PHYS 225
Fundamentals of Physics: Mechanics

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Lecture 4: Motion along a straight line (1D motion)

CALIFORNIA STATE UNIVERSITY FULLERTON

Chapter 2: Motion along a straight line

- We can use units to describe the **motion of objects** in a quantitative way:
  - position, velocity, acceleration

porscheboost.com

Point particle approximation: Assume all parts of the object move in the same way.

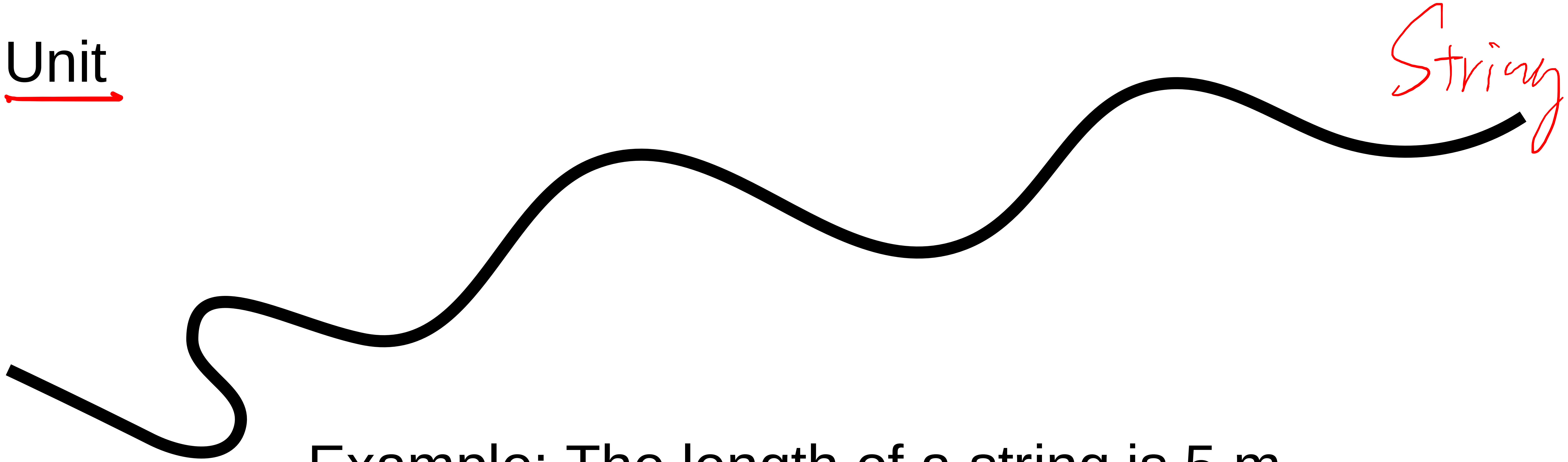
Learning goals for today

- Fundamental concepts of 1D motion:
  - ✓Scalar vs. Vector
  - ✓Distance and displacement
  - ✓Speed and velocity
  - ✓Acceleration

Scalars vs. vectors

Scalars

- **Scalars**: A quantity without a direction
- Scalars can be described by:
  - Number + Unit



Example: The length of a string is 5 m

Number

unit

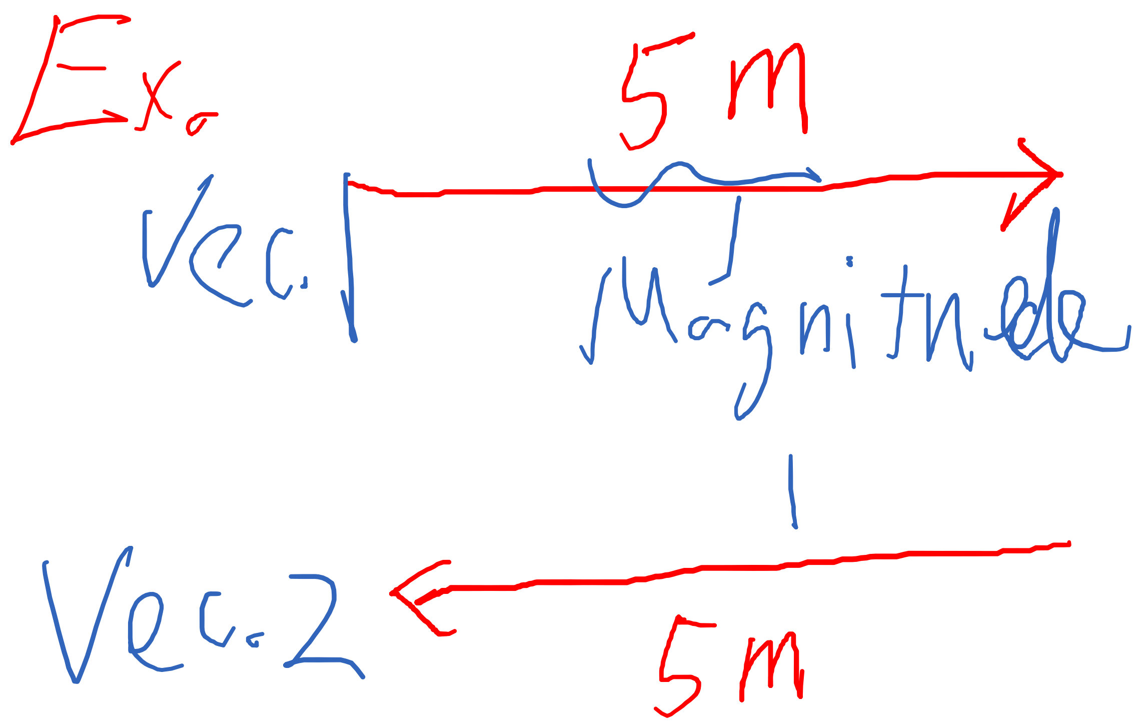
Vectors

Very important

- **Vectors:** A quantity with **magnitude (size)** and **direction**:
  - **Magnitude** = abs number + units
  - **Direction**: pointing from start point to end point
    - First, define the axis (i.e., positive direction)
    - Second, use the sign to indicate the direction (at least for 1D vectors)

      \+ same as axis

      − opposite to axis
  - **Examples**:



Direction: → +X Axis

Vec.1 as: 5m

Vec.2 as: −5m

Clicker question 1: Vector or scalar?

- The **displacement** from CSUF to the California Science center is 24.91 miles to the northwest, and the **distance** from CSUF to the California Science center via the I-105 rout is 34.6 Miles. Which of the following is true?

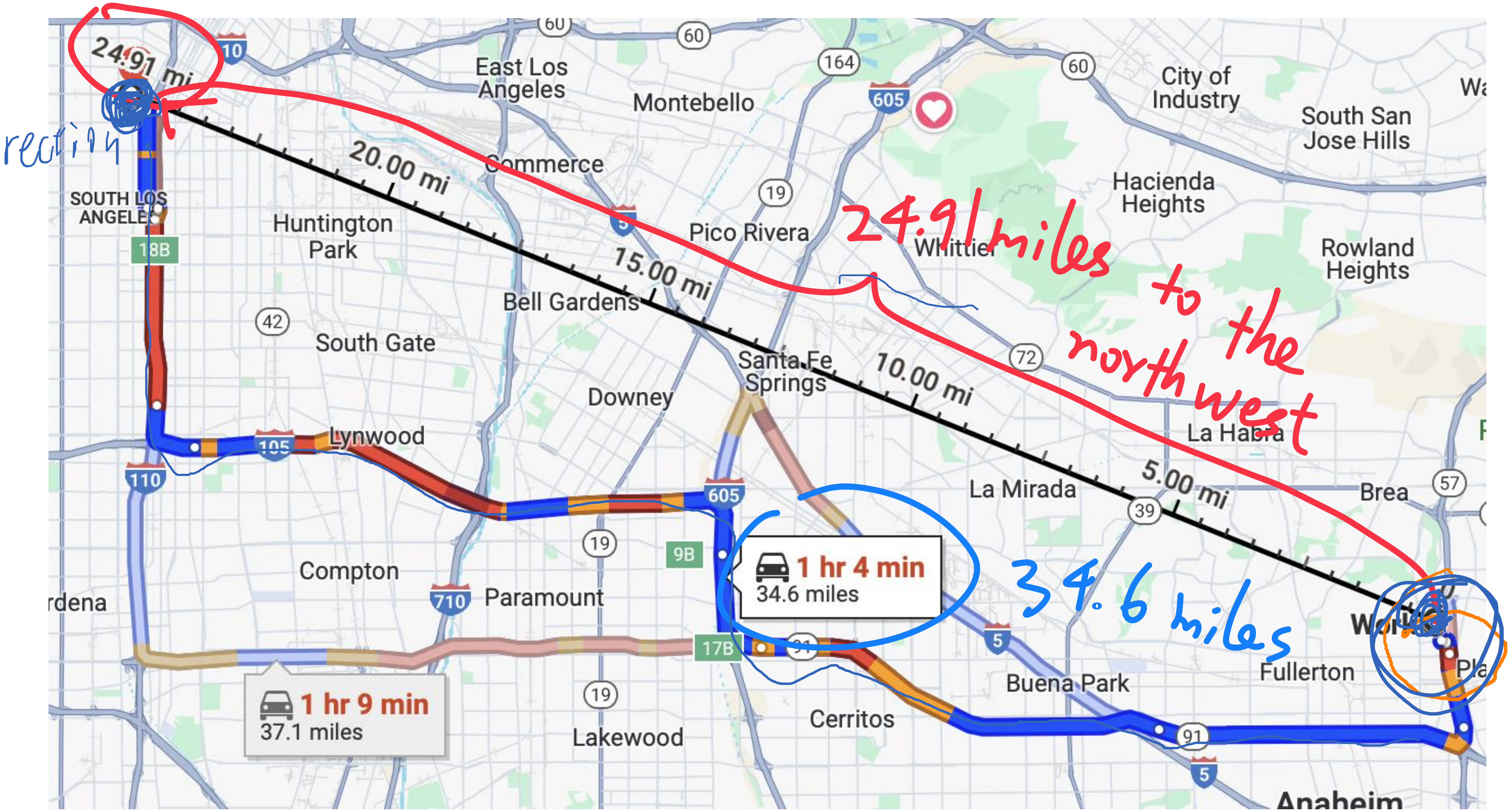
Direction

A Displacement is a scalar, distance is a vector.

[✓ B] Displacement is a vector, distance is a scalar.

C Both displacement and distance are vectors.

D Displacement is the distance and the direction.



