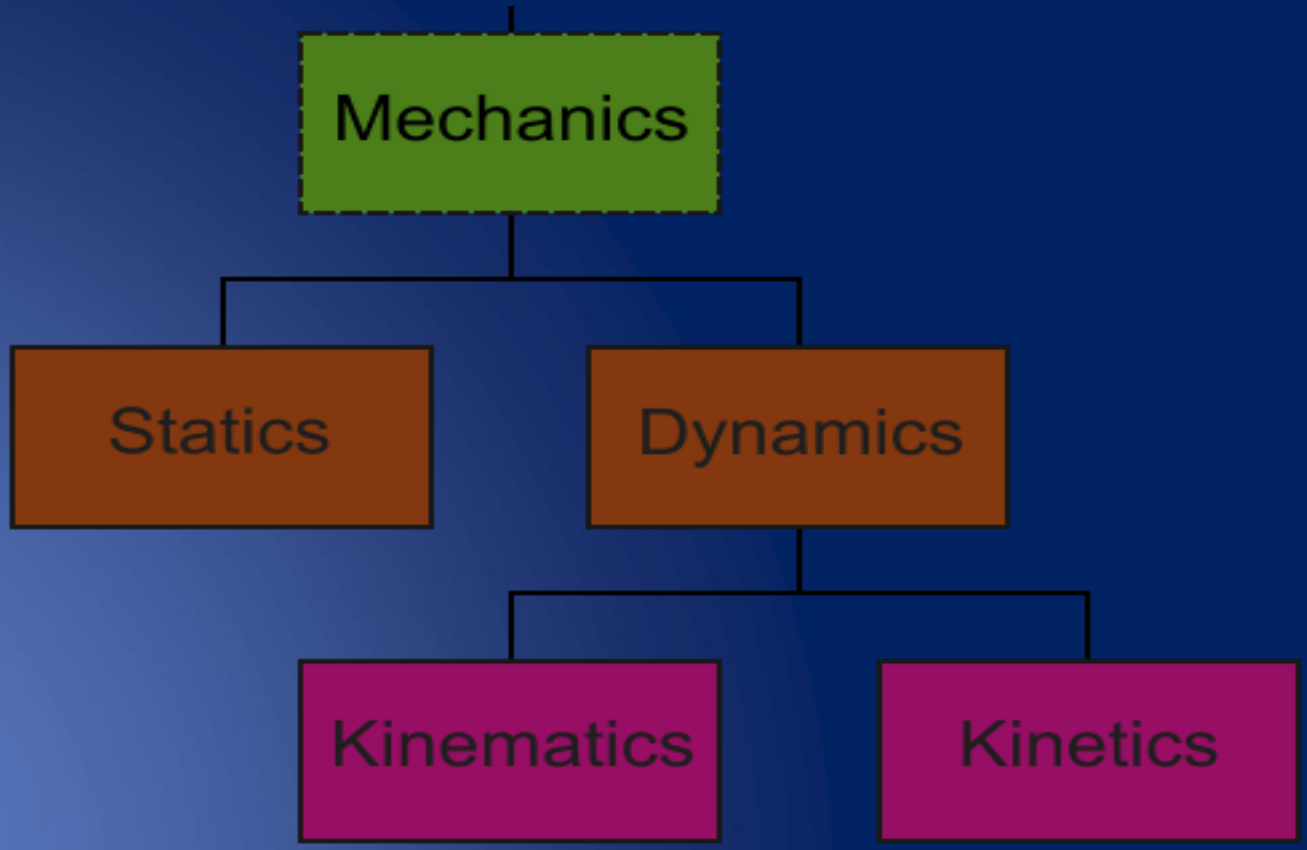

Classification of mechanics

1. **Statics:** The branch of mechanics which deals with bodies at rest under the action of system of forces is called statics.
2. **Dynamics:** The branch of mechanics which deals with moving bodies under the action of system of forces is called dynamics.

