CUBE NOTES

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Kinematics: Instantaneous Acceleration

Key Idea

Acceleration

- Acceleration is the rate of change of velocity. When velocity increases or decreases, the body is said to be accelerating.
- When velocity remains constant, the body has zero acceleration.

Average Acceleration

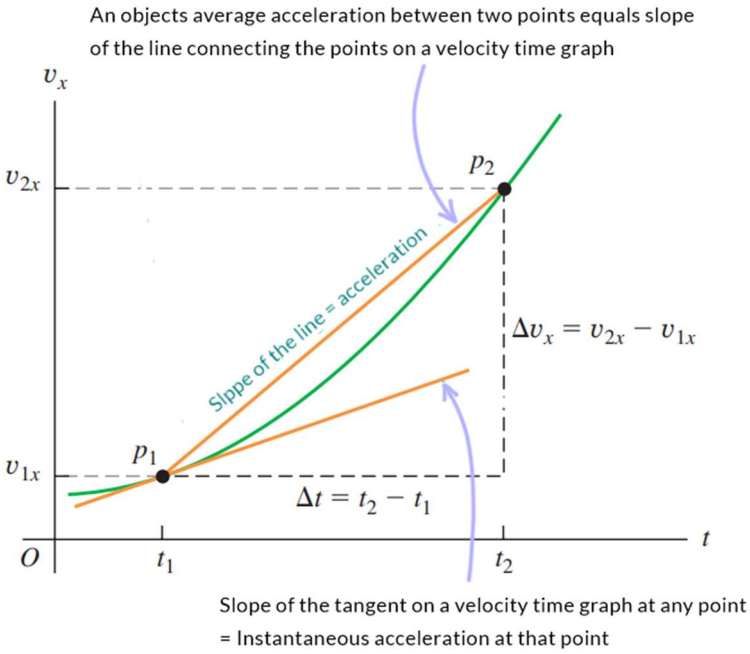
It represents the change in velocity over a specific time interval.

Units of acceleration

If you observe the units of acceleration ($\frac{m}{s^2}$ or $\frac{\frac{m}{s}}{s}$) you could interpret them as how many "meters per second", the velocity changes every second

Instantaneous Acceleration

- Instantaneous acceleration is the rate of change of velocity at a specific instant or point in time.
- It is also equal to the second derivative of position with respect to time.



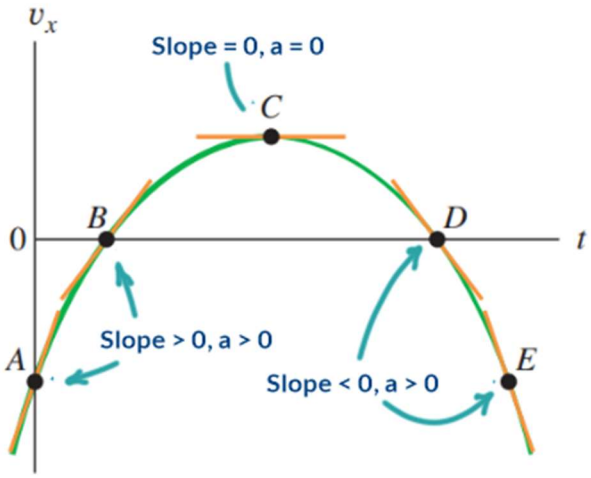
Velocity-Time Graphs and Acceleration

- On a velocity-time graph, the slope of the graph (tangent to the curve) at any point represents instantaneous acceleration.
- Positive slope indicates positive acceleration, negative slope indicates negative acceleration

Direction of Acceleration

- Acceleration is a vector quantity, so it has both magnitude and direction.
- The sign of acceleration indicates its direction. Positive acceleration acts in the positive X direction, negative acceleration acts in the negative X direction.
- Positive acceleration does not always mean velocity is increasing, and negative acceleration does not always mean velocity is decreasing.

Slope of the tangent also represents the direction of acceleration. On the LHS of point C, the slope of the tangent is +ve or acceleration is positive or in the + X direction. On the RHS of point C the slope turns negative and the acceleration is -ve or points in the - X direction



