PHYS 225
Fundamentals of Physics: Mechanics

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Lecture 4: Motion along a straight line

CALIFORNIA STATE UNIVERSITY
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Learning goals

Vector $\begin{cases} \text{Magnitude} \\ \text{direction} \end{cases}$

- Practice on displacements, velocity and acceleration
- 1D motion with a constant acceleration

Special condition

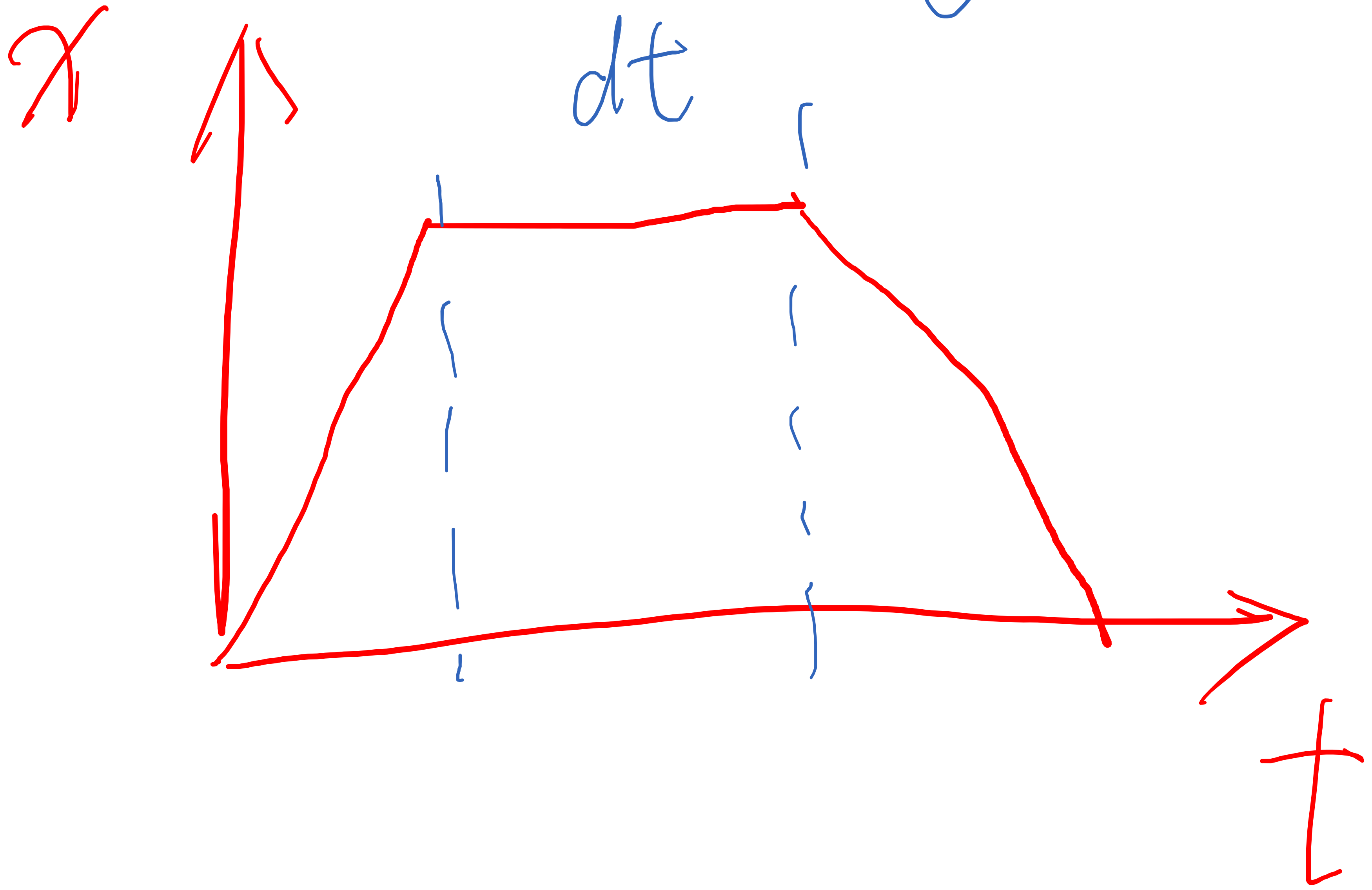
$$\vec{x}$$

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