Dynamics again has been divided into two parts viz. **Kinematics and Kinetics.**

Classification of mechanics

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Kinematics: The branch of mechanics which deals only with the nature of motion without having any regard to the cause of motion is called **Kinematics**.

Kinetics: The branch of mechanics which deals with both the nature and causes of motion is called **Kinetics.**

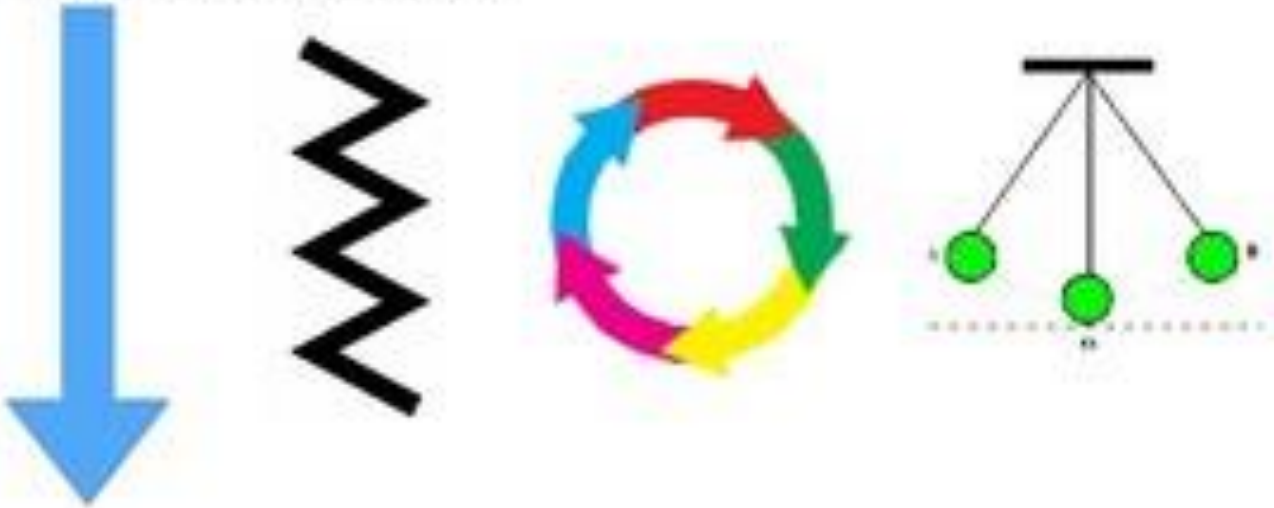
Rest and Motion

- **Rest:** When an object does not change its position in course of time with respect to its surroundings, then that state of the body is said to be at rest and the object is called stationary object. For example, houses, trees etc. are stationary object or bodies.

- **Motion:** When an object or an object changes its position in course of time with respect to its surroundings, then that state of the body is said to be in motion and the object is called moving object. For example, running men, trains, cars etc..

How Objects Move

- Objects can be moved in a variety of ways, such as straight, zigzag, circular and back and forth.

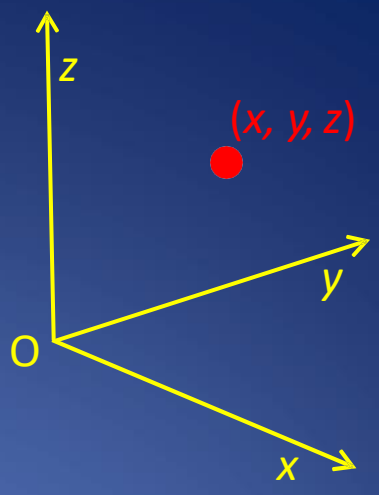


Nature of motion

- There are five kinds of motion;
- Translational motion (the motion of a stone falls vertically downward due to gravitational attraction)
- Rotational motion (motion of electric fan)
- Transla-rotational motion (motion of the wheel of a car)
- Periodic motion (the motion of the Earth around the Sun) and
- Vibrational motion (motion of a pendulum).

