

KINEMATICS

Motion

- **Distance:** the total length between two points
- **Speed:** the total distance travelled per unit of time
- **Displacement:** the distance of an object from a fixed point in a specified direction
- **Velocity:** the rate of change of displacement of an object
- **Acceleration:** the rate of change of velocity of an object
- **Equation:**

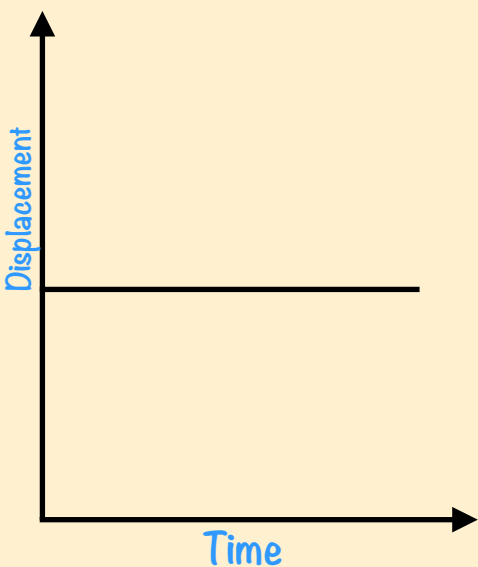
$$\text{Velocity} = \frac{\text{change in displacement}}{\text{Time taken}} = \frac{\Delta s}{\Delta t}$$

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{Time taken}} = \frac{\Delta V}{\Delta t}$$

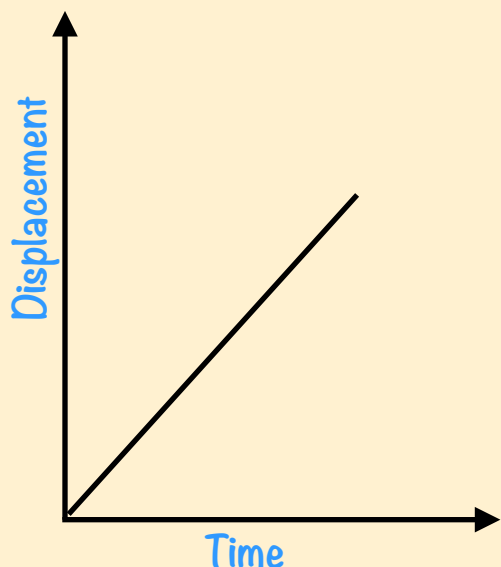
Motion Graph

Displacement-Time graph:

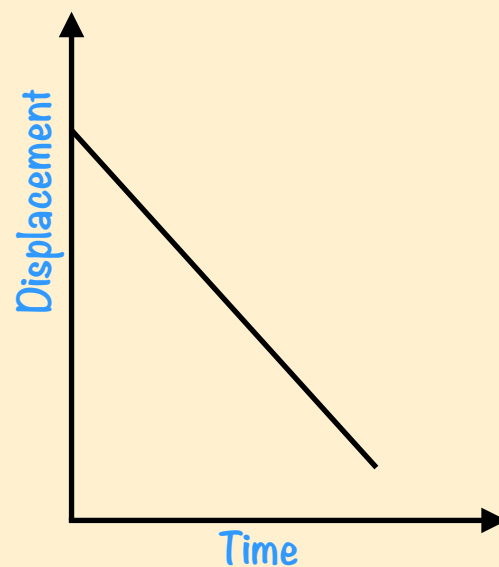
- Slope equals velocity.
- The y- intercept equals the initial displacement.
- A straight line represents a constant velocity.
- A curve line represents an acceleration.
- A positive slope represents motion in positive direction.
- A negative slope represents motion in negative direction.