Average acceleration versus instantaneous acceleration

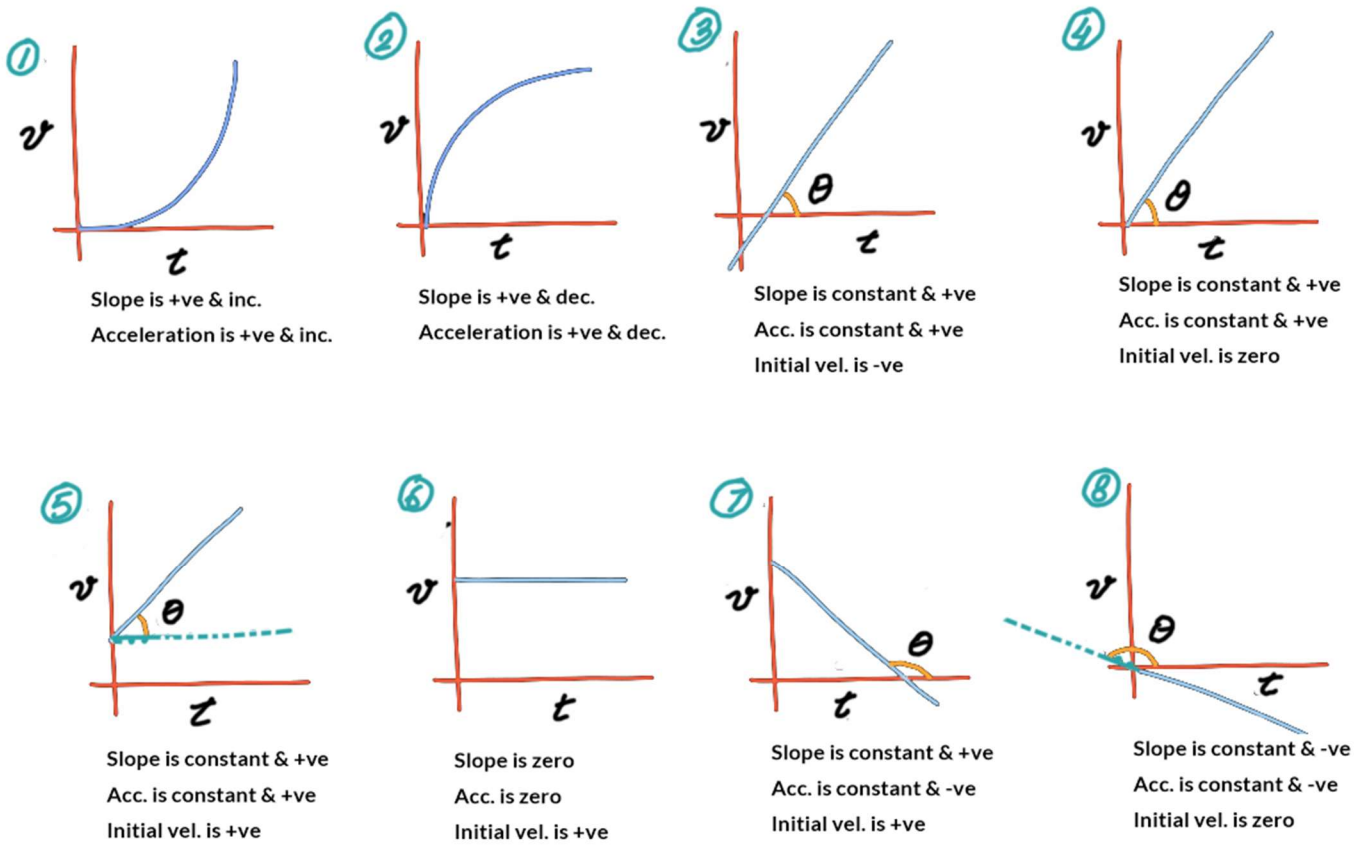
Aspect	Average Acceleration	Instantaneous Acceleration
Definition	Change in velocity over a specific time interval.	Rate of change of velocity at an exact moment in time.
Time Interval	Measured over a finite time interval (Δt).	Measured at an infinitesimally small moment in time (Δt → 0).
Formula	$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1}$	a = $lim(\Delta t \to 0)$ $\frac{\Delta v}{\Delta t}$ or $a = dv / dt$
Significance	Describes overall change in velocity during a period.	Describes the velocity at an exact instant.
Graphical Interpretation	Represents the slope of the velocity-time graph over an interval.	Obtained from the slope of the velocity-time graph at a specific point or as the second derivative of the position-time graph.
Application	Used when velocity changes gradually over time.	Used when you want to know the acceleration at a particular moment.

Example	If a car starts from rest and reaches 60 km/h in 10 seconds, its average acceleration over that time that is 10 s is calculated as a = (60 km/h – 0 km/h)/ 10s = 6 $\frac{m}{s^2}$	When calculating the acceleration of a car at the moment it reaches 60 km/h, you are finding the instantaneous acceleration.

List of formulas and equations

Concept	Equation	Description
Average Acceleration	$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1}$	Average acceleration represents the change in velocity over a specific time interval.
Instantaneous Acceleration		Instantaneous acceleration is the rate of change of velocity at an exact moment in time.
Instantaneous Acceleration (in terms of Δt)	a = $\lim(\Delta t \to 0)$ Δv/Δt	As Δt approaches zero, average acceleration becomes instantaneous acceleration.
Instantaneous Acceleration (in terms of derivative of v)	$a = dv/dt$	On a velocity-time graph, the slope of the curve at a point represents the instantaneous acceleration.
Instantaneous Acceleration (Alternative)	$a = \frac{d^2x}{dt^2}$	Instantaneous acceleration can also be defined as the second derivative of position with respect to time.

Various velocity time graphs and their interpretation



if you throw a ball up in the air and it reaches its maximum height, its velocity becomes zero. This does not mean that its acceleration is zero. You must understand that its velocity is not constant at the top because it is changing direction from upwards, to downwards. Accelereation is zero only when velocity remains constant, not necessarily zero.