Chapter 2: kinematics in one dimension

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CONCEPTS

2–1 Reference Frames and Displacement
2–2 Average Velocity
2–3 Instantaneous Velocity

2.0 INTRODUCTION

Mechanics
The study of the motion of objects, and the related concepts of force and energy

kinematics
description of how objects move

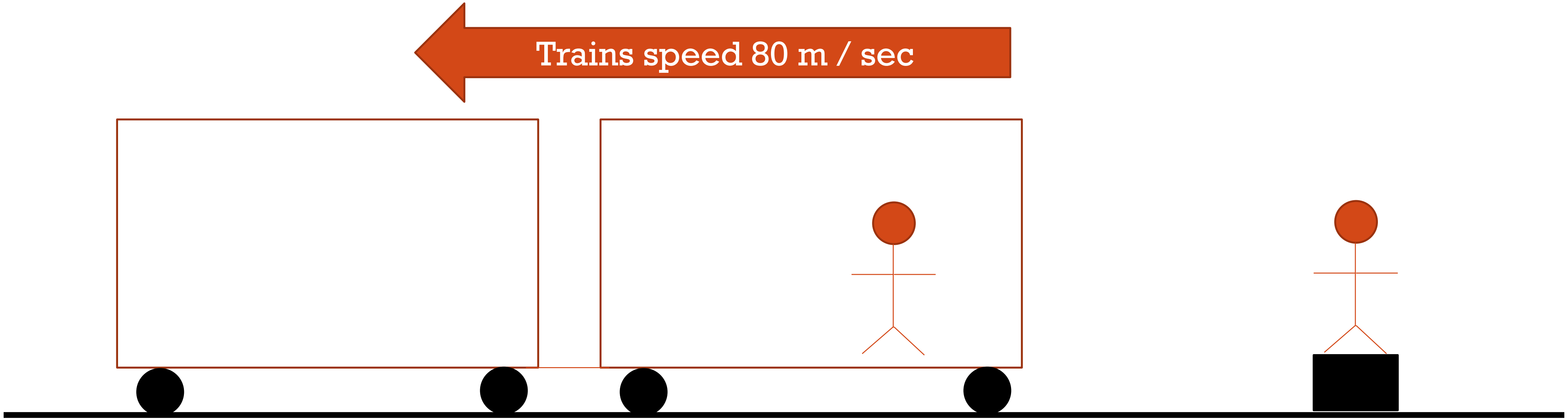
dynamics
deals with force and why objects move as they do

In Chapter 2 we will be concerned with describing an object that moves along a straight-line path, which is one dimensional translational motion.

In Chapter 3 we will describe translational motion in two (or three) dimensions along paths that are not straight.

2.1 REFERENCE FRAMES AND DISPLACEMENT

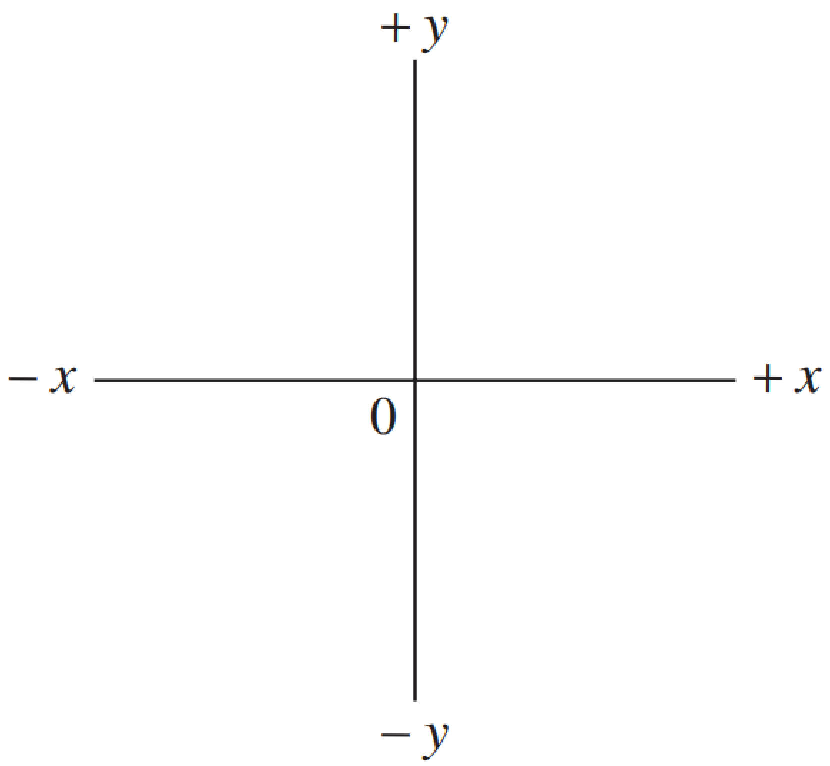
- Frame of reference : نقطة الإسناد
- E.g. on frame of reference: A person walked to a train at a speed of 2 m/s, when he got in the train, the train moved at a speed 80 m / sec, then this person walked in the train while it's moving at a speed of 2 m/s, what is the:
  Person speed while he is walking on the floor when the floor is the frame of reference? 2m/s
  person speed in the train while he is walking when the train is the frame of reference? 2m/s
  person speed in the train while he is walking when the floor is the frame of reference? 82m/s