Measuring Motion: a Frame of Reference

Frame of reference:



The frame can be envisioned as three meter sticks at right angles to each other, like the beginning of the frame of a structure.

Frame of reference may be defined as a coordinate system or set of axes within which position, orientation and other properties of objects can be measured.

We measure position relative to some fixed point O, called the origin.

We give the ball's location as (x, y, z): we reach it from O by moving x meters along the x-axis, followed by y parallel to the y-axis and finally z parallel to the z-axis.

Parameters required for explain the One-Dimensional Motion

- **Displacement: Distance in a particular direction**
- **units: meters (can be positive or negative)**

- **Velocity = rate of change of displacement,**
- **units: Meters per second, written m/s or $m.sec^{-1}$.**

- **Acceleration = rate of change of velocity,**
- **units: Meters per second per second, written m/s^2 or $m.sec^{-2}$.**

Displacement & Distance

Displacement: The distance moved in a particular direction is called displacement. So, both magnitude and direction is important here. It is denoted by the symbol 'x'. It is a vector quantity. Its SI unit is meter (m).

If the displacement $\Delta x = x_2 - x_1$, magnitude is written

$|\Delta x| = |x_2 - x_1|$.

Distance: The total length of the path traveled by a moving body in a particular time is called distance. It is denoted by the symbol's'. It is a scalar quantity. Its SI unit is meter (m).

QUESTION

What differs from distance and displacement?

Direction

Velocity

The velocity of an object is the rate of change of its position with respect to a frame of reference and is a function of time. Velocity is equivalent to a specification of an object's speed and direction of motion.

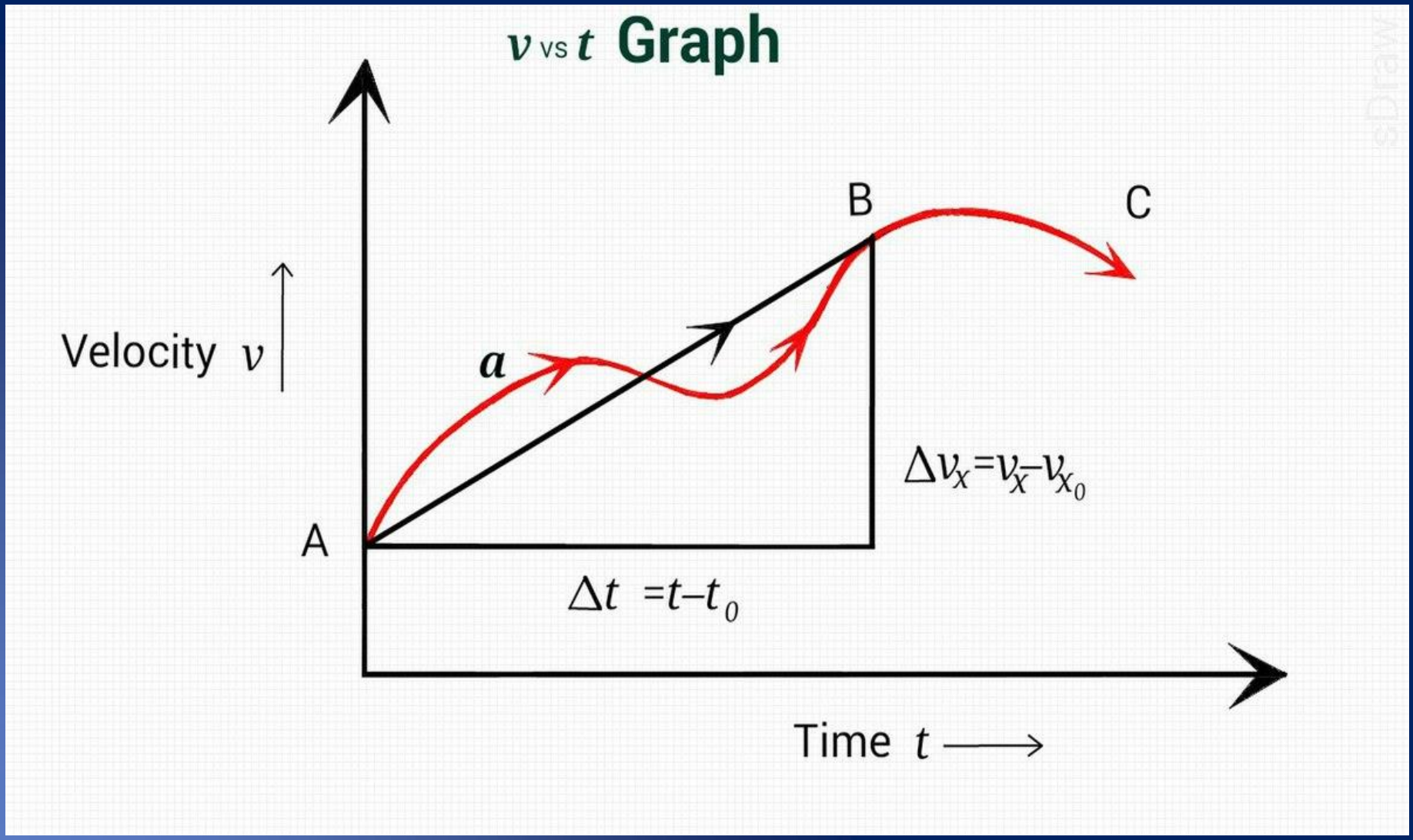
Velocity is a fundamental concept in kinematics, the branch of classical mechanics that describes the motion of bodies.