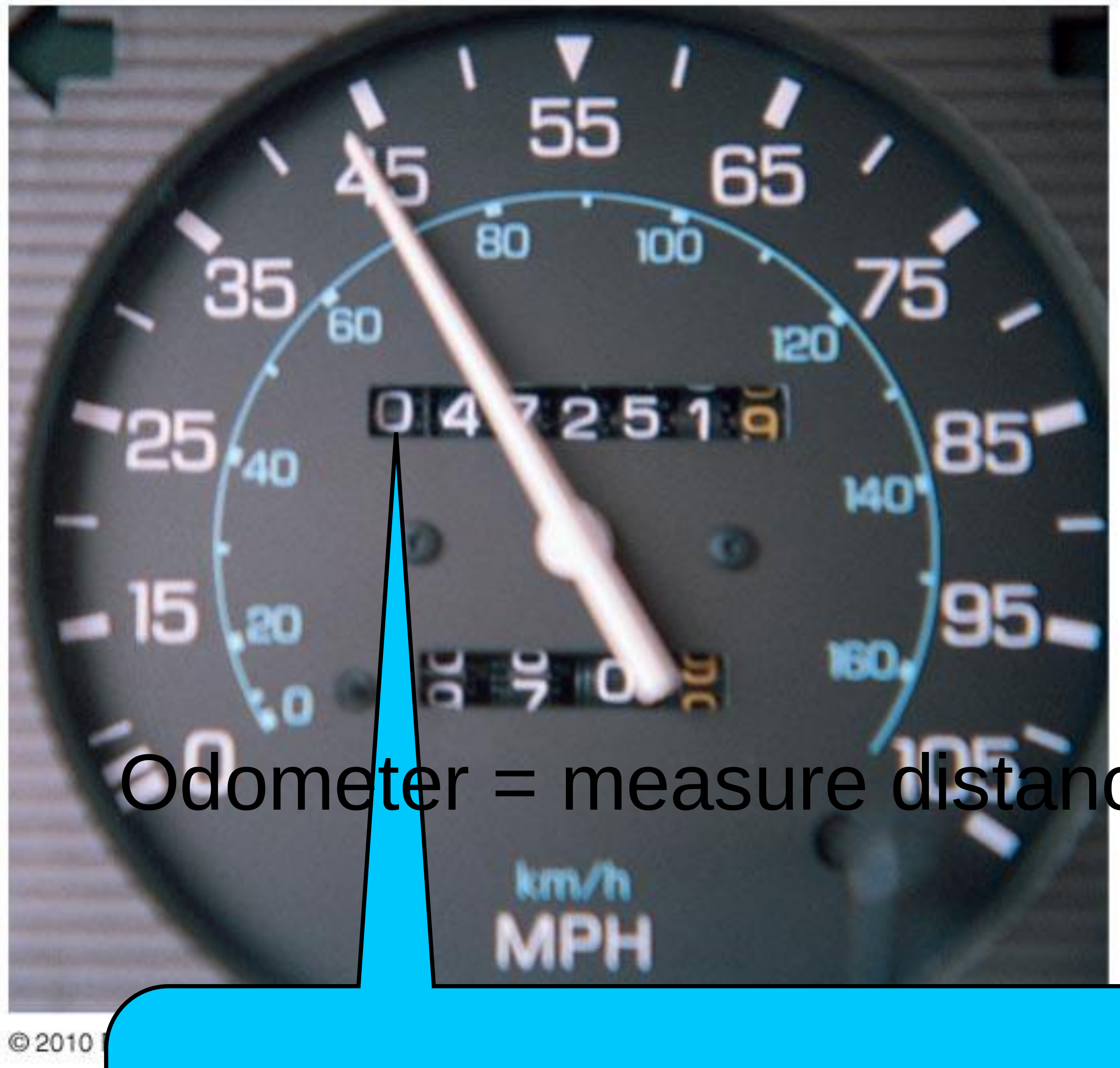
24.91 miles to the northwest

34.6 miles

1. Travel distance and displacement

Distance

- Travel distance, d = length of path traveled (SI unit: m)
  - **Scalar** = number + units
  - Travel distance **depends on path**



Odometer = measure distance

Example:

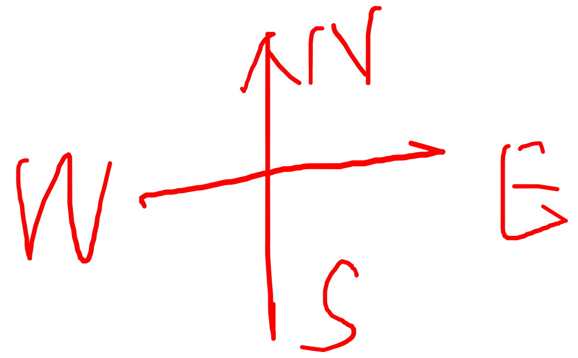
East: $d_E = 81$ km

West: $d_W = d_{HP} + d_{PS}$

$= 97\text{ km} + 48\text{ km}$

$= 145\text{ km}$

Clicker question 2: U-turn on Nutwood ave



- A car drives 0.3 miles west toward campus. Then the car makes a u-turn and drives 0.2 miles east. The axis is defined as to the east. **What distance did the car travel?**

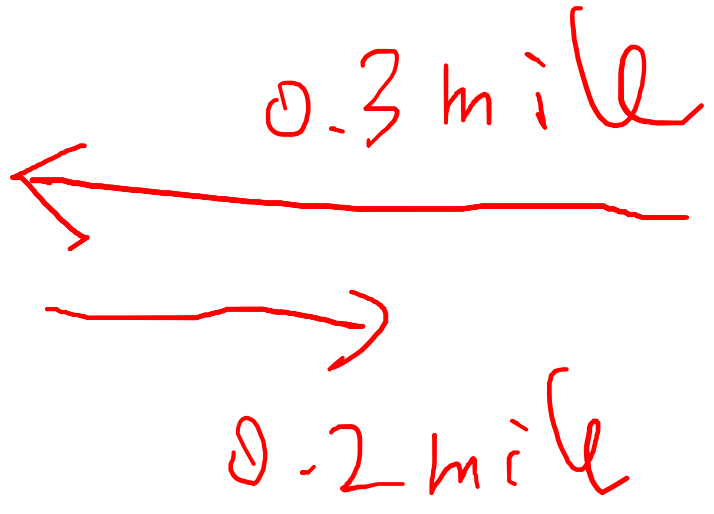
A 0.1 miles

C 0.3 miles

B 0.2 miles

[✓ D] 0.5 miles

Sketch:



No direction

(0.3 + 0.2) mile

Displacement — A vector

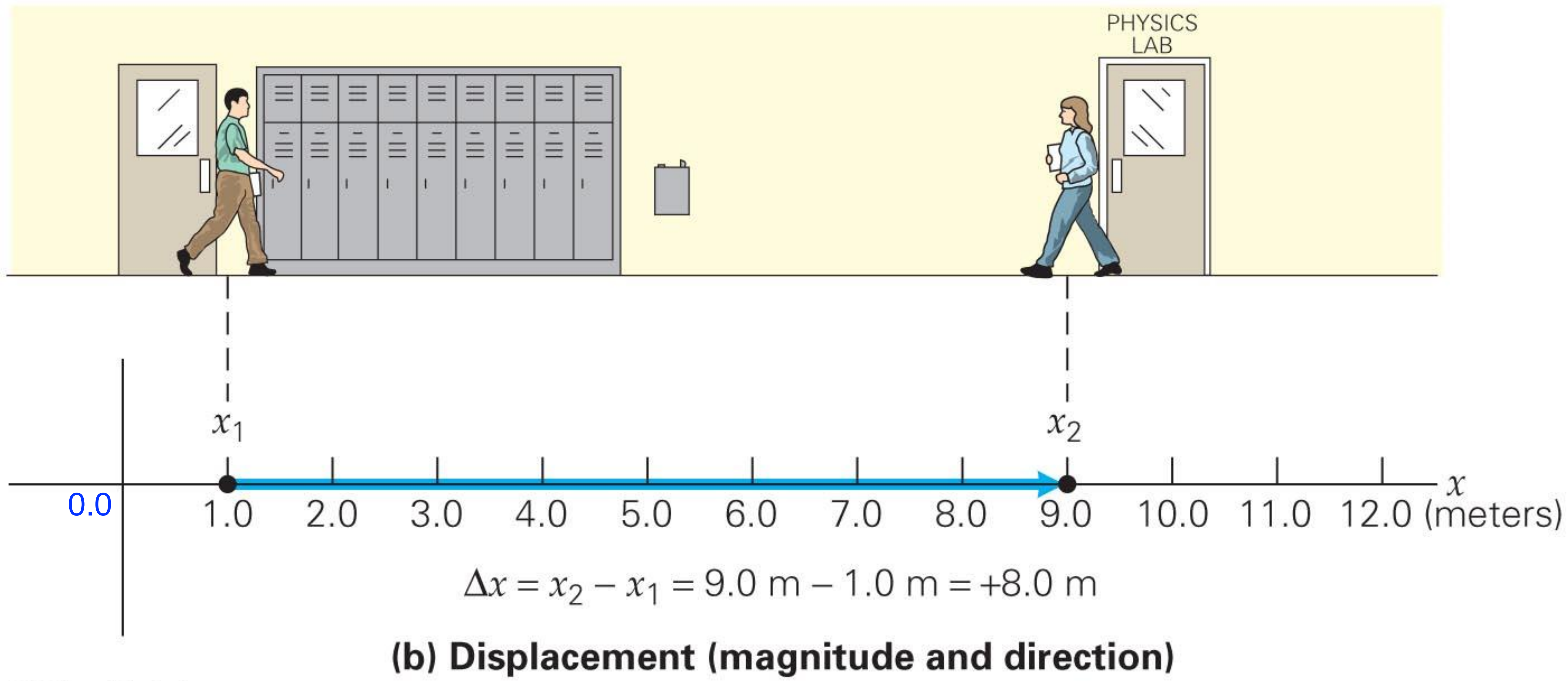
- **Displacement:** Straight-line distance + direction.
  - **Magnitude** = **straight-line distance** from start point to end point (SI unit: m)
  - **Direction** = from start point to end point

final pos.

- Depends only on start, end point (***not depend on path***): $\Delta\vec{x} = \vec{x}_f - \vec{x}_i$
  - **Position** = displacement from chosen point ("origin")

change

initial pos.



(b) Displacement (magnitude and direction)

Clicker question 3: U-turn on Nutwood ave

- A car drives 0.3 miles west toward campus. Then the car makes a u-turn and drives 0.2 miles east. The axis is defined as to the east. What is the the car's **displacement**?