- Internal frame of reference : when the frame of reference is constant or moving at a constant speed (Newton's law applies in this field)

2.1 REFERENCE FRAMES AND DISPLACEMENT

FIGURE 2–3 Standard set of *xy* coordinate axes, sometimes called "rectangular coordinates."



Cartesian coordinate system

- We often draw a set of coordinate axes, to represent a frame of reference.
- X & Y axes are perpendicular to each other
- Objects positioned to the right of the origin of coordinates (0) on the x axis have an x coordinate which we almost always choose to be positive; then points to the left of 0 have a negative x coordinate. The position along the y axis is usually considered positive when above 0, and negative when below 0.
- In three dimensions, a z axis perpendicular to the x and y axes is added

2.1 REFERENCE FRAMES AND DISPLACEMENT

- Example: A person starts at $x = 0$ cm on a piece of graph paper and walks along the x axis to $x = 20$ cm, he then turns around and walks back to Determine $x = -10$ cm. Determine: (a) the person's displacement and (b) the total distance traveled.
- Answer:

(a) Displacement = $\Delta X = x_2 - x_1 = -10 - 0 = -10$ cm

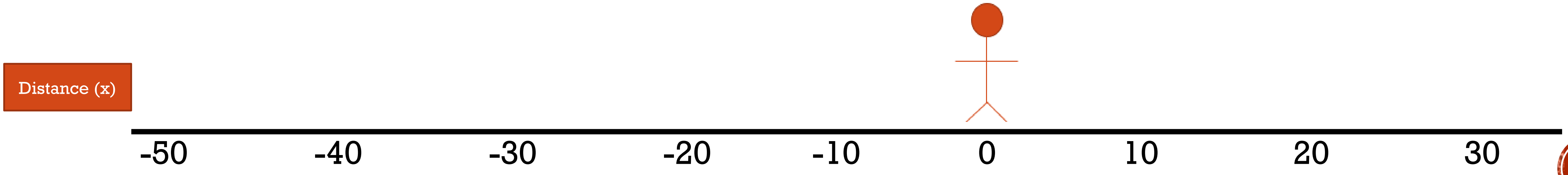
(b) Distance = All distance travelled = (difference between 20 & 0) + (difference between 20 & -10) = 20 + 30 = 50 cm

Movement

Displacement - difference between start and end point - **(vector)**

Distance (scalor)

- Vector and scalor quantities
  → Vector: quantity that has both magnitude and direction
  e.g. Displacement (**ΔX**), velocity, force, acceleration
  → Scalor: quantity that has magnitude ONLY
  e.g mass, distance, temperature, pressure, work, energy ..etc



EXERCISES

- 1) An ant starts at $x = 20$ cm on a piece of graph paper and walks along the x axis to $x = -20$ cm. It then turns around and walks back to $x = -10$ cm
  Determine (a) the ant's displacement and (b) the total distance traveled
- 2) A Train moves from $x = 40$ cm backwards to $x = 0$ cm, find the (a) displacement and (b) the distance

- Answer of q1
  a) $\Delta X = x_2 - x_1 = -10 - 0 = -10$ cm
  b) Distance = All distance travelled = (difference between 20 & -20) + (difference between -20 & -10) = 40 + 10 = 50 cm
- Answer of q2
  a) $\Delta X = x_2 - x_1 = 0 - 40 = -40$ cm
  b) distance = 40 cm

