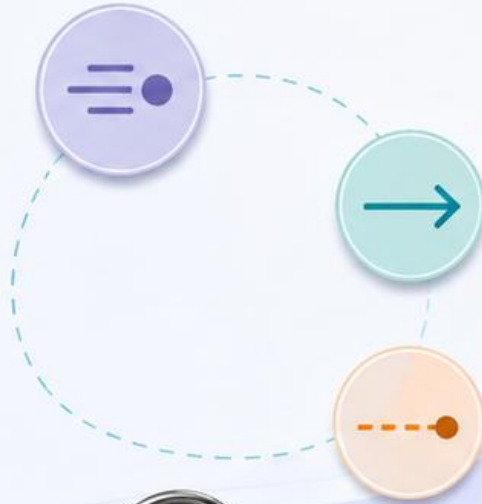
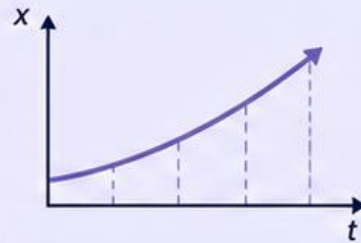
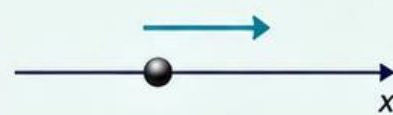
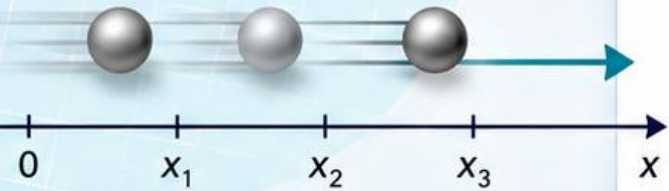


Chapter 2

Motion in a Straight Line

Displacement • Velocity • Acceleration

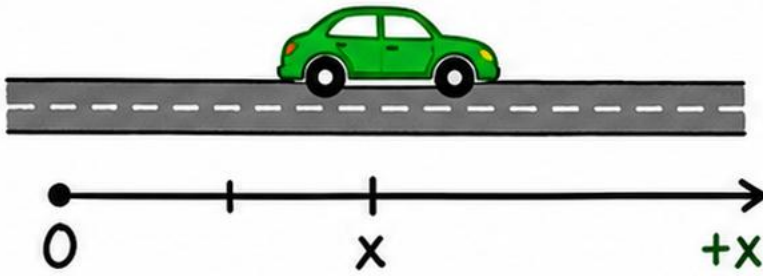


MOTION IN A STRAIGHT LINE

Kinematics describes how objects move without asking what forces cause the motion.

RECTILINEAR MOTION

motion along one chosen straight axis



MOTION

position changes with time relative to a chosen reference frame

motion $\rightarrow$ x changes as t changes

POINT-OBJECT MODEL

- replace an object by one point when its size is negligible compared with the distance and length scales of interest
- the model describes translation, not rotation or shape change

position $x(t)$



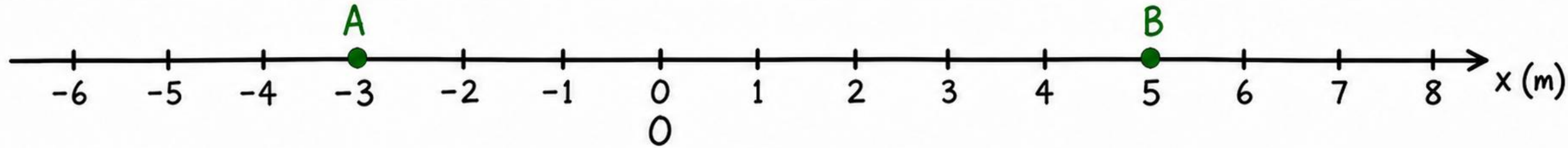
velocity $v(t)$



acceleration $a(t)$

Always state the origin, positive direction and time origin before assigning signs.

POSITION, DISTANCE & DISPLACEMENT



POSITION: signed coordinate measured from the chosen origin

$$x_A = -3 \text{ m}$$

$$x_B = +5 \text{ m}$$

DISPLACEMENT: straight-line change in position from start to finish

A (-3 m)  B (+5 m)

depends only on endpoints; may be positive, negative or zero

$$\begin{aligned}\Delta x &= x_B - x_A \\ &= 5 - (-3) = +8 \text{ m}\end{aligned}$$

DISTANCE/PATH LENGTH: actual route traveled; add up all segments



total path length; scalar and never negative

$$\begin{aligned}\text{distance} &= 10 \text{ m} + 2 \text{ m} \\ &= 12 \text{ m}\end{aligned}$$

$$\boxed{\text{distance} \geq |\text{displacement}|}$$

equality holds only when motion does not reverse direction.

AVERAGE SPEED & AVERAGE VELOCITY

Average velocity is net displacement per elapsed time.