→ +x

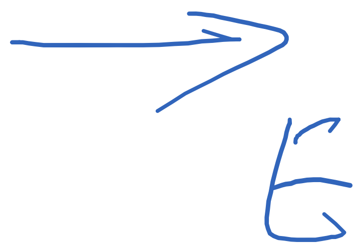
E

A 0.1 miles

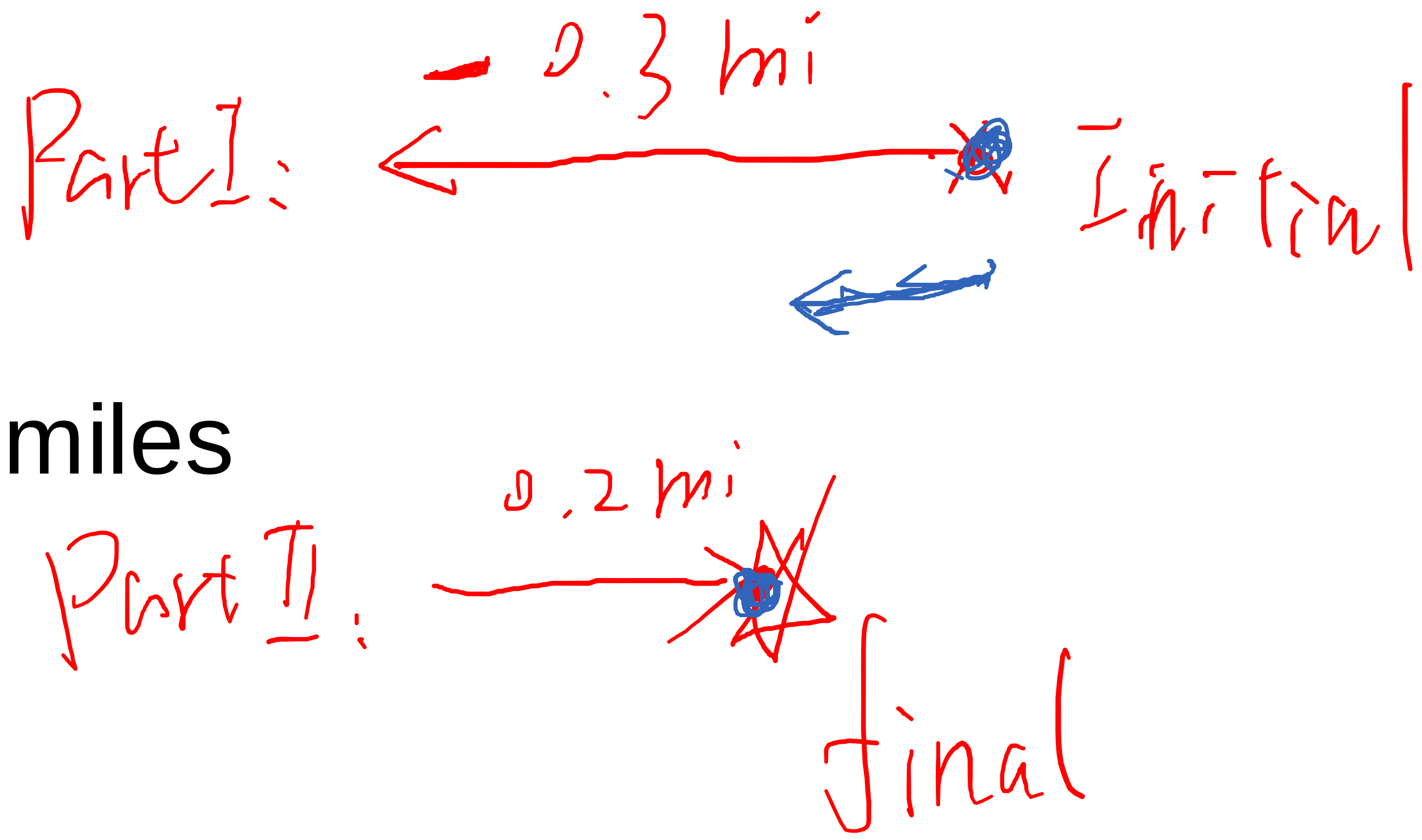
[✓ C] -0.1 miles

B 0.2 miles

D 0.5 miles



Draw a sketch.



Clicker question 4: U-turn on Nutwood ave

$\vec{\Delta x} = -0.1\ mi$

- A car drives 0.3 miles west toward campus. Then the car makes a u-turn and drives 0.2 miles east. The axis is defined as to the east. What is the **magnitude** of the car's **displacement**?

$|\vec{\Delta x}| = |0.1\ mi|$

$= 0.1\ mi$

[✓ A] 0.1 miles

B 0.2 miles

C -0.1 miles

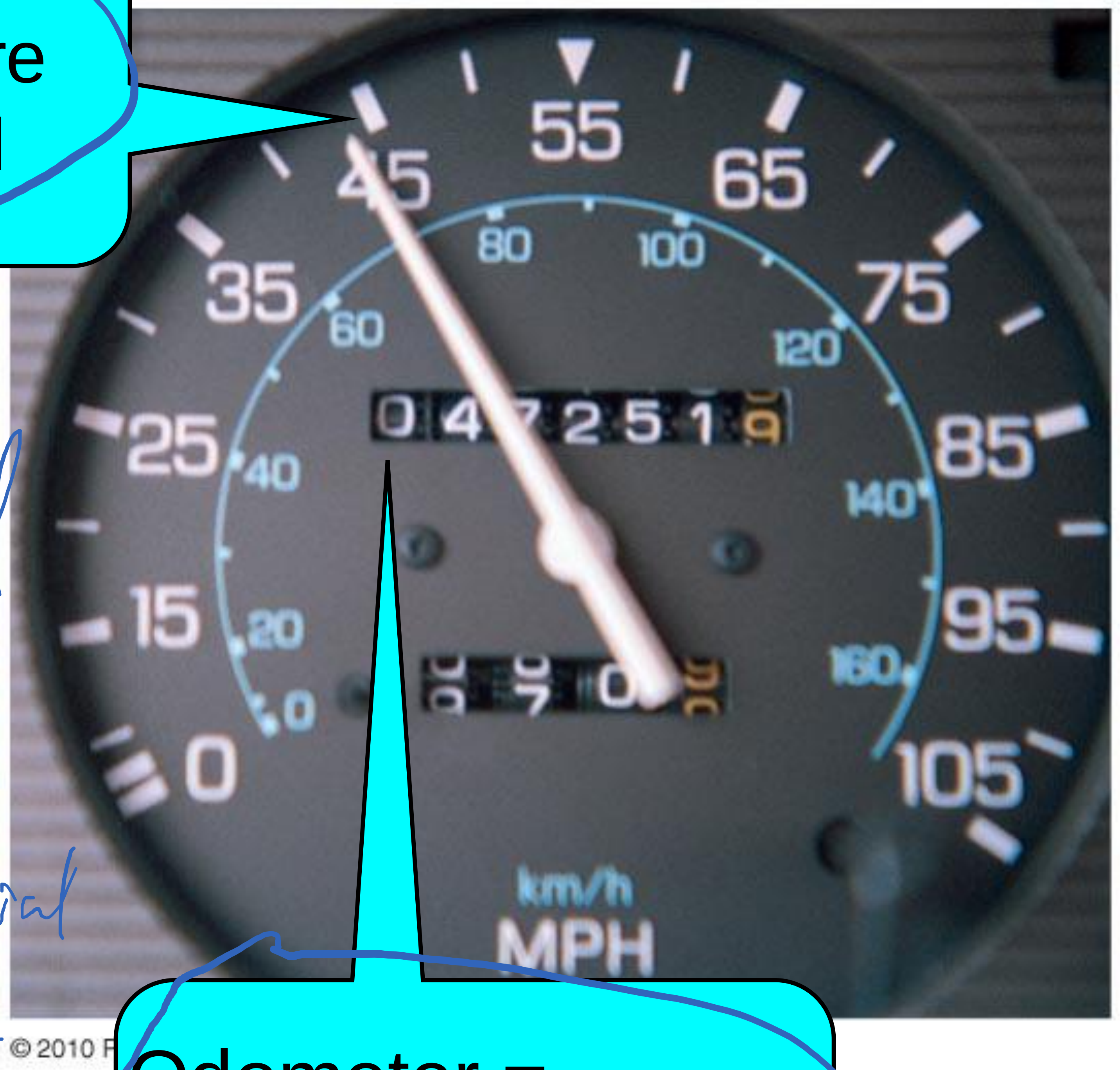
D 0.5 miles

Demo 1

2. Speed and velocity

Speed

Speedometer: measure (instantaneous) speed



Odometer = measure distance

- **Speed:** Distance per unit time
- Average speed:
  - A **scalar**
  - SI unit: m/s

$$\bar{s} = \frac{d}{\Delta t} = \frac{d}{t - t_0}$$

distance Travelled

Time duration

final time

Initial t

- Instantaneous speed: $\bar{s} \to s$ as $\Delta t \to 0$

$$s = \lim_{\Delta t \to 0} \frac{d}{\Delta t}$$

$s =$ speed at a particular instant of time

Clicker question 5

Speed is a scalar

$\bar{s} = \frac{d}{\Delta t}$

$d \rightarrow$ dist ~ 110 m

$\Delta t \leftarrow$ time duration

- The distance around a baseball diamond is 110 m. A runner runs the bases in 10.0 s.
  The runner's **average speed** is...