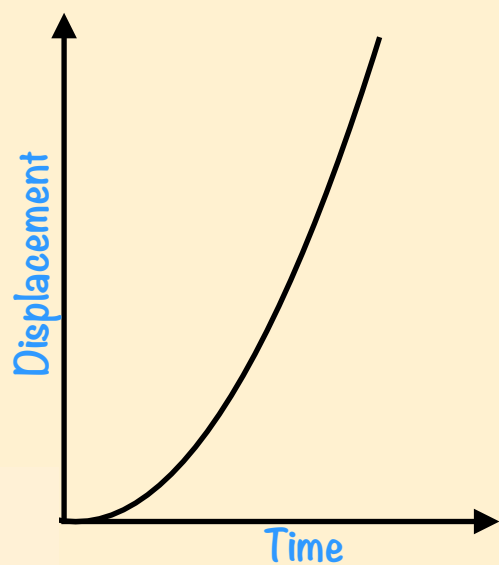
Displacement- time graph with zero velocity.(i.e the object is at stationary)



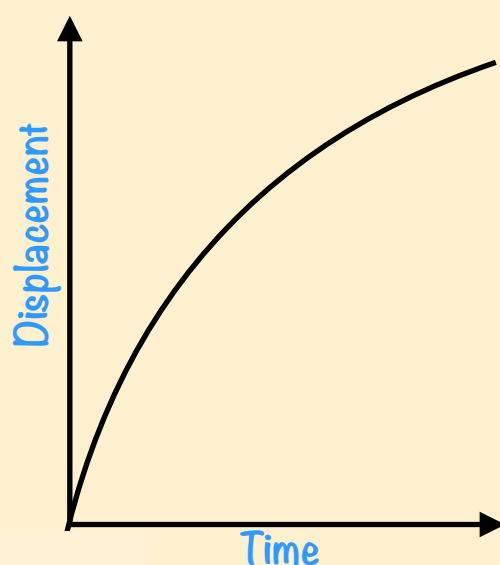
Displacement- time graph with constant velocity and moving away from observer.



Displacement- time graph with constant negative velocity.(i.e the object is moving towards the observer)



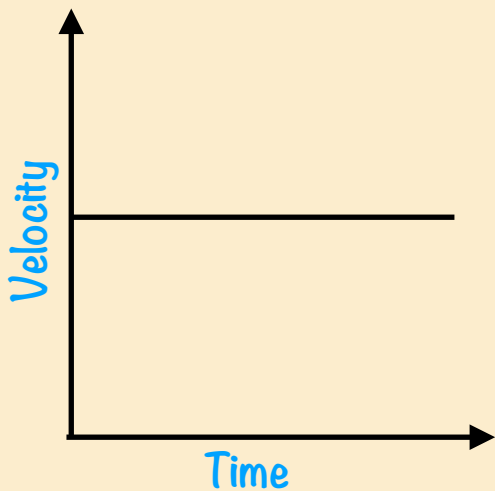
Displacement- time graph with increasing velocity.



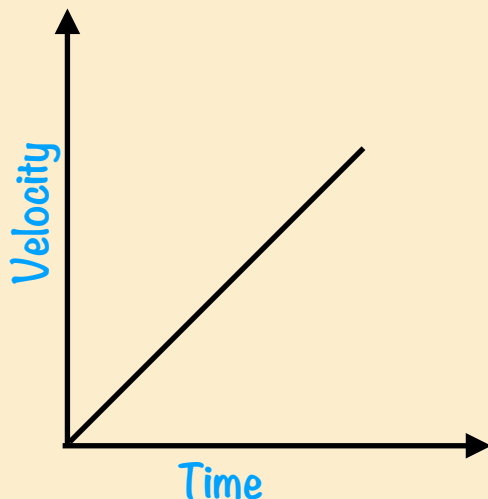
Displacement- time graph with decreasing velocity.

Velocity-Time graph:

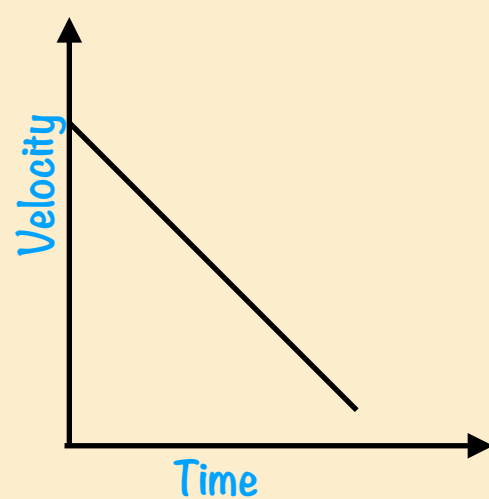
- Slope equals acceleration.
- The y- intercept equals the initial velocity.
- A straight line represents a constant acceleration.
- A curve line represents non uniform acceleration.
- The area under the curve equals the change in displacement.