Average Speed and Average Velocity

- Average speed = distance /time taken.
- Average velocity = displacement/time taken

so average velocity is a vector!

- Formula for average velocity: $\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$


v vs t Graph
Velocity v
a
B
C
A
Δv_x=v_x–v_x0
Δt =t–t_0
Time t ⟶

Velocity Vs. Speed

Velocity:

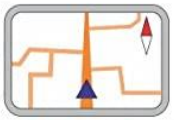
Velocity is the vector quantity that signifies the magnitude of the rate of change of position and also the direction of an object's movement.

Speed:

Speed is the scalar quantity that Signifies only the magnitude of the rate of change of an object's movement.

Example:

25 meters
sec



North

Example:

25 meters
sec

Instantaneous Velocity

- If the time interval approaches zero, the rate of change of displacement with time is called instantaneous velocity or simply velocity.

- Mathematically, we write:

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}.$$

Acceleration

- Average acceleration = change in velocity/time taken

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

- Acceleration is the rate at which velocity changes with time.
- It is a measure of how quickly the velocity is changing; if velocity does not change, there is no acceleration.
- When the acceleration is in the same direction as the object is moving, the speed of the object increases (the car speeds up)
- When the acceleration is opposite to the motion, the speed of the object decreases (the car slows down). This is also called deceleration.

Slowing Down (opposite signs)

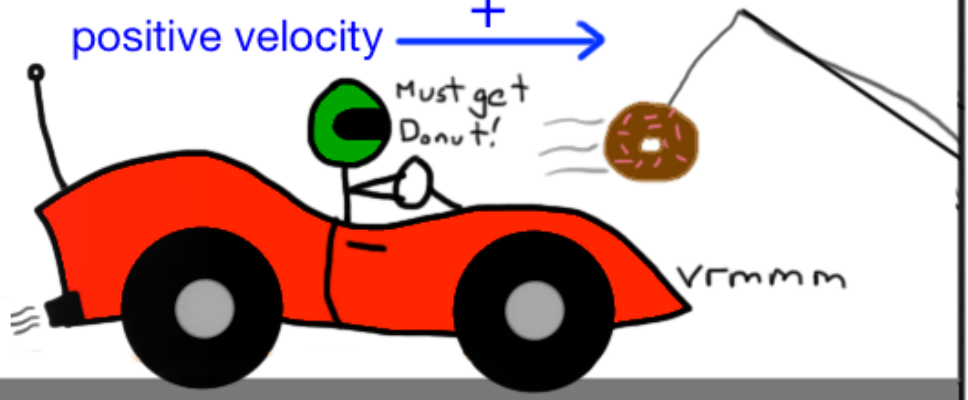
negative acceleration (−)

positive velocity (+)