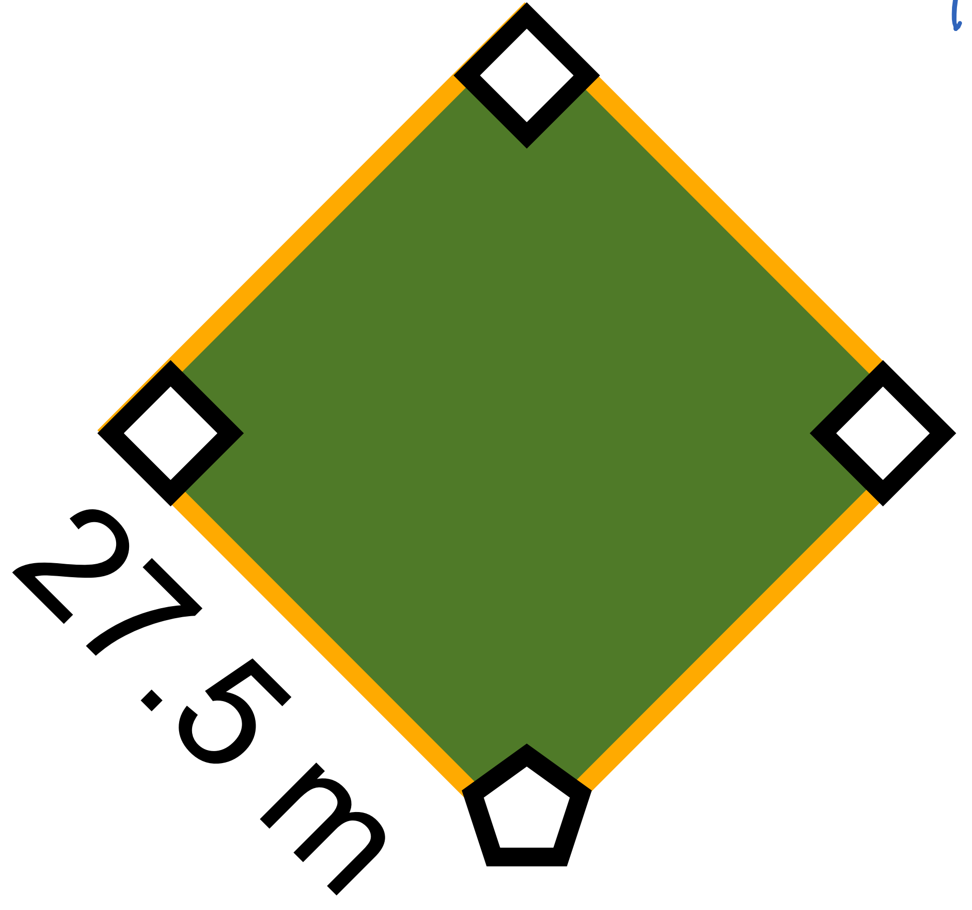
10 s.

A 11.0 m/s, clockwise

B 11.0 m/s, counterclockwise.

