General Physics (PHY 170)

Chap 2

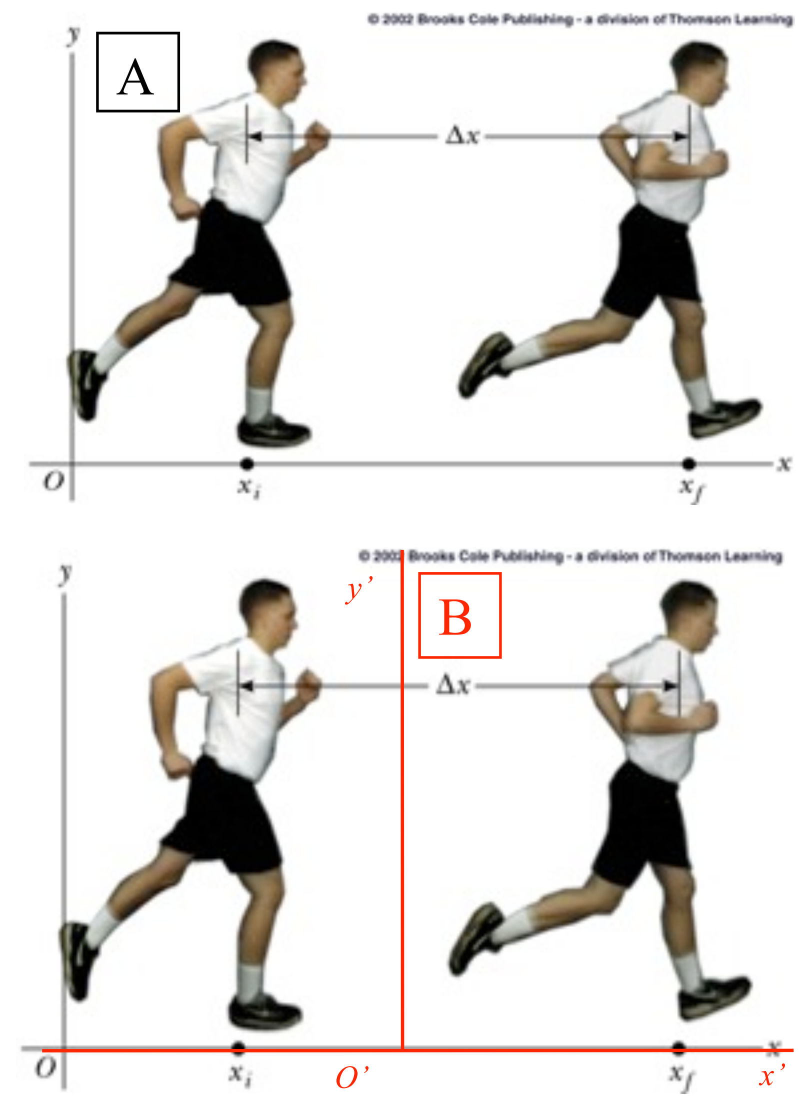
- Motion in one dimension
  - Position and displacement
  - Velocity
    - average
    - instantaneous
  - Acceleration
    - motion with constant acceleration
- Motion in two dimensions

Dynamics

- The branch of physics involving the motion of an object and the relationship between that motion and other physics concepts
- **Kinematics** is a part of dynamics
  - In kinematics, you are interested in the description of motion
  - Not concerned with the cause of the motion

Position and Displacement

- Position is defined in terms of a frame of reference
  - Frame A: $x_i > 0$ and $x_f > 0$
  - Frame B: $x_i < 0'$ but $x_f > 0'$

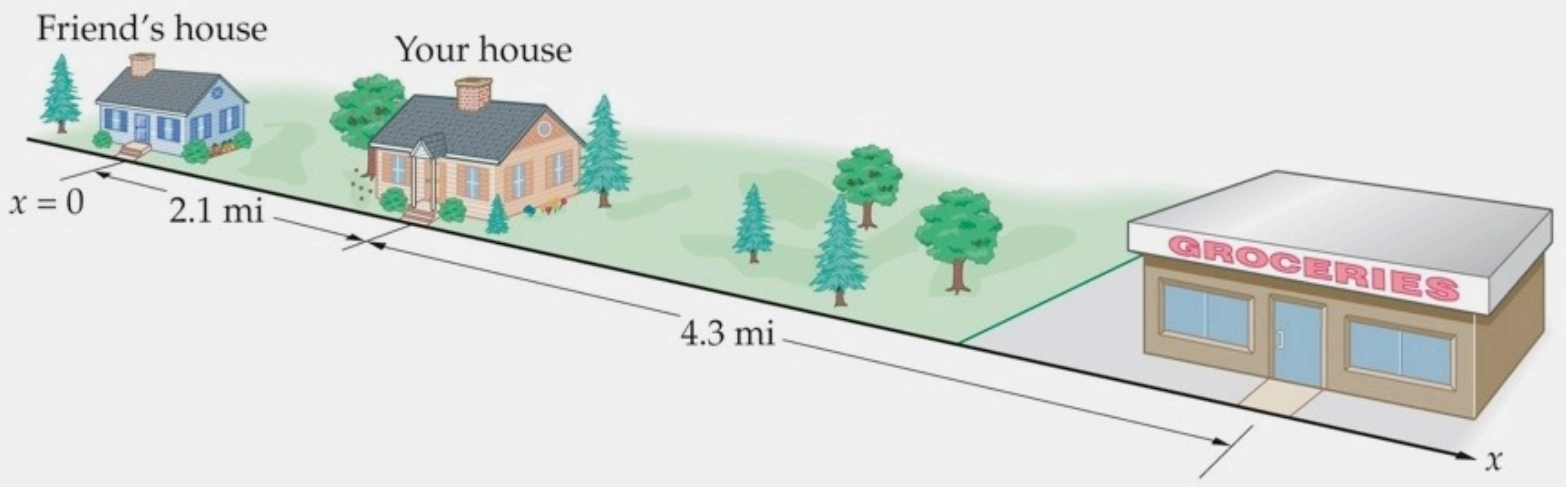


Before describing motion, you must set up a **coordinate system** – define an origin and select a positive direction.

Distance

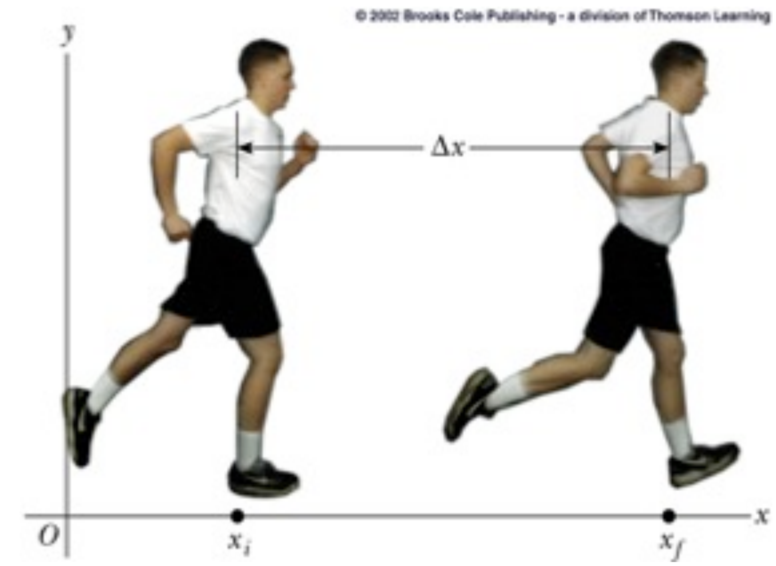
Distance is the total length of travel.

If you drive from your house to the grocery store and back, you have covered a distance of 8.6 mi.