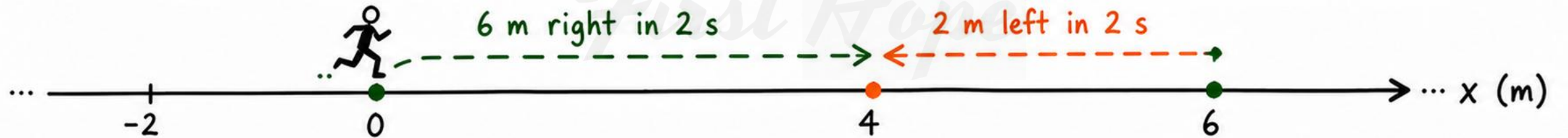
$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

unit: m s^{-1} $\longrightarrow$ direction matters

Average speed is total distance per elapsed time.

$$\text{speed}_{\text{avg}} = \frac{\text{total path length}}{\Delta t}$$

unit: m s^{-1} $\longrightarrow$ non-negative



Total time elapsed: $2 \text{ s} + 2 \text{ s} = 4 \text{ s}$
Distance traveled: $6 \text{ m} + 2 \text{ m} = 8 \text{ m}$
Displacement: $x_f - x_i = 4 \text{ m} - 0 \text{ m} = +4 \text{ m}$

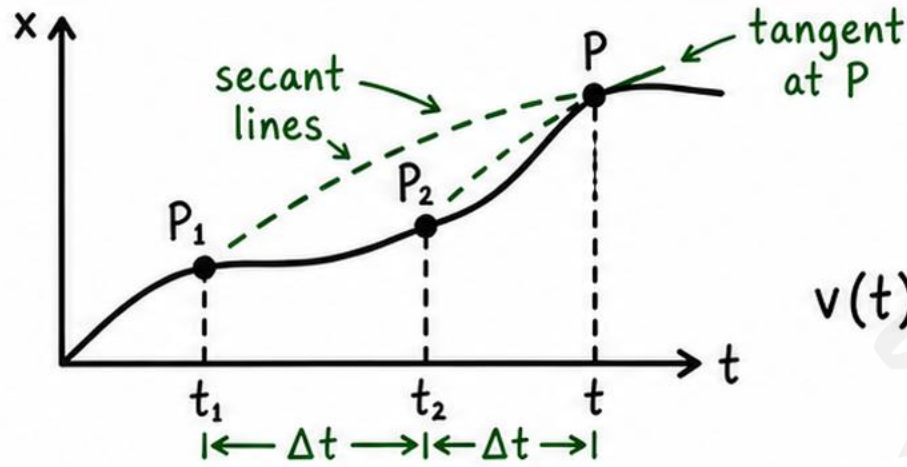
$$\text{Average speed} = \frac{\text{total distance}}{\Delta t} = \frac{8 \text{ m}}{4 \text{ s}} = 2 \text{ m s}^{-1}$$
$$\text{Average velocity} = \frac{\text{displacement}}{\Delta t} = \frac{4 \text{ m}}{4 \text{ s}} = +1 \text{ m s}^{-1}$$

$$\text{average speed} \geq |\text{average velocity}|$$

QUICK IDEA: A round trip can have non-zero average speed but zero average velocity.

INSTANTANEOUS VELOCITY & SPEED

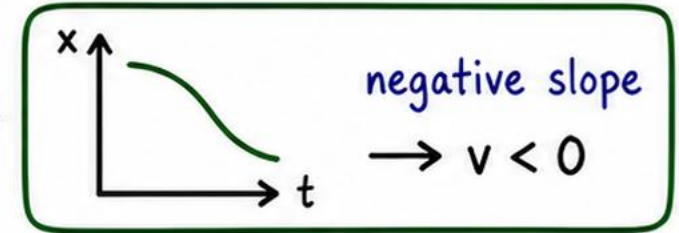
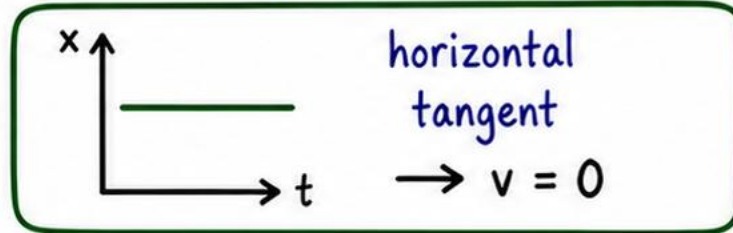
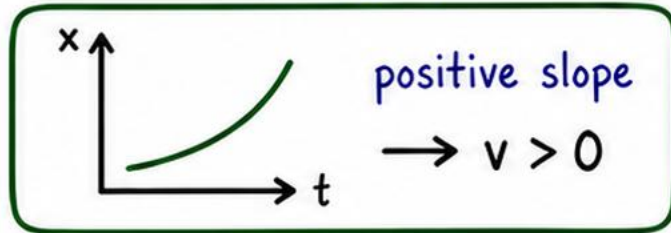
FROM AN INTERVAL TO AN INSTANT:



$$v_{avg} = \frac{\Delta x}{\Delta t}$$

$$v(t) = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

- instantaneous velocity is the rate of change of signed position at that instant.
- on an x-t graph it is the slope of the tangent.



INSTANTANEOUS SPEED:

$$\text{speed} = |v|$$

- examples: $+24 \text{ m s}^{-1}$ and -24 m s^{-1} both have speed 24 m s^{-1} .

⚠ Instantaneous speed equals |instantaneous velocity|, but average speed need not equal |average velocity|.

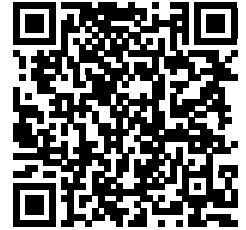


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