[✓ C] 11.0 m/s

D 0.00 m/s



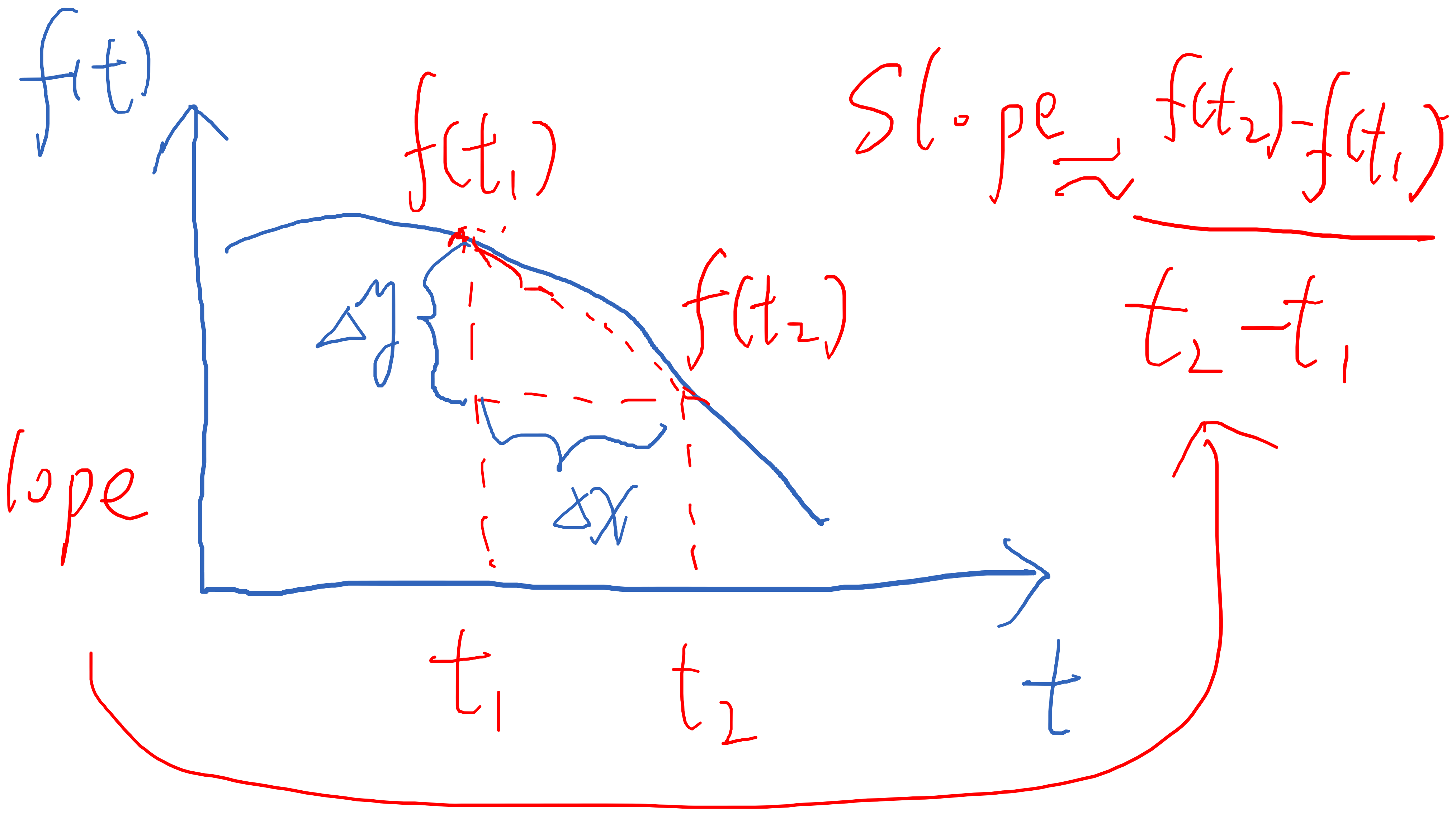
Calculus mini-review

if $f(t) = t^n$

- Derivative: $\frac{d}{dt}(t^n) = nt^{n-1}$

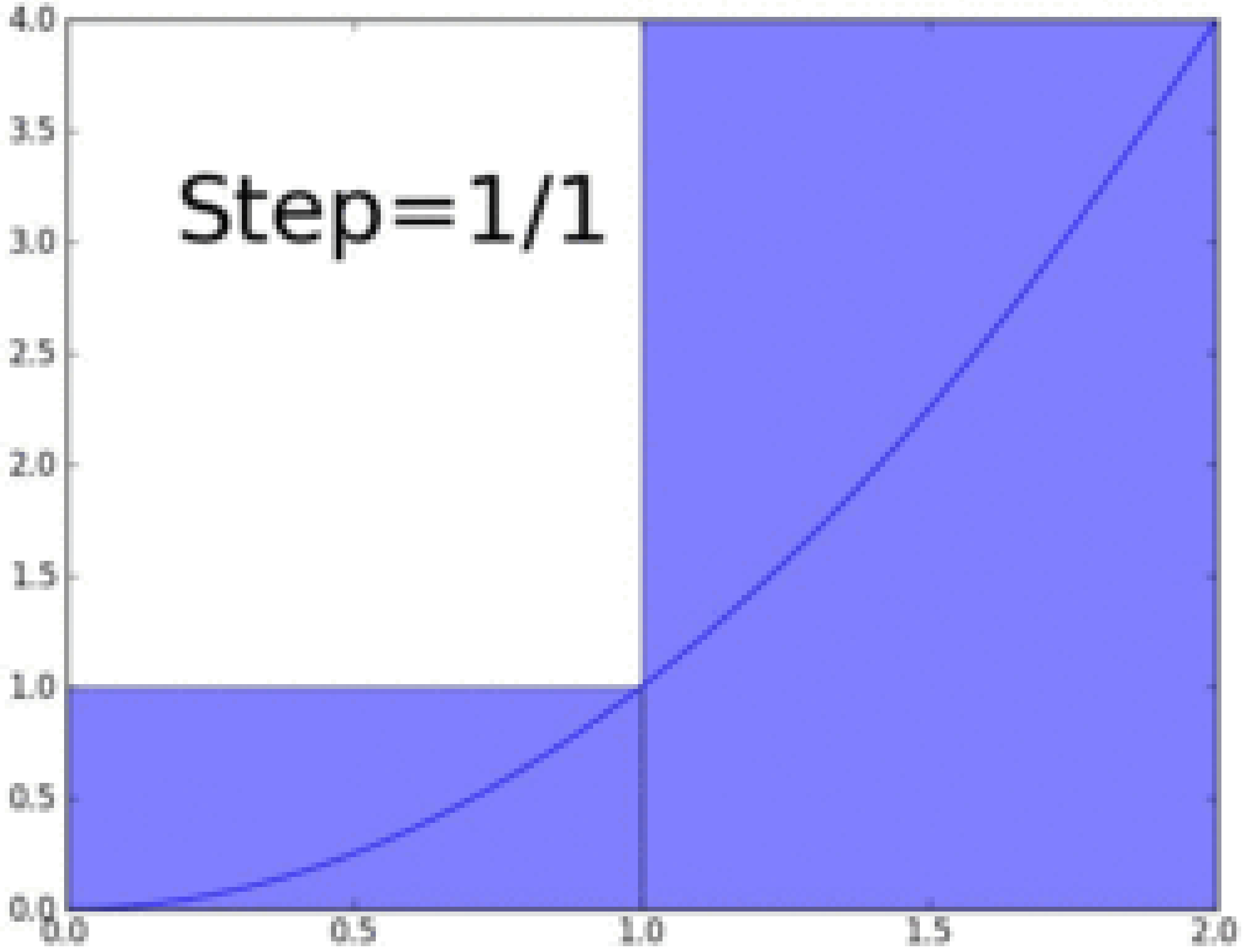
$$\frac{d}{dt}(t^3 - 3) = 3t^2$$

$$\frac{df(t)}{dt} = \lim_{t_2 \to t_1} \text{slope}$$

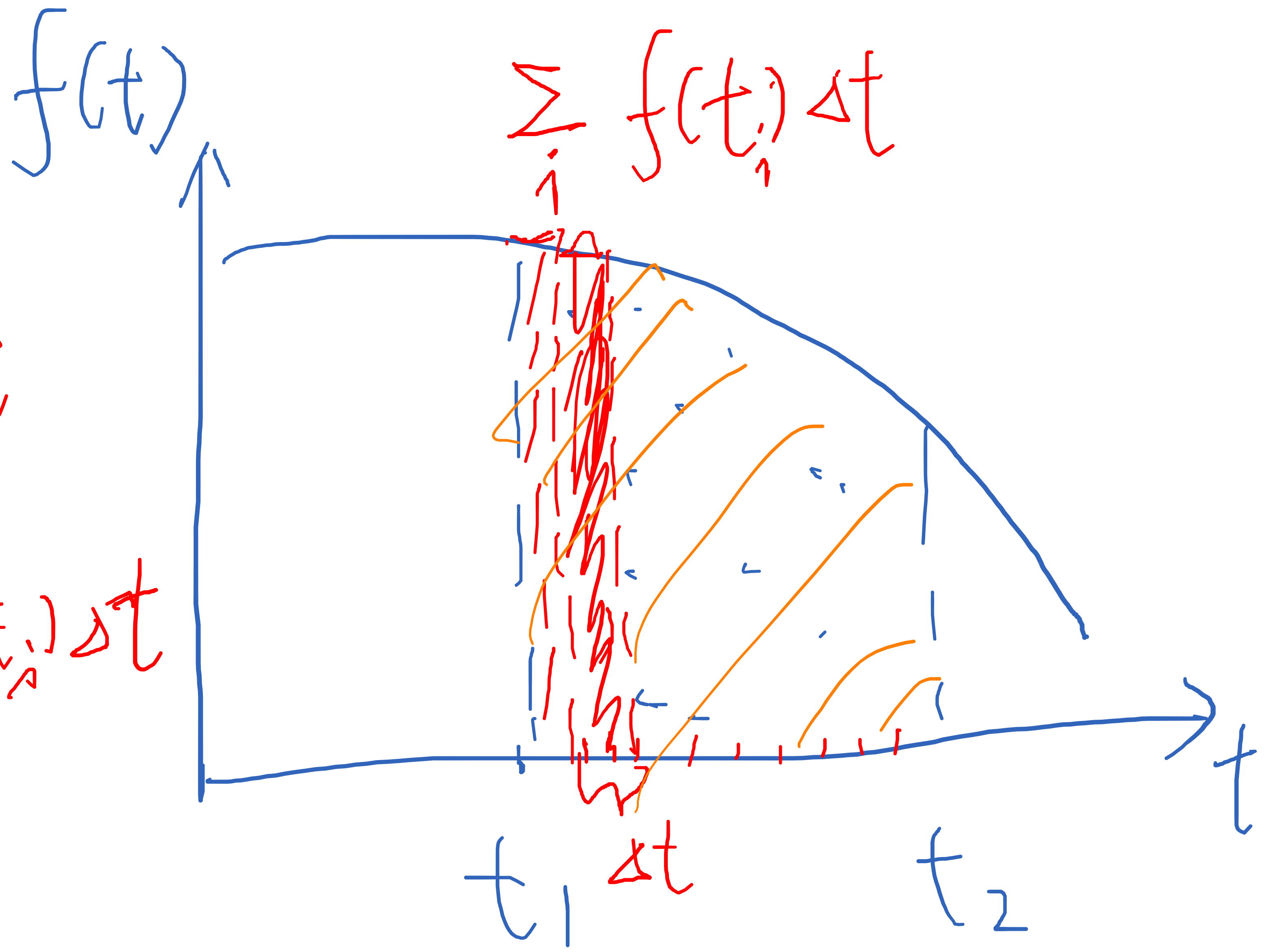


$$\text{Slope} \approx \frac{f(t_2) - f(t_1)}{t_2 - t_1}$$

- Definite integral: $\int_a^b t^n dt = \frac{t^{n+1}}{n+1}|_a^b$



$$\int_{t_1}^{t_2} f(t)\,dt = \lim_{\Delta t \to 0} \sum_i f(t_i)\Delta t$$



Velocity

- **Velocity:** Displacement per unit time
- Velocity is a **vector**: magnitude and direction
  - Average velocity (SI unit: m/s), $\bar{\vec{v}}$:

$$\overset{\text{Ave.}}{\bar{\vec{v}}} = \frac{\overset{\text{Disp.}}{\Delta\vec{x}}}{\underset{\text{time duration}}{\Delta t}} = \frac{\overset{\text{final pos.}}{\vec{x}} - \overset{\text{initial pos.}}{\vec{x}_0}}{\underset{\text{final t.}}{t} - \underset{\text{time}}{t_0}}$$

  - Instantaneous velocity, $\vec{v}$:

$$\bar{\vec{v}} \to \vec{v} \text{ as } \Delta t \to 0$$

$$\vec{v} = \frac{d\vec{x}}{dt}$$

$\vec{v}$ is the time derivative of disp.

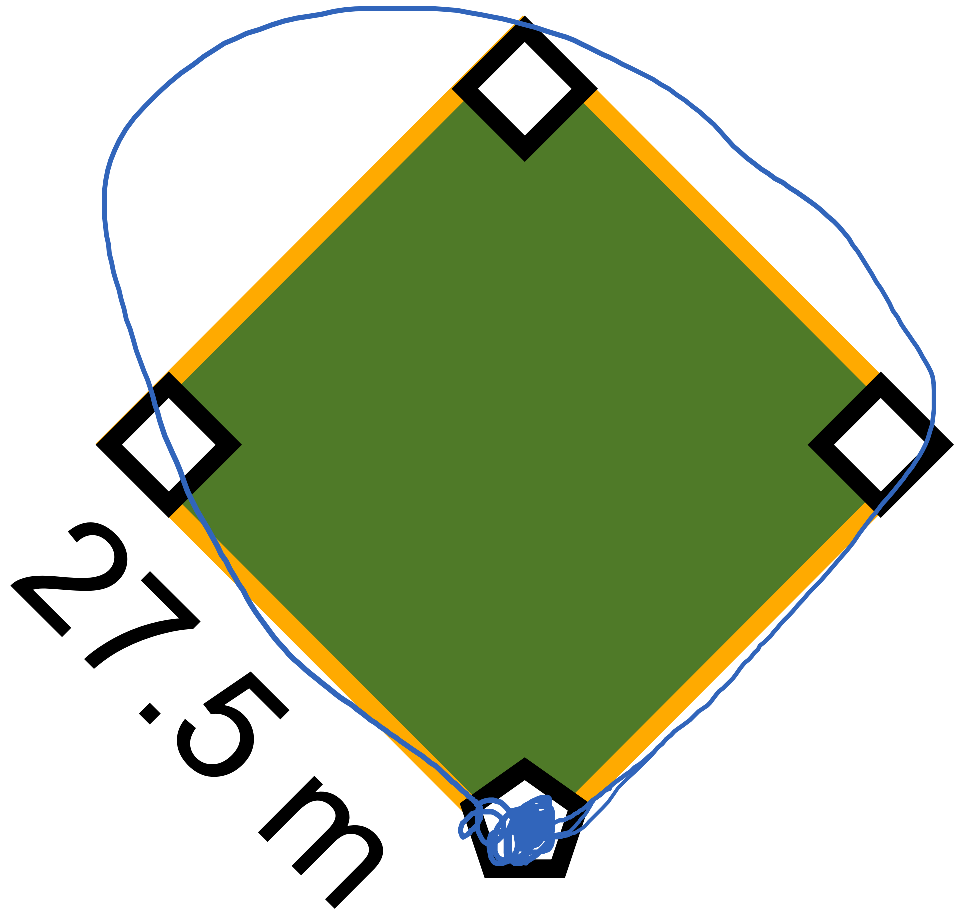
35 mi/hr, northbound

Direction and magnitude

Clicker question 6

Ave $\overline{\vec{v}} = \frac{\Delta \vec{x}}{\Delta t}$ disp 0

- The distance around a baseball diamond is 110 m. A runner runs the bases in 10.0 s.
  The runner's **average velocity** is …



A 11.0 m/s, clockwise

B 11.0 m/s, counterclockwise.

C 11.0 m/s

[✓ D] 0.00 m/s

Demo 2

Demo 2: Simulation

https://phet.colorado.edu/en/simulation/moving-man

3. Acceleration

Acceleration: $\vec{a}$

- Definition: Rate of change of velocity.
- Acceleration is a **vector**
  - Average acceleration:

Change in velocity

final initial vel.

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t - t_0}$$

final intitial time

Time duration

    - (SI unit: m/s/s = m/s^2)
    - Direction points toward **change in velocity**.
  - Instantaneous acceleration: $\bar{a} \rightarrow a$ as $\Delta t \rightarrow 0$

a = accel. at a particular instant of time

Derivative of $\vec{v}$ w.r.t. time.

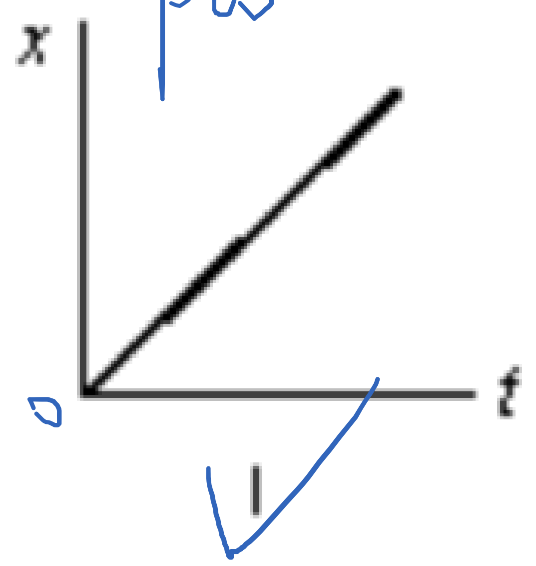
$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{x}}{dt^2}$$

Clicker question 7

$\vec{v} = \frac{d\vec{x}}{dt}$

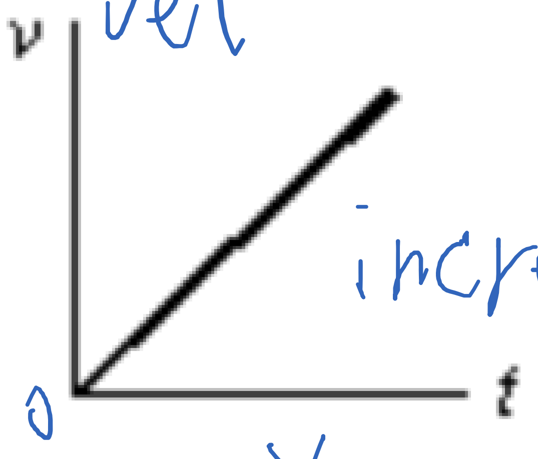
- Consider the following five graphs (note the axes carefully). Which of these represent(s) motion at a constant speed?