Displacement

- **Displacement** measures the change in position
  - Represented as Δx if horizontal or Δy if vertical.
  - $\Delta x = X_{final} - X_{initial}$
  - Vector quantity (needs directional information): + or - is generally sufficient to indicate direction for one-dimensional motion

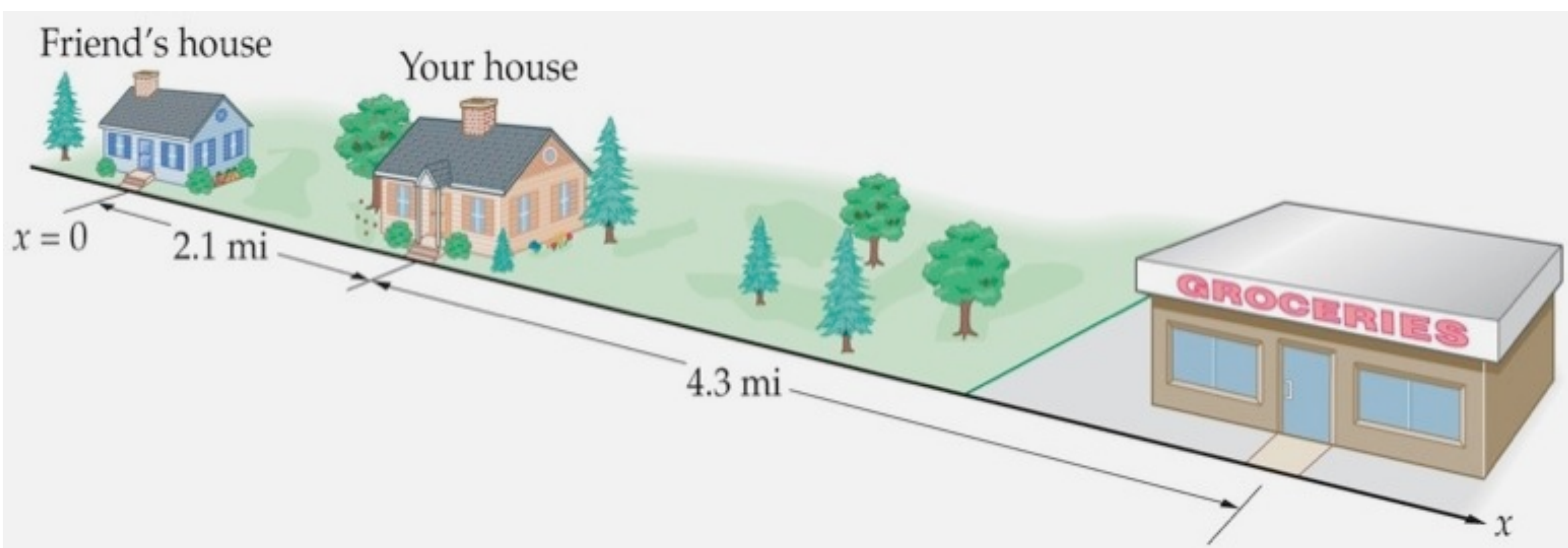


	Units
SI	Meters (m)
CGS	Centimeters (cm)
US Cust	Feet (ft)

Displacement

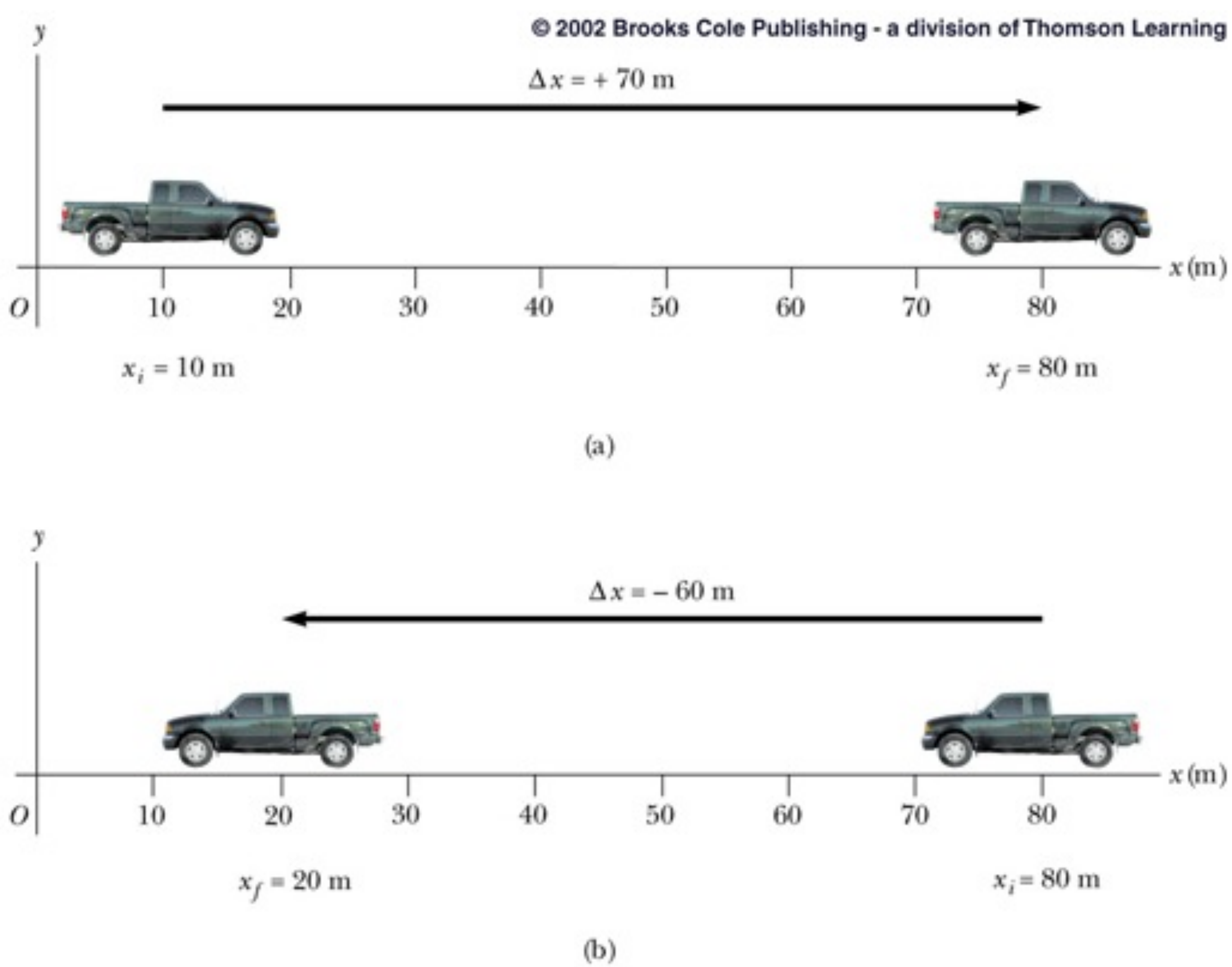
Displacement is the net change in position.

If you drive from your house to the grocery store and then to your friend's house,
the distance you have traveled is 10.7 mi,
your displacement is -2.1 mi.