CONCEPTS

2–1 Reference Frames and Displacement
2–2 Average Velocity
2–3 Instantaneous Velocity

2.2 AVERAGE VELOCITY

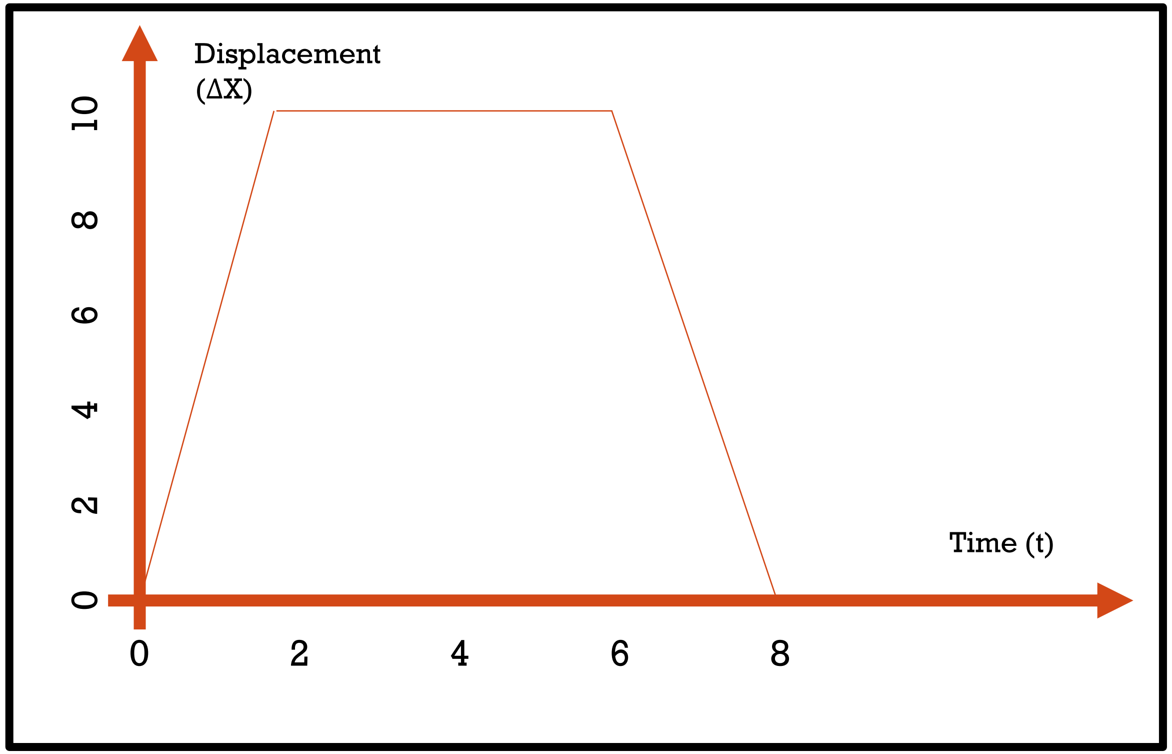
- Average velocity ($\bar{v}$) = $\frac{\Delta x}{\Delta t}$
- Example: A person moved along the x-axis from (x =0 m) to (x = 10 m) in 2 sec, then he stopped for 6 sec until he decided to return back to (x = 0 m) which took from him 2 sec, calculate:
  a) Average velocity along all his pathway
  b) Average velocity from t 0→2
  c) Average velocity from t 2→6
  d) Average velocity from t 6→8
- Answers:

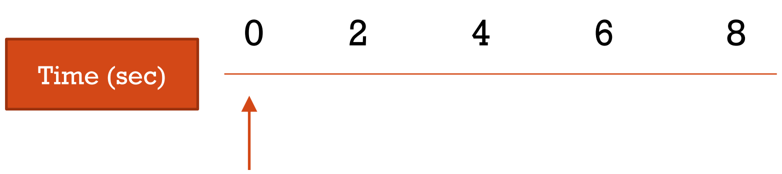
a) $(\bar{v}) = \frac{\Delta x}{\Delta t} = \frac{x2 - x1}{t2 - t1} = \frac{0 - 0}{8 - 0} = 0$ m/s