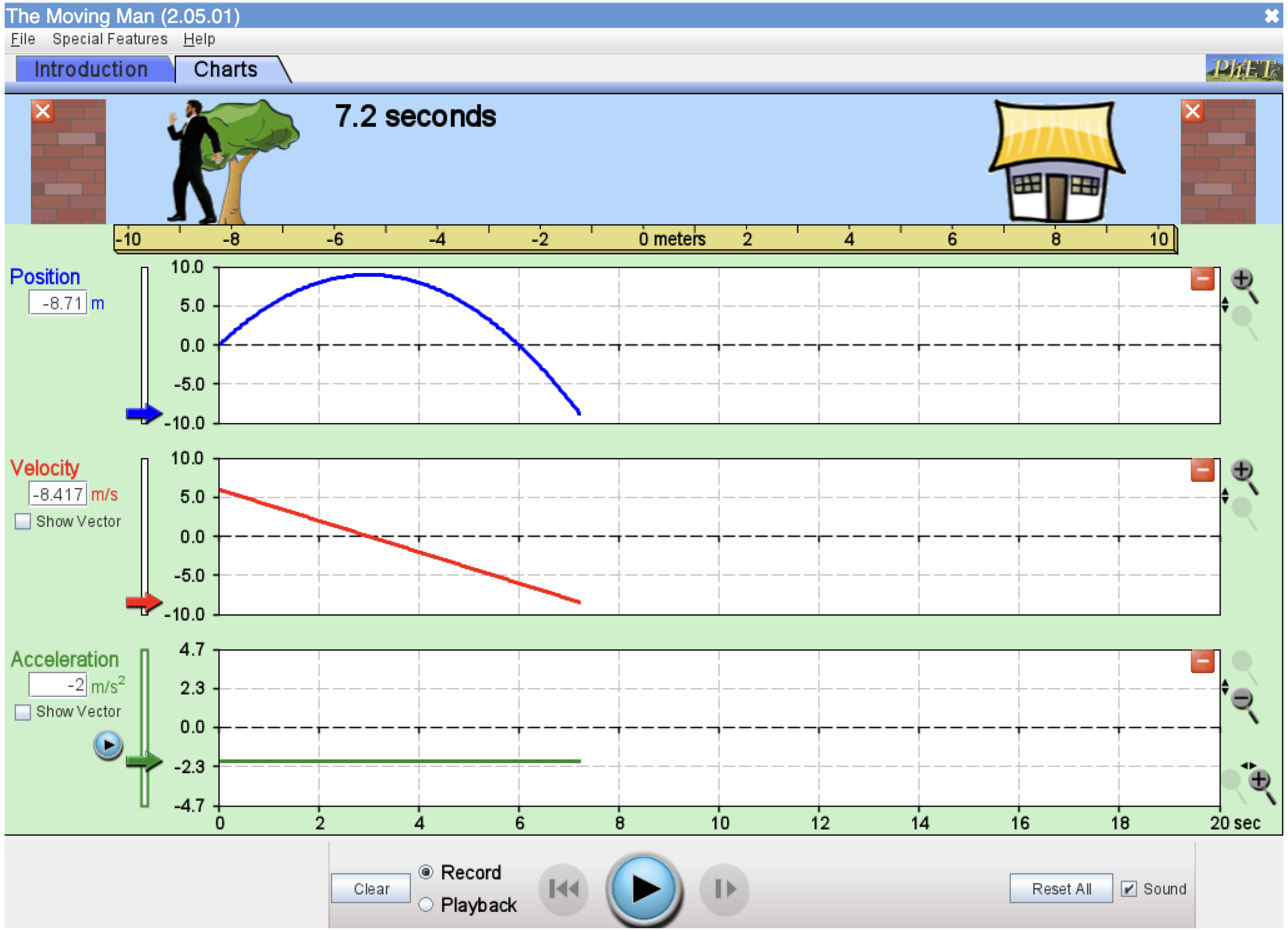
$$\vec{a} = \frac{d\vec{v}}{dt}$$

Demo

$$\frac{d\vec{x}}{dt} = 0$$



Simulation demo



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

Speed is a scalar

More 1D motion examples

when $\vec{a}$ is opp to $\vec{v_0}$: slow down

Example 1

Step0: Given: $t_0 = 0s$, $t = 5.4s$, $\vec{v}_0 = 33\,ms^{-1}$, $\vec{v} = -74\,ms^{-1}$

Goal: $\vec{a}$

- At time t_0=0s, a race car had an initial 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**.