Example: Displacement

- Displacement measures the change in position

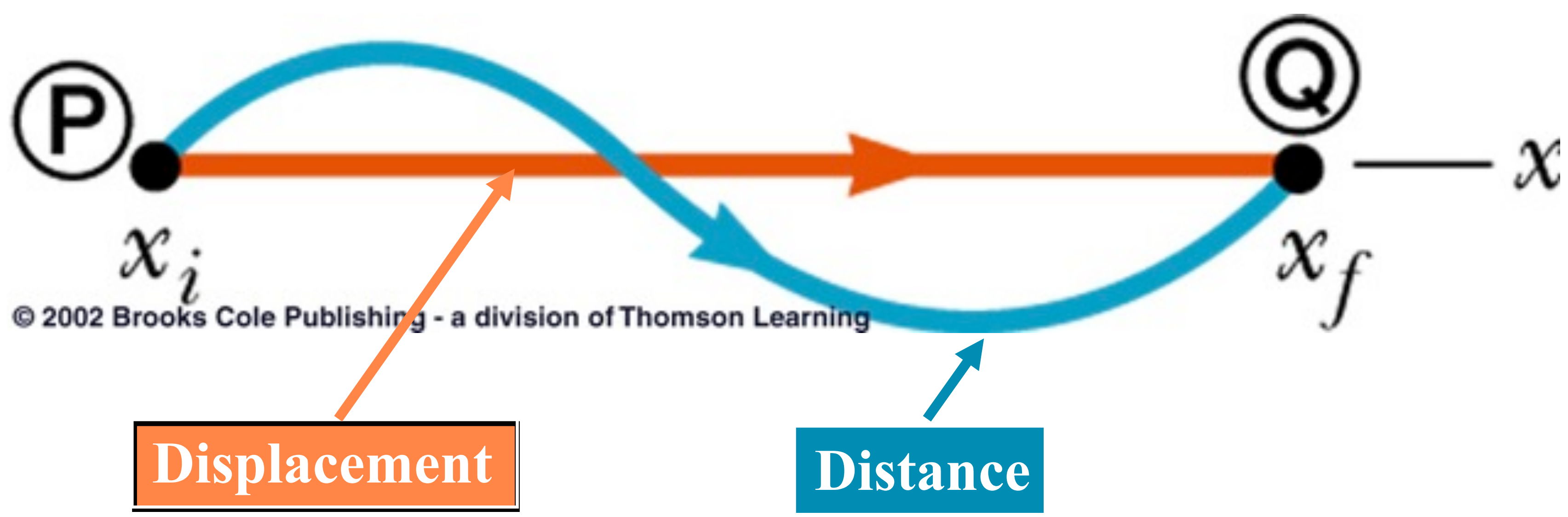


$$
\begin{aligned}
\Delta x_1 &= x_f - x_i \\
&= 80\,m - 10\,m \\
&= \underline{+70\,m}
\end{aligned}
$$

$$
\begin{aligned}
\Delta x_2 &= x_f - x_i \\
&= 20\,m - 80\,m \\
&= \underline{-60\,m}
\end{aligned}
$$

Distance or Displacement?

- Distance may be, but is not necessarily, the magnitude of the displacement

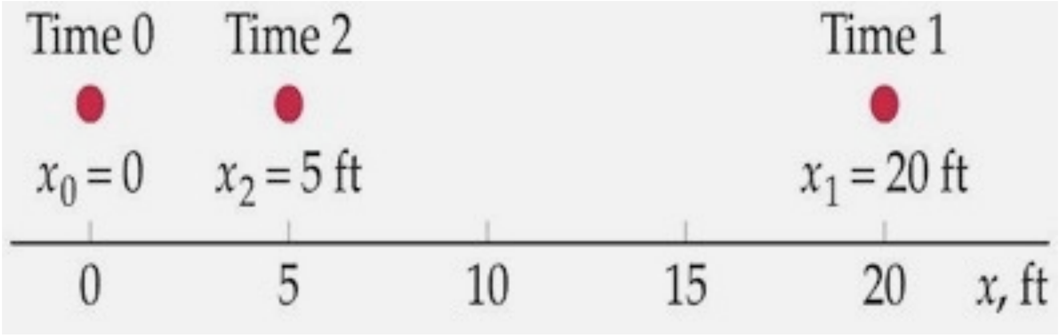


Example: Distance & Displacement of a Dog

You are playing a game of catch with your dog. The dog is initially standing near your feet. Then he runs 20 feet in a straight line to retrieve a stick and carries it 15 feet back toward you before lying down on the ground to chew on the stick.

What is the total distance the dog travels?

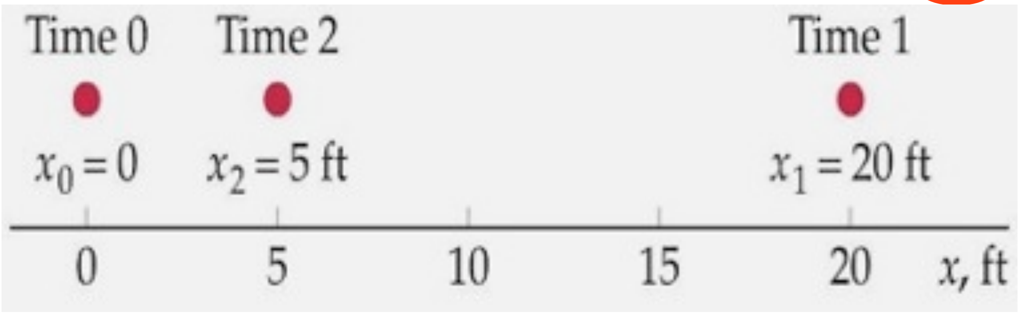
What is the net displacement of the dog?



Show that the net displacement for the trip is the sum of the net displacements that make up the trip.

Example: Distance & Displacement of a Dog

What is the total distance the dog travels?
What is the net displacement of the dog?



Show that the net displacement for the trip is the sum of the net displacements that make up the trip.

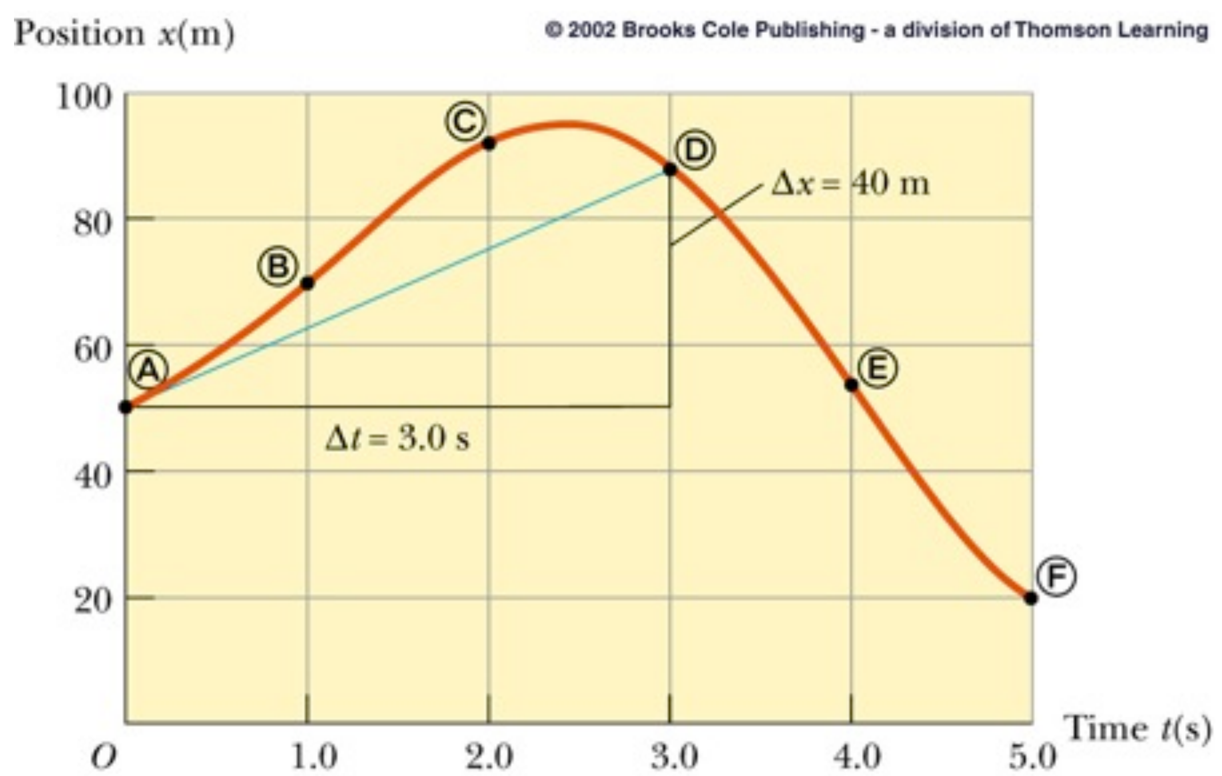
$$s_{02} = s_{01} + s_{12} = (20\text{ ft}) + (15\text{ ft}) = 35\text{ ft}$$