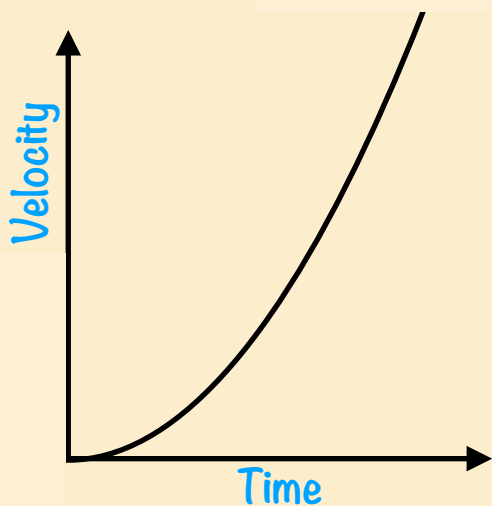
Velocity-time graph with
constant velocity.
(i.e zero acceleration)



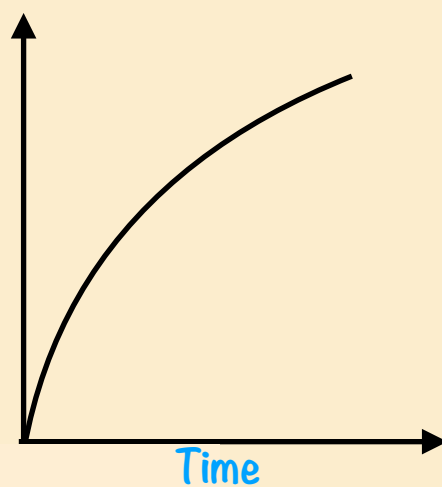
Velocity-time graph with
increasing velocity.
(i.e constant positive acceleration)



Velocity-time graph with
decreasing velocity.
(i.e constant negative acceleration)



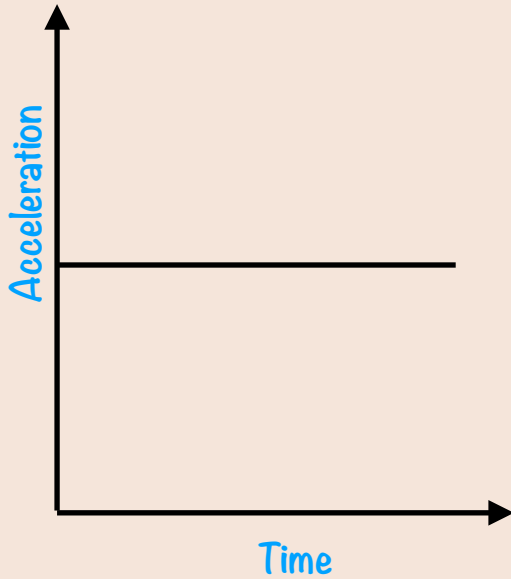
Velocity-time graph with
increasing acceleration.



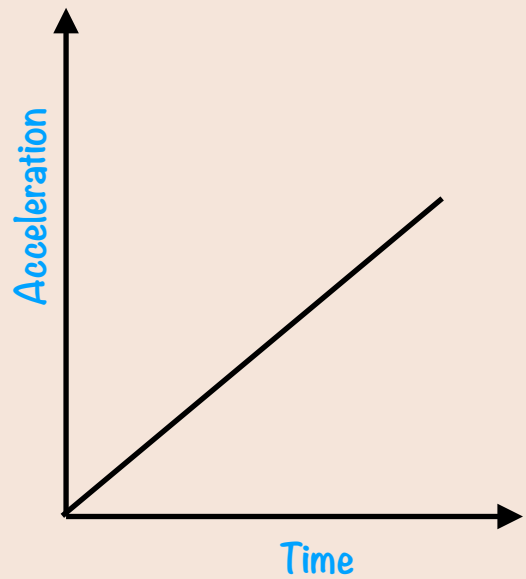
Velocity-time graph with
decreasing acceleration.