pos



I ✓

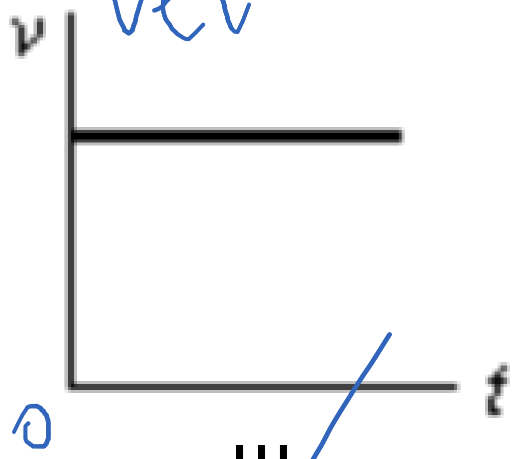
vel



increases

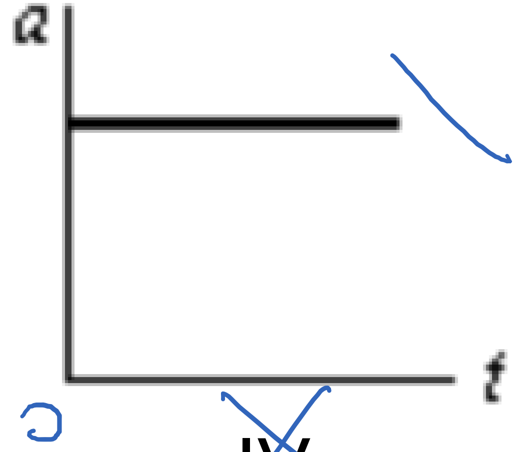
II ✗

vel



III ✓

accl. > 0



IV ✗

rate of change of $\vec{v}$

A I only

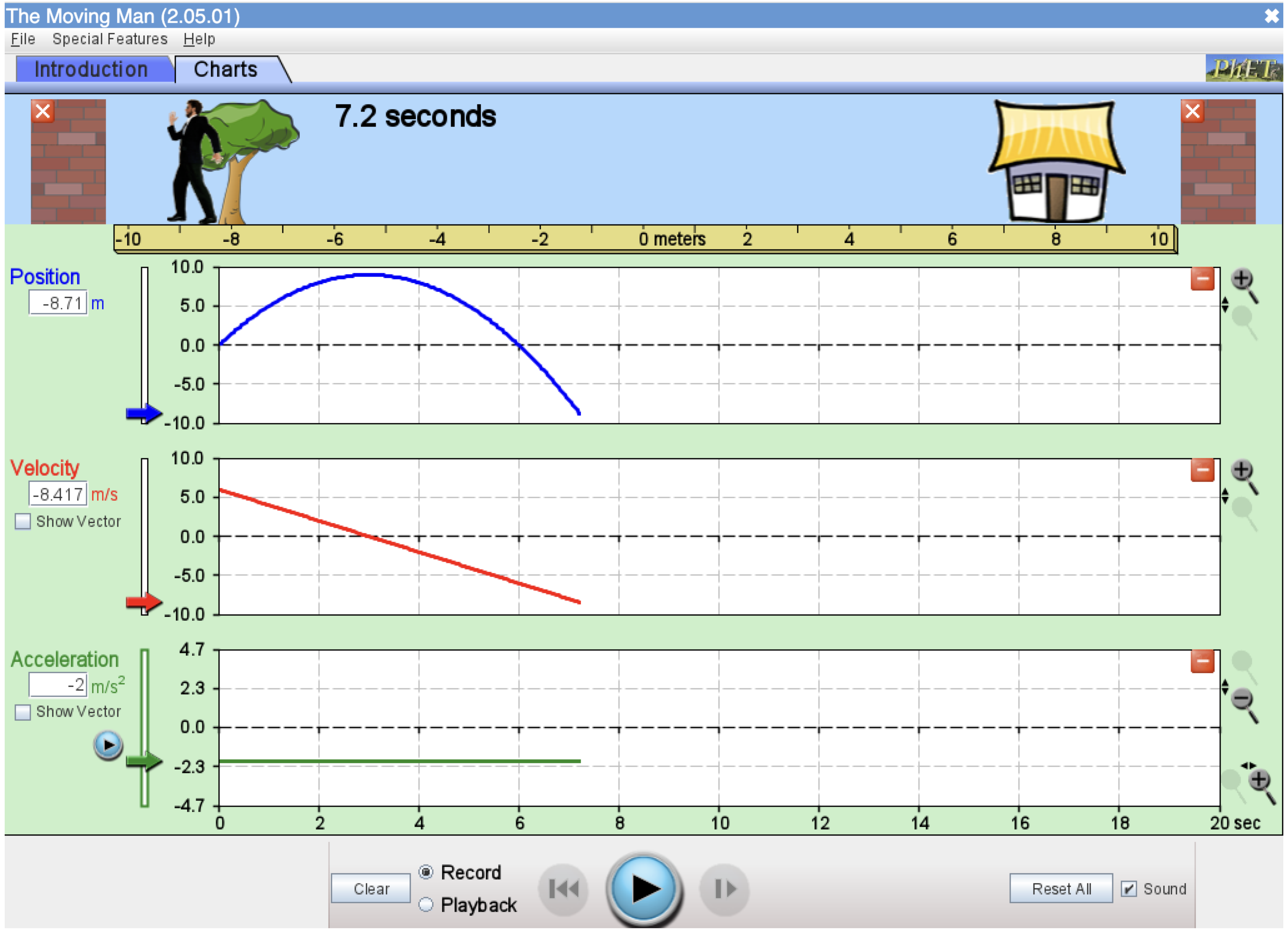
[✓ B] I & III

C III only

D IV only

Demo 2 continued: Simulation

- **Set up the acceleration to an arbitrary constant**
- **What happens to the position and velocity?**



7.2 seconds

Position -8.71 m

Velocity -8.417 m/s

Acceleration -2 m/s^2

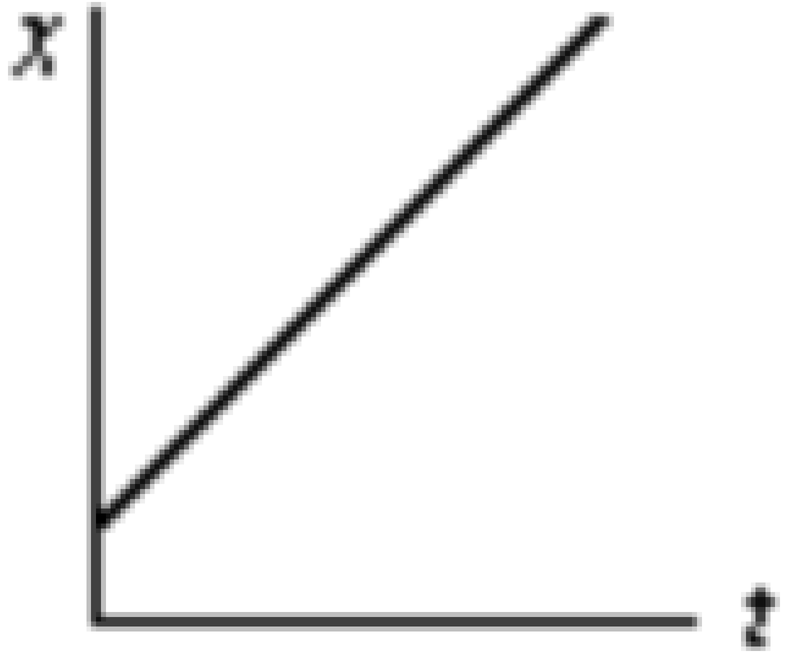
● Record
○ Playback

https://phet.colorado.edu/en/simulation/moving-man

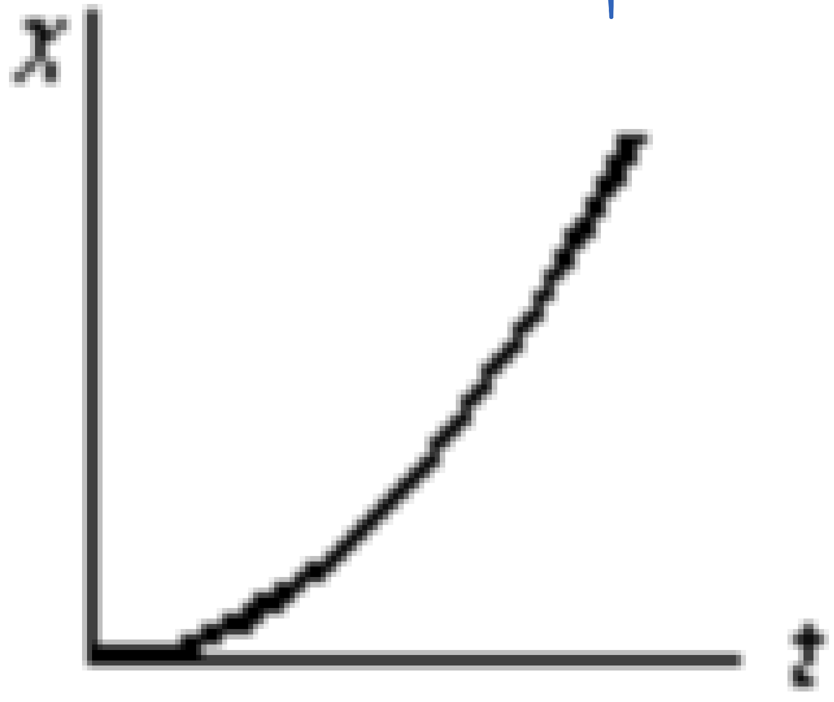
Clicker question 8

Which of the following five coordinate versus time graphs represents the motion of an object whose speed is increasing?

slope increases

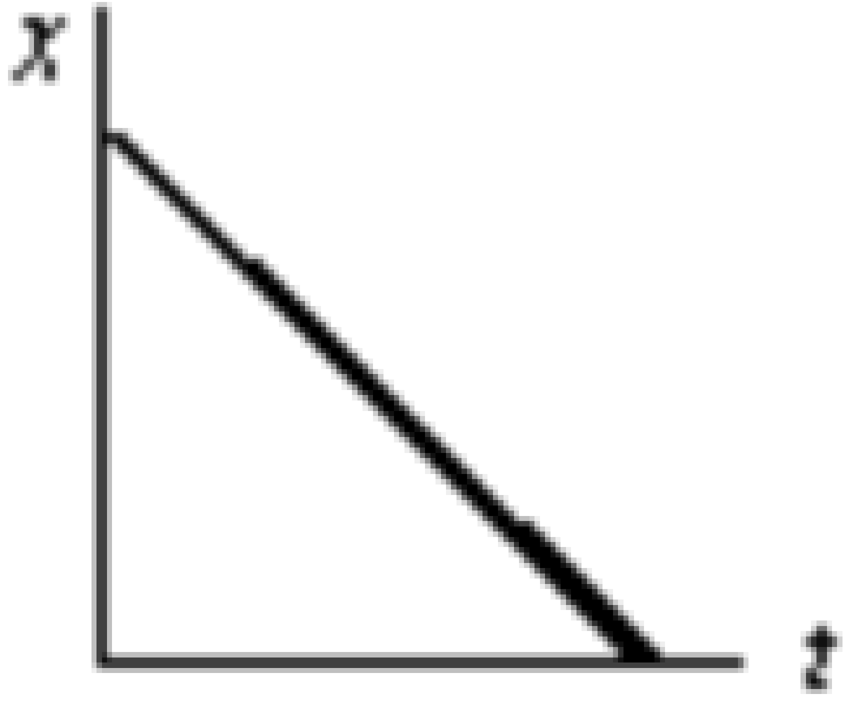


A



[✓ B]