$$\Delta x_{02} = x_2 - x_0 = (5\text{ ft}) - (0\text{ ft}) = 5\text{ ft}$$

$$\Delta x_{01} = x_1 - x_0 = (20\text{ ft}) - (0\text{ ft}) = 20\text{ ft}; \quad \Delta x_{12} = x_2 - x_1 = (5\text{ ft}) - (20\text{ ft}) = -15\text{ ft}$$

$$\Delta x_{01} + \Delta x_{12} = (x_1 - x_0) + (x_2 - x_1) = x_2 - x_0 = \Delta x_{02}$$

Position-time graphs



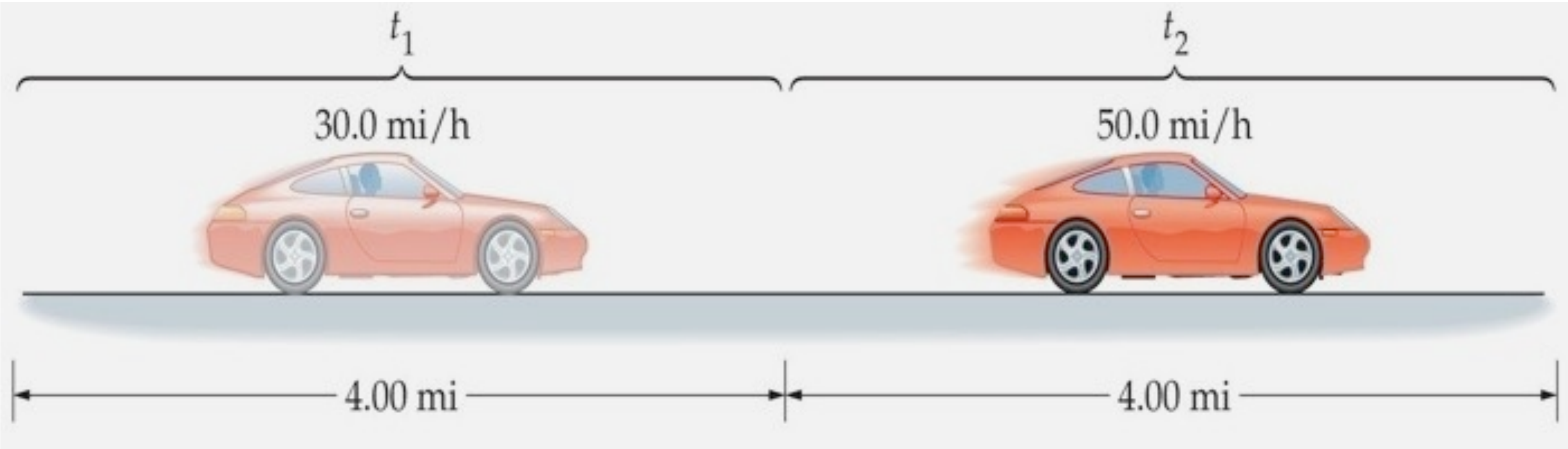
- Even though the motion is along x-direction, position-time graph is not necessarily a straight line

Speed

- Speed is a scalar quantity (no information about sign/direction)
- Average speed = total distance / total time
- Units [v] = [L]/ [T] => m/s, km/h, mi/h ...

Average Speed

- The average speed is defined as the distance traveled divided by the time the trip took:
- Average speed = distance / elapsed time
- Question: Is the average speed of the red car 40.0 mi/h, more than 40.0 mi/h, or less than 40.0 mi/h?