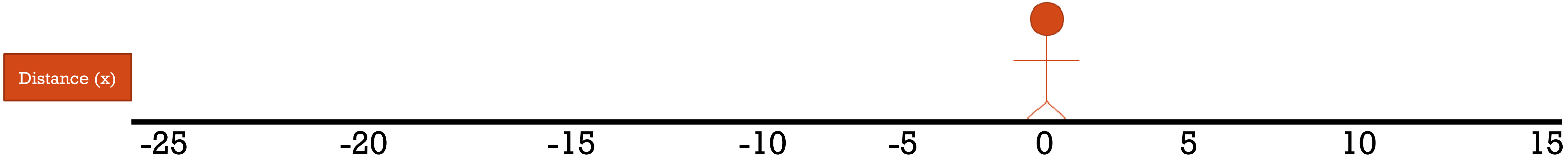
b) $(\bar{v}) = \frac{\Delta x}{\Delta t} = \frac{x2 - x1}{t2 - t1} = \frac{10 - 0}{2 - 0} = 5$ m/s

c) $(\bar{v}) = \frac{\Delta x}{\Delta t} = \frac{x2 - x1}{t2 - t1} = \frac{10 - 10}{6 - 2} = 0$ m/s

d) $(\bar{v}) = \frac{\Delta x}{\Delta t} = \frac{x2 - x1}{t2 - t1} = \frac{0 - 10}{8 - 6} = -5$ m/s







2.2 AVERAGE VELOCITY

- Average speed $(\bar{s}) = \frac{distance\ travelled}{\Delta t}$

- Example: A person moved along the x-axis from (x =0 m) to (x = 10 m) in 2 sec, then he stopped for 6 sec until he decided to return back to (x = 0 m) which took from him 2 sec, calculate:
  a) Average speed along all his pathway
  b) Average speed from t 0→2
  c) Average speed from t 2→6
  d) Average speed from t 6→8

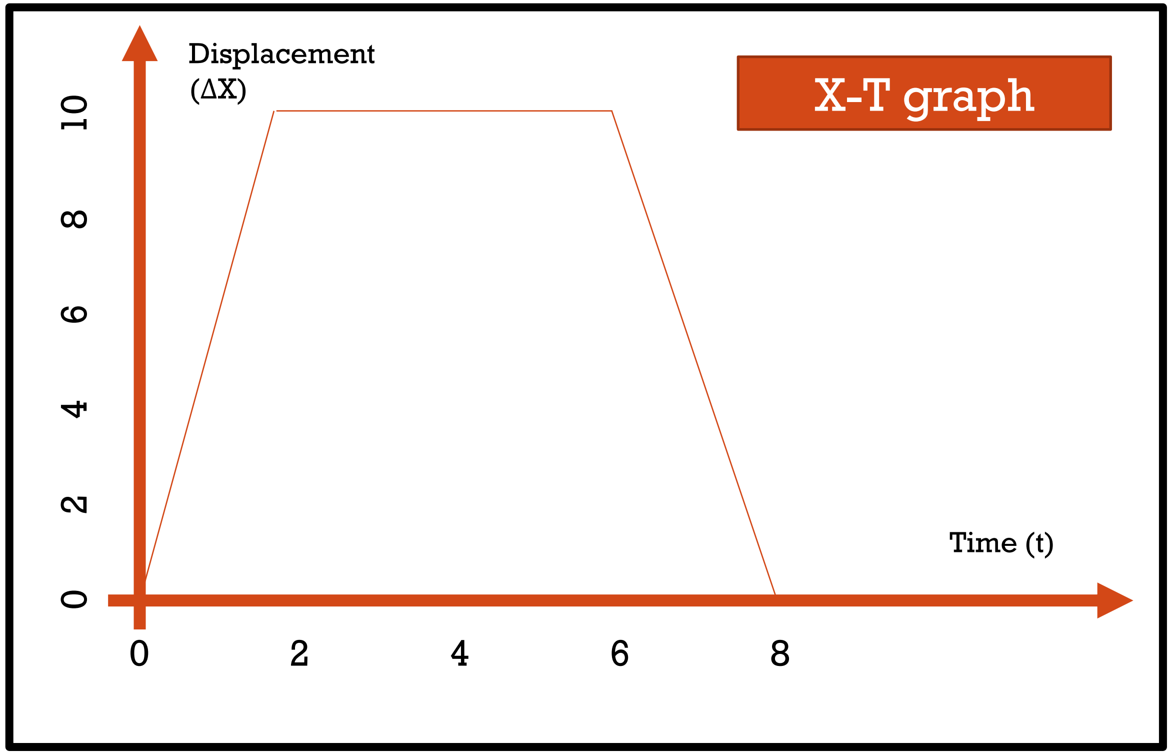
- Answers:

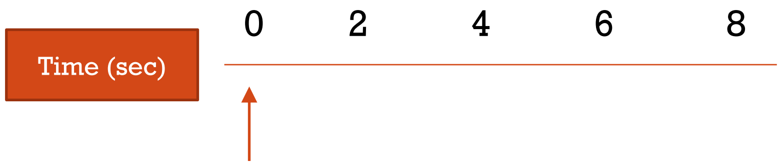
a) $(\bar{s}) = \frac{distance\ travelled}{\Delta t} = = \frac{10+10}{8-0} = 2.5\ m/s$

b) $(\bar{s}) = \frac{distance\ travelled}{\Delta t} = \frac{10}{2-0} = 5\ m/s$

c) $(\bar{s}) = \frac{distance\ travelled}{\Delta t} = \frac{0}{6-2} = 0\ m/s$

d) $(\bar{s}) = \frac{distance\ travelled}{\Delta t} = \frac{10}{8-6} = 5\ m/s$





2.2 AVERAGE VELOCITY

- We can conclude from the previous two slides :

  $|\Delta X| = d$ (if there is no change in direction)
  |Average velocity| = Average speed (if there is no change in direction)

  In general:
  $|\Delta X| \leq d$ & |Average velocity| ≤ Average speed

EXAMPLE 2–1 Runner's average velocity. The position of a runner as a function of time is plotted as moving along the x axis of a coordinate system. During a 3.00-s time interval, the runner's position changes from $x_1 = 50.0\,\text{m}$ to $x_2 = 30.5\,\text{m}$, as shown in Fig. 2–7. What is the runner's average velocity?

APPROACH We want to find the average velocity, which is the displacement divided by the elapsed time.

SOLUTION The displacement is

$$\Delta x = x_2 - x_1 = 30.5\,\text{m} - 50.0\,\text{m} = -19.5\,\text{m}.$$

The elapsed time, or time interval, is given as $\Delta t = 3.00\,\text{s}$. The average velocity (Eq. 2–2) is

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{-19.5\,\text{m}}{3.00\,\text{s}} = -6.50\,\text{m/s}.$$

The displacement and average velocity are negative, which tells us that the runner is moving to the left along the x axis, as indicated by the arrow in Fig. 2–7. The runner's average velocity is 6.50 m/s to the left.

EXAMPLE 2–2 Distance a cyclist travels. How far can a cyclist travel in 2.5 h along a straight road if her average velocity is 18 km/h?

APPROACH We want to find the distance traveled, so we solve Eq. 2–2 for Δx.

SOLUTION In Eq. 2–2, $\bar{v} = \Delta x / \Delta t$, we multiply both sides by Δt and obtain

$$\Delta x = \bar{v}\,\Delta t = (18\,\text{km/h})(2.5\,\text{h}) = 45\,\text{km}.$$

EXAMPLE 2–3 Car changes speed. A car travels at a constant 50 km/h for 100 km. It then speeds up to 100 km/h and is driven another 100 km. What is the car's average speed for the 200-km trip?

APPROACH At 50 km/h, the car takes 2.0 h to travel 100 km. At 100 km/h it takes only 1.0 h to travel 100 km. We use the defintion of average velocity, Eq. 2–2.

SOLUTION Average velocity (Eq. 2–2) is

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{100\,\text{km} + 100\,\text{km}}{2.0\,\text{h} + 1.0\,\text{h}} = 67\,\text{km/h}.$$

NOTE Averaging the two speeds, $(50\,\text{km/h} + 100\,\text{km/h})/2 = 75\,\text{km/h}$, gives a wrong answer. Can you see why? You must use the definition of $\bar{v}$, Eq. 2–2.

2–3 INSTANTANEOUS VELOCITY

- instantaneous velocity at any moment is defined as the average velocity over an infinitesimally short time interval (velocity at any instant of time) (v)
- Notice in these two graphs, they have equal average velocities as a whole, but different spontaneous velocities at different points
- (Spontaneous velocity = average velocity) if the velocity is constant

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}. \qquad \text{[instantaneous velocity]}$$