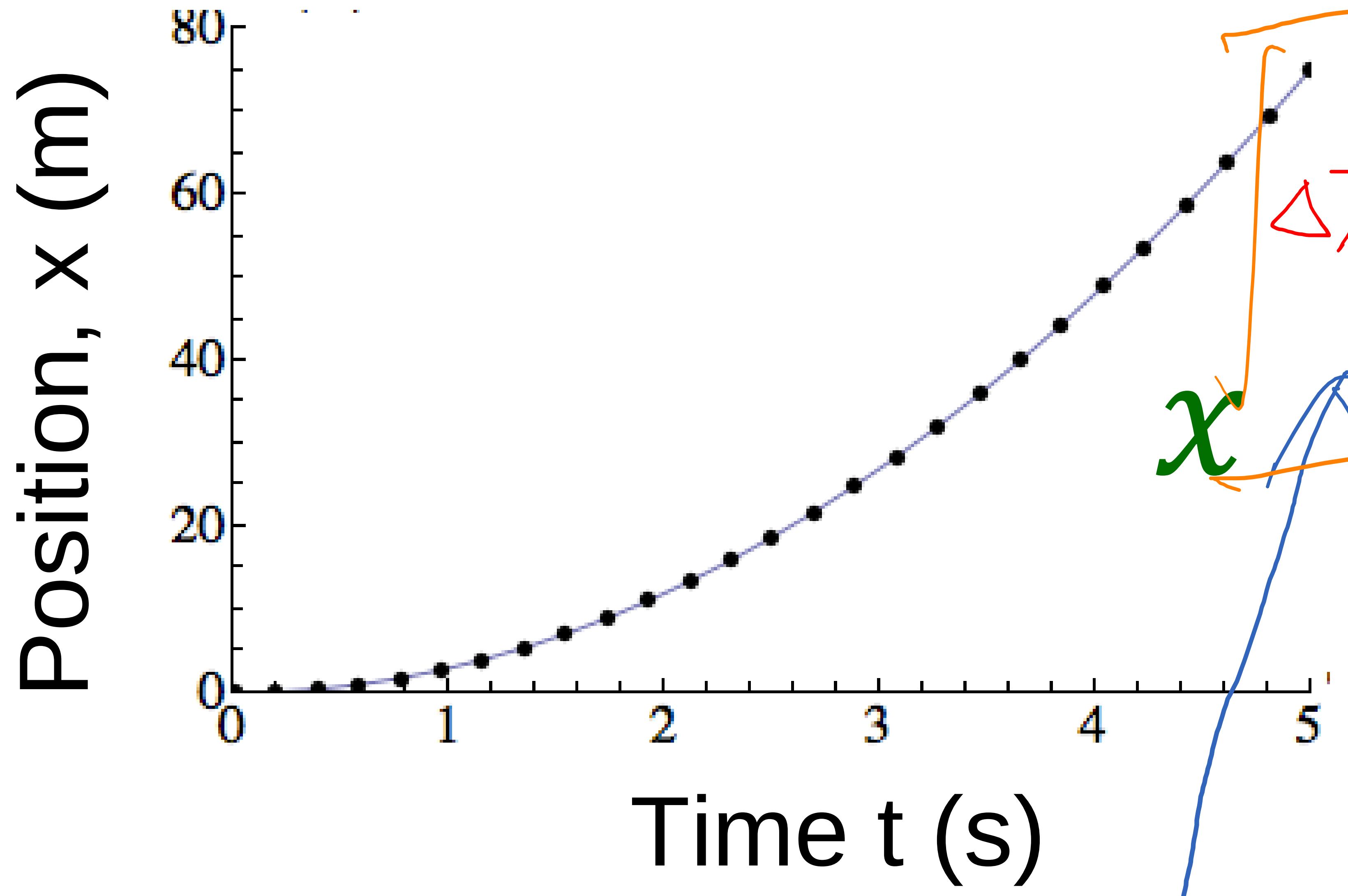
Step1: $\vec{a} = \dfrac{\vec{v} - \vec{v}_0}{\Delta t}$