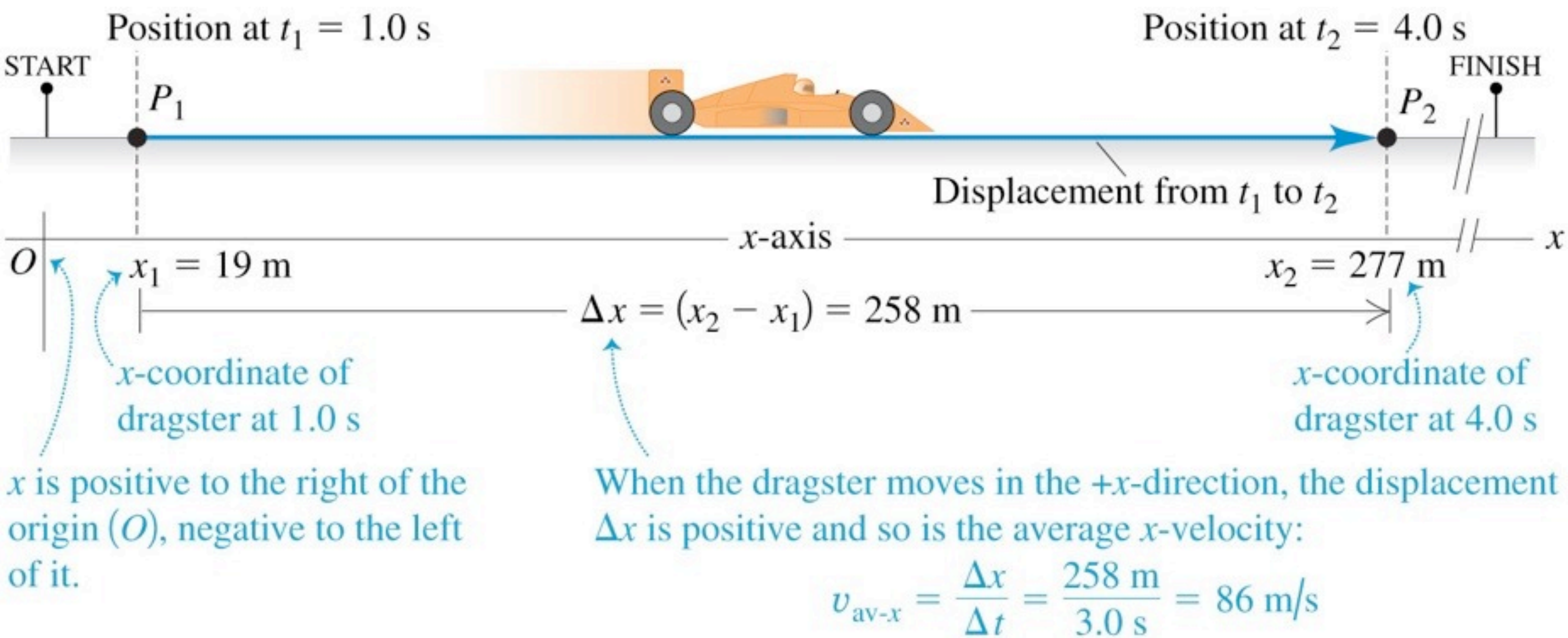


Average Velocity

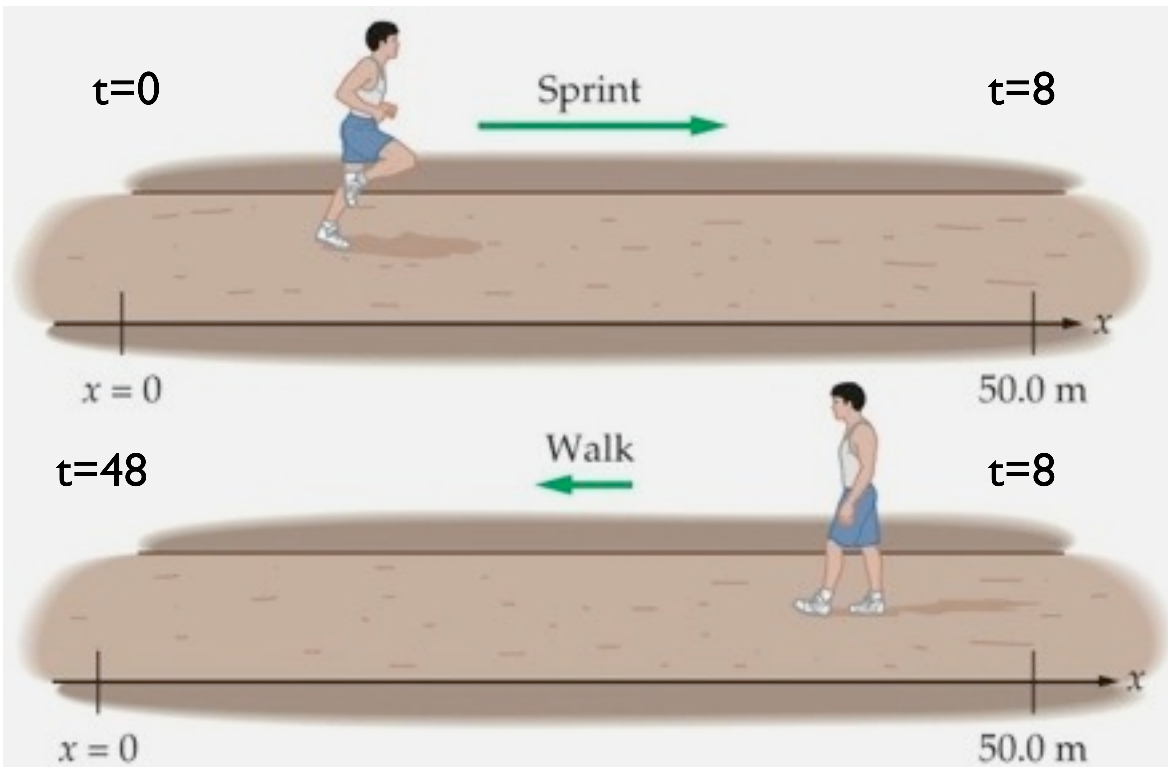
- The **average velocity** is rate at which the displacement occurs
- it's a vector
- Direction of the average velocity will be the same as the direction of the displacement (Δt is always positive)
- Average velocity = displacement / elapsed time

$$v_{\text{av-}x} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} \qquad \text{(average } x\text{-velocity, straight-line motion)} \qquad (2.2)$$

Example: Average Velocity



Example: Average Velocity



$$v_{run} = \frac{\Delta x}{\Delta t} = \frac{50.0\text{ m} - 0}{8.0\text{ s} - 0} = 6.25\text{ m/s}$$

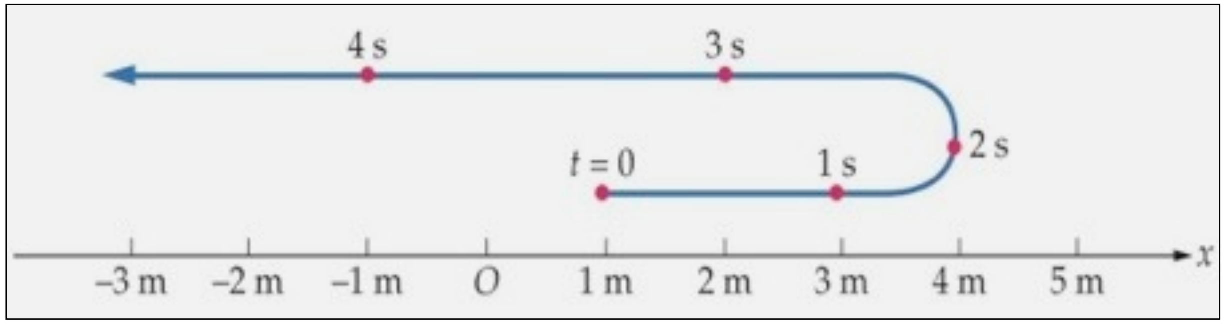
$$v_{walk} = \frac{\Delta x}{\Delta t} = \frac{0 - 50.0\text{ m}}{48.0\text{ s} - 8.0\text{ s}} = -1.25\text{ m/s}$$

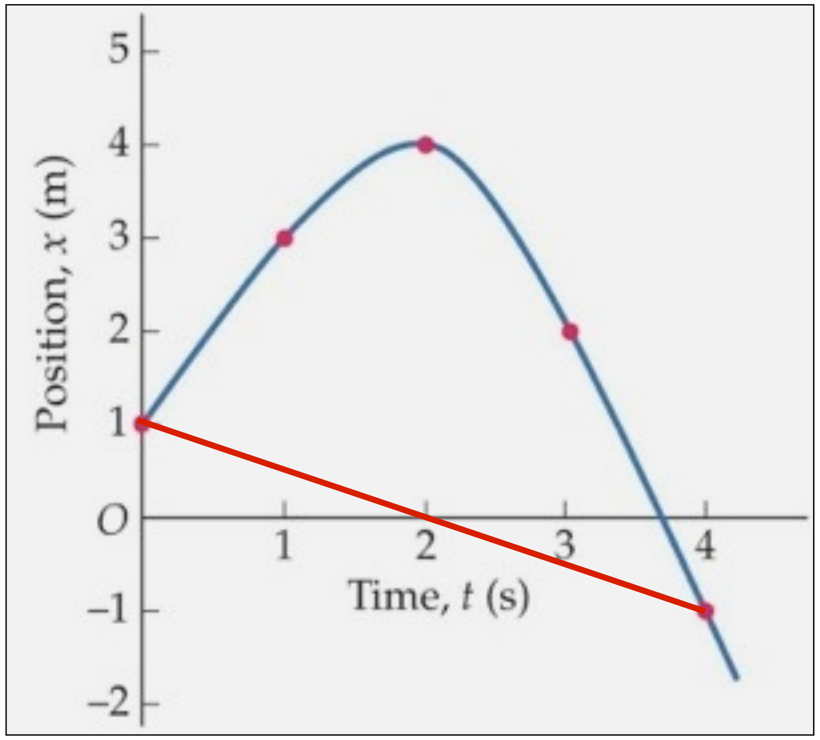
$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{0}{48.0\text{ s} - 0} = 0.0\text{ m/s}$$

- If you return to your starting point, your average velocity is zero.
- Question: Calculate your average speed

Example: Average Speed and Velocity

- Graphical Interpretation of Average Velocity:
- The same motion, plotted one-dimensionally and as a two dimensional position-time graph:



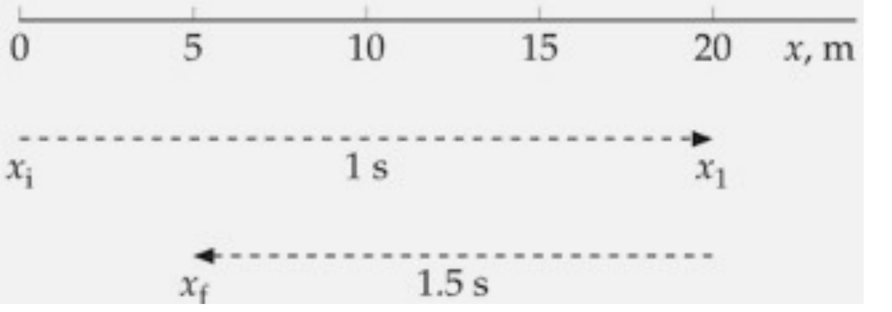


Average speed (0-4 s) = (8 m)/(4 s) = 2 m/s

Average velocity (0-4 s) = (-2 m)/(4 s) = -0.5 m/s

Example: Speed & Velocity of the Dog

The dog that you were playing with in the previous example jogged 20 ft away from you in 1.0 s to retrieve the stick and ambled back 15 feet in 1.5 s.



a. **Calculate the dog's average speed.**

$$s = s_1 + s_2 = 20\text{ ft} + 15\text{ ft} = 35\text{ ft}$$

$$\Delta t = (t_1 - t_i) + (t_f - t_2) = 1.0\text{ s} + 1.5\text{ s} = 2.5\text{ s}$$

$$\text{Average speed} = \frac{35.0\text{ ft}}{2.5\text{ s}} = 14\text{ ft/s}$$

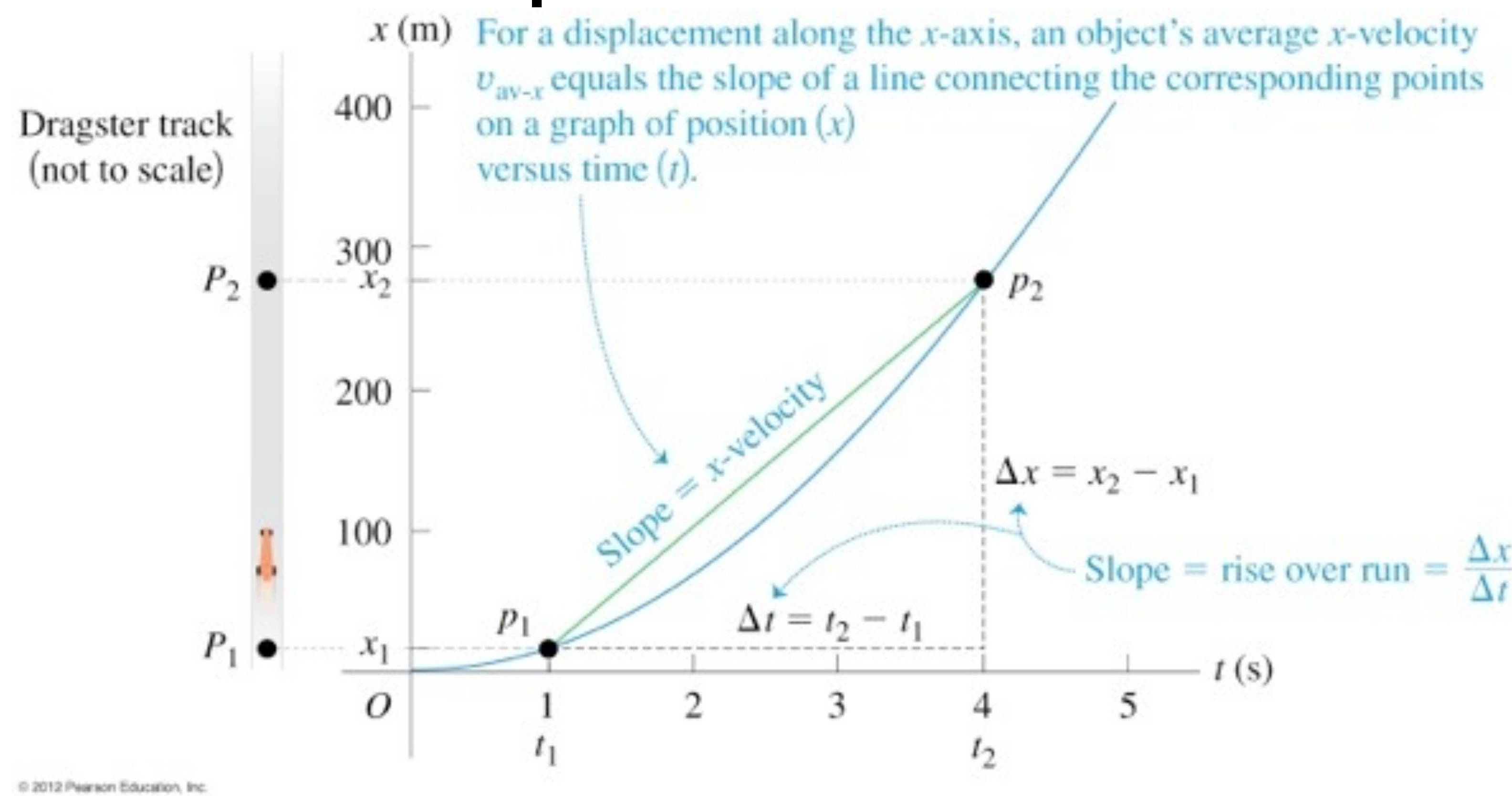
b. **Calculate the dog's average velocity for the total trip.**

$$v_{av,x} = \frac{\Delta x}{\Delta t} \qquad \Delta x = x_f - x_i = 5.0\text{ ft} - 0\text{ ft} = 5.0\text{ ft}$$

$$v_{av,x} = \frac{\Delta x}{\Delta t} = \frac{5.0\text{ ft}}{2.5\text{ s}} = 2.0\text{ ft/s}$$

Graphical Interpretation of Average Velocity

- Velocity can be determined from a position-time graph
- Average velocity equals the slope of the line joining the initial and final positions



Instantaneous velocity

- This plot shows the average velocity being measured over shorter and shorter intervals. Instantaneous velocity is the slope of the tangent to the curve at the time of interest