Acceleration-Time graph:

- The y- intercept equals the initial acceleration.
- A zero slope (horizontal line) represents an object undergoing constant acceleration.
- The area under the curve equals the change in velocity.



Acceleration-time graph with constant acceleration.

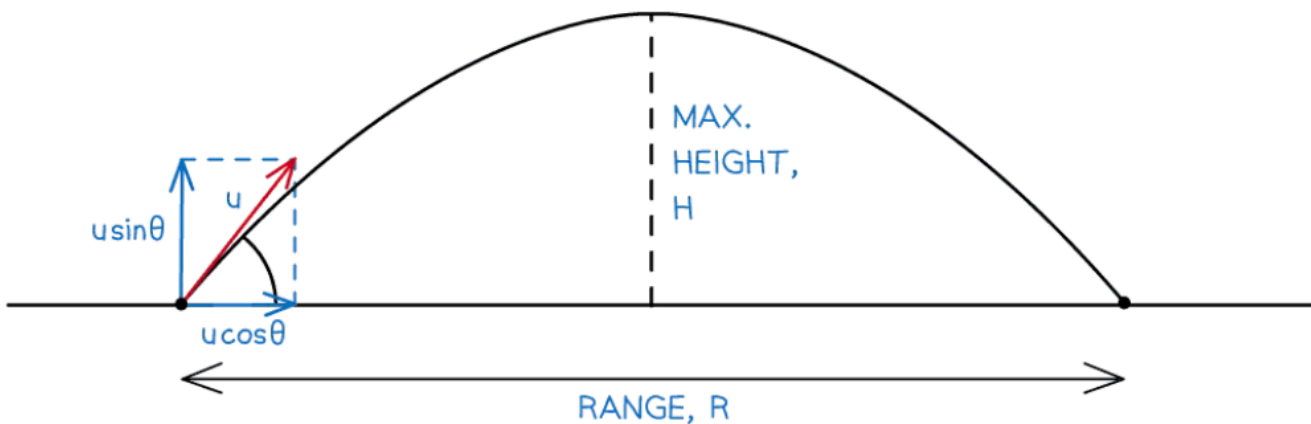


Acceleration-time graph with increasing acceleration.

Projectile Motion

Projectile motion: uniform velocity in one direction and constant acceleration in perpendicular direction.

- The trajectory of an object undergoing projectile motion consists of a **vertical** component and **horizontal** component. And this should be evaluated separately.
- Some terms and calculation used in projectile motion:**
 - Time of flight:** how long the projectile is in the air.
 - Maximum height attained:** the height at which the projectile is momentarily at rest.
 - Range:** the horizontal distance travelled by the projectile.



Time of flight:

Considering vertical motion,

$$u = u \sin \theta, \quad a = -g, \quad v = 0$$

$$v = u + at$$

$$0 = u \sin \theta - gt$$

$$\therefore t = \frac{u \sin \theta}{g}$$

If the time to reach maximum height is t ,

Then time of flight is $2t$.

$$\text{so, time of flight} = 2t = \frac{2u \sin \theta}{g}$$

Maximum height:

Considering vertical motion,

$$u = u \sin \theta, \quad a = -g, \quad v = 0$$

$$v^2 = u^2 + 2as$$

$$0 = (u \sin \theta)^2 - 2gH$$

$$\therefore H = \frac{(u \sin \theta)^2}{2g}$$

so the maximum height attained is $\frac{(u \sin \theta)^2}{2g}$.

Range:

Considering vertical motion,

$$u = u \cos \theta, \quad a = 0, \quad t = \frac{2u \sin \theta}{g}$$

$$\begin{aligned} \text{range} &= \text{velocity} \times \text{time} = u \cos \theta \times \frac{2u \sin \theta}{g} \\ &= \frac{u^2 \sin 2\theta}{g}. \end{aligned}$$

so, the range of projectile motion is $\frac{u^2 \sin 2\theta}{g}$.