Speeding Up (same signs)

positive acceleration (+)

positive velocity (+)



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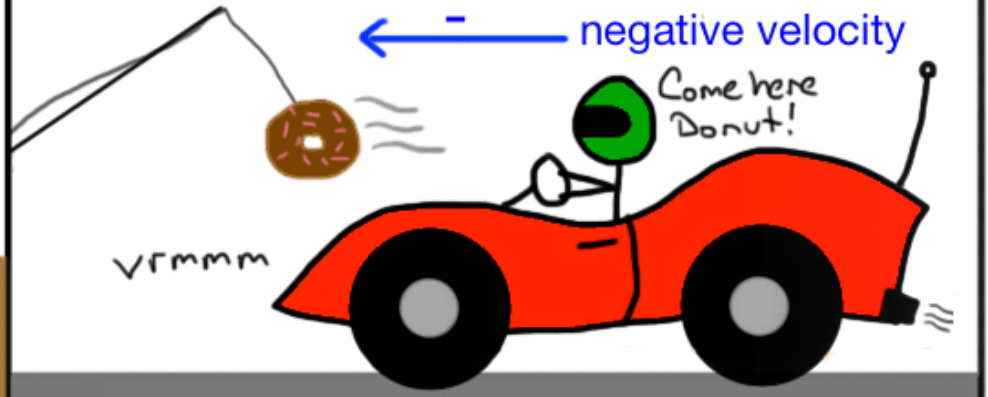


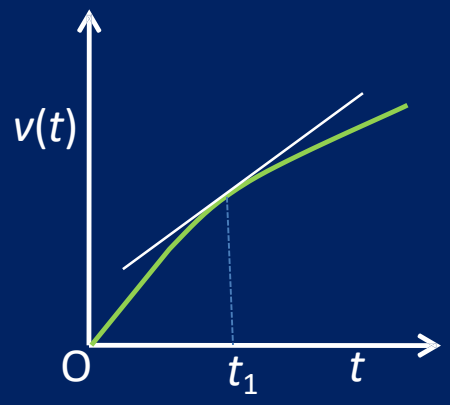
Instantaneous Acceleration

- If the time interval approaches zero, the rate of change of velocity with time of a body is called the instantaneous acceleration or simple acceleration.

- The instantaneous acceleration

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}.$$

- The acceleration at time t_1 is the slope of the velocity graph $v(t)$ at that time.



s=vt

some quantities like distance, displacement, speed, velocity and acceleration etc. These quantities are related to each other which are expressed by some equations. These equations are called **equations of motion**