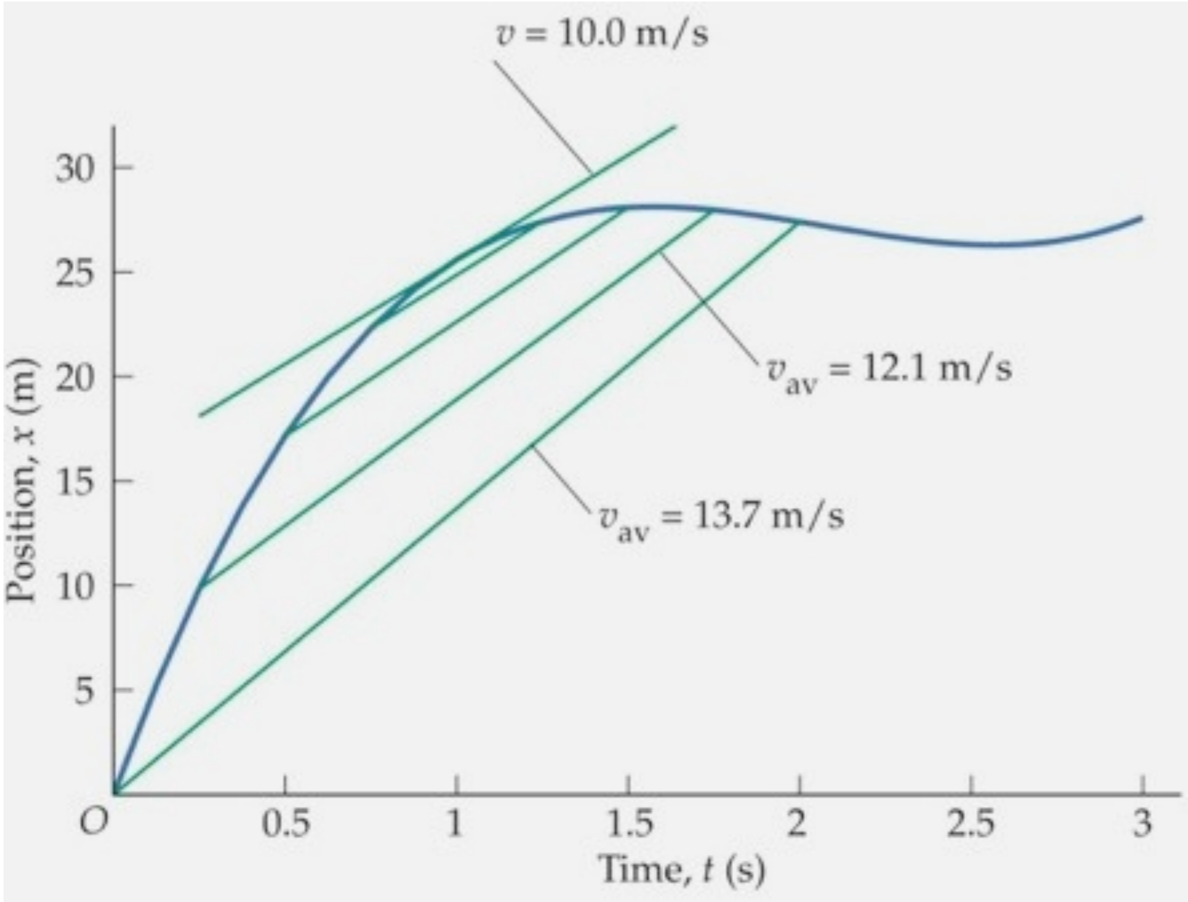
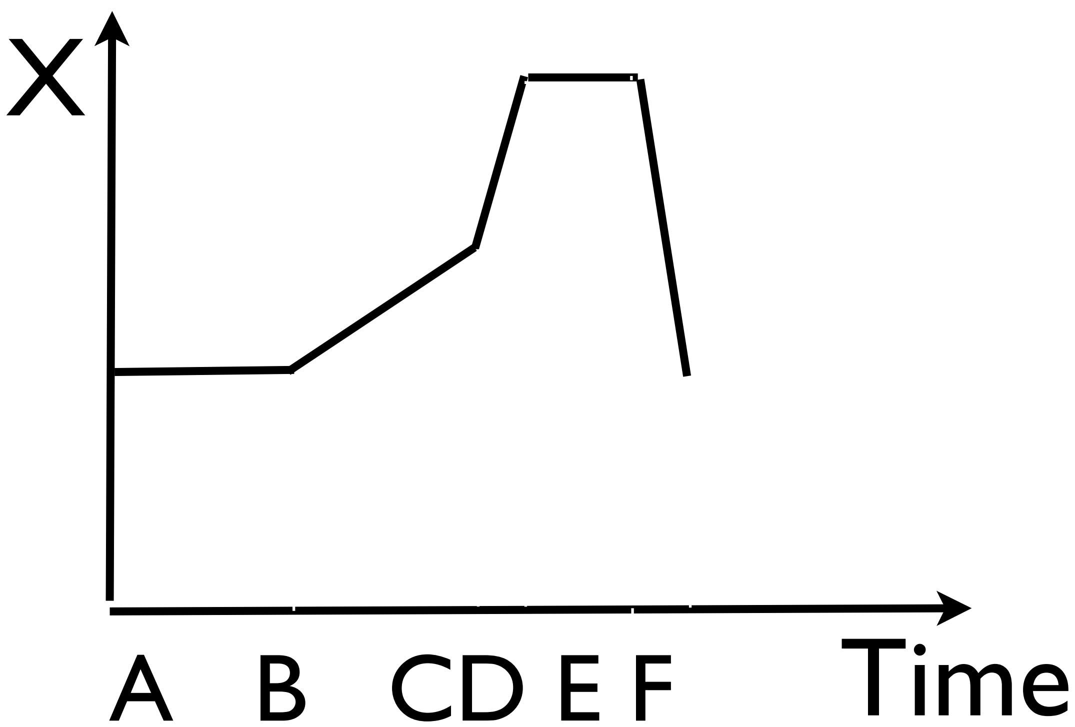


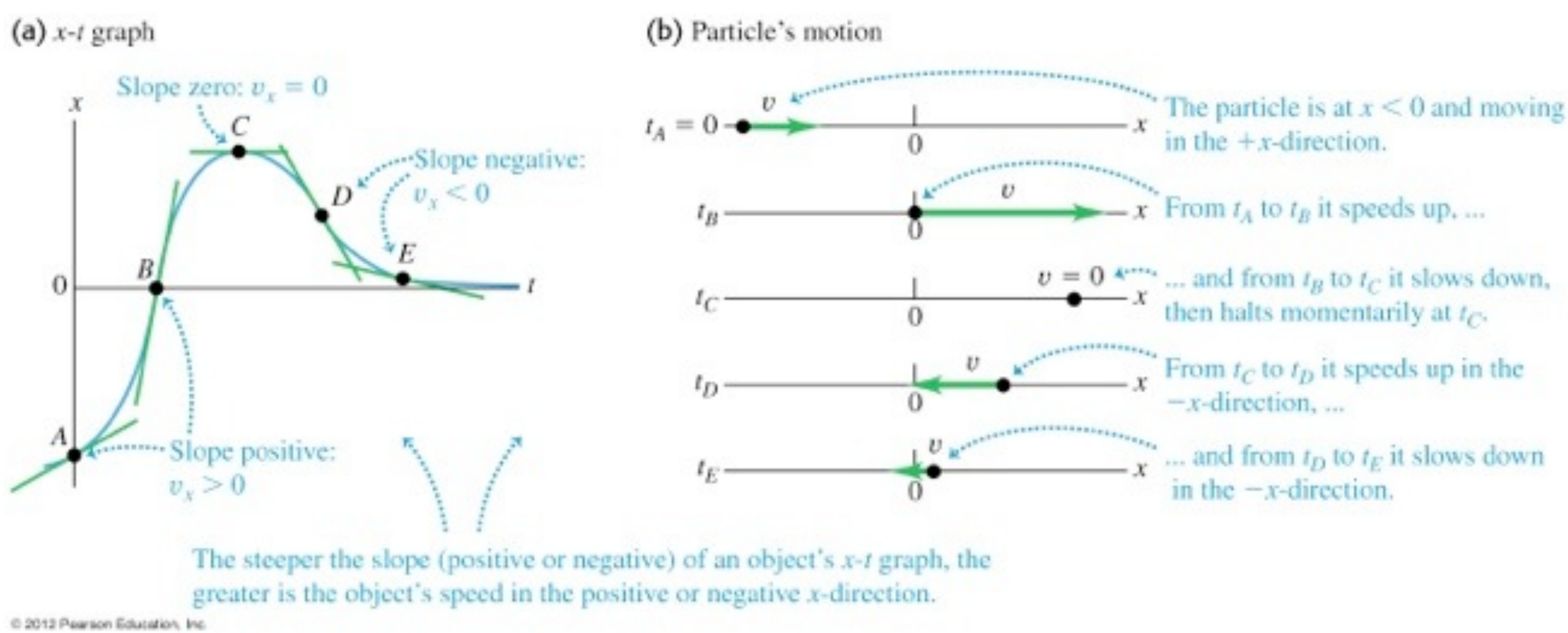
TABLE 2–2 Calculating the Instantaneous Velocity at $t = 1$ s.