C



D

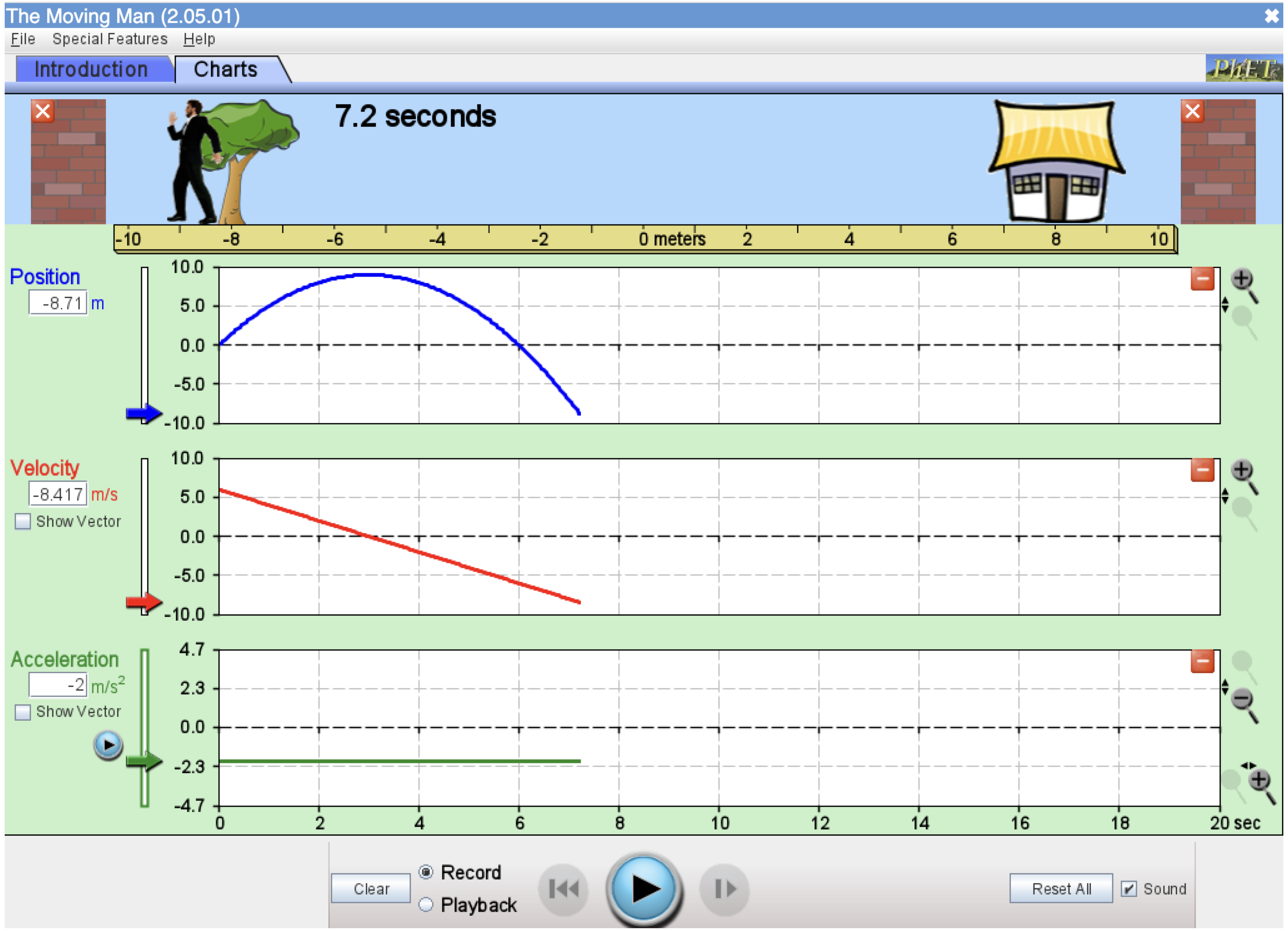
More examples of 1D motion

Example 1

- At time t_0=0s, a race car had a speed of 33 m/s in the positive x direction, and $t =$5.4 s later its speed was 74 m/s in the opposite direction. **Please find the average acceleration**.

Demo: 1D motion with constant acceleration

- **Visit:** https://phet.colorado.edu/en/simulation/moving-man
- **Work in groups of 2-3 people**
- **Step 1:**
  - Click Charts
- **Step 2:**
  - Set up the initial position and velocity
  - Set up the acceleration
  - Observe the displacement, velocity and acceleration.