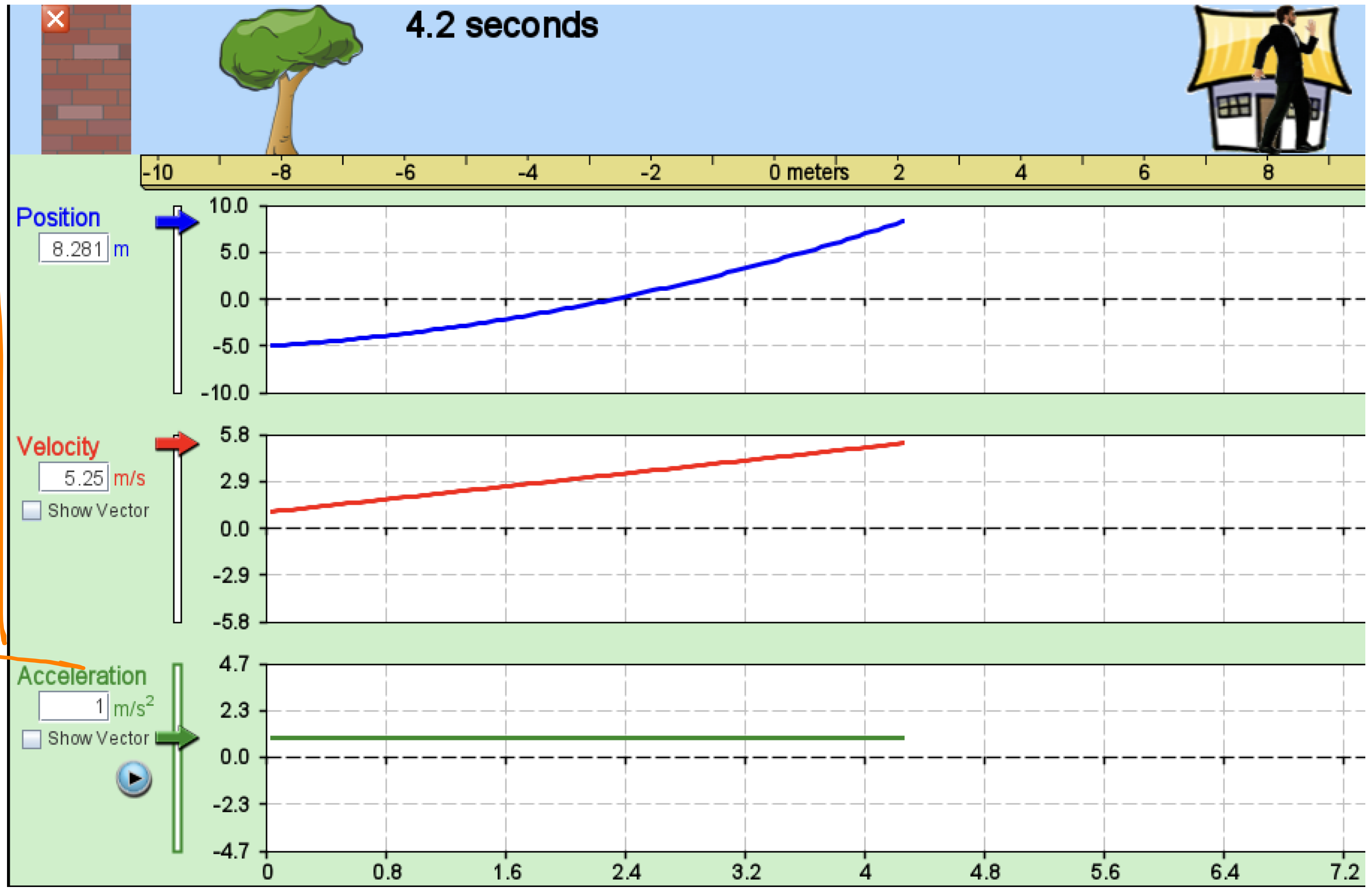
Step2: $= \dfrac{-74\,ms^{-1} - 33\,ms^{-1}}{5.4s} \approx -19.8\,ms^{-2}$