1. $s = vt$ or, $x = x_0 + v_x t$

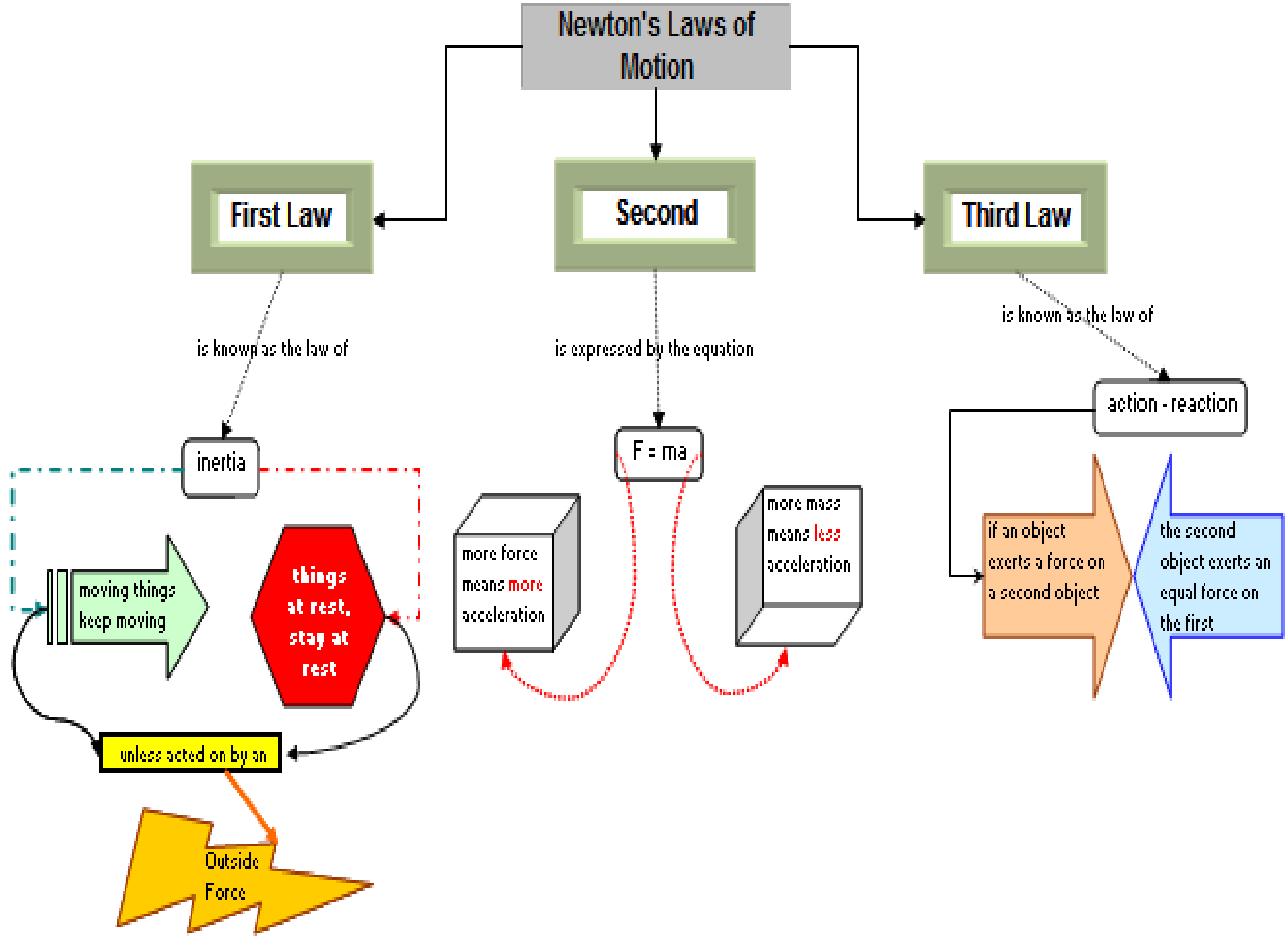
2. $v = v_0 + at$ or, $v_x = v_{x0} + a_x t$

3. $s = v_0 t + \frac{1}{2} a t^2$ or, $x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$

4. $v^2 = v_0^2 + 2as$ or, $v_x^2 = v_{x0}^2 + 2a_x (x - x_0)$

5. $s_t = v_0 + \frac{1}{2} a(2t - 1)$ or, $(x - x_0)_t = v_{x0} + \frac{1}{2} a_x (2t - 1)$

Concepts from Newton's Law's of motion


Newton's Laws of Motion
First Law
Second
Third Law
is known as the law of
is expressed by the equation
is known as the law of
inertia
F = ma
action - reaction
moving things keep moving
things at rest, stay at rest
more force means more acceleration
more mass means less acceleration
if an object exerts a force on a second object
the second object exerts an equal force on the first
unless acted on by an
Outside Force

Newton's Laws of Motion

The concept comes from this law

- Inertia
- Mass
- Force

Inertia is the resistance of any physical object to any change in its state of motion. This includes changes to the object's speed, direction or state of rest.