t_i(s)	t_f(s)	Δt(s)	x_i(m)	x_f(m)	Δx(m)	v_{av}(m) = $\Delta x/\Delta t$(m/s)
0	2.00	2.00	0	27.4	27.4	13.7
0.250	1.75	1.50	9.85	28.0	18.2	12.1
0.500	1.50	1.00	17.2	28.1	10.9	10.9
0.750	1.25	0.50	22.3	27.4	5.10	10.2
0.900	1.10	0.20	24.5	26.5	2.00	10.0
0.950	1.05	0.10	25.1	26.1	1.00	10.0

Example



- A-B v=0
- B-C walking
- C-D running
- D-E v=0
- E-F running faster



Instantaneous velocity

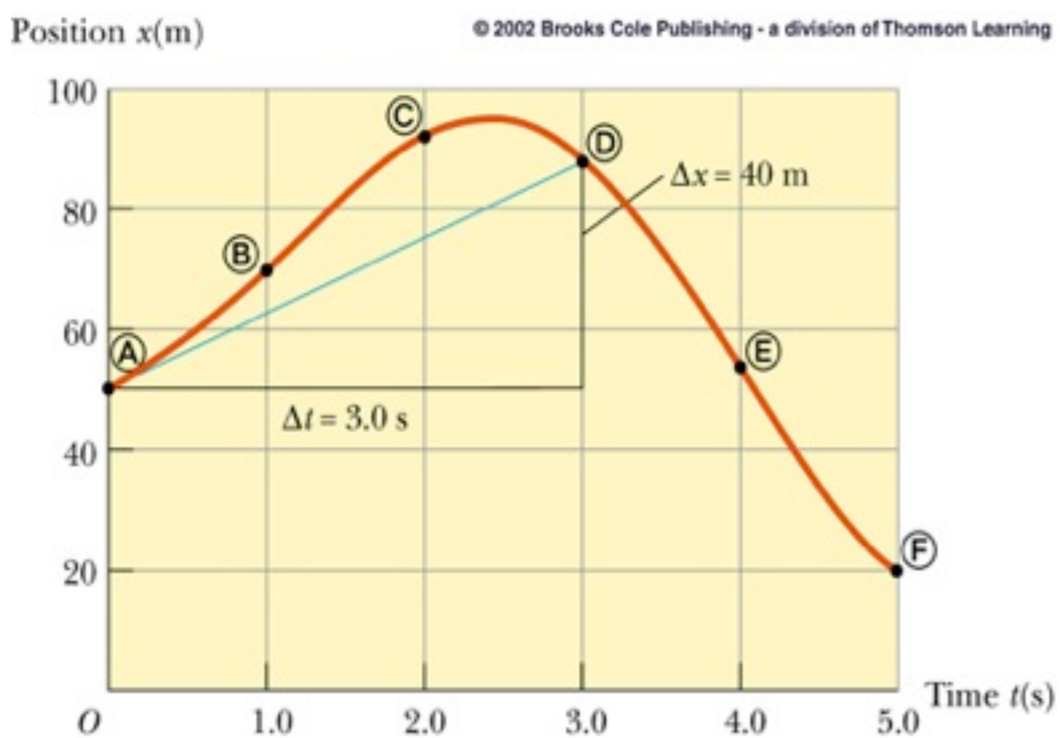
- Instantaneous velocity is defined as the limit of the average velocity as the time interval becomes infinitesimally short, or as the time interval approaches zero

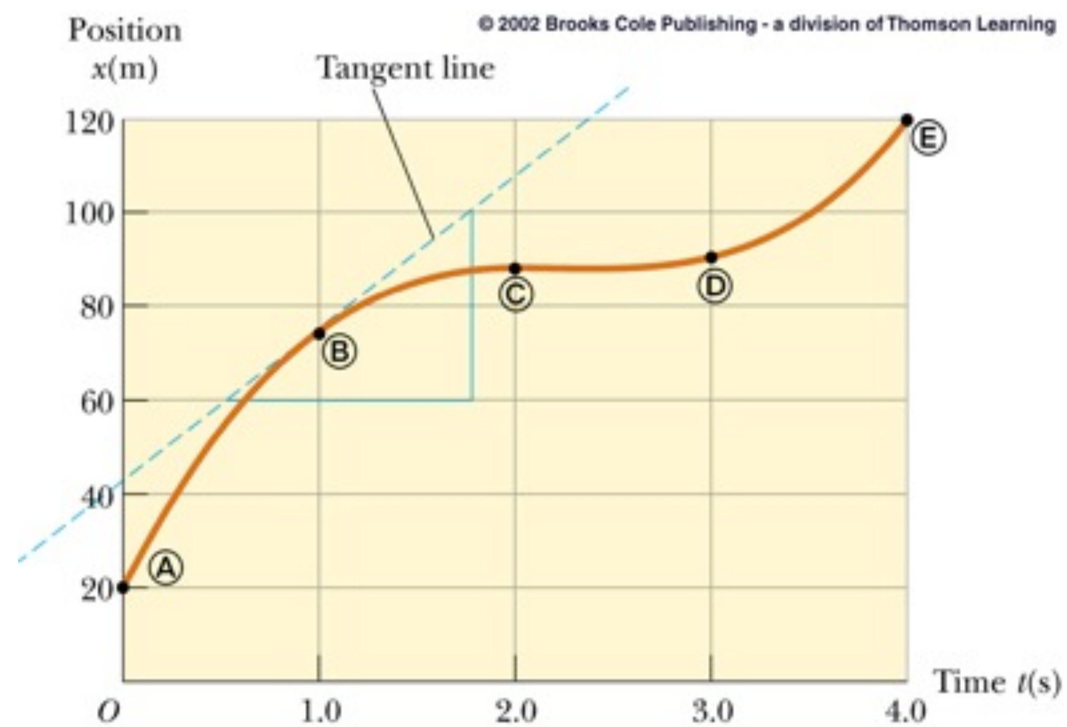
- This means that we evaluate the average velocity over a shorter and shorter period of time; as that time becomes infinitesimally small, we have the instantaneous velocity.

Definition:

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

Average vs Instantaneous velocity





Average velocity

Slope

$v = \Delta x / \Delta t$

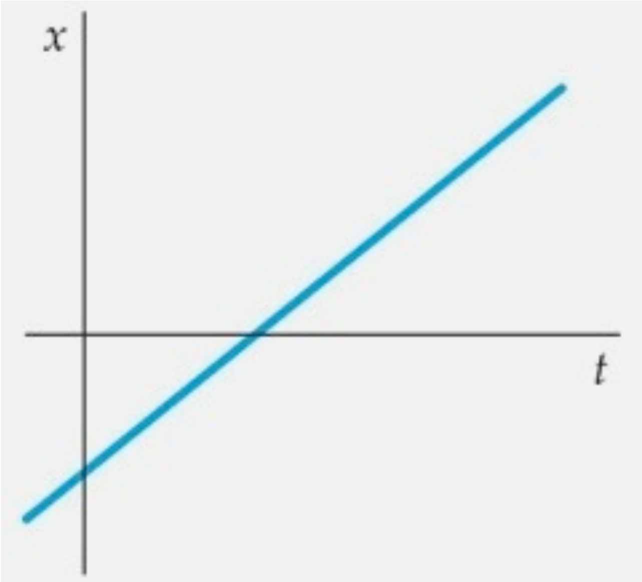
Instantaneous velocity

Tangent

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

Uniform velocity

- Uniform velocity is constant velocity
- The instantaneous velocities are always the same
- All the instantaneous velocities will also equal the average velocity



The position vs. time graph of a particle moving at constant velocity has a constant slope.