plug in #'s

Kinematics relations

displacement from x=0 m



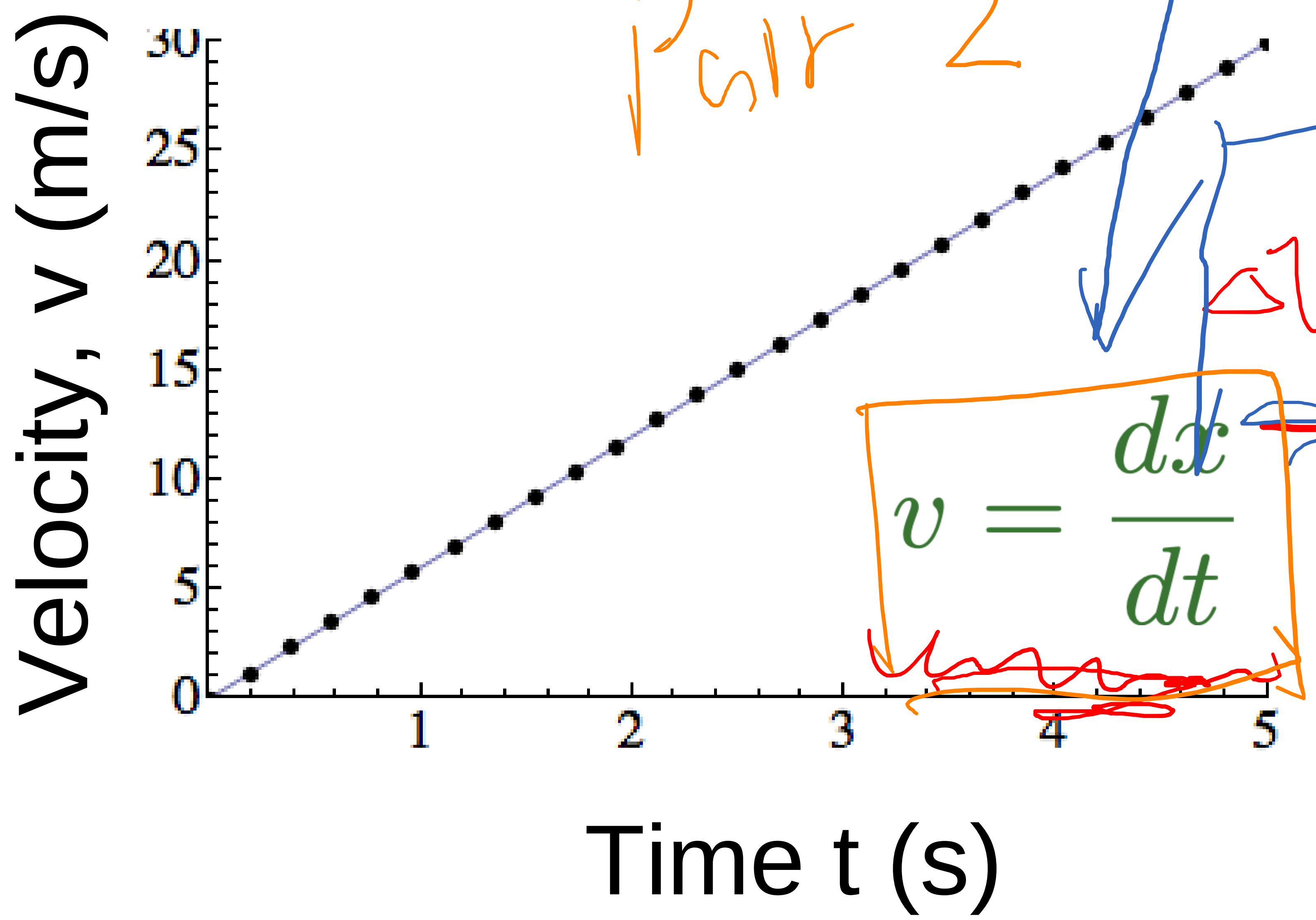


x

$$\Delta x = x_f - x_i = \int_{t_0}^{t_f} \vec{v}\, dt$$

Derivative ↓ ↑ Integral

Pair 2



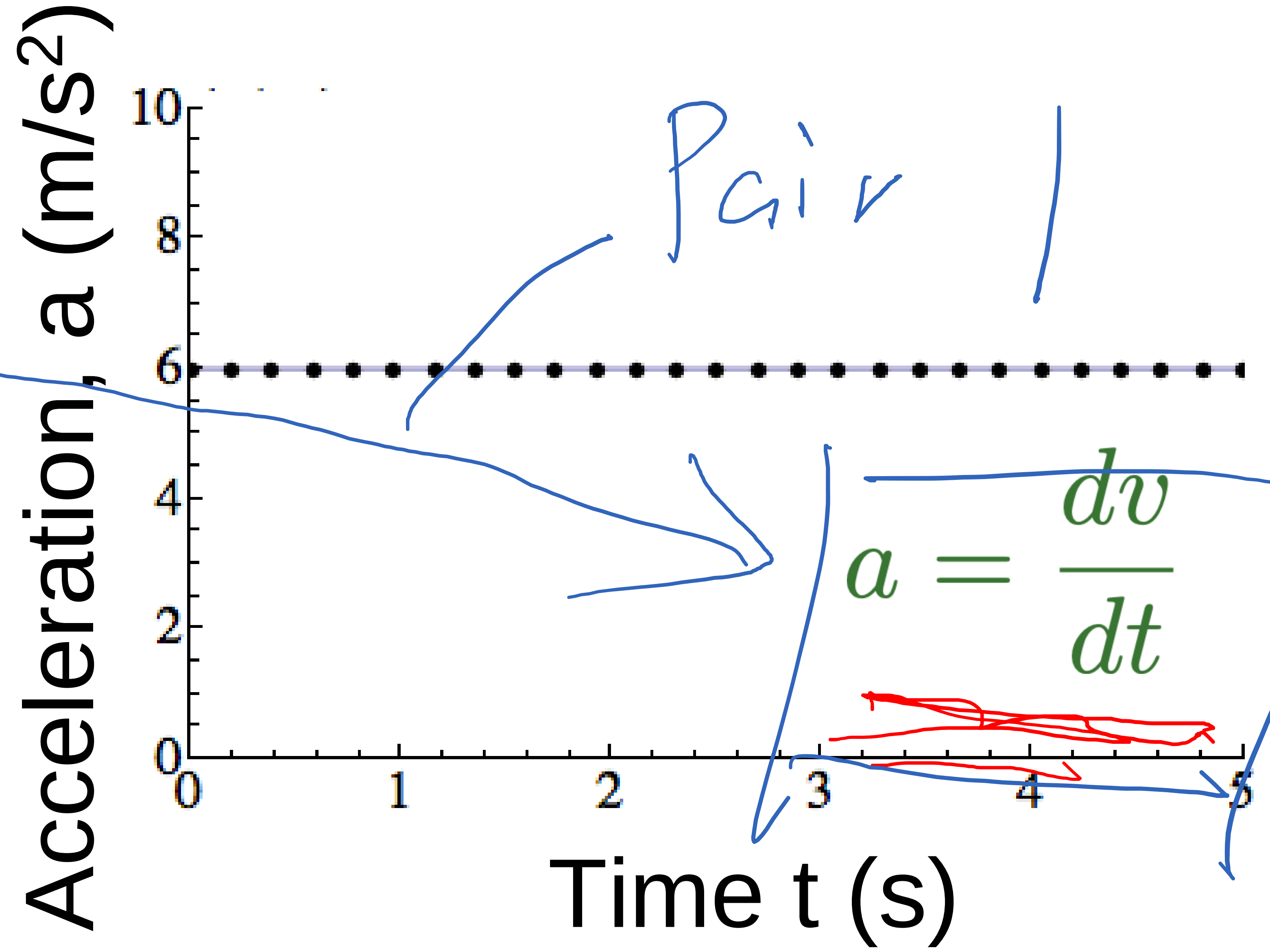
$$\Delta v = v_f - v_0 = \int_{t_0}^{t_f} \vec{a}\, dt$$

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

← Integral

→ Derivative

Pair 1



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

Chapter 2.4. 1D motion with constant acceleration

- Assume the simplified condition that:

  - $\vec{a}$ is a constant

Relations between $\vec{x}$, $\vec{v}$, and $\vec{a}$

$\vec{v}_i, \vec{v}_o$

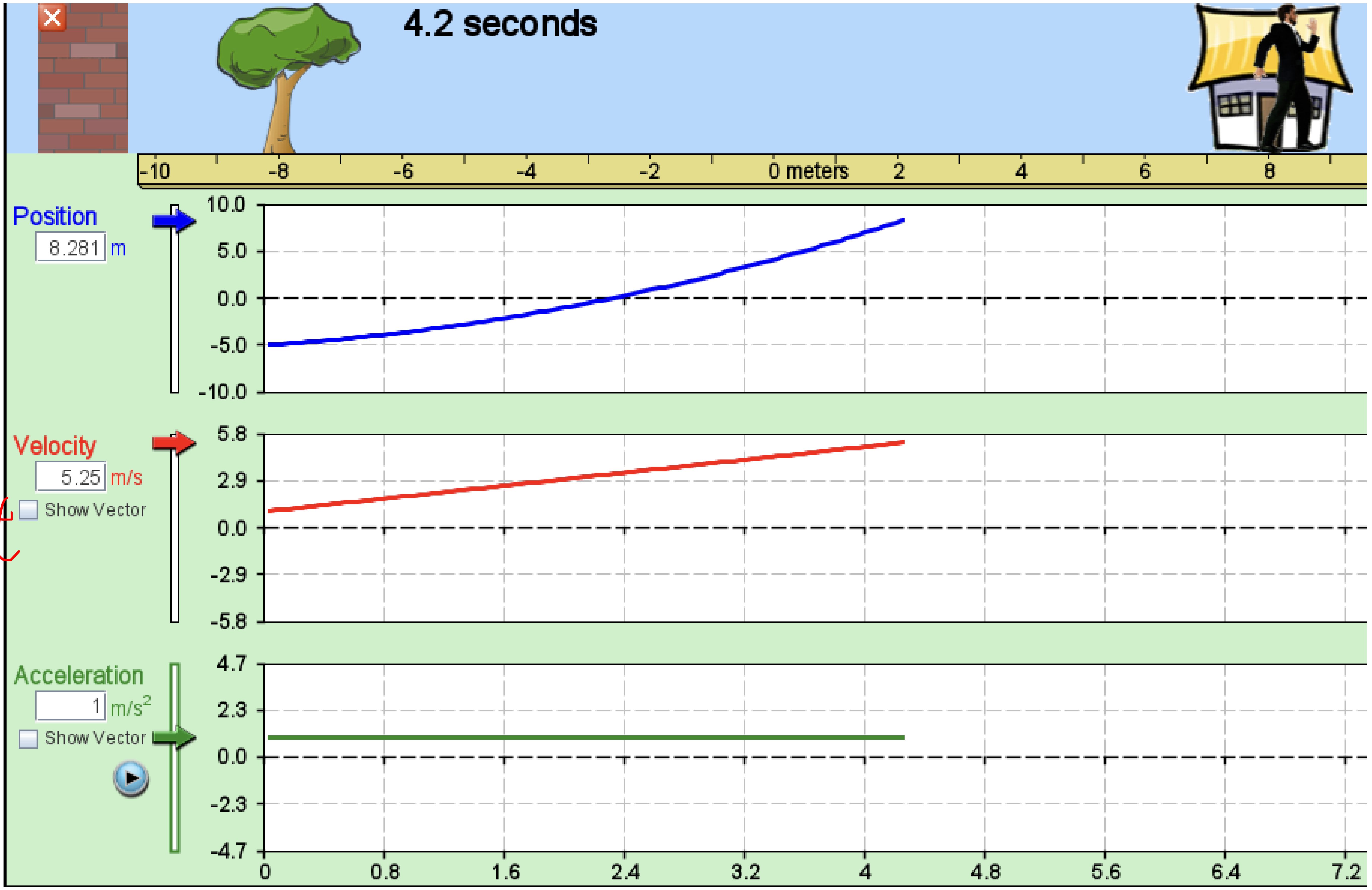
- Conditions:
  - Acceleration $\vec{a}$ is a constant
  - Initial time $t_0 = 0$ s , $t_f = t$

$$\vec{v}_f - \vec{v}_i = \int_{t_0}^{t} \vec{a}\, dt = \vec{a}\, t$$

$$\rightarrow \boxed{\vec{v}_f = \vec{v}_i + \vec{a}\, t}$$

$$\vec{x}_f - \vec{x}_i = \int_{t_0}^{t_f} \vec{v}\, dt = \int_{t_0}^{t_f} (\vec{v}_i + \vec{a}\, t)\, dt$$

$$= \vec{v}_i\, t + \frac{1}{2} \vec{a}\, t^2$$



The first 2 kinematic equations for constant $\vec{a}$

If a is a constant:

(and $t_0 = 0$)

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

Clicker question 1

Step 0: Given: $\vec{v}_i = 30\,m\,s^{-1}$, $\vec{a} = -10\,m\,s^{-2}$, $\vec{v}_f = 0$. Goal: Δt

$\rightarrow v_i \quad \leftarrow \vec{a}$

https://www.caranddriver.com/tesla/cybertruck

$\longrightarrow$ +x

Axis: East is +

- A Tesla Cybertruck is traveling at an initial velocity of 30 m s^{-1} to the east. It slows down at a constant acceleration of 10 m s^{-2} to the west. How long does it take for it to stop? (Axis defined in figure.)

A	10 s.
B	3 s.
C	Unknown
D	It will never stop.

Step 1: $\vec{v}_f = \vec{v}_i + \vec{a}\,\Delta t$

$$\rightarrow \Delta t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}} = \frac{0 - 30\,m s^{-1}}{-10\,m s^{-2}}$$

Step 2: #'s

$= 3\,s$

Example 2

Given: $\vec{v}_0 = 5 ms^{-1}$, $\vec{a} = 5ms^{-2}$

$\Delta t = 6 s$

Goal: Δx

- A Tesla Cybertruck speeds up from 5 m s^{-1} to the east at a constant acceleration of 5 m s^{-2} to the east. Please find its displacement in 6 s. (Axis defined in figure.)

https://youtu.be/eNNCZl2QpXg

+x

Axis

East.