Newton's First Law of Motion

- ***Law of Inertia***
- **Inertia**
  - Tendency of an object an object to resist a change in motion
  - Inertia means that the object's motion will stay constant in terms of speed and direction
  - Depends on the **mass** of an object
  - Does NOT depend of the presence of gravity
    - An object's inertia is the same on Earth and in space

  - Objects with a greater mass have greater inertia
  - Example
    - It is more difficult to change the motion of bowling ball than the motion of a golf ball

Mass (Inertia)

- ***Inertia*** ≡ The tendency of a body to maintain its state of rest or motion.
- **MASS:** Property of an object that specifies how much resistance an object exhibits to changes in it's velocity.
  - A measure of the inertia of a body
  - Quantity of matter in a body
  - A scalar quantity
  - Quantify mass by having a standard mass = **Standard Kilogram (kg)** (Similar to standards for length & time).
  - SI Unit of Mass = Kilogram (kg)
    - cgs unit = gram (g) = 10^{-3} kg
- **Weight:** (***NOT*** the same as mass!) The force of gravity on an object.

Force and Acceleration

What does F = ma say?

- F = ma basically means that the force of an object comes from its mass and its acceleration.
- If you *double* the mass, you *double* the force. If you *double* the acceleration, you *double* the force.
- Doubling the mass *and* the acceleration *quadruples* the force.

$$(2m)(2a) = 4F$$

So . . . what if you *decrease the mass by half*? How much force would the object have now?

Momentum

Momentum

- Momentum depends on mass and velocity
- Momentum is a vector and is defined as:

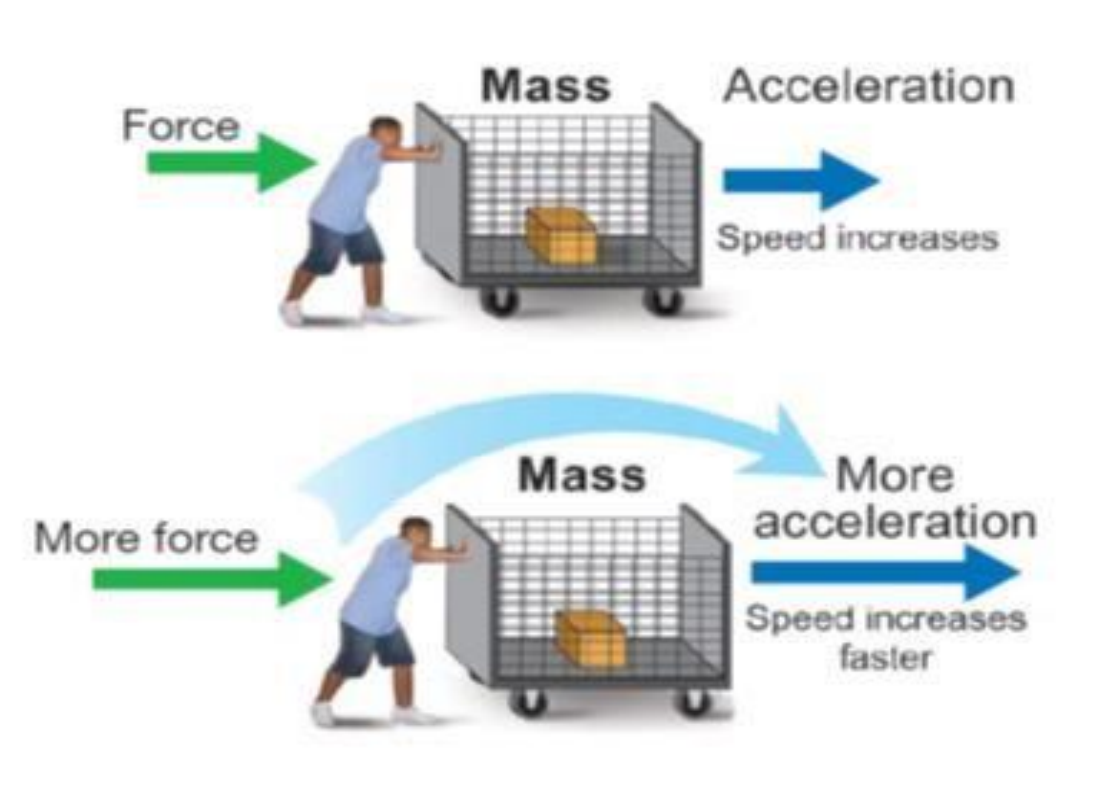
$$\vec{p} = m\vec{v}$$

- where momentum p is measured in kg·m/s when mass is measured in kg and velocity is measured in m/s

Conservation of Momentum

A corner stone of physics is the conservation of momentum. This can be seen in all types of collisions.

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

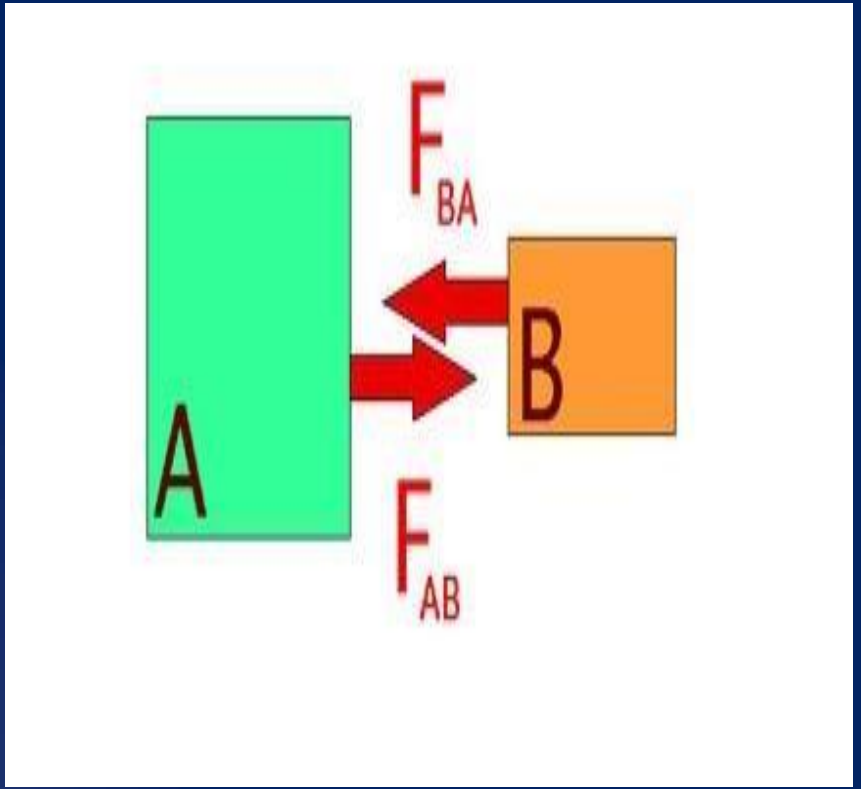


Newton's Third Law

- If two bodies interact, the force on B from A is equal in magnitude to the force on A from B, and opposite in direction :

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

In the example shown here, the glove suffers a force exactly equal in magnitude to that felt by the face.



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Examples to Illustrate Newton's Third Law of Motion

How do we walk?

When we walk on the ground, our foot pushes the ground backward and in return the ground pushes our foot forward.

Why the cannon recoil

When ball is fired from a cannon, the force sends the ball forward and is equal to the force sending the cannon backward, hence the cannon is said to be recoiled.

Newton's 3rd Law Examples

Action Force	Reaction Force
A gun is fired, propelling a bullet forward.	The gun fired backwards, in the opposite direction of the bullet.
A person pushes on a wall.	The wall pushes back on the person.
A person walks down a street, exerting a frictional force against the ground.	The ground exerts a normal force against the person, propelling them forward.

Thank You!