Position -8.71 m

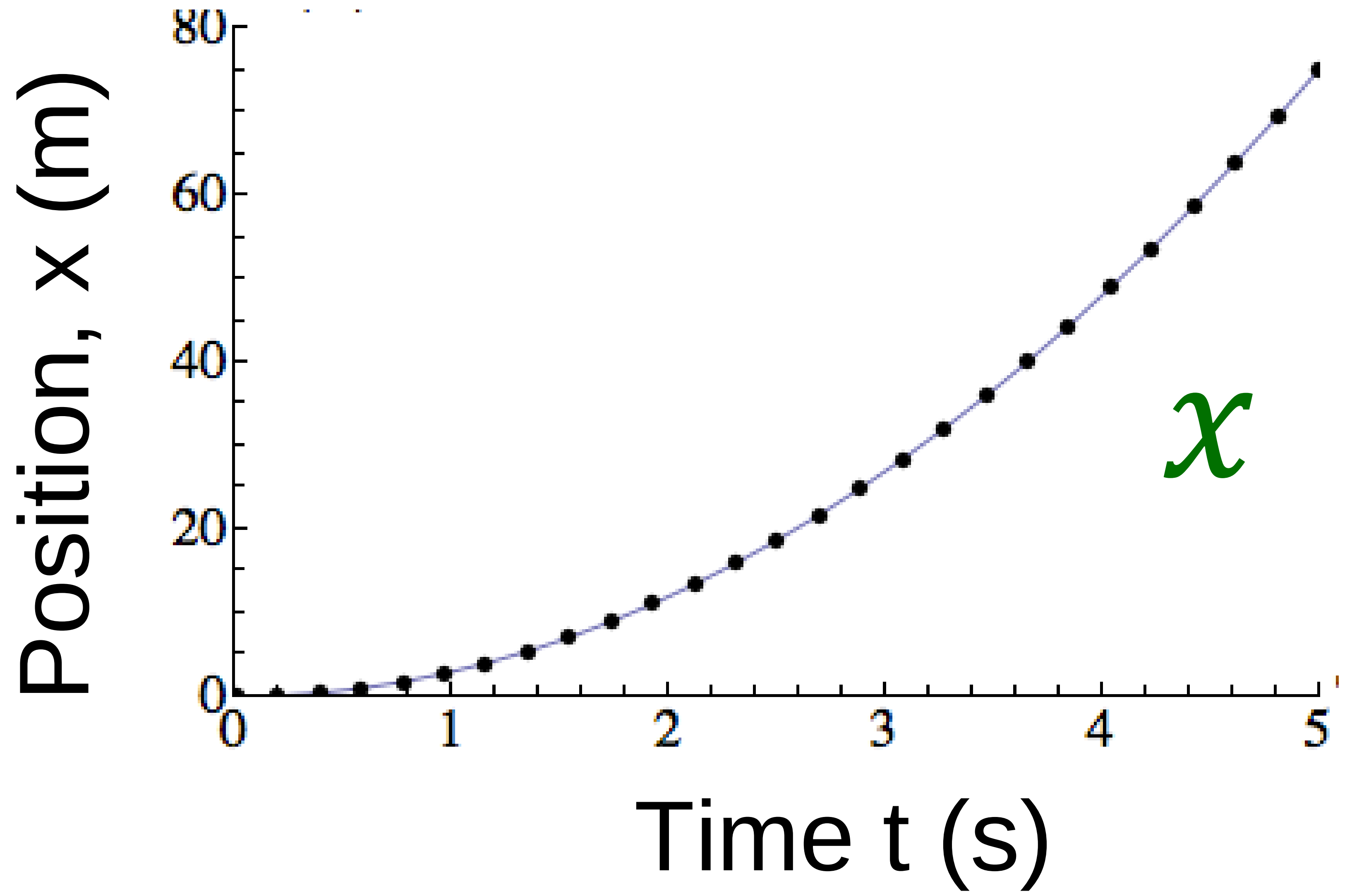
Velocity -8.417 m/s

Acceleration -2 m/s^2

https://phet.colorado.edu/en/simulation/moving-man

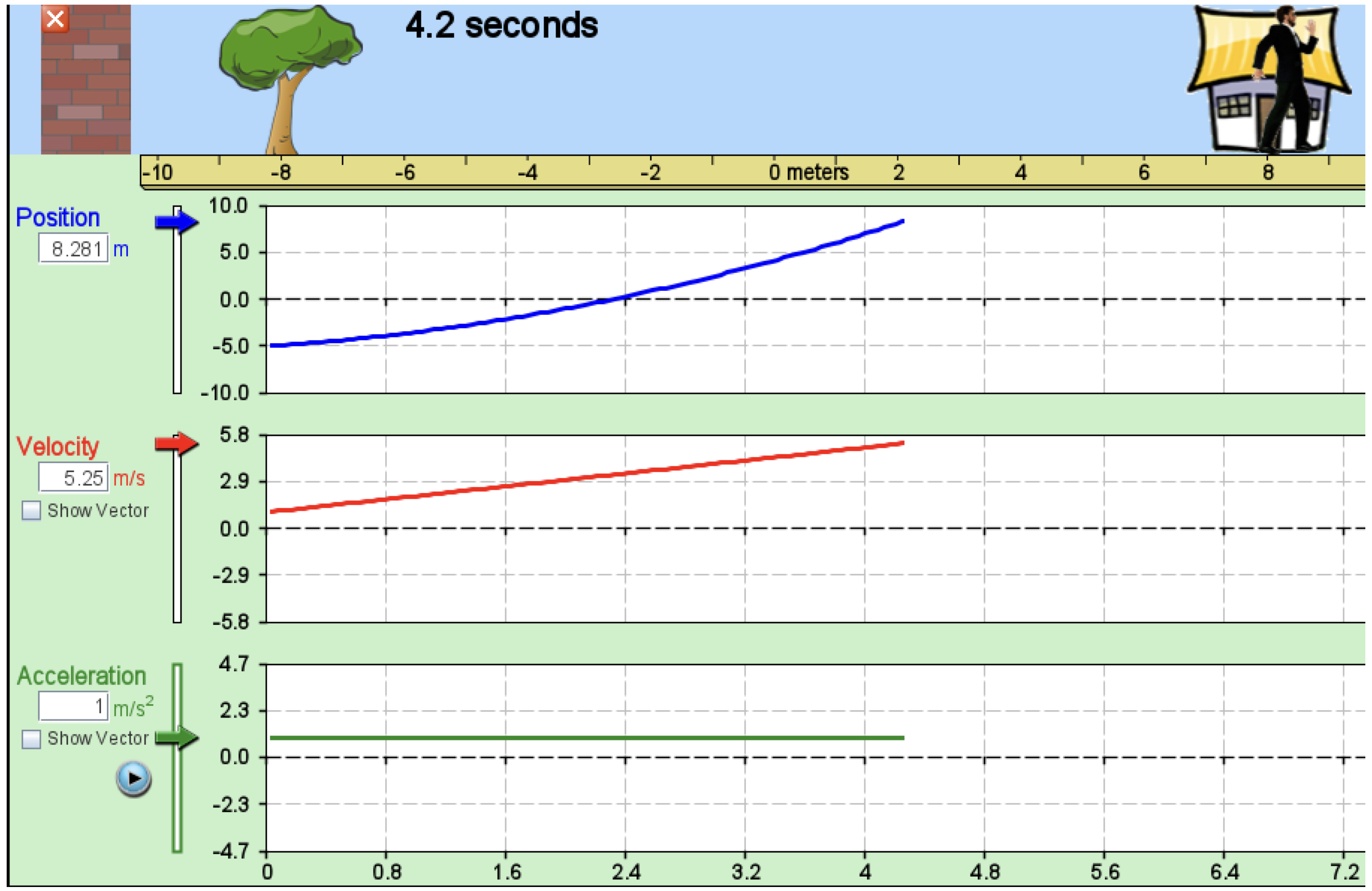
Plots of motion

displacement from x=0 m



↓ Derivative

↑ Integral



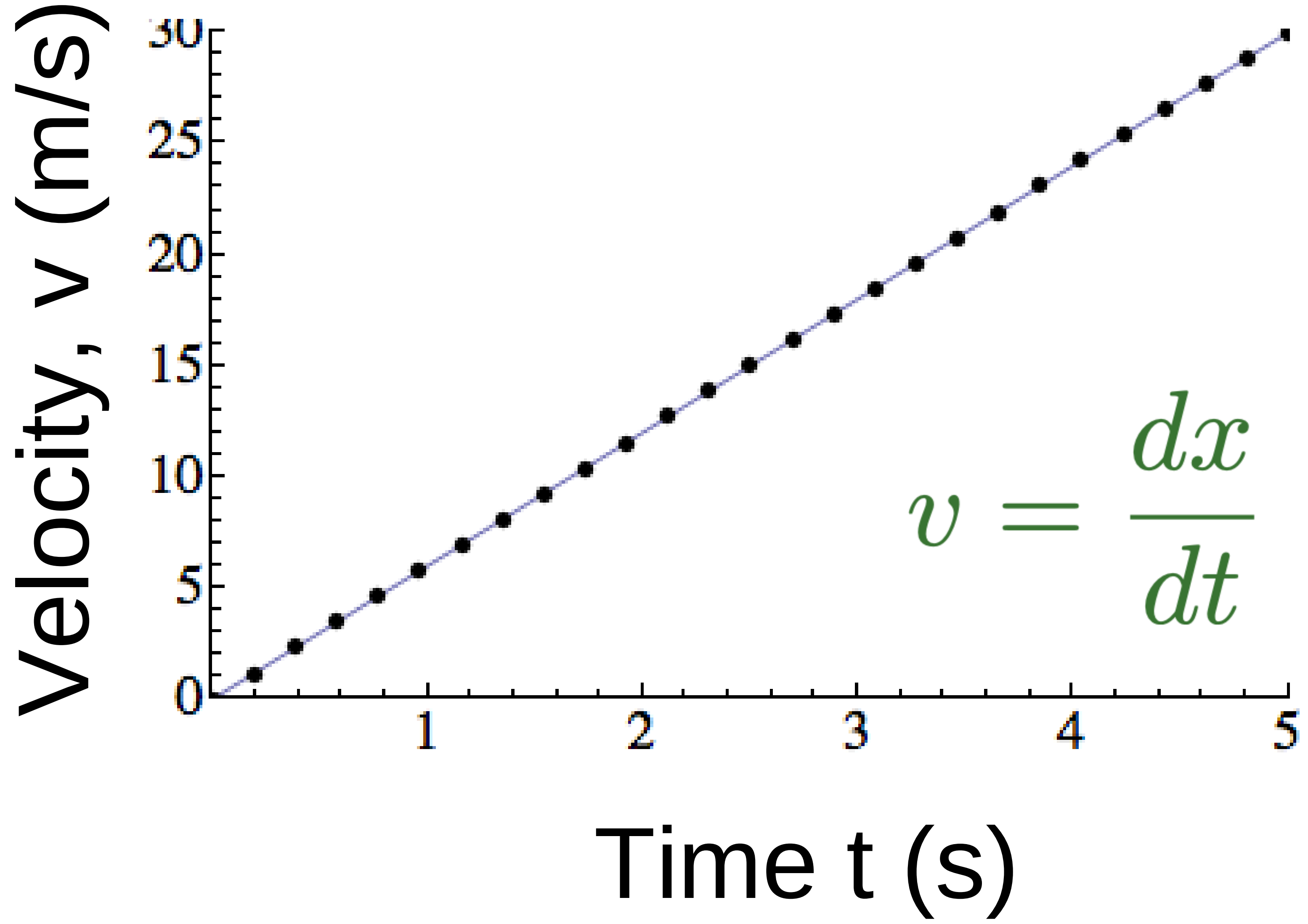
Position 8.281 m

Velocity 5.25 m/s

☐ Show Vector

Acceleration 1 m/s^2

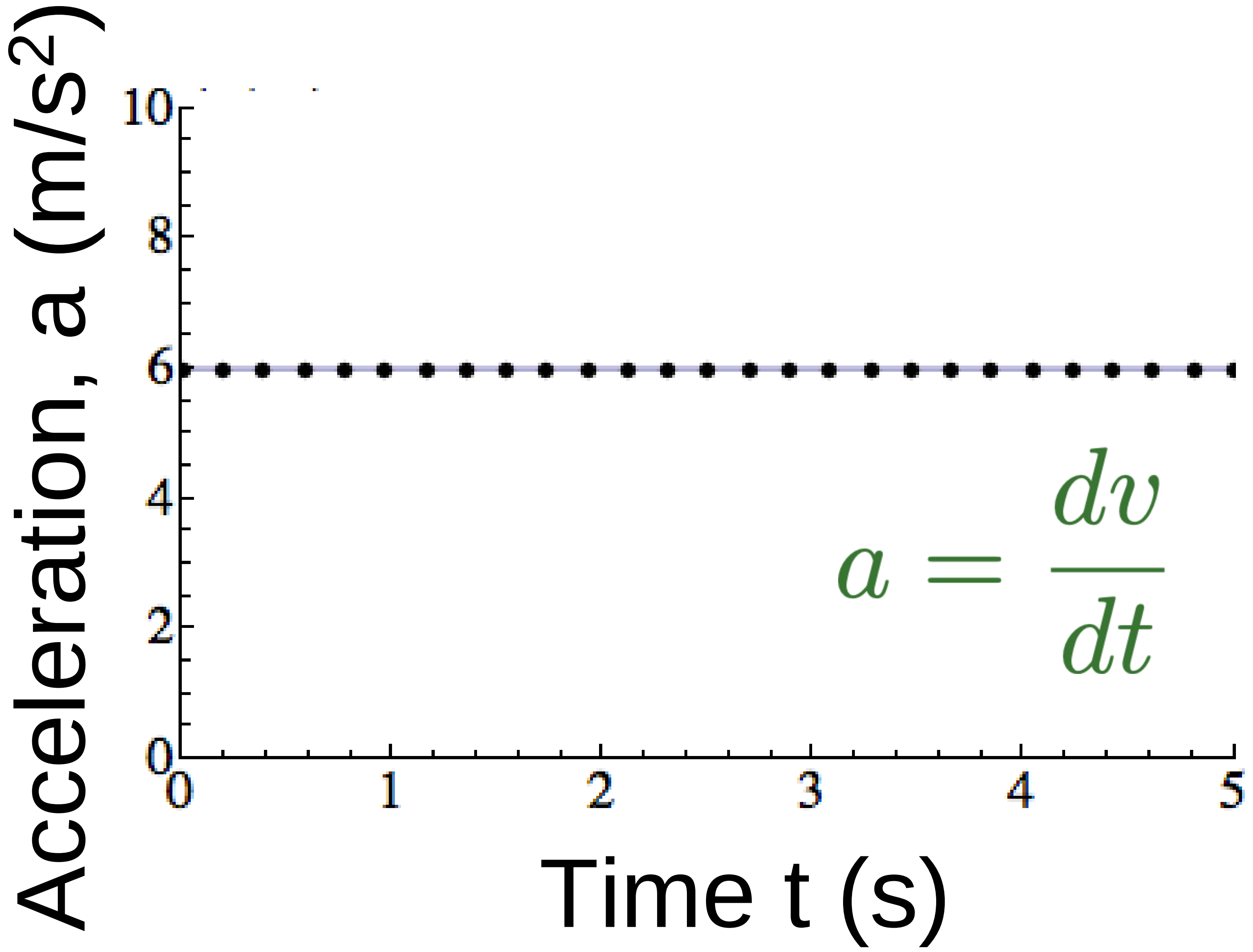
☐ Show Vector



$$v = \frac{dx}{dt}$$

← Integral

→ Derivative



$$a = \frac{dv}{dt}$$

Next time:

- 1D motion with a constant acceleration