Step 1: $\underbrace{\vec{\Delta x}}_{\text{change in pos.}} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$

~2: Plug in #S:

$\vec{\Delta x} = 5 ms^{-1} \cdot 6s + \frac{1}{2} \times 5 ms^{-2} \cdot (6s)^2$

$= 120 \ m$

The 4 kinematic equations for constant $\vec{a}$

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

Eliminate $\vec{a}$: $$x = x_0 + \frac{1}{2}\left(v_0 + v\right)t$$

Eliminate t: $$v^2 = v_0^2 + 2a\left(x - x_0\right)$$

The 4 kinematic equations

- Why do we need **4** equations to describe constant acceleration?
- We don't!… but additional equations may be useful to solve certain problems.

If a is a constant: $(and\, t_0 = 0)$

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

Eliminate $\vec{a}$:

$$x = x_0 + \frac{1}{2}(v_0 + v)\,t$$

Eliminate t:

$$v^2 = v_0^2 + 2a\,(x - x_0)$$

Clicker question 3

https://www.caranddriver.com/tesla/cybertruck

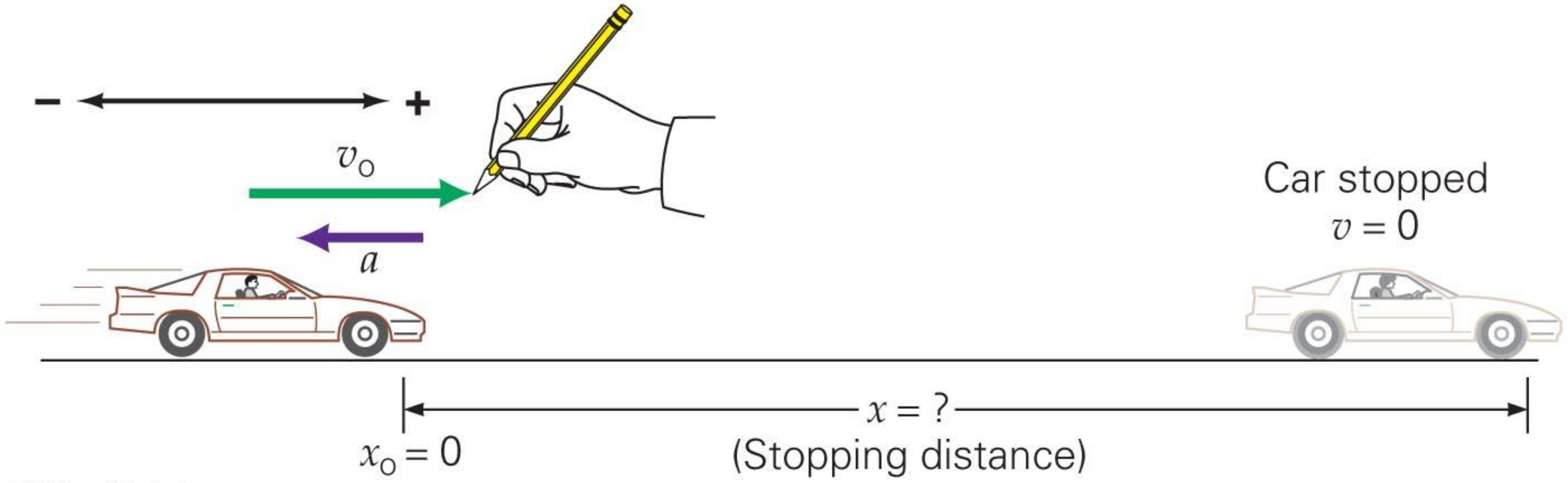
- A Tesla Cybertruck is traveling at an initial velocity of 30 m s^{-1} to the east. It slows down at a constant acceleration of 10 m s^{-2} to the west. How far does it travel before it stops? Which equation to use?

A $$v = v_0 + at$$

B $$x = x_0 + v_0 t + \frac{1}{2}at^2$$

C $$x = x_0 + \frac{1}{2}(v_0 + v)\,t$$

D $$v^2 = v_0^2 + 2a\,(x - x_0)$$



Example 3

https://www.caranddriver.com/tesla/cybertruck

- A Tesla Cybertruck is traveling at a velocity of 30 m s^{-1} to the east. It slows down at a constant acceleration of 10 m s^{-2} to the west. How far does it travel before it stops?