Chapter 2

Motion along a straight line

Kinematics: description of motion

Dynamics: origins of motion

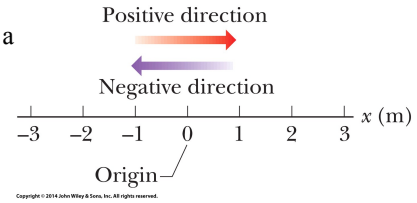
Assumptions

- motion takes place in a straight line
- moving object is a point-like particle

Position and displacement

- Position is measured relative to a reference point:
  - The **origin**, or zero point, of an axis
- Position has a sign:
  - **Positive direction** is in the direction of increasing numbers
  - **Negative direction** is opposite the positive

Position described by a function $x(t)$



Position and displacement

Position x_1 at time t_1: $x_1 = x(t_1)$

Position x_2 at time t_2: $x_2 = x(t_2)$

- A change in position is called **displacement**
  - Δx is the change in x: (*final position*) – (*initial position*)

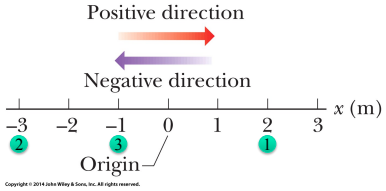
$$\Delta x = x_2 - x_1$$

  - can be positive or negative
  - is therefore a vector quantity (has both magnitude and direction)
  - is independent of the origin of the coordinate system
  - Δt is the time interval

$$\Delta t = t_2 - t_1$$

  - is a scalar quantity

Displacement vs. Distance



$x_1 = x(0) = 2$ m

$x_2 = x(5\text{ s}) = -3$ m

$x_3 = x(8\text{ s}) = -1$ m

Displacement	Distance
$\Delta x_{21} = x_2 - x_1 = (-3\text{ m}) - (2\text{ m}) = -5\text{ m}$	$d = 5$ m
$\Delta x_{32} = x_3 - x_2 = (-1\text{ m}) - (-3\text{ m}) = 2\text{ m}$	$d = 2$ m
$\Delta x_{31} = x_3 - x_1 = (-1\text{ m}) - (2\text{ m}) = -3\text{ m}$	$d = (5\text{ m}) + (2\text{ m}) = 7\text{ m}$

Average Velocity

Average velocity, or v_{avg}, is defined as the ratio of the displacement Δx to the time interval Δt:

It is a vector quantity, and has the same sign as the displacement, since $\Delta t > 0$.

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

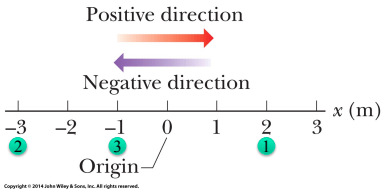
Average Speed

Average speed is the ratio of the total distance travelled to the total time interval Δt.

It is a scalar quantity, and does not carry any sense of direction.

$$s_{avg} = \frac{\text{total distance}}{\Delta t}$$

Velocity vs Speed

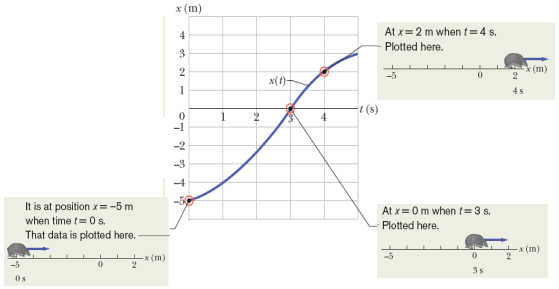


$x_1 = x(0) = 2$ m
$x_2 = x(5\text{ s}) = -3$ m
$x_3 = x(8\text{ s}) = -1$ m

Displacement	Average velocity	Distance	Average speed
$\Delta x_{21} = -5$ m	$v_{21} = \frac{-5\text{ m}}{5\text{ s}} = -1$ m/s	$d = 5$ m	$s_{21} = \frac{5\text{ m}}{5\text{ s}} = 1$ m/s
$\Delta x_{32} = 2$ m	$v_{32} = \frac{2\text{ m}}{3\text{ s}} = 0.67$ m/s	$d = 2$ m	$s_{32} = \frac{2\text{ m}}{3\text{ s}} = 0.67$ m/s
$\Delta x_{31} = -3$ m	$v_{31} = \frac{-3\text{ m}}{8\text{ s}} = -0.38$ m/s	$d = 7$ m	$s_{321} = \frac{7\text{ m}}{8\text{ s}} = 0.88$ m/s

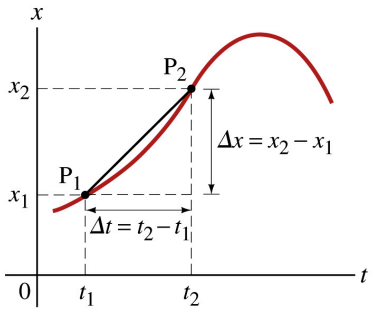
Visualization

A common way to visualize the motion of an object is to show a graph of the position as a function of time.

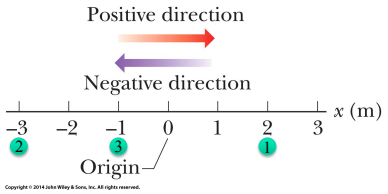


Average Velocity

The value of the slope of the $x(t)$ vs t graph gives the average velocity v_{avg}



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



$x_1 = x(0) = 2$ m
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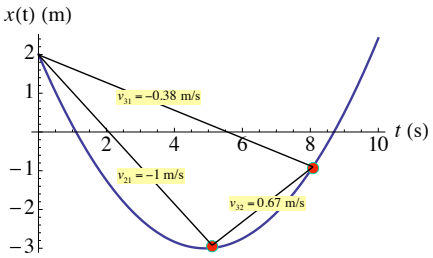


Example

Car A is travelling at a speed of 20 m/s. Car B is travelling towards car A at a speed of 30 m/s. At a given time car B is 500 m ahead of car A. When and where do they meet?

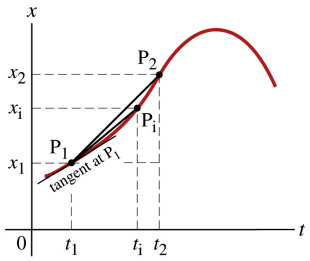
Ans: After 10 s, 200 m ahead of car A (or 300 m ahead of car B).

Instantaneous Velocity and Speed

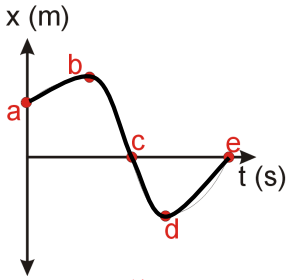
The **instantaneous** velocity v of a particle is the velocity of the particle at that particular time t. It is therefore a function $v(t)$. Here Δt approaches a limiting value of 0:

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \equiv \frac{dx}{dt}$$ (definition of derivative)

$v(t)$ is the **slope** of the tangent of the position-time graph at that particular instant of time.



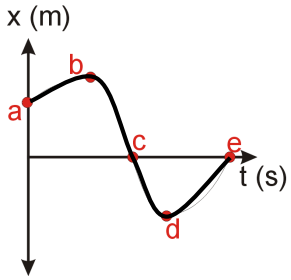
Example A



The instantaneous velocity is zero at ___

A) a
B) b & d
C) c & e

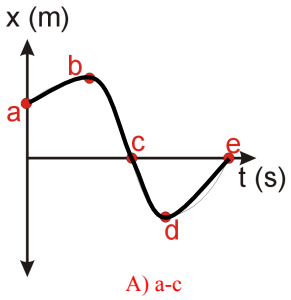
Example B



The instantaneous velocity is negative at _____

A) a
B) b
C) c
D) d
E) e

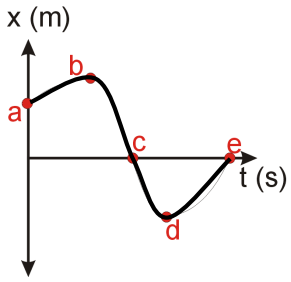
Example C



The average velocity is zero in the interval _____

A) a-c
B) b-d
C) c-d
D) c-e
E) d-e

Example D



The average velocity is negative in the interval(s) _____

A) a-b
B) a-c
C) c-e
D) d-e